BIBLIOGRAPHY

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(Articles entered into the data base at the Lunar and Planetary Institute Library, January 1983 through April 1983)

1. Motion of the Moon and Dynamics of the Earth–Moon System: Shape and Gravity Field of the Moon

Hostetter, H. C. (California Polytechnic State Univ., San Luis Obispo, CA 93407): 'The Eclipse that Failed', *Griffith Observer* **47**(3), 11–20 (1983).

Understanding the movements of the Moon is no trivial matter. Its complex behavior commanded the time and attention of the ancient skywatchers. They could not know the nature of the forces that move the Moon, but they certainly saw it go through its paces. And even though they grew familiar with some of its less usual theatrics – eclipses, for example – they could be surprised now and then by an unexpected event in the pattern of the Moon. H. Clyde Hostetter deals here, however, with another challenge to the old moonwatchers: an eclipse that was supposed to happen and didn't. The *Griffith Observer* has carried Professor Hostetter's articles before. In the February, 1982, issue he explore the possibility of astronomical symbolism in the Mesopotamian myth of the journey of the goddess Inanna to the Land of the Dead. And in the July, 1979, issue he interpreted details in the ornament on an antique copper bowl in terms of celestial cycles. Some of these involve the Moon and the cues for eclipse prediction he discussed in this article.

2. Physical Structure of the Moon; Thermal and Stress History of the Moon

Nakamura, Y. (Univ. of Texas, Inst. for Geophysics, Galveston Marine Geophysics Lab., Galveston, TX 77550): 'Seismic Velocity Structure of the Lunar Mantle', *J. Geophys. Res.* **88**, 677–686 (1983).

I have inverted the recently completed set of seismic arrival times from the Appollo lunar seismic network to estimate the average seismic velocities in three sections of the lunar mantle: tow for the upper mantle and one for the middle mantle. The method used is a variatoj of the linearized least squares inversion where the inversion in accomplished in steps. The estimated average velocities in the upper mantle decrease from $V_p = 7.74\,\mathrm{km\,s^{-1}}$ and $V_s = 4.49\,\mathrm{km\,s^{-1}}$ in the section above 270 km depth to $V_p = 7.46\,\mathrm{km\,s^{-1}}$ and $V_s = 4.25\,\mathrm{km\,s^{-1}}$ in the section between 270 and 500 km depth, confirming the earlier finding of negative gradients based on seismic amplitude variations. The average velocities in the middle mantle between the depths of 500 km and 1000 km of $V_p = 8.26\,\mathrm{km\,s^{-1}}$ and $V_s = 4.65\,\mathrm{km\,s^{-1}}$ are significantly higher than those in the upper mantle, contradicting earlier estimates based on more limited data. The higher velocities may suggest initial melting of the Moon down to at least 1000 km depth.

Srnka, L. J. and Runcorn, S. K. (Long Range Research Div., Exxon Production Research Co., Houston, TX 77001): 'Probing the Lunar Interior', *Nature* **6**, 15–16 (1983)

Studies of the lunar interior are reviewed; the need for further measurements with sensitive magnetometers in low orbit is emphasized.

Stock, J. D. R. and Woolfson, M. M. (University of York, Heslington, York YO1 5DD, UK): 'Constraints on the Size of the Moon's Core', *Monthly Not. Roy. Astron. Soc.* **202**, 287–291 (1983)

It is possible in very simple and general terms to put an upper limit on the radius of a lunar core. The estimated core size is a fairly insensitive function of the poorly known quantities determing the Moon's radial density profile and of the observed lunar moment-of-inertia facotr. An iron core can be expected to be less than 400 km in radius and only a core consisting solely of iron and sulphur compounds is consistent with a core of radius 500 lm or more. This result has implications for any dynamo theory for the origin of lunar magnetism.

Stock, J. D. R. and Woolfson, M. M. (University of York, Heslington, York YO1 5DD, UK): 'Volcanism and Magnetism of the Moon', *Monthly Not. Roy. Astron. Soc.* **202**, 511–530 (1983)

It is proposed that the early Moon had molten material close to its surface, particular in the equatorial region, due to a combination of fast accretion and tidal flexing after Earth capture. An eccentric orbit of the Earth–Moon system about an early Sun with a high magnetic dipole moment (8×10^{25} T m^3) would give magnetic fields over 10^{-4} T on the lunar surface. These are produced by circular currents in an equatorial conducting ring, induced by variations in the solar field.

3. Morphology of the Lunar Surface: Origin and Stratigraphy of Lunar Formations: Mapping of the Moon

André, G. G. and Strain, P. L. (Center for Earth and Planetary Studies, National Air and Space Museum, Washington, DC 20560): 'The Lunar Nearside Highlands: Evidence of Resurfacing' Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A544–A552 (1983)

Comparative frequency distributions of aluminium, magnesium, titanium, iron, and thorium concentrations from orbital geochemical data show a chemical dichotomy between the lunar nearside and farside terra surfaces. Nearside terra rock types (indicated by modes in the histograms) are more mafic and less aluminous than those on the farside. To explore this chemical asymmetry, terra regions exhibiting either anomalously high or low Mg/Al concentration ratios were examined. Low Mg/Al material excavated from depth by basin and large crater impacts indicates that the highly 'anorthositic' farside crustal composition is also present in the subsurface of the near side at widely scattered locations. Study of high Mg/Al areas of the nearside terra suggests resurfacing of the preexisting terra, possibly by impact excavation of local mafic 'pockets' in the crust or early extrusion of volcanic materials.

Hunter, R. H. and Taylor, L. A. (Dept. of Geological Sciences, Univ. of Tennessee, Knoxville, TN 37996): 'The Magma Ocean from the Fra Mauro Shoreline: An overview of the Apollo 14 Crust', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2 *J. Geophys. Res.* **88**, Suppl. A591–A620 (1983)

Numerous coarse-grained, polymineralic, textrually-monomict, igneous clasts from the Apollo 14 breccias have been studied petrographically and mineralogically. The aims of these clast studies were to evaluate the range of crustal lithologies present at the Apollo 14 site, to bracket their constituent mineralogical compositions, and to assess their relative abundances. Troctolite and troctolitic anorthosite are the most abundant rock types. These are related to the Mg-rich trend. Three distinct plutons may be represented. There is a distinct paucity of noritic lithologies. The second most abundant group

consists of plagioclase cumulates (alkali-rich anorthosites) with more evolved mineral compositions than the Mg-rich trend cumulates; their provenance is indeterminate. Coarse-grained ilmenite gabbros and mineralogically-evolved monzonoritic and granitic clasts are widespread in occurrence but not abundant. An olivine-gabbronorite clast (14305.92) is pristine. Petrographically and mineralogically, it shows a striking resemblance to Apollo 12 olivine mare basalts. The paucity of ferroan anorthosites at this and the Apollo 17 site is attributed to a higher density of Mg-rich and related intrusives in the primitive anorthositic crust in comparison with other sites. Our data provide further support for widespread regional heterogeneities within the early lunar crust.

4. Chemical Composition of the Moon. Lunar Petrology, Mineralogy, and Crystallography

Etchegaray-Ramirez, M. I., Metzger, A. E., Haines, E. L., and Hawke, B. R. (Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA 91109): 'Thorium Concentrations in the Lunar Surface: IV. Deconvolution of the Mare Imbrium, Aristarchus and Adjacent Regions', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *Geophys. Res.* **88**, Suppl. A529–A543 (1983)

The distribution of Th over the Mare Imbrium and northern Oceanus Procellarum portions of the Apollo 15 lunar ground track has been modeled by deconvoluting several fields of orbital gamma ray spectroscopy data. Including a prior study of the Apenninus region, a continuous swath from 10° E to 60° W in the northwest quadrant has now been analyzed. In the Aristarchus region, the crater dominates the Th distribution with a concentration of 20 ppm. Other enhancements are seen on the Aristarchus Plateau and south of the plateau. The concentration across the Aristarchus Plateau is not uniform. The average Th concentration in Oceanus Procellarum is less to the west than to the east of the Aristarchus Plateau. Substantial enhancements are found in mare regions around Brayley, and at the ejecta blankets of Timocharis and Lambert. Th in the Eratosthenian mare regions is generally low with one notable exception lying roughly between the craters Euler and Carlini. The existence of enhanced Th concentrations in mare basalt regions suggests that reservoirs of some late stage mare basalts incorporated KREEP-rich material during formation or transit.

Eugster, O., Eberhardt, P., Geiss, J., and Grogler, N. (Physikalisches Institut, Univ. of Bern, 3012 Bern, Switzerland): 'Neutron-induced Fission of Uranium: A Dating Method for Lunar Surface Material', *Science* **219**, 170–172 (1983)

Volcanic glasses collected on the rim of Shorty Crater in the Apollo 17 area were formed 3.63×10^9 yr ago. THe amounts of xenon-136 produced by neutron-induced fission of uranium-235 indicate that the glasses resided on the the lunar surface for about 38 million yr before they were deeply buried. The glass spherules were reexcavated by the impact that formed Shorty Crater 17 million yr ago, and remained undisturbed until they were collected.

Fang, C. Y., Yinnon, H., and Uhlmann, D. R. (Dept. of Materials Science and Engineering, MIT, Cambridge, MA 02139): 'Cooling Rates for Glass Containing Lunar Compositions', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A907–A911 (1983)

Cooling rates required to form glassy or partly-crystalline bodies of 14 lunar compositions have been estimated using a previously introduced, simplified model. The calculated cooling rates are found to be in good agreement with cooling rates measured for the same compositions. Measurements are also reported of the liquidus temperature and glass transition temperature for each composition. Inferred cooling rates are combined with heat flow analyses to obtain insight into the thermal histories of samples 15422, 14162, 15025, 74220, 74241, 10084, 15425, and 15427. The critical cooling rates required to form glasses of 24 lunar compositions, including the 14 compositions of the present study, are suggested to increase systematically with increasing ratio of total network modifiers/total network formers in the compositions. This reflects the importance of melt viscosity in affecting glass formation.

Ishii, T., McCallum, S., and Ghose, S. (Dept. of Geological Sciences, Univ. of Washington, Seattle, WA 98195): 'Petrological and Thermal Histories of a Lunar Breccia 73217 as Inferred from Pyroxene Crystallization Sequences, Exsolution Phenomena and Pyroxene Geothermomentry', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* 88, Suppl. A631–A644 (1983)

Electron probe microanalyses, X ray diffraction studies, and pyroxene geothermometry of blue-gray breccia 73217 indicate a record of an early plutonic period and a later thermal event. The breccia contains two domains; one (breccia A) contains coarse orthopyroxene clasts, whereas the other (breccia B) contans coarse pigeonit clasts. Pyroxene trends, deduced from pyroxene clasts from breccias A and B, are analogous to the early and late fractionation stages, respectively, of terrestrial basic layered intrusions. Minor element compositions of both augite and Ca-poor pyroxenes from breccias A and B vary continuously with FeO/(MgO + FeO) ratio. Optical and X ray observations reveal that pyroxene clasts show a great variety of exsolution textures, but that individual pyroxene grains show relatively simple and less intensive exsolution patterns. There is no overlap in mineral compositions of pyroxenes as well as plagioclase and ilmenite clasts between breccias A and B. These characteristics are consistent with a model that the coarse mineral clasts of both breccias A and B possibly originated from the same relatively small layered intrusion, i.e., breccia A being derived from an early stage (1100°–1060°C ± 20°C) and B from a later stage of fractionation (1060°–1050°C). Both breccias experienced a later common annealing event (1040°–1070°C).

James, O. B. and Flohr, M. K. (959 National Center, U.S. Geological Survey, Reston, VA 22092): 'Subdivision of the Mg-Suite Noritic Rocks into Mg-Sabronorites and Mg-Norites', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* 88, Suppl. A603–A614 (1983)

Mg-suite noritic rocks can be divided into two groups, the Mg-gabbronorites and the Mg-norites. The rocks of these groups differ in ratios of high-Ca pyroxene to toal pyroxene, compositions of pyroxene and plagioclase, assemblages of Ti-, Nb-, and Zr-bearing minerals, compositions of chrome spinel, bulk-rock Ti/Sm and Sc/Sm, and measured ages. The two groups probably crystallized from different types of parent magmas. Two hypotheses are offered for the differences in composition of the parent magmas. One hypothesis ascribes the differences to compositional heterogeneity of the mantle source areas. The other hypothesis ascribes the differences to variations in extent of partial melting of the mantle source regions and variations in extent of assimilation of the anorthosite and the highly differentiated residual liquid tht were produced during the primordial lunar differentiation.

Jovanovic, S. and Reed, G. W. Jr. (Chemistry Div., Argonne National Lab., IL 60439): 'The Role of Phosphorus in Lunar Samples – A Chemical Study', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* 88, Suppl. A705–A712 (1983)

Up to 60% of the REE, P, halogens, and U in basalt 75055 and basalt mineral separates, KREEP-rich breccia 14312, and components from highland breccia 66095 are in phases that are rapidly dissolved by Phl HNO_3 acid; these could be phosphates. The REE patterns of the pH1 acid soluble fractions are distinctly different from those of the post-leach residues. The REE pattens of the dilute acid soluble fractions in the breccia samples are similar. The basalt samples also have similar acid soluble REE patterns but different from the breccia samples. Significant fractions of P (25%), LREE (40%), and HREE (16%) in whole rock basalt are pH1 acid soluble. Large fractions of P (47% and 61%) are small fractions of LREE (10%) associated with plagioclase and pyroxene mineral separates are acid soluble. Thus for this igneous rock, the acid soluble phases associated with the whole rock and with the major minerals may be different.

Lindsley, D. H. and Andersen, J. J. (Dept. of Earth and Space Sciences, S.U.N.Y., Stony Brook, NY 11794): 'A Two-Pyroxene Thermometer', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* 88, Suppl. A887–A906 (1983)

Experimentally determined pyroxene phase relations at 800°–1200°C are combined with calculated phase equilibria for the Di–En and Hd–Fs joins to produce a graphical two-pyroxene thermometer that should be applicable to a wide variety of rocks from the Earth, Moon, and meterorites. The thermometer can be used directly with natural pyroxenes that have low contents of Al and other minor components. Samples with higher contents of 'others' components require special projection onto the Ca–Mg–Fe pyroxene quadrilateral, Wo, En, and Fs as normally calculated will not yield correct temperatures! The special projection is necessary to approximate the activities of those components in natural pyroxenes. The effects of pressure are non-negligible but can be corrected for. Use of the thermometer for slowly-cooled rocks may pose special problems if the pyroxenes have undergone granule exsolution (coalescence of exsolved material to form separate grains). For example, published analyses of Mg-rich augites from the Skaergaard intrusion give temperatures that are 50°–100°C below expected magmatic values. Textural and experimental evidence confirms that these augites have undergone granule exsolution. The primary pyroxene compositions must be reconstructed from textural evidence before correct igneous or peak-metamorphic temperatures can be obtained from this or any two-pyroxene thermometer. Of the numerous two-pyroxene thermometers proposed in the literature, those of Ross and Huebner (1975) and of Kretz (1982; Ca-reaction) yield temperatures most similar to our own, although the former tends to give temperatures about 50°C lower for some igneous pyroxenes. Other thermometers generally overestimate temperatures for metamorphic rocks (hornblende granulite facies) by 50°–100°C.

Lindstrom, M. M. and Salpas, P. A. (Dept of Earth and Planetary Sciences, Washington, Univ., St. Louis, MO 63130): 'Geochemical Studies of Feldspathic Fragmental Breccias and the Nature of North Ray Crater Ejecta', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* 88, Suppl. A671–A683 (1983)

Major and trace element analyses of clasts and matrix from feldspathic fragmental breccias show that these breccias are not all alike but vary widely in their bulk compositions and clast assemblages. These studies, together with analyses of toher North Ray Crater large rocks, reveal the major components to be anorthosites, ferroan anorthositic norites, magnesian granulites, feldspathic melt rocks, and VHA impact melts. The ferroan anorthositic norites are important lunar crustal rocks identified here for the first time. The KREEPy VHA melts are found to be much more important in North Ray Crater ejecta than was previously assumed. Sodic ferrogabbro is an important minor component. The compositional characteristics of bulk breccias and feldspathic melt rocks are modeled quantitatively as mixtures of two to five components: anorthosites, ferroan anorthositic norites, magnesian granulites, sodic ferrogabbros, and VHA melt rocks. Breccia 67455 is unique in consisting wholly of ferroan, KREEP-free components.

Marvin, U. B. and Lindstrom, M. M. (Harvard–Smithsonian Center for Astrophysics, Cambridge, MA 02138): 'Rock 67015: A Feldspathic Fragmental Breccia with KREEP-rich Melt Clasts', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* 88, Suppl. A659–A670 (1983)

Breccia 67015, one of the feldspathic fragmental breccias (FFBs) from the rim of North Ray Crater, contains a wider range of clast lithologies than has been described previously in FFB's. Our petrologic and INAA studies have revealed two components of major petrologic and geologic significance. One of thes is a dark, vesicular, KREEP-rich melt rock of VHA (ver high alumina) basalt composition, which occurs in clasts up to 6 cm long. Melt rocks of this type are common at the Apollo 16 site, but in previous years had not been discovered as prominent constituents of the feldspathic fragmental breccias. Their apparent absence led to hypotheses, no longer valid, that the KREEPy melt rocks were younger than the anorthositic breccia matrices and that the two lithologies might represent Imbrian and Nectaris ejecta, respectively. The second lithology we discovered is in a large clast of medium-grained ferroan anorthositic norite with a composition that falls among the most magnesian members of the ferroan anorthosite suite of pristing cumulate rocks. This material constitutes a previously 'missing' member of certain mixing models designed to account for the North Ray Crater melt rocks and bulk breccias.

Nord, G. L. Jr. and Wandless, M.-V. (959 National Center, U.S. Geological Survey, Reston, VA 22092): 'Petrology and Comparative Thermal and Mechanical Histories of Clasts in Breccia 62236', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A645–A657 (1983)

Lunar breccia 62236 contains large lithic fragments of troctolite, norite, and anorthosite. The mafic phases, olivine, inverted pigeonite, and augite, fill interstitial areas between larger plagioclases and appear to be cumulate phases with extensive adcumulus growth. Pyroxene compositional homogeneity indicates that cation exchange during cooling was limited to an area of about 1 mm. Primary augite and pigeonite both contain 30 μm-wide lamellae of the other along '001'. Pigeonite inverted to orthopyroxene without retaining any crystallographic orientation and subsequently exsolved fine lamellae of augite on (100). Profiles across orthopyroxene-augite interfaces obtained in the analytical transmission electron microscope show an increase of ~ 5% wollastonite in augite within 0.5 μm of the interface, suggesting that short-range cation exchange continued to temperatures below 500 °C. The entire sample has undergone heterogeneous shock deformation. Shock meling of the troctolitic clast suggests pressures of 200–300 kb and well-developed basal twinning in augute from the norite clasts suggests pressures of 50–300 kbars. The present evidence indicates that 62236 contains parts of a slowly cooled microlayered adcumulate that has been heterogeneously shocked several times and combined into the present breccia.

Warren, P. H., Taylor, G. J., Keil, K., Kallemeyn, G. W., Rosener, P. S., and Wasson, J. T. (Dept. of Geology, Univ. of New Mexico, Alburquerque, NM 87131): 'Sixth Foray for Pristine Nonmare Rocks, and an Assessment of the Diversity of Lunar Anorthosites', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A615–A630 (1983)

Eleven nonmare samples are characterized, generally both compositionally and petrographically. Five are almost certainly pristime (ferroan anorthosite 10056c, alkali anorthosite 14047c, ferroan anorthosite 14312c, anorthositic troctolite 14321c3, and granite 14321c4), and four are probably pristine (norite 14318c, noritic anorthosite 67215, 'quasi-pristine' ferroan anorthosite 73217c, and norite 78527). Five are unique anorthosites, extending the diversity of lunar anorthosites considerably. Alkali anorthosites, particularly 14047c, are extremely rich in incompatible elements. The first anorthosite from Apollo 11 with manifestations of pristinity (10056c) appears to be a normal member of the ferroan group. However, the first pristine ferroan anorthosites from Apollo 14 and 17 to be studied in detail (14312c and 73217c) both have unusually sodic plagioclase by ferroan standards. With only 75% plagioclase, 67215 is the first large (273 g) probably pristine ferroan sample with less than ~ 83% plagioclase. The nature of the correlations between longitude and such parameters as Eu and Sm concentrations, and Sc/Sm, Ti/Sm, and Ca/Na ratios, among pristine ANT samples has been elucidated, becuase five of the new pristine samples are from a western site (Apollo 14). Interestingly, ferroan anorthosite 14312c has Ca/Na, Sc/Sm, and Ti/Sm ratios close to the normal ferroan values, but significantly displaced in the direction of the nonferroan western pristine rocks. This suggests that the composition-longitude relationships are as old as the late stages of the crystallization of the putative magma ocean.

5. Electromagnetic Properties of the Moon

Anderson, K. A. (Physics Dept. and Space Sciences Lab., Univ. of California, Berkeley, CA 94720): 'Magnetic Dipole Moment Estimates for an Ancient Lunar Dyanmo', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A588–A590 (1983)

The four measured planetary magnetic moments combined with a recent theoretical prediction for dynamo magnetic fields suggests that no dynamo exists in the moon's interior todya. For the moon to have had a magnetic moment in the past of sufficient strength to account for at least some of the lunar rock magnetism, the rotation would have been about twenty times faster than it is today and the radius of the fluid, conducting core must have been about 750 km. The argument depends on the validity of the Busse solution to the validity of the MHD problem of planetary dynamos.

Cisowski, S. M., Collinson, D. W., Runcord, S. K., Stephenson, A., and Fuller, M. (Dept. of Physics, Univ. of Newcastle upon Tyne, England): 'A Review of Lunar Paleointensity Data and Implications for the Origin of Lunar Magnetism', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A691–A704 (1983)

The saturation remanence normalization method of paleointensity estimation has been apllied to more than 50 lunar samples, and has been calibrated in terms of standard intensity determinations done on 14 samples. These results suggest that a lunar surface field, comparable in intensity to the Earth's magnetic field, existed from about 3.6 to 3.8 AE. Absolute paleointensity estimates and lunar surface field strength determinations are consistent with this observation. The data presented here differ from previous descriptions of the variation in the lunar field with time in that (A) the oldest samples (> 3.9 AE) are among the most weakly magnetized; and (B) an order of magnitude drop in paleointensity is suggested between the time of extrustion of the Apollo 11 low and high potassium basalts. The limited range in age of the strongly magnetized lunar samples and the absence of shocked samples in this set argues against a solar source for the lunar paleofield or for fields arising from transient phenomena such as impacts. The coincidence of this high field era with the termination of basin forming impacts and the beginning of mare basalt extrusion suggests a common cause. A close approach of the Moon to the Earth at about 3.8 AE might account for all three phenomena. The confined duration of the strong lunar field may allow for the assignment of relative ages for certain lunar samples and surface features.

Cowley, S. W. H. and Shull, P. Jr. (Blackett Lab., Imperial College, London, SW7 2BZ, U.K.): 'Current Sheet Acceleration of ions in the Geomagnetic Tail and the Properties of Ion Bursts Observed at the Lunar Distance', *Planetary Space Sci.* **31**, 235–245 (1983)

Recent analyses of measurements obtained from the Rice University Apollo 14 SIDE on the lunar surface have revealed the frequent appearance of fast tailward-streaming ion 'bursts' near the centre plane of the geomagnetic tail. In this paper the properties of these 'bursts' are tested for compatibility with tail current sheet tangential stress balance conditions assuming that they are produced by current sheet acceleration of tail lobe plasma downstream and tailward of a magnetic netural line. Calculations are performed taking the ions to be either protons or singly charged oxygen, the latter possibility being directly suggested by several recent observations. When 'burst' bulk parameters are calculated by assuming that the ion distribution functions are convecting isotropic Maxwellians, the results are found to be difficult to reconcile with current sheet stress balance conditions for either protons or oxygen. Use of a different ion distribution based on theoretical expectations and observations in the near-Earth tail, however, results in number density estimates being increased by factors of around an order of magnitude. When the revised densities and ion distribution functions are taken into account, reasonable agreement between observed and expected ion bulk speeds in obtained. In some cases the agreement is better assuming oxygen ions rather than protons, but not by a large factor.

Sugiura, N. and Strangway, D. W. (Dept. of Geology, Univ. of Toronto, Toronto, Ontario, M521A1, Canada): 'Magnetic Paleointensity Determination on Lunar Sample 62235', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A684–A690 (1983)

There have been very few determinations of the ancient lunar magnetic field using the full Thellier technique. Samples studied range in age from 4.0 by to very young. Four samples show values less than 0.1 oersteds. The fifth sample reported on earlier by Collinson *et al.* (1973) has a reported value of 1.3 oe. In this paper, we have repeated this determination and found essentially the same very high value. It remains to be assessed by further sample studies whether this value is anomalous and somehow associated with impact or whether this reflects a high intensity field in early lunar history.

6. Radiation of the Moon; Optical and Thermal Properties of the Lunar Surface

Wieler, R., Etique, PH., Signer, P., and Poupeau, G. (Swiss Federal Inst. of Tech., Sonneggstrasse, 5 CH-8092 Zürich, Switzerland): 'Decrease of the Solar Flare Solar Wind Flux Ratio in the Past Several Aeons Deduced from Solar Neon and Tracks in Lunar Soil Plagioclases', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A713–A724 (1983)

We determined the He, Ne, and Ar concentrations and isotopic compositions of mineral separates of six lunar subsurface samples and of two regolith breccias which were exposed to the sun as early as 2–3 by ago. The results are compared with our noble gas data obtained previously on mineral separates of lunar surface soil samples most of which contain recently implanted solar gases. The mean solar flare track densities were determined on aliquots of several of the plagioclase separates analyzed for noble gases. Solar wind retentive mafic minerals and ilmenites show that a possible secular increase of the $^{20}Ne/^{22}Ne$ ratio in the solar wind during the last 2–3 Ga is $< 2\%$. In plagioclases, which are less retentive for solar wind Ne, a considerable fraction of the retained Ne is of solar flare origin. The data are compatible with values for $^{20}Ne/^{22}Ne$ of ~ 11.3–11.8, reported for solar flare Ne retained in plagioclase separates from lunar soils. The solar flare track data and the Ne data independently show that plagioclases exposed to the sun over the last 10^8 yr recorded a lower mean ratio of solar flare to solar wind intensities than samples exposed about 1–3 by ago. On the basis of track data we estimate these ratios to differ by a factor ~ 2.

7. Lunar Environment

Borg, J., Bibring, J. P., Cowsik, G., Langevin, Y., and Maurette, M. (Laboratoire Rene-Bernas, 91406 Orsay, France): 'A Model for the Accumulation of Solar WInd Radiation Damage Effects in Lunar Dust Grains, Based on Recent Results Concerning Implanation and Erosion Effects', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A725–A730 (1983)

In this paper we present our most recent results on ion implantation and erosion effects, intended to reproduce the superficial amorphous layers layers of radiation damage observed with a high voltage electron microscope on μm-sized grains extracted from the lunar regolith and which result from the exposure of the grains to the solar wind. We next outline theoretical computations which yield the thickness distribution of such amorphous layers as a function of the exposure time of the grains at the surface of the Moon, the He/H ratio, and the speed distribution in the solar wind. From this model, the position of the peak in the solar wind speed distribution is the major parameter controlling the thickness of the amorphous layer.

8. Exploration and Untilization of the Moon

Koltz, C. (Washington, Univ., St. Louis, MO 63130): 'Mining the Moon', *Space World*, Vol. T-2-230, 30-31 (1983)

Larry Haskin and David Linstrom have shown in the laboratory that we can take ordinary lunar soil and, using electrolysis, separate it, into iron, titanium, silicon, and oxygen.

10. General Reviews of Lunar Studies

Allen, D. A. (Anglo-Australian Observatory): 'Infrared Views of the Giant Planets', *Sky Telesc.* **65**, 110–112 (1983)

Infrared observations of Jupiter, Saturn, Uranus, and Neptune, with the Anglo-Australian Telescope are discussed.

Chou, C.-L., Shaw, D. M., and Crocket, J. J. (Dept. of Geology, McMaster Univ., Hamilton, Ontario L8S4M1, Canada): 'Siderophile Trace Elements in the Earth's Oceanic Crust and Upper Mantle' Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A507–A518 (1983)

Abundances of Re, Ir, and Au have been determined in a suite of oceanic basalts using radiochemical neutron activation analysis. Mean abundances of highly siderophile elements in the oceanic crust have been estimated. Siderophile elements are fractionated during basalt genesis. Iridium, Os, Pd, Pt, Ru, and Rh are depleted in basalts relative to periodotites. Gold is only slightly enriched in basalts. Rhenium is favorably partitioned into the liquid during partial melting of periodotites. Concentrations of siderophile elements in the Earth's upper mantle are higher than that expected from core-mantle equilibrium. Six platinum-group elements, Re, and Au have chondritic ratios in the upper mantle, indicating the presence of a meteoritic component. The abundances of eight highly siderophile elements can be accounted for by 0.74% of CI-chondritelike material in the upper mantle. The low-Ti mare basalts have lower Re contents and lower Re/Ir ratios than oceanic basalts, which may be interpreted by a lower partition ratio of Re under extremely dry and reducing conditions in the lunar interior.

Coradini, A., Federico, C., and Lanciano, P. (Istituto di Astrofisica Spaziale del CNR, Reparto di Planetologia, Viale dell'Universita 11, 00185 Roma, Italy): 'Rarth and Mars: Early Thermal Profiles', *Physics of the Earth and Planetary Interiors* **31**, 145–160 (1983)

The extent of formation heating for the Earth and Mars has been evaluated assuming that the terrestrial planets accumulated from planetesimals. The main result is that, even if a long accumulation time is assumed ($\tau \geqslant 100$ Ma), it is possible to obtain a planetary structure with a larg melted shell taking into account the role played by massive projectiles, which, upon reaching depths of several kilometres, are able to deposit heat significantly below the planetary surface. Internal temperatures, sufficient for the downward migration of the liquid iron alloy, have been obtained.

Fegley, B. Jr. (Harvard College Observatory, Cambridge, MA 02138): 'Primordial Retention of Nitrogen by Terrestrial Planets and Meteorites', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A853–A868 (1983)

Thermodynamic calculations of the amount of dissolved nitrogen in Fe–Ni alloy in a solar composition gas were done over a wide range of temperatures and pressures. The stabilities of the nitride minerals found in meteorites, a large number of other nitrides, and ammonium aluminosilicates were also calculated in a solar gas. This through study indicates that equilibrium mechanisms cannot account for the nitrogen contents of the terrestrial planets and meteorites. The best available data indicate that the observed nitrogen contents of planets and meteorites are several orders of magnitude greater than the predicted nitrogen contents of condensed material in a solar gas. It is suggested that the nitrogen in meteorites was originally reatined as organic compounds produced by disequilibrium mechanisms. Nitrogen retention by the terrestrial planets could be due to homogeneous accretion or to accretion of a volatile-rich veneer. However the actual mode of nitrogen accretion cannot yet be determined.

Gierasch, P. J. (Center for Radiophysics and Space Research, Cornell Univ., Ithaca, NY 14853): 'Dynamical Consequences of Orthohydrogen-Parahydrogen Disequilibrium on Jupiter and Saturn', *Science* **219**, 847–849 (1983)

The Voyager observation of high zonal flow speeds (about 400 m per second) in the atmosphere of Saturn has raised fundamental questions about the flow on both Jupiter and Saturn. One possibility is that the flow is extremely deep, perhaps extending through the planet. Another is that the flow is confined near the cloud tops and is associated with very strong buoyance contrasts. It is demonstrated that the heat of conversion from parahydrogen to orthohydrogen can provide buoyancy contrasts of the required magnitude, and a feedback mechanism is proposed to couple the heat of conversion to the flow dynamics.

Kane, V. R. and Kohlhase, C. E.: 'Voyager to Uranus and Neptune', *Astronomy* **11**(4) 7–15 (1983)

The technical problems and scientific objectives of the Voyager 2 flyby mission to Uranus and Neptune are outlined.

Kivelson, M. G. and Russell, C. T. (Dept. of Earth and Space Sciences, Univ. of California, Los Angeles, CA 90024): 'The Interaction of Flowing Plasmas with Planetary Ionospheres: A Titan–Venus Comparison', *J. Geophys. Res.* 88, 49–57 (1983)

Titan and Venus are both unmagnetized bodies enveloped by induced magnetospheres created within the flowing plasmas in which they are embedded. When Saturn's magnetosphere extends beyond the position of Titan, as during the Voyager 1 flyby on November 12, 1980, the plasma incident at Titan contains a steady magnetic field approximately perpendicular to the plasma flow velocity. At Venus the incident plasma usually contains a time-varying magnetic field, but occasionally, the interplanetary conditions remain steady for the few hours required for the Pioneer Venus orbiter to pass through the induced magnetosphere. In particular, on February 28, 1979, the interplanetary field appears to have been stable and transverse to the solar wind velocity during the wake pass which was selected for a comparative Venus–Titan study. For both wakes, symmetry properties of the measured magnetic fields were used to infer the directions of ambient plasma flow. In each case the flow direction differed from nominal, with the flow of Titan aberrated about 27° radially inward of the corotation direction and the flow at Venus aberrated about 10° relative to the heliocentric radial directions. Corroborating evidence for the aberrated flows was provided by plasma observations. The wake field magnitudes were nonuniform, and in both cases, reduced magnitudes were found on field lines linked to the illuminated (dayside) ionospheres. Finally, both induced magnetotails contained regions in which the projection of the magnetic field onto the incident magnetic field was negative. This observation may indicate that in an induced magnetosphere the plasma flows toward the mid-tail current sheet in the near wake, thus producing a filed configuration that corresponds to a reconnection geometry.

Klein, L. C., Fasano, B. V., and Wu, J. M. (Rutgers Univ., Dept. of Ceramics, Piscataway, NJ 08854): 'Viscous Flow Behavior of Four Iron-Containing Silicates with Alumina. Effects of Oxidation Conditions', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* 88, Suppl. A880–A886 (1983)

The viscosity of four iron-containing silicates with alumina has been measured under oxidizing and reducing conditions over the temperature range 450° to 700 °C. Initially, the compositions contain approximately 2, 5, 10, and 20 mol.% of trivalent metal oxide. The viscosities of compositions with approximately equimolar Fe^{3+} and Al^{3+} are compared to those determined for compositions with travalen cation all Fe or all Al. Then the batch composition calculated to replace one half of the Fe^{3+} by Al^{3+} under oxidising conditions is corrected for the divalent iron present under mildly reducing conditions in forming gas (95% N_2–5% H_2) and strongly reducing conditions with carbon. In general, the viscosity measured in air was higher than the viscosity measured in forming gas with or without carbon for a given temperature and composition. The glasses prepared under oxidizing conditions had Fe^{2+}/Fe total ratios less than 0.25 and the glasses prepared under reducing conditions had Fe^{2+}/Fe total ratios between 0.27 and 0.91. The viscosities for these glasses can be represented by a Vogle–Fulcher relation for each of the three oxidation conditions.

McCammon, C. A., Ringwood, A. E., and Jackson, I. (Research School of Earth Sciences, Australian National Univ., Canberra, A.C.T. 2600 Australia): 'A Model for the Formation of the Earth's Core', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* 88, Suppl. A501–A506 (1983)

The recent discovery of a phase transformation in $Fe_{0.94}O$ by Jeanloz and Ahrens has allowed a more detailed development of a model for core formation involving oxygen as the principal light alloying element of the core. It is predicted, based on calculations, that an increasing pressure in the system FeO-MgO will result in a gradual exsolution of an almost pure high-pressure phase FeO(hpp), leaving

an iron-depleted (Fe, Mg)O rocksalt (B1) phase. We also predict that FeO(hpp) will form a low-melting point alloy with Fe at high temperature and high pressure. On the basis of our interpretations, we have constructed a model for core segregation. Assuming the earth to have accreted from the primordial solar nebula as a relatively homogeneous mixture of metallic iron and silicate-oxide phases, core segregation involving oxygen would commence at a depth where pressure is sufficiently high to cause exsolution of FeO(hpp) from the rocksalt phase, and temperature is sufficiently high to allow formation of an Fe–FeO(hpp) melt. A gravitational instability arises, leading to vertical differentiation of the earth as molten blobs of the metal sink downwards to form the core and the residual depleted silicate material coalesces to form large bodies which rise diapirically upwards to form the mantle.

Melosh, H. J. and Gaffney, E. S. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 85721): 'Acoustic Fluidization and the Scale Dependence of Impact Crater Morphology', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A830–A834 (1983)

A phenomenological Bingham plastic model has previously been shown to provide an adequate description of the collapse of impact craters. This paper demonstrates that the Bingham parameters may be derived from a model in which acoustic energy generated during excavation fluidizes the rock debris surrounding the crater. Experimental support for the theoretical flow law is presented. Although the Bingham yield stress cannot be computed without detailed knowledge of the initial acoustic field, the Bingham viscosity is derived from a simple argument which shows that it increases as the 3/2 power of crater diameter, consistent with observation. Crater collapse may occur in material with internal dissipation Q as low as 100, comparable to laboratory observations of dissipation in granular materials. Crater collapse thus does not require that the acoustic field be regenerated during flow.

Mizutani, H., Kawakami, S.-I., Takagi, Y. Kumazawa, M., and Kato, M. (Dept. of Earth Sciences, Nagoya Univ., Nagoya, 464, Japan): 'Cratering Experiments in Sands and a Trial for General Scaling Law', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A835–A845 (1983)

We report results of vertical impacts on aluminum projectiles into quartz sand. The impacts were performed at velocities of 35 to 830 m s^{-1} with a single stage powder gun. Morphology of craters formed in loose sands is generally conical, whereas morphology of craters formed in self-compacted sands varies from a flat-floor type to a double ring type, with increasing impact velocity. The present data together with previous experimental data and Dienes and Walsh's 'late-stage equivalence' indicate that crater diameter is expressed by a function of the 'late-stage effective energy' but not of the impact kinetic energy. The diameter of a crater formed in a noncohesive sand was found to be proportional to one-fourth the power of the late-stage effective energy. For a general impact cratering in a target with a finite strength, the diameter, D, versus impact velocity, v, relation is written as follows:

$$\left\{\frac{v}{v^*}+\left(\frac{v}{v^*}\right)^2\right\} = K\left\{\left(\frac{D}{D^*}\right)^4+\left(\frac{D}{D^*}\right)^{5/2}\right\}$$

where v^* and D^* are normalizing values of the impact velocity and diameter, and K is a constant related to target and projectile properties. The relation suggests that there are four regimes in crater diameter versus the kinetic energy relation.

Neugebauer, M. (Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA 91109): 'Mariner Mark II and the Exploration of the Solar System', *Science* **219**, 443–449 (1983)

Mariner Mark II is a concept for the next generation of deep-space missions. The project would provide limited, focused sets of Voyager- and Galileo-quality planetary observations at a fraction of the cost of the Voyager and Galileo projects. This article discusses Mariner Mark II's cost goals, scientific objectives, and mission requirements. Strategies for limiting costs include the use of a reconfigurable spacecraft, a multimission ground-support system, and selected new technologies.

Newsom, H. E. and Drake, M. J. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 85721): 'Experimental Investigation of the Partitioning of Phosphorus Between Metal and Silicate Phases: Implications for the Earth, Moon, and Eucrite Parent Body', *Geochim. Cosmochim. Acta* **47**, 93–100 (1983)

The solid metal/silicate melt partition coefficient for P, $D(P)$, has been determined experimentally at 1190 °C and 1300 °C. The dependence of the partition coefficient on oxygen fugacity has been investigated, and is consistent with a valence state of 5 for P in the silicate melt. The experimental partition coefficients are given by:

$$\log D(P) = -1.21 \log fO_2 - 15.95 \quad \text{at} \quad 1190\,^{\circ}C$$

$$\log D(P) = -1.53 \log fO_2 - 17.73 \quad \text{at} \quad 1300\,^{\circ}C.$$

The experimentally determined partition coefficients may be used to interpret the low P/La ratios of the Earth, Moon and eucrites relative to C1 chondrites. The low P/La ratios in the eucrites may be explained by partitioning of P into 5% to 25% of a sulfur-bearing metallic liquid assuming equilibration and separation of the liquid metal from the silicates at low degrees of partial meling of the silicates. The low W/La ratios in the eucrites compared to C1 chondrites require the separation of an additional 2% to 10% solid metal.

The lowering of both P/La and W/La ratios in the Moon may be explained by partitioning of P and W into metal during formation of a small core by separation of liquid metal from silicate at low degrees of partial melting of the silicates. The W/La ratios in the Earth and Moon are virtually indistinguishable, while P/La ratios differ by a factor of two. The concentrations of FeO also appear to be different. These observations are difficult to reconcile with the hypothesis of a terrestrial origin of the Moon following formation of the Earth's core, but are consistent with independent formation of the Earth and Moon.

Patchett, P. J. (U.S. Geological Survey, Denver Federal Center, Lakewood, CO 80225): 'Importance of the Lu–Hf Isotopic System in Studies of Planetary Chronology and Chemical Evolution', *Geochim. Cosmochim. Acta* **47**, 81–91 (1983)

The ^{176}Lu-^{176}Hf isotope method and its applications in earth sciences are discussed. Greater fractionation of Lu/Hf than Sm/Nd in planetary magmatic processes makes $^{176}Hf/^{177}Hf$ a powerful geochemical tracer. In general, proportional variations of $^{176}Hf/^{177}Hf$ exceed those of $^{143}Nd/^{144}Nd$ by factors of 1.5–3 in terrestrial and lunar materials. Lu-Hf studies therefore have a major contribution to make in understanding of terrestrial and other planetary evolution through time, and this is the principal importance of Lu-Hf. New data on basalts from oceanic islands show unequivocally that whereas considerable divergences occur in $^{176}Hf/^{177}Hf$–$^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$–$^{87}Sr/^{86}Sr$ diagrams, $^{176}Hf/^{177}Hf$ and $^{143}Nd/^{144}Nd$ display a single, linear isotopic variation in the suboceanic mantle. These discordant $^{87}Sr/^{86}Sr$ relationships may allow, with the acquisition of further Hf-Nd-Sr isotipic data, a distinction between processes such as mantle metasomatism, influence of seawater-altered material in the magma source, or recycling of sediments into the matle. In order to evaluate the Hf-Nd isotopic correlation in terms of mantle fractionaltion history, there is a need for measurements of Hf distribution coefficients between silicate minerals and liquids, and specifically for a knowledge of Hf behaviour in relation to rare earth elements. For studying ancient terrestrial Hf isotopic variations, the best quality Hf isotope data are obtained from granitoid rocks or zircons. New data show that very U-Pb discordant zircons may have upwardly-biased $^{176}Hf/^{177}Hf$, but that at least concordant to slightly discordant zircons appear to be reliable carriers of initial $^{176}Hf/^{177}Hf$. Until the controls on addition of radiogenic Hf to zircon are understood, combined zircon-whole rock studies are recommended. Lu-Hf has been demonstrated as a viable tool for dating of ancient terrestrial and extraterrestrial samples, but because it offers little advantage over existing methods, is unlikely to find wide application in pure chronological studies.

Reedy, R. C., Arnold, J. R., and Lal, D. (Nuclear Chemistry Group, Los Alamos National Lab., Los Alamos, NM 87545): 'Cosmic-Ray Record in Solar System Matter', *Science* **219**, 127–135 (1983)

The energetic nuclei in cosmic rays interact with meteoroids, the Moon, planets, and other solar system matter. The nuclides and heavy nuclei tracks produced by the cosmic-ray particles in these targets contain a wealth of information about the history of the objects and temporal and spatial variations in the particle fluxes. Most lunar samples and many meteorites have complex histories of cosmic ray exposure from erosion, gardening, fragmentation, orbital changes, and other processes. There appear to be variations in the past fluxes of solar particles, and possibly also galactic cosmic rays, on time scales of 10^4 to 10^7 yr.

Rhodes, J. M. (Univ. of Massachusetts, Amherst, MA 01003): 'Homogeneity of Lava Flows: Chemical Data for Historic Mauna Loan Eruptions', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* 88, Suppl. A869–A879 (1983)

Chemical analyses of basalts collected from the major historic eruptions of Mauna Loa volcano show that many of the flow fields are remarkably homogeneous in composition. Despite their large size (lengths 9–85 km), large areal extents (14–114 km^2), and various durations of eruption (1–450 days), many of the flow fields have compositional variability that is within, or close to, the analytical error for most elements. The flow fields that are not homogeneous vary mainly in olivine content in an otherwise homogeneous melt. Some are composite flow fields made up of several, apparently homogeneous vary mainly in olivinc content in an otherwise homogeneous melt. Some are composite flow fields made up of several, apparently homogeneous subunits erupted at different elevations along the active volcano rifts. Not all volcanoes produce lavas that are homogeneous like those of Mauna Loa. If we are to use studies such as this to evaluate compositional diversity in lavas where there is a lack of sampling control, such as on other planets, it is necessary to understand why some flow units and flow field are compositionally homogeneous and others are not, and to develop criteria for distinguishing between them.

Shirley, D. N. (Inst. of Geophysics and Planetary Physics, Univ. of California, Los Angeles, CA 90024): 'A Partially Molten Magma Ocean Model', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* 88, Suppl. A519–A527 (1983)

The properties of the lunar crust and upper mantle can be explained if the outer 300–400 km of the Moon was initially only partially molten rather than fully molten. The top of the partially molten region contained about 20% melt and decreased to 0% at 300–400 km depth. Nuclei of anorthositic crust formed over localized bodies of magma segregated from the partial melt, then grew peripherally until they covered the Moon. Throughout most of its growth period the anorthosite crust floated on a layer of magma a few km thick. The thickness of this layer is regulated by the opposing forces of loss of material by fractional crystallization and addition of magma from the partial melt below. Concentrations of Sr, Eu, and Sm in pristine ferroan anorthosites are found to be consistent with this model, as are trends for the ferroan anorthosites and Mg-rich suites on a diagram of An in plagioclase vs mg in mafics. Clustering of Eu, Sr, and mg values found among pristine ferroan anorthosites are predicted by this model.

Slavin, J. A., Holzer, R. E., Spreiter, J. R., Stahara, S. S., and Chaussee, D. S. (Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA 91109): 'Solar Wind FLow About the Terrestrial Planets 2. Comparison with Gas Dynamic Theory and Implications for Solar-Planetary Interactions', *J. Geophys. Res.* 88, 19–35 (1983)

This study utilizes gas dynamic calculations in conjunction with observational bow shock models to investigate the solar wind flow patterns about the terrestrial planets. Average dayside bow shock position could be predicted for the Earth by theory with an error of only ~ 2%, given the observed shape and location of the magnetopause. Accordingly, our findings confirm the validity of the single-fluid gas dynamic approximation for describing this major aspect of solar wind flow past the Earth. Modeled using gas dynamic theory, the solar wind interactions with Venus and Mars exhibit very significant differences. At Mars the mean inferred altitude of the solar wind–obstacel interface varies from 510 km at the stagnation point to almost 1000 km near the terminator. The effective magnetic moment required to produce a magnetosphere of this size for average solar wind dynamic pressures

and terrestrial-type internal current systems is $1.4 \pm 0.6 \times 10^{22}$ G cm^3. Gas dynamic modeling of the January 21, 1972, Mars 3 and July 20, 1976, Viking 1 lander particles and fields observations supports the conclusion that the Martian obstacle to the solar wind lies at altitudes too high for it to be associated with only an ionospheric or atmospheric interaction. In contrast with Mars, our modeling of the Venus observations has found that the bow wave is closer to the planet than would be expected for a purely ionospheric obstacle. The subsolar width of the Venus ionosheath in the Venera and PVO measurements is only 60% and 90%, respectively, of that predicted by the gas dynamic model. This result is attributed to the presence of solar wind–neutral atmosphere interactions in the lower ionosheath that are not included in the gas dynamic code.

Stiller, D., Belderson, R. H., and Higgins, C. G.: 'Comments and Reply on Drainage Systemds Developed by Sapping on Earth and Mars', *Geology* **11**, 54–56 (1983)

Turcotte, D. L. (Dept. of Geological Sciences, Cornell Univ., Ithaca, NY 14853): 'Thermal Stresses in Planetary Elastic Lithospheres', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A585–A587 (1983)

The role of thermal stresses in the tectonics of the Moon is reexamined in this paper. A model is used that considers a spherical elastic shell overlying a fluid core. It is shown that the thermal stresses generated by temperature changes within the shell usually dominate over the thermal contraction or expansion of the core. During the entire evolution of the Moon the cooling of the lithosphere is likely to have dominated the cooling of the interior and the result would be tensional lithospheric thermal stresses. However, during the recent evolution of the Moon the change in the near surface thermal stresses is compressional. It is argued that the surface compressional features on Mercury are not due to the thermal contraction of the interior.

PLANETS

Brown R. A., Shemansky, D. E., and Johnson, R. E. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 85721): 'A Deficiency of O III in the Io Plasma Torus', *Astrophys. J.* **264**, 309–323 (1983)

A search for the O III 5007 Å line in the hot region of the Io plasma torus has set a stringent upper limit on O III abundance (< 4 cm^{-3}). Plasma model calculations of electron collisional ionization-diffusive equilibrium, constrained by observations of other species in the torus, predict much higher O III concentrations. We suggest that an explanation of the apparent O III deficiency may lie in fast ion–ion and ion–atom charge exchange reactions, and a depleted high energy electron component in the post-*Voyager 2* epoch. We use theoretical estimates of a number of charge exchange reactions in a model calculation to predict plasma species partitioning, but it is necessary to assume that the O III is kinetically hot in order to approach the observational limit on concentration. The observed behavior of S II and kinetic energy measurements of S II and S III are also not satisfactorily accounted for in the present calculations in which charge exchange reactions are included. We suggest that an understanding of such peculiarities in the torus plasma may lie in further investigation of ion–ion reactions. We certainly require further observations of emission-line shapes in the torus to establish kinetic energy distributions. An attempt to observe the Cl III lines at 5518 Å and 5538 Å has set emission rate upper limits of 2 R at 2.9 R_J. We report further observations of the S III 6312 Å line at 5.9 R_J giving an average intensity of 58 R with variations ± 40 R.

Gladstone, G. R. and Yung, Y. L. (Div. of Geological and Planetary Sciences, California Inst. of Tech., Pasadena, CA 91109): 'An Analysis of the Reflection Spectrum of Jupiter from 1500 Angströms to 1740 Angströms', *Astrophys. J.* **266**, 415–424 (1983)

A study is made of the UV reflection spectrum of Jupiter as measured by the *International Ultraviolet Explorer*. Detailed modeling reveals the mixing ratios of C_2H_2, C_2H_6, and C_4H_2 to be $(1.0 \pm 0.1) \times 10^{-7}$, $(6.6 \pm 5.3) \times 10^{-6}$, and $(2.9 \pm 2.0) \times 10^{-10}$, respectively, in the pressure region between ~ 3 and

40 mbar. Upper limits in this pressure region for the mixing ratios of C_2H_4 and NH_3 were determined to be $(3.9^{+4.9}_{-3.9}) \times 10^{-10}$ and $(4.2^{+6.7}_{-4.2}) \times 10^{-9}$, respectively. An upper limit to the optical depth of dust above the tropopause, assumit it is well mixed, is $0.2^{+0.3}_{-0.2}$, and an upper limit on the dayglow emission by the Lyman bands of H_2 is $1.4^{+2.4}_{-1.4}$ kR. Comparison with *Voyager results* suggests that the scale height of C_2H_2 in the region of 150–10 mbar is approximately twice that of the bulk atmosphere, consistent with the *IUE* observation of cosine-like limb darkening in the north–south direction on Jupiter in this spectral range. These results are of use in the photochemical modeling of the upper atmosphere of Jupiter.

Goldstein, M. L., Sharma, R. R., Ben-Ari, M., Eviatar, A., and Papadopoulos, K. (NASA Goddard Space Flight Center, Lab. for Extraterrestrial Physics, Greenbelt, MD 20771): 'A Theory of Jovian Decameter Radiation', *J. Geophys. Res.* 88, 792–802 (1983)

A theory of the Jovian decameter radiation is presented based on the assumed existence of beams of energetic electrons in the inner Jovian magnetosphere. Beam-like electron distributions are shown to be unstable to the growth of both upper hybrid and lower hybrid electrostatic waves. The upconversion of these waves to fast extraordinary mode electromegnetic radiation is calculated by using a fluid model. Two possibilities are considered. First, we make a random phase approximation which leads to a very conservative estimate of intensity that can be expected in decameter radiation. The alternative possibility is also considered, viz, that the upconversion process is coherent. A comparison of both processes suggests that an incoherent interaction may be adequate to account for the observed intensity of decametric radiation except perhaps near the peak of the spectrum (8 MHz). The coherent process is intrinsically more efficient and can easily produce the observed intensity near 8 MHz if only 0.01% of the energy in the beam is converted to electrostatic energy.

Kostiuk, T., Mumma, M. J., Espenak, F., Deming, D., Jennings, D. E., Maguire, W., And Zipoy, D. (Infrared and Radio Astronomy Branch, Lab. For Extraterrestrial Physics, NASA Goddard Space Flight Center, Greenbelt, MD 20771): 'Measurements of Stratospheric Ethane in the Jovian South Polar Rgeion from Infrared Heterodyne Spectroscopy of the V, Band near 12 Microns', *Astrophys. J.* **265**, 564–569 (1983)

Ethane emission-line profiles from the South Polar Region of Jupiter were measured at the sub-Doppler resolving powders ($v/\Delta v \approx 10^6$) using the Goddard Space Flight Center infrared heterodyne spectrometer. Lines in the ${}^RQ_3$-branch of the v_9 fundamental of ethane near the $P42$ ${}^{14}C^{16}O_2$ laser transition at 829.9273 cm^{-1} were observed. Comparison with diode laser laboratory spectroscopy showed that the planetary line widths were limited by velocity broadening (~ 200 MHz) due to Jovian rotation within our field of view (FWHM = 2″). Peak brightness temperatures of the lines were measured to be ~ 160 K implying monochromatic (unbroadened) line brightnesses approaching 170 K. Analytical fits to our data were made by direct modeling of the radiative transfer euation using a *Voyager 2* polar temperature profile and various vertical profiles for C_2H_6, H_2, and NH_3. The best fit required a constant C_2H_6:H_2 mixing ratio above the 100 mbar level of 1.2×10^{-6}. These results are compared with previous work and *Voyager* infrared interferometer spectrometer results.

Lanzerotti, L. J. and Brown, W. L. (Bell Labs., Murray Hill, NJ 07974): 'Supply of SO_2 for the Atmosphere of Io', *J. Geophys. Res.* **88**, 989–990 (1983).

We point out that in addition to a vapor pressure equilibrium source for SO_2 in an atmosphere of Io, recent laboratory sputtering results, combined with Voyager-measured particle fluxes, indicate the SO_2 could also result from charged particle erosion of frost deposits on the satellite's surface. On the nightside, and for dayside frost patches where the temperature may be $\leqslant$ 100 K, such erosion will be a dominant mechanism.

McKibben, R. B., Pyle, K. R., and Simpson, J. A. (Enrico Fermi Inst., Univ. of Chicago, Chicago, IL 60637): 'Pioneer 11 Observations of Trapped Particle Absorption by Amalthea', *J. Geophys. Res.* **88**, 36–44 (1983)

During its flyby of Jupiter in 1974, Pioneer 11 passed through a region in which low-energy (~ 1 MeV) trapped protons had been exposed to absorption by Amalthea ($L \simeq 2.5$) only ~ 5 hr earlier. In passing through this region, a brief (~ 10 s duration) decrease was observed in the counting rate of ~ 1 MeV protons measured by the University of Chicago charged particle instrument. We interpret this decrease as a transient signature of the recent absorption of the proton flux by Amalthea. No such clear effects were observed in fluxes of electrons ($E \geqslant 3.4$ MeV) or high-energy nuclei ($Z > 5$, $E \gtrsim 70$ MeV/nucleon) at any corssing of Amalthea's orbit. These observations place an upper limit on the radial diffusion coefficient, κ, for ~ 1 MeV protons at the orbit of Amalthea of $2 \times 10^{-10} R_J^2$/s. By comparison with diffusion coefficients derived from absorption effects by Io ($L \simeq 6$), this limit requires that if the radial diffusion coefficient between $L \simeq 2.5$ and $L \simeq 6$ varies with L as L^n, then $n \geqslant 5$, whereas diffusion driven by atmospheric neutral winds would predict $\kappa \propto L^3$ for low-energy protons. Our results are consistent with diffusion driven by fluctuating electric ($\kappa \propto L^{7-10}$) or magnetic ($\kappa \propto L^{10}$) fields.

Pang, K., Ajello, J. M., Lumme, K., and Bowell, E. (Jet Propulsion Lab., Pasadena, CA 91109): 'Interpretation of Integrated-Disk Photometry of Callisto and Ganymede', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2 *J. Geophys. Res.* 88, Suppl. A569–A576 (1983)

Integrated phase curves of Callisto and Ganymede have been interpreted using the Lumme-Bowell theory. The brightness of these satellites up to about 80° solar phase angle can be explained by the theory, but at larger phase angles (~ 120°), the observed brightness drops off more rapidly than predicted. We suggest a physical explanation for the discrepancy: single regolith particles must have phase functions which are much more elongated in the forward or backward scattering directions than allowed for by the Lumme-Bowell theory. The model parameters derived for Callisto and Ganymede therefore can only approximately represent the surface-scattering properties. For the dark hemisphere of Ganymede, we derive: ρ (roughness) = 1.0, g (asymmetry factor of the single particle scattering function) = −0.2, $\tilde{\omega}_0$ (single-scattering albedo of a particle) = 0.9. For the eastern hemisphere of Callisto, we obtain $\rho = 1.0$ and for the western hemisphere $\rho = 0.4$, with g = − 0.2 and $\tilde{\omega}_0 = 0.5$ for both hemispheres. The hemispheric asymmetry in Callisto's surface texture can be explained by invoking the formation of an ice film on the trailing side. Such an explanation is consistent with Voyager detailed photometry and thermometry of Callisto. Earth-based polarimetric measurements of Callisto are reinterpreted so as not co conflict with the Voyager results.

Pyle, K. R., McKibben, R. B., and Simpson, J. A. (Enrico Fermi Inst., Univ. of Chicago, Chicago, IL 60637): 'Pioneer 11 Observations of Trapped Particle Absorption by the Jovian Ring and the Satellites 1979, J1, J2, and J3', *J. Geophys. Res.* 88, 45–48 (1983)

Pioneer 10 and 11, during their encounters with Jupiter in 1973 and 1974, penetrated to L values of 2.8 and 1.7, respectively. During these encounters, at several L values, decreases in the intensity of energetic trapped particles were observed, some of which could be explained as due to absorption by the known moons Io and Amalthea; however, some decreases inside $L = 4$ could not be explained. The recent Voyager 1 and 2 optical discoveries of several new moons and a ring in this region has led us to reexamine our particle data, and we summarize results in this report. We report observations in three channels: protons 0.5–8.7 MeV; electrons > 3.4 MeV; and medium-Z nuclei, probably oxygen and sulfur > 70 MeV/nucleon. We find that with the additional moons and the ring, all observed intensity features in the stably trapped radiation are accounted for by satellite and ring absorption.

Riddle, A. C. (Cooperative Inst. for Research in Environmental Sciences, Univ. of Colorado/NOAA Boulder, CO 80309): 'Identification of Radio Emission from the Io Flux Tube', *J. Geophys. Res.* 88, 455–458 (1983)

Many theories and observations suggest that Jovian decametric radio emission is generated in flux tubes that pass close to Io's orbit. However, comparison of theory and observation is hindered by lack of knowledge as to which specific flux tube is responsible for a particular emission. In this note, emission from the instantaneous Io flux tube is identified. This makes possible a mapping of emissions onto the causative flux tubes for a significant range of Jovian longitudes (240°–360°).

Skinner, T. E., Durrance, S. T., Feldman, P. D., and Moos, H. W. (Dept. of Physics, Johns Hopkins Univ., Baltimore, MD 21218): 'Temporal Variation of the Jovian H I Lyman-α Emission (1979–1982)', *Astrophys. J.* **265**, L23–L27 (1983)

Observations of the Jovian H I Lyα emission have been made with the *International Ultraviolet Explorer* (*IUE*) observatory beginning in 1978 December, just before the time of the *Voyager* encounters and extending through 1982 January. A nearly constant disk center brightness of about 8.5 kilorayleighs is observed for the central meridian longitude range $\lambda_{III} = 200°$ to 360° and a variable brightness of between 9 and 15 kilorayleighs is found for the range $\lambda_{III} = 50°$ to 150°. These brightness values have persisted throughout the 3 yr of observation, and the hydrogen bulge near $\lambda_{III} = 100°$ appears to be a fixed feature of the Jovian atmosphere. These results indicate that no substantial changes in the Jovian atomic hydrogen concentration, or the average atmospheric conditions have taken place between the time immediately preceding the *Voyager* encounters and the present. The question of Jovian Lyα variability prior to 1978 is reexamined in the light of the *IUE* results.

Smyth, W. H. (Atmospheric and Environmental Research Inc., Cambridge, MA): 'Io's Sodium Cloud: Explanation of the East–West Asymmetries', II., *Astrophys J.* **264**, 708–725 (1983)

A new model has been developed for the sodium cloud of Io to describe its geocentric phase-angle dependent interaction with the solar radiation pressure arising from resonance sacttering of sunlight in the D_1 and D_2 lines. Solar radiation pressure, acting along the Sun–Jupiter line, introduces an asymmetrically directed force into the otherwise cylindrically symmetric gravitational three-body problem as described in a coordinate frame moving with the orbital motion of the satellite about Jupiter. The new model was developed to more quantitatively explore the hypothesis, originally presented in Paper I, that solar radiation pressure provides a mechanism for explaining the east–west asymmetry in the cloud shape discovered by Goldberg *et al.* and the east–west asymmetry in cloud intensity discovered by Bergstralh *et al.* From more recent observational data these separately reported asymmetries now appear to be interrelated. Model calculations presented here confirm the original hypothesis and uncover explicit mechanisms for the observed east–west asymmetries. Model results presented for the cloud intensity do not, however, include the spatially and time dependent sodium lifetime produced by the oscillation of the Io plasma torus about the orbital plane of the satellite. Modifications to these results anticipated upon inclusion of the Io plasma torus in the model are, however, discussed and represent the only major improvement to this model required before proper inversion of the east–west asymmetry data may be undertaken.

Squyres, S. W. (Theoretical and Planetary Studies Branch, M.S. 245-3, NASA Ames Research Center, Moffett Field, CA 94035): 'Gaynmede and Callisto', *American Scientist* **71**, 56–64 (1983)

One of Jupiter's icy moons shows evidence of a period of intense geologic activity, whereas the other appears to have remained dormant.

Squyres, S. W., Reynolds, R. T., and Cassen, P. M. (NASA Ames Research Center, Moffett Field, CA 94035): 'Liquid Water and Active Resurfacing on Europa', *Nature* **301**, 225–226 (1983)

Voyager images of the Jovian moon Europa show a bright icy surface transected by a complex pattern of long, linear fracture-like markings with a slightly lower albedo. Very few impact craters are observed, with size generally in the range 10–20 km. Indicators of surface composition and texture include deep IR H_2O absorption features, UV absorption features characteristic of sulphur in a water matrix on the trailing hemisphere, and a photometric function indicating much more homogeneous scattering than areas of equal albedo on Ganymede and Callisto. Europa's mean denstiy is 3.03 g cm^{-3}, indicating a primarily silicate composition. However, if the density of the silicates is the same as for Io, the H_2O mass fraction would be ~ 7%, enough to form an outer layer of H_2O > 100 km thick if completely differentiated. Several models have been suggested for the evolution and present state of Europa. We present here arguments for recent resurfacing by H_2O from a liquid layer, based on new interpretations of recent spacecraft and Earth-based observations and revised theoretical calculations.

2. Mars

Carr, M. H. (U.S. Geological Survey, Menlo Park, CA 94025): 'The Surface of Mars: A Post-Viking View', *Mercury* **12**, 2–15 (1983)

In many ways Mars resembles the Earth. It has an atmosphere, although a much thinner one than the Earth, and a surface that has been modified by the wind to produce a variety of erosional and depositional landforms. There is abundant evidence of near-surface water, either as ice of liquid. The water appears to have eroded parts of the surface and reacted with the surface materials to produce weathering. The surface also provides abundant evidence of deformation and volcanism, and both seem to have continued into the relatively recent geologic past. However, despite these similarities, differences between Mars and the Earth are profound.

A major cause of the differences between the two planets is the contrasting mobility of their crusts. The geology of the Earth's surface is dominated by the effects of plate motion. Interaction between the Earth's plates controls the distribution of continents, the formation of mountain chains, the location of volcanic and tectonic activity, and the general style of crustal deformation. Indeed there are few geologic processes that are not affected in some way by plate tectonics. In contrast, the Mars crust is fixed, and all those earthly features that characterize interaction between the plates (such as linear mountain chains and linear ocean deeps) are absent. The stability also results in preservation of the ancient surface record in almost all areas of the planet.

The second reason for the differences between the surfaces of Earth and Mars is the presence of abundant liquid water on Earth. Water plays an essential role in two major processes: (1) weathering – the chemical breakdown of rock-forming minerals to form assemblages more in balance with conditions at the surface, and (2) gradation–the steady smoothing of the surface by erosion. Both processes are complemented on Earth by opposing processes such as metamorphism, in which the rocky materials' characteristics are continually altered by heating, and tectonic activity, which tends to accentuate heights and depths on the surface. The Earth's surface is thus a complicated system, in which material is being recycled both through the mantle (by subduction, where one continental plate is forced downward, under another, and by ocean-floor spreading) and within the crust and oceans (by weathering, metamorphism, and erosion).

The dynamics of the Martian crust are totally different. Although the planet has been volcanically and tectonically active throughout much of its history, the crust appears not to have been recycled through underlying regions. Huge volcanoes have formed, as well as vast fracture systems, but the activity is not concentrated in linear zones as on the Earth, but rather affects areas of broad regional extent. Furthermore, although water has probably flowed across the Martian surface at times in the past, fluvial erosion has been trivial. Where channels are present, they mostly wind between the craters or down the crater rims, but rarely has erosion been sufficiently sustained to wear away the craters themselves. Erosion of young features, such as the large volcanoes, is imperceptible.

On Earth, formation of large features like mountains is followed by enhanced erosion and other levelling processes, so that a rough equilibrium is maintained. On Mars, because of the very limited erosion and deposition rates, no such equilibrium is achieved. If relief is created (such as a volcano or impact crater), it remains almost indefinitely. If any equilibrium is achieved it is not by way of surface processes (like erosion), but rather with the ability of the crust to support the loads created by the relief. As a consequence Mars, despite its smaller size, has a surface with considerably more spectacular height differences than does the Earth. Volcanoes have grown to almost three times the height of Mt. Everest, canyons several kilometers deep have survived for billions of years, and a broad 10 km high bulge of continental dimensions has apparently persisted in Tharsis for much of the planet's history.

The end result of the peculiar Martian crust and erosion characteristics is an active planet with enormous surface relief, on which features with a wide range of ages are preserved in almost pristine conditions.

Cordell, B. (California State College, Bakersfield, CA 93309): 'The First Martians', *Astronomy* **11**(3) 7–17 (1983)

The merits of manned missions to Mars are outlined.

Eberhart, J.: 'Message from Earth: Viking Phone Home', *Science News* **123**, 20 (1983)

The interruption of the Viking 1 transmissions from Mars is reported.

Eberhart, J.: 'Viking: Still No Word from Mars', *Science News* **123**, 117 (1983)

Gibson, E. K., Wentworth, S. J., and McKay, D. S (SN4, Experimental Planetology Branch, NASA Johnson Space Center, Houston, TX 77058): 'Chemical Weathering and Diagenesis of a Cold Desert Soil from Wright Valley, Antarctica: An Analog of Martian Weathering Processes', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A912–A928 (1983)

Weathering, diagenesis, and chemical alteration of a soil profile from the Dry Valleys of Antarctica have been studied as an analog to soil development within the Martian regolith. Soil samples from a one-meter-deep soil pit on Prospect Mesa, Wright Valley, have been examined for their major element concentrations, water soluble cations and anions, carbon, sulfur, and water concentrations, and related petrographic characteristics of weathering in a cold, dry environment. Petrographic study of the soil samples indicates that most silicate mineral and lithic fragments exhibit some degree of alteration. Chemical alteration occurs in samples both from above and from within the permanently frozen zone. Concentrations of water soluble cations (Na^+, K^+, Ca^{2+}) and anions (Cl^-, SO_4^{2-}, NO_3^-) decrease significantly from the surface to the permanently frozen zone, suggesting major movement of water soluble species. Enrichments in secondary mineral abundances correlate with the water soluble ion concentrations. Formation of zeolites is observed throughout the soil column and may be potential reservoirs for volatile storage within the regolith. From the detailed study of the Dry Valley soils, an idealized soil profile for the regolith has been developed and is suggested as applicable to other planetary surfaces, especially the Martian near-surface environment. The soil profile consists of four zones: aeolian, salt, active, and permanently frozen.

Hutchings, E. Jr. (Div. of Humanities and Social Sciences, California Inst. of Tech. Pasadena, CA 91125): 'The Autonomous Viking', *Science* **219**, 803–808 (1983)

The two Viking spacecraft launched to Mars in 1975 were designed for 90 days of intense observations followed by an extended mission phase to end in 1978. Because the spacefraft were still operating so well in 1978, three more mission phases were added and the project was not officially terminated until 1980. During these last three mission phases delays in controlling the orbiters from the Earth increased. The spacecraft were kept functioning and the length of the Viking mission was extended because the ground crew, over a period of 2 yr, gradually made the orbiters autonomous.

Lucchitta, B. K. and Ferguson, H. M. (U.S. Geological Survey, 2255 North Gemini Drive, Flagstaff, AZ 86001): 'Chryse Basin Channels: Low Gradients and Ponded Flows', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A553–A586 (1983)

Gradients on the floors of the Martian outflow channels that are derived from radar-elevation profiles across Lunae Planum and the Chryse Basin have much lower values than those obtained from the U.S. Geological Survey's topographic map. To arrive at this conclusion, 26 radar-elevation profiles clustered at four latitudinal channel crossings were analyzed and approximate longitudinal gradients of the channel floors were constructed. Whereas the gradients of Maja and Ares Valles are similar to those of the catastrophic flood channels in the Scablands of Washington State and water or ice could have moved through them without difficulty, the gradients of Simud and Tiu Valles are essentially level, and the movement of fluids to the north poses problems. It is proposed that pondering from local runoff occurred before channel formation along the course of Simud and Tiu Valles. The ponding may have formed lakes in depressions associated with the Valles Marineris grabens, ancient craters in the chaotic terrain area, and possible even the regional low where most chaotic terrains occur. It is envisioned that lakes eventually overflowed, drainages became integrated, and headward erosion breached interfluves, thus forming the present channel configurations. When dams broke, floods, mudflows, or mixtures of

water, sediments, and ice were released catastrophically, with a ninal gigantic flood from the Valles Marineris system of troughs. This flood would have had sufficient head to move fluids across nearly level gradients through the Simud and Tiu channels. The ponding and flooding probably occurred during a time when the climate was different from that at present, permitting surface runoff of fluids and standing bodies of water.

Nummedal, D., Masursky, H., and Mainguet, M.: Comment on 'Origin of Martian Outflow Channels: The Eolian Hypothesis', by James A. Cutts and Karl R. Blasius,' *J. Geophys. Res.* **88**, 1243–1244 (1983)

Parker, D. C., Capen, C. F., and Beish, J. D. 'Exploring the Martian Arctic', *Sky Telesc.* **65**, 218–220 (1983)

5. Pluto

Binzel, R. P. and Mulholland, J. D. (McDonald Observatory and Dept. of Astronomy, Univ. of Texas at Austin, Austin, TX 78712): 'Photometry of Pluto During the 1982 Opposition', *Astron. J.* **88**, 222–225 (1983)

Observations of Pluto's brightness were obtained by two-channel photometry on 18 nights during the 1982 opposition, using the 2.1 m and 91 cm reflectors at Mt. Locke. The resulting light curve suggests that the 'secular' decrease in intrinsic brightness is flattening, qualitatively consistent with a latitude dependence of the surface albedo distribution. Speculations are projected for the long-term behavior of the apparent light curve. Understanding of the current rotational brightness variation is important to the maximum utilization of photometric observations obtained during the imminent series of mutual eclipses between Pluton and its satellite.

Zappala, V., De Sanctis, G., and Ferreri, W. (Osservatorio Astronomico di Torino, I-10025 Pino Torines, Italy): 'Astrometric Positions of Pluto from 1980–1982', *Astron. Astrophys.* Suppl. **51**, 385–387 (1983)

16 positions of the planet Pluto were obtained at the Astronomical Observatory of Torino from 1980 to 1982. An analysis of the differences $(O\text{-}C)_x$ and $(O\text{-}C)_\delta$ obtained by a comparison with the ephemerides by Kaplan *et al.* (1972) and Kaplan (1980) suggests to continue the observational program for improving the accuracy of the ephemeris.

6. Saturn

Aubier, M. G., Meyer-Vernet, N., and Pedersen, B. M. (Observatoire de Meudon, 92190 Meudon, France): 'Shot Noise from Grain and Particle Impacts in Saturn's Ring Plane', *Geophys. Res. Letters* **10**, 5–8 (1983)

The ring plane event detected by the Voyager 1 and 2 Planetary Radio Astronomy experiment is distinct from Saturn kilometric radiation (SKR) and from Saturn electrostatic discharges (SED). It consists of radio noises recorded only during Saturnian ring plane crossings. Several models are tested. The electrostatic noise on the antennas resulting from the passage of electrons and ions near the antennas (quasi-thermal noise) leads to order of magnitude much lower than the observed values. Shot noise due to electrons and ions collected and/or emitted by the antennas and spacecraft can explain the noise recorded during Saturn Voyager 1 ring plane crossing and partly what is observed in the case of Voyager 2. For this latter event we must introduce the shot noise due to grain impacts. A quantitative approach of this process gives an estimation of the dust size $\sim 2.3\ \mu m$ just outside the G-ring.

Blake, J. B., Hilton, H. H., and Margolis, S. H. (Space Sciences Lab., The Aerospace Corp., Los Angeles, CA 90009): 'On the Injection of Cosmic Ray Secondaries into the Inner Saturnian Magnetosphere 1. Protons from the Crand Process', *J. Geophys. Res.* **88**, 803–807 (1983)

The energy spectra and pitch angle distributions of energetic protons injected into the inner Saturnian magnetosphere by the cosmic ray albedo neutron decay (CRAND) process have been calculated using the nucleon transport code HETC. These calculations predict spectra and pitch angle distributions consonant with the Pioneer and Voyager observations for proton energies above ~ 50 MeV assuming that the ring particles are ice, not rock, and that the mean mass seen by the cosmic rays is several tens to a few hundred grams per square centimeter.

Eviatar, A., McNutt, R. L., Jr., Siscoe, G. L., and Sullivan, J. D. (Dept. of Atmospheric Sciences, Univ. of California, Los Angeles, CA 90024): 'Heavy Ions in the Outer Kronian Magnetosphere', *J. Geophys. Res.* **88**, 823–831 (1983)

Data from the plasma science experiment on Voyager 1 show the existence of a cold heavy ion component in the plasma populating the outer Kronian magnetosphere ($L \approx 15$). The mass resolution is not sufficient to determine unambiguously whether the ions are oxygen (O^+ mass 16) or nitrogen (N^+ mass 14). If the former, their most probably origin is sputtering off the rings and icy satellites, which lie well inside the site of observation. Outward transport is therfore required. If the latter, the most probably source is the plume of Titan, and inward transport to the observing site is required. The near-resonant charge exchange reaction between oxygen ions and hydrogen atoms in the neutral hydrogen torus of Titan makes it most probably that the heavy ions are nitrogen from Titan. Mass loading of the outer magnetisphere by ions from Titan impedes corotation but to a somewhat lesser extent than would be expected on the basis of the inferred source strength of Titan and the Pedersen conductance of the ionosphere of Saturn. However, the disagreement falls within the combined reasonable uncertainties in the governing parameters. The presence of heavy ions tends to exclude hydrogen ions from the equator, since lighter ions 'float' to the top in the centrifugal potential. We speculate that depletion of heavy ions near $L = 14$ by charge exchange with neutral hydrogen may be the cause of the observed absence of hydrogen ions off the equator in this region.

Eviatar, A. and Podolak, M. (Dept. of Atmospheric Sciences, Univ. of California, Los Angeles, CA 90024): 'Titan's Gas and Plasma Torus', *J. Geophys. Res.* **88**, 833–840 (1983)

We asses the implications of the Voyager observations for a steady state model of a torus of hydrogen and nitrogen neutral gas and plasma. We constrain the nitrogen neutral density, the neutral hydrogen and nitrogen escape fluxes (from Titan), and the diffusion rate in terms of observed or inferred quantities. The results obtained are consistent with the Voyager observations.

Handel, P. H. and James, P. B. (Physics Dept., Univ. of Missouri, St. Louis, MO 63121): 'Polarization Catastrophe Model of Static Electrification and Spokes in the B-Ring of Saturn', *Geophys. Res. Letters* **10**, 1–4 (1983)

An explanation of the charging mechanism operating in the B-ring of Saturn is offered in terms of a Clausius-Mossotti type polarization catastrophe based on the peculiar ferroelectric properties of ice. Polarization charges of 400 Coulombs and electrostatic energies of 3×10^9 Joules are estimated.

Hood, L. L. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 85721): 'Radial Diffusion in Saturn's Radiation Belts: A Modeling Analysis Assuming Satellite and Ring E Absorption', *J. Geophys. Res.* **88**, 808–818 (1983)

Phase space density profiles derived by Pioneer 11 and Voyager 1 investigators for Saturnian radiation-belt protons with zero second adiabatic invariants and first invarienats μ of 600. 1100, 2500, 5000, 10 000, and 20 000 MeV/G have been analyzed for the purpose of inferring the amplitude and L dependence of the time-averaged radial diffusion coefficient $D(L)$ in the inner magnetosphere. Three models for solid-body absorption outside of $L = 3$ were considered. The first included satellite absorption only with satellites represented as simple geometric absorbers in an axially symmetric planetary magnetic field. The remaining two models included additional absorption by Ring E using a representative optical depth profile derived from ground-based telescopic measurements and two possible characteristic latitudinal ring thicknesses. Minimum Ring E encounter times were estimated by

assuming that the mirror latitude appropriate for the sampled protons is less than the maximum magnetic latitude of Ring E. The Ring E encounter times are generally longer than the estimated satellite absorption times for protons of these energies. Additional Ring E loss processes such as charge exchange in a possible associated torus could significantly reduce the effective loss times but are not considered in the present work. A low-order L dependence ($D(L) \propto L^2$, L^3, or L^4) was selected via a minimum-variance criterion for five of the six data prodiles studied for either of the three assumed absorption models. The cumulative number of selection occurrences for given assumed L dependences suggests a diffusion coefficient proportional to $L^{3\pm1}$. The preferred amplidude D_0 obtained for a given set of experimental phase space densities varies by a factor of 2 or 3 depending on which solid-body absorption model was assumed. For $\mu \leqslant 2500$ MeV/G forms for $D(L)$ ranging from $0.5 \times 10^{-9} L^{3\pm1}$ to $1.5 \times 10^{-9} L^{3\pm1}\,s^{-1}$ were obtained. For $\mu > 2500$ MeV/G the inferred amplitudes increased approximately monotonically with increasing μ reaching a maximum near $10^{-8} L^{3\pm1}\,s^{-1}$ at $\mu = 20{,}000$ MeV/G. The latter increase may be an artificial consequence either of inappropriateness of the higher-energy proton data profiles for analysis assuming simple diffusive transport or of underestimating the satellite absorption times at the highest proton energies. The inferred form for $D(L)$ is least consistent with 'terrestrial-type' diffusion mechanisms including magnetic impulses ($D(L) \propto L^{10}$) and electrostatic impulses of magnetospheric origin ($D(L) \propto L^6$ for $\mu \ll 20L^2$ MeV/G and $D(L) \sim L^{10}/\mu^2$ for $\mu \gg 20L^2$ MeV/G). Theoretical models for 'Jovian-type' diffusion via the ionospheric dynamo mechanism or the centrifugal interchange instability in regions of strong negative radial plasma density gradients predict lower-order L dependences that appear to be more consistent with the inferred form.

Ip, W.-H. (Max-Planck-Institut für Aeronomie, D-3411 Katlenburg-Lindau 3, F.R.G.): 'On Plasma Transport in the Vicinity of the Rings of Saturn: A Siphon Flow Mechanism', *J. Geophys. Res.* 88, 819–822 (1983)

The unique combination of a rapidly rotating ionosphere and meteroid impact ionization at the rings of Saturn provides the elements of many interesting plasma transport phenomena. One of the most significant processes might be the upward field-aligned flow of the impact plasma at the equatorial region inside $1.6252\,R_S$. Such a siphoning mechanism limits the efficiency of ring plane matter recycling to a minimum and could lead to appreciable loss of ring mass in this region. At the same time, channeling of the heavy ions into the mid-altitude ionosphere could also cause a large reduction in the ionospheric electron content as observed by the Pioneer 11 and the Voyager radio science experiments. The resulting electrodynamical coupling of the Saturnian rings with the ionosphere thus represents a completely new kind of ionospheric process than studied before.

Mendis, D. A., Hill, J. R., and Houpis, H. L. F. (Dept. of Electrical Engineering and Computer Science, Univ. of California at San Diego, La Jolla, CA 92093): 'Charged Dust in Saturn's Magnetosphere', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* 88, Suppl. A929–A942 (1983)

Gravito-electrodynamic theory of charged dust grains is used to explain a variety of phenomena in those portions of the Saturnian ring system that are known to be dominated by fine (micron- and submicron-sized) dust, and in which collisonal forces and Coulomb drag can be neglected. Among the phenomena discussed are the formation and evolution of the rotating near-radial spokes in the B-ring, the formation of waves in the F-ring, the cause of eccentricities of certain isolated ringlets, and the origin and morphology of the broad diffuse E-ring. Several novel processes predicted by the gravito-electrodynamic theory, including 'magneto-gravitational capture' of exogenic dust by the magnetosphere, '1:1 magneto-gravitational orbital resonances' of charged dust with nearby satellites, and 'gyro-orbital resonances,' are used to explain individual observations. The effect of a ring current associated with this charged dust is also evaluated. Finally, the cosmogonic implications of the magneto-gravitational theory are briefly discussed. While several (although not all) of these processes have been discussed by one or more of the present authors elsewhere, the purpose of this paper is to synthesize all these processes within the framework of graviot-electrodynamics, and also to show its range of applicability within Saturn's ring system.

Moore, J. M. and Ahern, J. L. (School of Geology and Geophysics, Univ. of Oklahoma, Norman, OK 73019): 'The Geology of Tethys', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A577–A584 (1983)

The surface of the Saturnian satellite Tethys has been recognized to consist of four major landforms or physiographic provinces: hilly cratered terrain, the Odysseus impact structure, rifts and lineaments (including Ithaca Chasma), and plains terrain. Two alternate scenarios for the geological evolution of the satellite are developed. The first model assumes that Ithaca Chasma and the other rifts and lineaments were created by the Odysseus impact event. The second model assumes that rifting was a result of the freeze-expansion of Tethys' liquid water interior. In both models, the hilly cratered terrain is postulated to be the oldest unit and the plains terrain, the youngest.

Plescia, J. B. and Boyce, J. M. (Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA 91109): 'Crater Numbers and Geological Histories of Iapetus, Enceladus, Tethys and Hyperion', *Nature* **301**, 666–670 (1983)

Tethys, Iapetus and Enceladus, satellites of Saturn, display surfaces which indicate that geological processes have been active suggesting a certain degree of internal evolution. On Iapetus activity seems to have been confied to the dark terrain and its timing and extent remain unknown. The widest variation of terrains and crater numbers occurs on Enceladus and indicates the most prolonged geological activity of any satellite. Activity on Tethys seems confined to the first few hundred million years. The satellite Hyperion and the co-orbitals 1980S1 and 1980S3 show no geological activity and apparently are fragments of once larger bodies.

Shemansky, D. E. and Ajello, J. M. (Center for Space Science of Southern California, Tucson, AZ 85713): 'The Saturn Spectrum in the EUV – Electron Excited Hydrogen', *J. Geophys. Res.* **88**, 459–464 (1983)

Recent laboratory observations of electron excited H_2 in the EUV have brought about the realization that higher Rydberg series band systems make a significant contribution to the emission spectrum. Theoretical cross section estimates for the excitation of the D, D', B', B'' states agree with these results. Model calcualtions for particle excitation of the Saturn atmosphere, including the higher states, now show excellent agreement with Voyager auroral and dayside equatorial spectra. The model data also confirm the relative spectral response calibration of the Voyager instruments, providing a basis for accurate analysis of the excitation processes on both Jupiter and Saturn.

Slavin, J. A., Smith, E. J., Gazis, P. R., and Mihalov, J. D. (Jet Propulsion Lab., California Inst. of Tech. Pasadena, CA 91109): 'A Pioneer–Voyager Study of the Solar Wind Interaction with Saturn', *Geophys. Res. Letters* **10**, 9–12 (1983)

Voyager 1/2 observations are used to confirm and quantify the unusual bluntness of the dayside Saturn magnetopause suggested by the earlier Pioneer 11 measurements. Once corrected for variations in solar wind pressure, the Saturn observations are found to indicate a magnetospheric radius in the terminator plane equal to 1.8 times the nose distance. This ratio is 30% greater than the terrestrial value and is corroborated by the very blunt shape of the Saturn bow shock and large width of the forward magnetosheath. Possible cause and ramifications of these results for the solar wind interaction with Saturn are discussed.

7. Uranus

Lockwood, G. W., Lutz, B. L., Thompson, D. T., and Warnock, A. (Planetary Research Center, Lowell Observatory, Flagstaff, AZ 86002): 'The Albedo of Uranus', *Astrophys. J.* **266**, 402–414 (1983)

New absolute spectrophotometry of Uranus between 3295 Å and 7676 Å obtained at spectral resolutions of 4 Å and 8 Å during its 1981 apparition is reported and compared with previous observations by Younkin, recorded during the 1961–1963 apparitions. Geometric albedos are calculated, and Bond

albedos are estimated for both sets of data. An increase in brightness of about 14% and a color change occurred during the interval between the epochs of observation, consistent with the high north-polar haze reported by Price and Franz and the change in aspect of the planet. An upper limit to the internal heat source is estimated from energy balance considerations.

Voight, G.-H., Hill, T. W., and Dessler, A. J. (Dept. of Space Physics and Astronomy, Rice Univ., Houston, TX 77251): 'The Magnetosphere of Uranus: Plasma Sources, Convection, and Field Configuration', *Astrophys. J.* **266**, 390–401 (1983)

At the time of the *Voyager 2* flyby of Uranus, the planetary rotational axis will be roughly antiparallel to the solar wind flow. If Uranus has a magnetic dipole moment that is approximately aligned with its spin axis, and if the heliospheric shock has not been encountered, we will have the rare opportunity to observe a 'pole-on' magnetosphere as discussed qualitatively by Siscoe. Qualitative arguments based on analogy with Earth, Jupiter, and Saturn suggest tht the magnetosphere of Uranus may lack a source of plasma adequate to produce significant internal currents, internal convection, and associated effects. In order to provide a test of this hypothesis with the forthcoming *Voyager* measurements, we have constructed a class of approximately self-consistent quantiative magnetohydrostatic equilibrium configurations for a pole-on magnetosphere with variable plasma pressure parameters. Given a few simplifying assumptions, the geometries of the magnetic field and of the tail current sheet can be computed for a given distribution of trapped plasma pressure. The configurations have a single funnel-shaped polar cusp that points directly into the solar wind and a cylindrical tail plasma sheet whose currents close within the tail rather than on the tail magnetopause, and whose length depends on the rate of decrease of thermal plasma pressure down the tail. Interconnection between magnetospheric and interplanetary fields results in a highly asymmetric tail-field configuration. These features were predicted qualitatively by Siscoe; the quantitative models presented here may be useful in the interpretation of *Voyager* encounter results.

8. Venus

Elphic, R. C. and Russell, C. T. (Inst. of Geophysics and Planetary Physics, Univ. of California, Los Angeles, CA 90024): 'Magnetic Flux Ropes in the Venus Ionosphere: Observations and Models', *J. Geophys. Res.* 88, 58–72 (1983)

In this paper we examine the detailed magnetic structure of ropes and quantitatively compare it with a general flux rope model. First, the seemingly chaotic ionospheric magnetic signature is shown to be ordered in a local coordinate system unique to each rope. This signature is also consistent with that expected of a flux rope. We have selected a special subset of the flux rope data that provides detailed information on rope magnetic structure. This subset, referred to as the small impact parameter subset, consists of flux rope traversals on which the spacecraft passed through the center of the structure. We have formulated a model of flux rope structure and have fit it successfully to cases from the small impact parameter subset. From these modeled cases we have inferred that flux ropes are comprised of primarily field-aligned currents with maximum current densities of a few tens of microamps m^{-2} and that parallel electric fields of less than a microvolt/m can drive these currents given the background ionospheric conductivity. We have also found that Joule heating rates within flux roles are much smaller than ambient photoelectron heating. These modeled cases also suggest that flux ropes are satble to pinch-related instabilities like the sausage and planar kink modes, but are unstable to the long-wavelength helical kink mode.

Hedin, A. E., Niemann, H. B., Kasprzak, W. T., and Seiff, A. (NASA Goddard Space Flight Center, Lab. for Planetary Atmospheres, Greenbelt, MD 20771): 'Global Empirical Model of the Venus Thermosphere', *J. Geophys. Res.* 88, 73–83 (1983)

Direct measurements of neutral CO_2, O, CO, N_2, He, and N densities from the Pioneer Venus Orbiter Neutral Mass Spectrometer are described in terms of a spherical harmonic representation (latitude and local time coordinates) of exospheric temperature and number densities at 150 km, using modified

Bates temperature profiles. The exospheric temperatures are determined from the altitude variations of atomic oxygen. A global average temperature of 228 K is derived with a first harmonic variation of 57%. The altitude profiles are extended downward to 100 km by using empirical formulas to provide a transition through the turbopause region (simulating the effect of eddy diffusion and vertical flows) and matching entry probe density data. The model reflects the observed variations of temperature and density with the 10.7 cm radio flux index. For a given change in flux at the planet, the exospheric temperature on Venus changes by only 10% of the change seen in the terrestrial thermosphere.

James, W. W. (Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA 91109): 'Venus Radar Mapping Mission', *Astronomy* **11**(4) 16–22 (1983)

Reasenberg, R. D. and Bills, B. G. (Dept of Earth and Planetary Sciences, Massachusetts Inst. of Technology, Cambridge, MA 02139): Critique of 'Elastic Thickness of the Venus Lithosphere Estimated from Topography and Gravity', by A. Cazenave and K. Dominh, *Geophys. Res. Letters* **10**, 93–96 (1983)

Cazenave and Dominh compare the topography in a portion of the rolling plains province of Venus with a measure of the corresponding gravity perturbations, the residual acceleration of the Pioneer Venus Orbiter. They ignore substantial geometric factors and make unsubstantiated geophysical assumptions to draw conclusions which we consider logically invalid and numerically implausible.

Sjogren, W. L., Bills, B. G., Birkeland, P. W., Esposito, P. B., Konopliv, A. R., Mottinger, N. A., Ritke, S. J., and Phillips, R. J. (Jet Propulsion Lab., Pasadena, CA 91109): 'Venus Gravity Anomalies and Their Correlations with Topography', *J. Geophys. Res.* **88**, 1119–1128 (1983)

This report provides a summary of the high-resolution gravity data obtained from the Pioneer Venus Orbiter radio tracking data. Gravity maps, covering a 70° latitude band through 360° of longitude, are displayed as line-of-sight and vertical gravity. Topography converted to gravity and Bouguer gravity maps are also shown in both systems. Topography to gravity ratios are made over several regions of the planet. There are markedly different ratios for the Aphrodite area as compared to the Beta and Atla areas.

Surkov, Yu. A., Moskalyeva, L. P., Shcheglov, O. P., Kharyukova, V. P., Manvelyan, O. S., Kirichenko, V. S., and Dudin, A. D., (V.I. Vernadsky Inst. of Geochemistry and Analytical Chemistry, U.S.S.R. Academy of Sciences, Moscow, U.S.S.R.): 'Determination of the Elemental Composition of Rocks on Venus by Venera 13 and Venera 14 (Preliminary Results)', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A481–A493 (1983)

Venera 13 and Venera 14 have determined for the first time ever the elemental composition of the Venusian rocks at the probes' landing sites. To study Venusian rocks, rolling upland and flat lowland have been chosen as the most typical of the entire planetary surface. Venera 13 landed on the rolling upland, while Venera 14 landed in the region with lower topography. The chemical composition of the rock at the Venera 13 landing site proved to be similar to the composition of potassium alkaline basalts of the Earth's crust, rocks which can be found on oceanic islands and in rift zones. The chemical composition of the rock at the Venera 14 landing sites is similar to that of tholeiitic basalts of the oceanic crust of the Earth. The comparison of new data on the composition of Venusian rocks with the composition of the rocks of similar provinces on the Earth and the Moon shows that the evolution of the surface and crust of Venus was not similar to that of the Earth and especially not that of the Moon.

Warner, J. L. (NASA Johnson Space Center, Houston, TX 77058): 'Sedimentary Processes and Crustal Cycling on Venus', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A495–A500 (1983)

Sediment exists on the Venus surface. It is observed on Venera images between outcrops and boulders of sedimentary rocks. Sediment is produced by pyroclastic volcanism and chemical weathering.

Chemical weathering is driven by an enhanced activity of water and an elevated surface temperature. Sediment is transported by wind action and lithified by cementation and diagenesis. Cementation may by by carbonate or silica cement; diagenesis may be by prodiucts of chemical weathering acting as cement, or by compaction and recrystallization of sediment into a texture with interlocking grains. Sediment may be transported from the top of sialic continents (such as Ishtar) to the modal plains where it is deposited, lithified, and integrated into the local crust. As new layers are added, the bottom of the crust melts and is, in part, returned to the mantle. A steady-state chemical exchange might exist by this mechanism of crustal cycling that links atmosphere, continents, modal plains, and mantle.

OTHER OBJECTS

1. Asteriods

Debehogne, H., De Sanctis, G., and Zappala, V. (Observatoire Royal de Belgique, 3, Avenue Circulaire, 1180 Bruxelles, Belgium): 'Positions of Asteroids (1981, Part II)', *Astron. Astrophys. Suppl.* **51**, 37–39 (1983)

240 positions of 22 asteroids were obtained from plates taken in 1981 by means of the GPO ($f = 4$ m, $D = 40$ cm) of the Eurpoean Southern Observatory at La Silla, Chile. The reductions were made by the method of dependences using 5 or 6 references stars.

Dermott, S. F. and Murray, C. D. (Lab. for Planetary Studies, Cornell Univ., Ithaca, MY 14853-0355): 'Nature of the Kirkwood Gaps in the Asteroid Belt', *Nature* **301**, 201–205 (1983)

The distributions of orbital eccentricities e and inclinations I near the Jovian resonances in the asteroid belt show that the observed Kirkwood gaps in the distribution of the semimajor axes were formed after the asteriods had dispersed from the near-coplanar disk in which they accreted.

Lagerkvist, C.-I. and Carlsson, I.-M. (Astronomiska Observatoriet, Box 515, 75120 Uppsala, Sweden): 'Studies of Small Asteroids. III. Positions of Asteroids Obtained During September 1978 with the ESO Schmidt Telescope', *Astron. Astrophys. Suppl.* **51**, 341–351 (1983)

48 positions of numbered asteroids, 930 positions of unnumbered asteroids as well as 9 positions of the comet Shajn-Schaldach obtained during September 1978 with the ESO Schmidt telescope are presented

Millis, R. L., Franz, O. G., Wassterman, L. H., and Bowell, E. (Lowell Observatory, Flagstaff, AZ 86002): 'Occultations of Stars by Solar System Objects. III. A Photographic Search for Occultations of Faint Stars by Selected Asteroids', *Astron. J.* **88**, 236–238 (1983)

Occultations of stars fainter than the AGK and SAO catalog limits by selected minor planets during their 1983 apparitions have been identified by scanning plates taken with the 13 in Lowell astrograph. A total of 33 upcoming occulatations have been found involving 1 Ceres, 10 Hygiea, 52 Europa, 65 Cybele, 451 Patientia, 511 Davida, and 704 Interamnia.

Millis, R. L., Wasserman, L. H., Franz, O. G., White, N. M., Bowell, E., Klemola, A., Elliott, R. C., Smethells, W. G., Price, P. M., McKay, C. P., Steel, D. I., Everhart, E., and Everhart, E. M. (Planetary Research Center, Lowell Observatory, Flagstaff, AZ 86002): 'The Diameter of 88 Thisbe from its Occultation of SAO 187124', *Astron. J.* **88**, 229–235 (1983)

The 7 October 1981 occultation of SAO 187124 by 88 Thisbe was observed at 12 sites. The occultation observations, together with information about the asteroids's light curve, give a mean diameter for Thisbe of 232 ± 12 km. This value is 10% larger than previously published radiometric diameter of Thisbe.

Schober, H. J. (Institut für Astronomie, Universitätsplatz 5, A-8010 Graz, Austria: 'Rotation Periods and Light curves of the Asteroids 136 Austria and 238 Hypatia', *Astron. Astrophys.* **117**, 362–364 (1983)

The asteroids 136 Austria and 238 Hypatia were observed photoelectrically in *UBV* during four nights in Feb. 1981 using the 0.6 m Bochum telescope (ESO-time) at the European Southern Observatory, La Silla, Chile.

For 136 Austria a rotation period of $P = 11\overset{h}{.}5 \pm 0\overset{h}{.}1$ ($\hat{=} 0\overset{d}{.}479 \pm 0\overset{d}{.}004$) could be derived with a light curve partially observed and an amplitude of at least 0.40 mag. 238 Hypatia has a rotation period of $P = 8\overset{h}{.}9 \pm 0\overset{h}{.}1$ ($\hat{=} 0\overset{d}{.}004$) and a lightcurve amplitude of 0.12 mag.

For both asteroids *UBV*-colours were measured frequently and no variation during rotation was remarked, exceeding the scatter.

Townsend, C. (Oxnard, CA): 'Minor Planet 1620 Geographos: Circumstances of Its 1983 Passage', *Griffith Observer* **47**(2) 17–18 (1983)

During the course of the photography for the *National Geographic* – Palomar Sky Survey with the 48 inch Schmidt, a streak was detected on one of the plates. It turned out to be the trail of a moving object – a minor planet, or asteroid, – and in honor of the National Geographic Society's part in the Sky Survey, the minor planet was named Geographos. Geographos is an interesting object. It is a member of the Apollo family of asteroids, whose orbits cross the Earth's. At times Geographos can come very close to the Earth, and in 1969, the nearest approach of the century brought Geographos within 5.6 million miles of Earth. The flyby of 1983 isn't that close, but Charles Townsend tellsu that it's worth watching and explains below how to do it.

Wroblewski, H., Torres, C., Barros, S., and Wischnjewsky, M. (Observatorio Astronomico Cerro Calan, Departmento de Astronomia, Universidad de Chile, Casilla 36-D Santiago, Chile): 'Minor Planet Positions Obtained at Cerro Calan Observatory During 1978–80', *Astron. Astrophys. Suppl.* **51**, 93–95 (1983)

236 positions of 19 minor planets observed during the period 1978, 1979, and 1980 with the Gautier Astrograph at Cerro Calan are presented.

2. Comets

Campins, H., Rieke, G. H., and Lebofsky, M. J. (Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 85721): 'Ice in Comet Bowell', *Nature* **301**, 405–406 (1983)

It has been widely accepted that frozen volatiles are the major constituent of a comet nucleus. However, the direct detection of these ices has proved to be difficult: bright comets which are easily observable are generally so close to the Sun that icy grains are too short lived to make an appreciable contribution to the coma brightness, while comets which are far enough from the Sun for ices to survive (heliocentric distance > 2 AU) are usually too faint to be observed adequately. Observations of the reflected light from comets in the 1–5 μm region of the spectrum are diagnostic of the presence of ices. Several attempts have been made to detect absorption bands in this region. A weak, unidentified band near 2.2 μm may have been detected in Comets Bowell and Panther, both of which are at large heliocentric distance; although for Comet Bowell the result could not be confirmed. We now report the detection of a deep absorption at 3.25 μm in Comet Bowell which provides the first direct evidence for the presence of H_2O ice in a comet.

Cook, A. (Griffith Observatory, 2800 East Observatory Road, Los Angeles, CA 90027): 'Comet Halley Update', *Griffith Observer* **47**(2) 8–9 (1983)

Edberg, S. J. (Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA 91109): 'Halley Watch '86', *Astronomy* **11**(3) 18–22 (1983)

Everhart, E. and Marsden, B. G. (Chamberlin Observatory and Physics Dept., Univ. of Denver, Denver, CO 80208): 'New Original and Future Cometary Orbit', *Astton. J.* **88**, 135–137 (1983)

Values of 'original' and 'future' reciprocal semimajor axes are calculated for 28 new osculating cometary orbits derived during the past few years. Values of planetary perturbations are also provided for 16 comets for which accurate osculating orbits are not yet available. No convincing evidence is found for original hyperbolic orbits.

Feldman, P. D. (Johns Hopkins Univ., Baltimore, MD 21218): 'Ultraviolet Spectroscopy and the Composition of Cometary Ice', *Science* **219**, 347–354 (1983)

Our current knowledge of the composition of the cometary nucleus is largely inferred from observations of the gas and dust comae that are produced by sublimation of cometary ice when a comet is near the Sun. During the past decade, far-ultraviolet spectroscopy from above the terrestrial atmosphere has shed new light on the physics and chemistry of the gaseous component of the coma. The advent of interplanetary missions to Halley's comet in 1986 and the development of a new generation of Earth-orbiting observatories promise further insights into the nature of these frozen remnants of the primordial solar system.

Festou, M. C., Keller, H. U., Bertaux, J. L., and Barker, E. S. (Service d'Aeronomie du CNRS, Verrieres-le-Buisson, France): 'Lyman-α Observations of Comets West VI 1976 and P/d'Arrest 1976 XI with Copernicus', *Astrophys. J.* **265**, 925–932 (1983)

Lyman-α observations by the *Copernicus* satellite have been used to determine the production rates of hydrogen atoms of comets West 1976 VI and P/d'Arrest 1976 XI at a time when they were dynamicallly active (splitting or outburst of the nucleus). The observed Lyman-α line widths are in agreement with those observed in comet Kobayashi-Berger-Milon 1975 IX and, consequently, do not contradict the assumption that the H atoms are produced by the photodissociation of water vapor, even in CO-rich comets.

Ip, W.-H. (Max-Planck Institut für Aeronomie, D-3411, Katlenburg-Lindau, F.R.G.): 'On Photochemical Heating of Cometary Comae: The Cases of H_2O and CO-Rich Comets', *Astrophys. J.* **264**, 726–732 (1983)

While energy addition due to photochemical processes in the cometary coma could cause heating as well as acceleration of the expanding neutral gas, this effect is limited by the kinematic property of the energy transfer from the energetic fragments to the bulk flow. For an H_2O comet, the effective scale length of the photochemical zone is estimated to be only 10% of the dimension of the collision region due to the large mass ratio of the H atom and H_2O molecule. If this physical property is taken into consideration, the H_2O gas is found to be expanding at highly supersonic speed (Mach number > 10 for radial distances $\approx 10^3$ km), unlike what was found in a recent study by Marconi and Mendis.

The addition of a mixture ($\sim 30\%$) of CO and/or CO_2 molecules in a medium-bright comet with total production rate $= 10^{29}$ molecule s^{-1} would not change this conclusion since the photodissociation length scales (and hence the dimension of the thermal energy source region) of these molecules are a factor of 10–30 larger than that of the H_2O molecules. Hence, most of the CO and CO_2 molecules will be dissociated outside of the collision zone without depositing the excess kinetic energy to the neutral atmosphere. On the other hand, if the gas production rate is controlled by CO or CO_2, the dimension of the collision zone of a CO comet at 1 Au, for example, will be increased by a factor of 7. This effect would allow the photochemical heating due to CO dissociation to be more effective, causing the atmospheric flow to be weakly supersonic (Mach number ≈ 2–3 for radial distances $\approx 10^4$ km). Hence, this analysis indicates that the neutral gas outflows from H_2O comets and CO comets could be substantially different.

Weissman, P. R. (Earth and Sciences Div., Jet Propulsion Lab., Mail Stop 183–301, 4800 Oak Grove Drive, Pasadena, CA 91109): 'Mass of the Oort Cloud', *Astron. Astrophys.* **118**, 90–94 (1983)

The total total mass of comets in the Oort cloud is calculated. The distribution of cometary masses is found based on the observed distribution of cometary magnitudes corrected for observational selection effects by Everhart (1967), and a derived relationship between brightness and nucleus mass. A cloud population of 1.4×10^{12} comets brighter than $H_{10} = 11$ as found by Weissman (1982) is used. The estimated total mass is 1.15×10^{28} g or 1.9 Earth masses. The probable error in the estimate is about one order of magnitude. Most of the mass of the Oort cloud is concentrated in the size range of the observed long-period comets. The mass estimate is consistent with either cometary formation among the outer planets, or in satellite fragments of the primordial solar nebula.

Yabushita, S. (Dept. of Applied Mathematics and Physics, Kyoto Univ., Kyoto, Japan): 'On the Formation of Cometary Nuclei in Dense Globules', *Astrophys. Space Sci.* **89**, 159–161 (1983)

Evolution of cometary orbits by planetary perturbations, weakly hyperbolic original orbits of comets calculated by Marsden *et al.* (1978) are taken to indicate the interstellar origin of comets, and the possible formation of cometary nuclei in interstellar globules is discussed. The process is sedimantation of dust grains. It is shown that if a globule is at 40 K, its lifetime is sufficiently long to allow the sedimentation.

3. Meteorites

Arnold, J. R., Testa, J. P. Jr., Friedman, P. J., and Kambic, G. X. (Dept. of Chemistry, Univ. of California at Sand Diego, La Jolla, CA 92093): 'Computed Tomographic Analysis of Meteorite Inclusions', *Science* **219**, 383–384 (1983)

The discovery of isotopic anomalies in the calcium- and aluminium-rich inclusions of the Allende meteorite has improved our knowledge of the origin of the solar system. Inability to find more inclusions without destroying the meteorite has hampered further study. By using a fourth-generation computed tomographic scanner with modifications to the software only, the interior of heterogeneous materials such as Allende can be nondestructively probed. The regions of material with high and low atomic numbers are displayed quickly. The object can then be cut to obtain for analysis just the areas of interest.

Bada, J. L., Cronin, J. R., Ho, M.-S., Kvenvolden, K. A., Lawless, J. G., Miller, S. L., Oro, J., and Steinberg, S. (Amino Acids Dating Lab., Scripps Institution of Oceanography, La Jolla, CA 92093): 'On the Reported Optical Activity of Amino Acids in the Murchison Meteorite', and Reply, *Nature* **301**, 494–497 (1983)

In analyses of extracts from the Murchison meteorite (a carbonaceous chondrite), Engel and Nagy reported an excess of L-enantiomers for several protein amino acids but found that the non-protein amino acids were racemic. They suggested that the excess of L-isomers might have resulted from asymmetric synthesis or decomposition. Their results disagree with those obtained previously and they claim this is due to improved methodology. In fact, their extraction method and analytical procedure (gas chromatography–mass spectrometry, GC–MS) was similar to those used in the original report of amino acids in the Murchison meteorite except that they used specific ion monitoring in the GC–MS measurements. We found the results of Engel and Nagy odd in that likely contaminants (the protein amino acids ala, leu, glu, asp and pro) were nonracemic while unlikely contaminants (isovaline and α-amino-*n*-butyric acid) were racemic. For example, Engel and Nagy report that the leucine is ~ 90% L-enantiomer in the water-extracted sample whereas isovaline (α-methyl-α-aminobutyric acid) is racemic. It would be most unusual for an abiotic stereoselective decomposition or synthesis of amino acids to occur with protein amino acids but not with non-protein amino acids. We now show here that the explanation of terrestrial contamination is consistent with their results and is much more probable.

Bogard, D. D., Unruh, D. M., and Tatsumoto, M. (NASA, Johnson Space Center, Houston, TX 77058): '$^{40}AR/^{39}AR$ and U-Th-Pb Dating of Separated Clasts form the Abee E4 Chondrite', *Earth Planet. Sci. Letters* **62**, 132–146 (1983)

Determinations of $^{40}Ar/^{39}Ar$ and U-Th-Pb are reported for three clasts from the Abee (E4) enstatite chondrite, which has been the object of extensive constorium investigations. The clasts give $^{40}Ar/^{39}Ar$ plateau ages and/or maximum ages of 4.5 Gy, whereas two of the clasts give average ages of 4.4 Gy. Within the range of 4.4–4.5 Gy these data do not resolve any possible age differences among the three clasts. ^{206}Pb measured in these clasts is only ~ 1.5–2.5% radiogenic, which leads to relatively large uncertainties in the Pb isochron age and in the $^{207}Pb/^{206}Pb$ model ages. The Pb data indicate that the initial $^{207}Pb/^{206}Pb$ was no more than 0.08 ± 0.07% higher than this ratio in Cañon Diablo troilite. The U-Th-Pb data are consistent with the interpretation that initial formation of these clasts occurred 4.58 Gy ago and that the clasts have since remained closed systems, but are contaminated with terrestrial Pb. The $^{40}Ar/^{39}Ar$ ages could be gas retention ages after clast formation or impact degassing ages. The thermal history of Abee deduced from Ar data appears consistent with that deduced from magnetic data, and suggests that various Abee component experienced separate histories until brecciaction no later than 4.4 Gy ago, and experienced no appreciable subsequent heating.

Chaikin, A.: 'A Stone's Throw from the Planets', *Sky Telesc.* **65**, 122–123 (1983)

Clayton, R. N. and Mayeda, T. K. (Enrico Fermi Inst., Univ. of Chicago, Chicago, IL 60637): 'Oxygen Isotopes in Eucrites, Shergottites, Nakhlites, and Chassignites', *Earth Planet. Sci. Letters* **62**, 1–6 (1983)

Oxygen isotopic analyses ($^{18}O/^{16}O$ and $^{17}O/^{16}O$) have been carried out on three shergottites, two nakhlites, two chassignites, nine eutrites, and seventeen terrestrial samples. The eucrites define a fractionation line displaced from the terrestrial line, with an ^{16}O excess of 0.4%. The shergottites, nakhlites, and Chassigny define another fractionation line with an ^{16}O deficiency of 0.6% relative to the earth. Within each of these two groups, the meteorites have been derived from a common oxygen reservoir, and perhaps a common parent body. The difference between the two groups requires separate reservoirs. Surprisingly, Brachina, previously classified as a chassignite, has an oxygen isotopic composition that lies within the eucrite group.

Di Cicco, D.: 'Wethersfield Meteorite: The Odds Were Astronomical', *Sky Telesc.* **65**, 118–119 (1983)

Eberhart, J.: 'Early Hints at A Moonish Meterorite', *Science News* **123**, 54 (1983)

Goswami, J. N. (Physical Research Lab., Ahmedabad 380 009, India): 'Nuclear Track Records in the Abee Enstatite Chondrite', *Earth Planet. Sci. Letters* **62**, 159–164 (1983)

Nuclear track records in fourteen samples taken from different locations of a cut-slab of the Abee enstatite chondrite were studied to determine its pre-atmospheric mass and de delineate its cosmic ray exposure history. The measured track densities in different samples range from 10^4 to 10^6 cm^{-2}. No significant variations in track densities for individual grains from a given location was found. Excess tracks of fissionogenic origin were found near the grain edges, and across cleavage planes in eight enstatite grains out of ~ 300 grains analysed in the present work. The compaction age of the meteorite could not be obtained due to the absence of suitable oldhamite-enstatite contacts in thick sections. The track data rule out pre-irradiation of any of the analysed samples with shielding less than a few tens of centimeter. The iso-track-density contours on the plane of the slab imply an asymmetric ablation of the Abee chondrite during its atmospheric transit. A spherical body having a radius of ~ 30 cm closely approximates the pre-atmospheric shape and size of the Abee meteorite. The mass loss during ablation was ~ 70% of the original mass.

Goswami, J. N. and MacDougall, J. D. (Physical Research Lab., Ahmedabad-380009, India): 'Nuclear Track and Compositional Studies of Olivines in CI and CM Meterorites', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A755–A764 (1983)

A small fraction of the olivines in CI and CM chondrites contain solar flare tracks. There are no major compositional differences between the irradiated and nonirradiated olivines, suggesting that they form

a single population. Solar flare irradiated grain aggregates and chondrules also occur in CM chondrites. The grain aggregates were irradiated as entities, indicating that they formed prior to solar flare irradiation. Angular distribution data for tracks in irradiated olivine grains suggest a single stage exposure to solar flare radiation in most cases. The combined solar flare track data for olivine grains, grain aggregates, and chondrules require that their irradiation took place with variable shielding and are compatible with the model of Goswami and Lal [1979] in which irradiation took place in the near-surface regions of bodies up to a meter in size. However, they also require partial disaggregation and mixing of these small bodies before or during agglomeration to form larger ($\gtrsim$ km) objects. Irradiation, fragmentation, and redistribution of CI and CM components in their parent body regoliths was probably minimal.

Grieve, R. A. F. and Head, J. W. (Earth Physics Branch, Dept. of Energy, Mines, and Resources, Ottawa, Canada K1A 0Y3): 'The Manicouagan Impact Structure: An Analysis of Its Original Dimensions and Form', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A807–A818 (1983)

Manicouagan, Quebec (51°23′ N; 68°42′ W) is the most intensively studied large complex terrestrial impact structure in a predominantly crystalline target. The ground truth data available from Manicouagan have considerable potential for interpreting the subsurface characteristics of lunar impact structures of comparable morphology and size. Two contrasting hypotheses, however, exist for the preerosional form of Manicouagan: (1) a multi-ring basin with a final diameter of 75 km and a transient cavity diameter of 30–45 km (Floran and Dence, 1976) and (2) an endogenically modified peak-ring basin with a final diameter of 100 km and a transient cavity diameter of 80 km (Orphal and Schultz, 1978). Both hypotheses are based largely on topographic data and interpret the prominent 65 km diameter annular moat as a graben-like feature formed either (1) by collapse of the outer slope of the transient cavity rim or (2) by uplift of the final crater floor through post-impact intrusive activity.

The present analysis suggests that this annualr moat is primarily an erosional feature and that the original form of the impact structure cannot be determined unequivocally on the basis of present topography. If all the available topographic, geologic, and geophysical data are considered, however, then an internally consistent interpretation of original dimensions is possible. The distribution of shock deformation effects in the basement rocks of the present crater floor suggests an original transient cavity diameter of 60 km. The 55 km-diameter, impact melt-covered inner plateau provides a minimum estimate for the diameter of the final floor of the crater and the annular moat, with its outliers of downdropped Ordovician limestone, is interpreted as marking the contact between the floor and the innermost slump blocks of the final rim. There is no compelling evidence to regard the annular moat as a graben. By analogy with fresh lunar and mercurian structures, a floor width of 55 km suggests a final rim diameter of 86–95 km. This is consistent with the topographic data from outside the annular moat and with the residual peripheral gravity low, which suggests a final rim diameter of 85–95 km. Due to erosion, it is difficult to assign Manicouagan to a particular morphological class of impact structure, but on the basis of the available data it is most likely that the preerosional form was that of a central peak crater or possibly a peak-ring basin. At the time of its formation, Manicougan may have been dimensionally and possibly morphologically similar to the 96 km diameter lunar crater Copernicus.

Harris, M. J. (W.K. Kellogg Radiation Lab., California Inst. of Tech., Pasadena, CA 91109): 'The Sp-Process and Allende Isotope Anomalies in Calcium and Titanium', *Astrophys. J.* **264**, 613–619 (1983)

Slow proton captures (on a time scale $\gg$ weak-interaction time scales) on $18 \leqslant Z \leqslant 25$ nuclei at temperatures in the range $1.25 \leqslant T_9 \leqslant 1.7$ can reproduce the Ca isotopic anomaly in Allende Ca-Al-rich FUN inclusion EK-1-4-1. At $T_9 = 1.55$ the required proton exposure approximately reproduces the EK-1-4-1 Ti anomaly also. Under these conditions the production of long-lived ^{41}Ca and ^{53}Mn and of an anomaly in Cr is predicted.

Hyman, M. and Rowe, M. W. (Dept. of Chemistry, Texas A and M Univ., College Station, TX 77843): 'Magnetite in CI Chondrites', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A736–A740 (1983)

On the basis of 939 measurements of the CI chondrites, their magnetite contents have been determined to be: Alais, 8.9 ± 0.9%, Ivina, 11.1 ± 0.3%, Orgueil, 11.0 ± 0.4%, Revelstoke, 9.4% and Tonk, 8.5%. Standard statistical analysis of the data indicates the existence of two subgroups, one comprised of Ivuna and Orgueil, the other of Alais, Revelstoke, and Tonk. While we are not proposing a change in classification, it is clear that distinctive differences exist between the two subgroups. The precision of the method is ≈ ± 3% so that the standard deviations listed reflect the extent of actual variation in magnetite distribution. The wide range, from 6 to nearly 50% Fe_3O_4, in previous estimates of the magnetite content of Orgueil is due to experimental error, not to a real heterogeneity.

Kaiser, T. and Wasserburg, G. J. (Lunatic Asylum, Div. of Geological and Planetary Sciences, California Inst. of Tech., Pasadena, CA 91125): 'The Isotopic Composition and Concentration of Ag in Iron Meterorites and the Origin of Exotic Silver', *Geochim. Cosmochim. Acta* **47**, 43–58 (1983)

The isotopic composition of Ag and the concentration of Ag and Pd have been determined in Canyon Diablo (IA), Grant (IIB), Hoba, Santa Clara. Tlacotepec and Warburton Range (IVB), Piñon and Deep Springs (anom.). Troilite from Grant and Santa Clara have also been analyzed. All of these meteorites, with the exception of Canyon Diablo, give $^{107}Ag/^{109}Ag$ in the metal phase that is greater than the terrestrial value with the enrichments of ^{107}Ag ranging from ~ 2% to 212%. These data show that Ag of anomalous isotopic composition is common to all IVB and anomalous meteorites. The results on Grant suggest that the anomalies may be widespread including more common meteorite groups. There is a general correlation of $^{107}Ag/^{109}Ag$ with Pd/Ag except for the data from FeS of Santa Clara. It is concluded that the excess ^{107}Ag is the result of decay of ^{107}Pd, a nuclide that is extinct at present with an abundance of $^{107}Pd/^{108}Pd$ of about 3×10^{-5}. The troilite in Grant exhibits normal $^{107}Ag/^{109}Ag$ to within errors, a high Ag concentration and a low ratio of $^{108}Pd/^{109}Ag \sim 0.17$. Grant metal has $^{107}Ag/^{109}Ag$ that is ~ 2% greater than normal and a high ratio of $^{108}Pd/^{109}Ag \sim 10^3$. The data from Grant appear to represent a ^{107}Pd-^{107}Ag isochron and indicate that the cooling rate at elevated temperatures was sufficiently rapid to preserve substantial isotopic differences between metal and troilite. Troilite in Santa Clara was found to contain Ag with a very high $^{107}Ag/^{109}Ag$ ratio (108% above normal), an Ag concentration only a factor of three above the metal and a high value of $^{108}Pd/^{109}Ag \sim 1.3 \times 10^4$. The troilite has a higher $^{107}Ag/^{109}Ag$ than the metal. These data are not compatible with a simple model of *in situ* decay and subsequent local Ag redistribution between metal and troilite during cooling. These data suggest that Ag in Santa Clara and possibly other IVB meterorites is made up of almost pure ^{107}Ag produced from ^{107}Pd decay and ^{109}Ag produced by nuclear reactions with only a small amount of 'normal' Ag. This indicates an intense energetic particle bombardment history in the early solar system (~ 10^{20} p/m^2) which occurred after the formation of small planetary bodies. We infer that a T-Tauri activity by the early Sun contributed to some late stage "nucleosynthesis" and the heating of a dust cloud. In addition, implications of the early thermal evolution of iron meterorites are presented based on ^{107}Pd decay and models of the cooling history.

Kashkarov, L. L., Genaeva, L. I., Tarasov, L. S., Baryshnikova, G. V., and Lavrukhina, A. K. (Vernadsky Inst. of Geochemistry and Analytical Chemistry, U.S.S.R. Academy of Sciences, Moscow, U.S.S.R.): 'Radiation History of Lunar Microbreccias and Lithic Chondrules from Weston Meteorite by Track Data', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A765–A772 (1983)

Tracks generated in the lithic chondrules of the brecciated Weston meteorites as well as in the lunar microbreccias by iron group nuclie of solar cosmic rays are studied. The results for about 2000 olivine and pyroxene grains contained in 67 lithic chondrules indicate that a relict irradiation of the material occurred at an early stage in solar system formation, i.e., before these chondrules were assembled. The results for about 1000 olivine and pyroxene grains in 13 microbreccias strengthen our earlier conclusion that part of the chondrules from the Weston meteorite may have formed in processes analogous to brecciation. The newly obtained data confirm that the formation processes of the Weston lithic chondrules, containing solar flare irradiated crystals, were similar to the impact formation of microbreccias on the lunar regolith without heating compacted material up to temperatures of 600°–700° C.

Lipschutz, M. E., Biswas, S., and McSween, H. Y. Jr. (Dept. of Chemistry, Purdue Univ., W. Lafayette, IN 47907): 'Chemical Characteristics and Origin of H Chondrite Regolith Breccias', *Geochim. Cosmochim. Acta* **47**, 169–179 (1983)

We report petrologic data and contents of Ag, Bi, Cd, Co, Cs, Ga, In, Rb, Se, Te, Tl, and Zn-trace elements spanning the volatility/mobility range in light and dark portions of H chondrite regolith breccias and L chondrite fragmental breccias. The chemical/petrologic characteristics of H chondrite regolith breccias differ from those of bon-brecciated chondrites or fragmental breccias. Petrologic characteristics and at least some trace element contents of H chondrite regolith breccias reflect primary processes; contents of the most volatile/mobile elements may reflect either primary or secondary processing, possibly within layered H chondrite parent object(s). Chemical/petrologic differences existed in different regions of the parent(s). Regolith formation and gardening and meteroid compaction were not so severe as to alter compositions markedly.

Marti, K. (Dept. of Chemistry, B-017, Univ. of California at San Diego, La Jolla, CA 92093): 'Preface: The Abee Consortium', *Earth Planet. Sci. Letters* **62**, 116–177 (1983)

Morgan, J. W. and Wandless, G. A. (U.S. Geological Survey, Reston, VA 22092): 'Strangways Crater, Northern Territory, Australia' Siderophile Element Enrichment and Lithophile Element Fractionation', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A819–A829 (1983)

The Strangways Crater, Northern Territory, Australia (15° 12′ S, 133° 35′ E), has a central core, about 10 km in diameter, of shocked granitic gneiss and amphibolite, and some remnants of a melt rock sheet surrounded by outer rings of quartzite and siltstone to a diameter of 20–25 km. Seven samples of melt rock (six granitic melts, one shale melt clast) and four samples of country rock (granitic gneiss, amphibolite, shale, quartzite) were analyzed by neutron-activation analysis: for Sc, Cr, Fe, Co, Zn, Rb, Zr, Sb, Cs, Ba, rare earth elements, Hf, Ta, Th, and U, the samples were analyzed instrumentally; and for Ni, Se, Pd, Ag, Cd, Re, Os, Ir, and Au, they were analyzed radiochemically. Siderophile elements are significantly enriched in the granitic melt rocks relative to country rocks; for example, the Ir enrichments range from 0.6 to 2.8 ppb. The low Ir/Ni ratio (~ 0.16 relative to C1 chondrites) excludes a chondritic impacting body, and Cr enrichment argues against impact by an iron meterorite. The Strangways Crater may have been formed by the impact of an olivine-rich achondrite and melt rocks appear to contain about 3 wt.% of projectile material. The composition of the granitic melt rocks cannot be reproduced by an simple mixture of analyzed country rock types and chemical fractionation by selective shock melting appears to have taken place.

Nagata, T. (National Inst. of Polar Research, Tokyo 173, Japan): 'High Magnetic Coercivity of Meteorites Containing the Ordered Feni (Tetrataenite) as the Major Ferromagnetic Constituent', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A779–A784 (1983)

Three chondrites, Yamato-74160 (LL_6), ALH-77260 (L_3), and St. Séverin (LL_6), contain a considerable amount of the ordered FeNi, tetrataenite, in their metallic components. Natural remanent magnetization (NRM) of the three chondrites contains a highly stable component which can hardly be demagnetized by alternating magnetic fields up to 1800 Oe peak. The highly stable NRM component is identified to the NRM of the tetrataenite phase which as a large magnetic and optical anisotropy. By heating up to about 800 °C, however, the tetrataenite phase is broken down to the ordinary disordered taenite which has a much weaker magnetic coercivity.

Nyquist, L. E. (NASA Johnson Space Center, Houston, TX 77058): 'Do Oblique Impacts Produce Martian Meteorties?', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A785–A798 (1983)

Geochronological and geochemical characteristics of several achondritic meteorites match those expected of Martian rocks. Several authors have suggested that these meteorites might have originated on

Mars, but no satisfactory explanation has been given of how they may have been ejected from the Martian surface. It is suggested here that the oblique impact of large meteroids may produce ejecta which is entrained with the ricoheting projectile and accelerated to velocities in excess of Martian escape velocity. This suggestion is based on earlier experimental studies of oblique impacts and on the observation of several large Martian craters with the characteristic 'butterfly' ejecta pattern produced by low angle impacts. Several acceleration methanisms may act on the Martian ejecta. At high impact velocities, the ricoheting projectile should be vaporized and fluid dynamic drag should act on the entrained ejecta. The drag equation can be integrated for an idealized representation of ricochet and explosion of the projectile. It is shown that large ejecta fragments, on the order of 1–10% of the initial projectile radius, could be drag accelerated to velocities in excess of the Martian escape velocity. Fragments greater than or equal to about a meter in size will escape the Martian atmosphere if they are launched at velocities significantly in excess of the Martian escape velocity. Impacts capable of launching sizable ejecta are expected to occur at a maximum rate of about $4 \times 10^{-8}\,\mathrm{yr}^{-1}$ on Mars and at a comparable or lower rate on the Moon. The long transit time between Mars and Earth would lead to establishment of a steady state population of potential Martian meteorites. The much shorter transit time from the Moon to Earth would cause any lunar ejecta to arrive in spurts which are short in comparison to their repetition rate. Thus the absence of lunar meteorites from our collection could be a simple observational effect due to the short terrestrial lifetime of meteorites. These considerations are preliminary in the sense that several simplifications and assumptions are made. However, they suggest that a Martian origin of the shergottite meteorites is dynamically possible.

Rubin, A. E. and Keil, K. (Dept. of Geology and Inst. of Meteoritics, Univ. of New Mexico, Albuquerque, NM 87131): 'Mineralogy and Petrology of the Abee Enstatie Chondrite Breccia and Its Dark Inclusions', *Earth Planet Sci. Letters* **62**, 118–131 (1983)

The Abee E4 enstatite chondrite breccia consists of clasts (many rimmed by metallic Fe, Ni), dark inclusions and matrix. The clasts and matrix were well equilibrated by thermal metamorphism, as evidenced by uniform mineral compositions, recrystallized chondrules, low MnO content of enstatite and high abundance of orthoenstatite. The clasts acquired their metal-rich rims prior to this metamorphic episode. The occurrence in Abee of relatively unmetamorphosed dark inclusions, clasts with nearly random magnetic orientations and a matrix with a uniform magnetic orientation indicates that clast and matrix metamorphism occurred prior to the agglomeration of the breccia.

The dark inclusions are an unusual kind of enstatie chondritic material, distinguished from the clasts and matrix by their relative enrichments in REE low relative abundances of kamacite, total metallic Fe, Ni and silica, lower niningerite/(total sulfide) ratios, high relative abundances of oldhamite and martensite, smaller euhedral enstatie, more heterogeneous enstatite and metallic Fe, Ni, more calcic enstatie and more nickeliferous schreibersite.

We propose the following model for the petrogenesis of the Abee breccia: The maximum metamorphic temperature of breccia parent materials was $\geqslant 840\,^{\circ}\mathrm{C}$ (the minimum temperature of formation of Abee niningerite) and perhaps near 950–1000 °C (the Fe–Ni–S eutectic temperature). Euhedral enstatite crystals in metallic Fe, Ni- and sulfide-rich areas grew at these metamorphic temperatures into pliable metal and sulfide. Breccia parent material was impact-excavated from depth, admixed with dark inclusions and rapidly cooled (700 to 200 °C in about 2 hr). During this cooling, clast and matrix material acquired thermal remanent magnetization. Random conglomeration of clasts and unconsolidated matrix materials caused the clasts to have random magnetic orientations and the matrix areas to have net magnetic intensities of zero (due to the cancellation of numerous randomly oriented magnetic vectors of equal intensity in the matrix). A subsequent ambient magnetic field imparted a uniform net magnetic orientation to the matrix and caused the magnetic orientations of the clasts to be somewhat less random. The Abee breccia was later consolidated, possibly by shock or by shallow burial and very long-period/low-temperature ($< 215\,^{\circ}\mathrm{C}$) metamorphism.

Rubin, A. E., Scott, E. R. D., Taylor, G. J., Keil, K., Allen, J. S. B., Mayeda, T. K., Clayton, R. N., and Bogard, D. D. (Dept, of Geology, Univ. of New Mexico, Alubquerque, NM 87131): 'Nature of the H Chondrite Parent Body Regolith: Evidence from the Dimmitt Breccia', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A741–A754 (1983)

The Dimmitt H chondrite regolith breccia consists of (in vol.%) 40% H4 and H5 chondrite clasts, 3% impact melt rock clasts, 0.5% shocked H chondrite clasts, 1.5% exotic clasts (including carbonaceous and LL5 chondrites), and 55% gas-rich matrix. The LL5 clast is the best documented example of an ordinary chondrite in a host of a different compositiona group. The matrix contains unequilibrated material, which differs from typical H3 material in having little (0.2 vol.%) fine-grained opaque silicate matrix, and having 20% of the olivines with compositions in the range Fa_{21-24}. About 10–15% of this unequilibrated material is probably derived from graphite-magnetite-rich chondrites and 2% from H3.0–3.5 chondrites. The absence of H3 clasts suggests that most of the unequilibrated material was derived from unconsolidated type 3 components. Many exotic clasts may have been derived from planetesimals that acreted to the H chondrite parent body prior to regolith development. One slowly cooled melt rock clast formed beneauth a 500 m-thick melt breccia pile on the floor of a large impact crater and was later excavated by additional impacts, incorporated into the regolith and consolidated with other components to form the Dimmitt breccia.

Sears, D. W., Kallemeyn, G. W., and Wasson, J. T. (Inst. of Geophysics and Planetary Physics, Univ. of California, Los Angeles, CA 90024): 'Composition and Origin of Clasts and Inclusions in the Abee Enstatite Chondrite Breccia', *Earth Planet. Sci. Letters* **62**, 180–192 (1983)

The concentrations of 25 major, minor and trace elements have been determined in four clasts, a metal-rich inclusion and two dark metal-poor inclusions from the Abee enstatite chondrite. The clasts are heterogeneous, displaying 2-fold enrichments or depletions in some elements. The data suggest that there are two generations of metal, one with low, the other with high concentrations of refractory siderophiles. The other elemental patterns can be understood in terms of variations in the abundance of major minerals. We infer that Sc and Mn are located largely in the niningerite ((Fe, Mg)S), V in the troilite (FeS) and rare earth elements in the oldhamite (CaS).

Heterogeneities among the clasts are probably primary, resulting from the accretion-agglomeration process, although shock processes in a regolithic setting remain a possibility provided that they were followed by a period of metamorphism sufficient to erase petrologic evidence.

In the dark inclusions the concentrations of the rare earths, Eu excepted, are 4 × higher than mean EH levels: this infers enhanced amounts of CaS. The dark inclusions are low in siderophiles, Sc, Mn, K, Na, and Al, implying low amounts of metal, niningerite and feldspar. The origin of the dark inclusions is unclear; they do not appear to be the result of a simple, single-stage process.

Simon, C.: 'Meteorite Study Stirs Debate over Earth's Amino Acids', *Science News* **123**, 118 (1983)

Recent arguments on the Murchison meteorite are reported.

Sparks, M. H., McKimmey, P. M., and Sears, D. W. G. (Dept. of Chemistry, Univ. of Arkansas, Fayetteville, AR 72701): 'The Thermoluminescence Carrier in the Dhajala Chondrite', Proceedings of the Thirteench Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A773–A778 (1983)

The thermoluminescence (TL) sensitivities of 58 chondrules separated from the Dhajala (H3.8) chondrite have been measured in order to investigate the cause of the 10^5-fold variation in the TL sensitivity of ordinary chondrites. The TL sensitivities of the individual chondrites range over nearly two orders of magnitude, from 0.002 to 0.12 (where 4 mg of bulk Dhajala poweder = 1), with no correlation with chondrule mass, cross-sectional area or diameter. Some chondrules have TL per unit mass ten times that of bulk Dhajala powder and mass-TL balance arguments suggest that these chondrules are a major TL carrier. The composition of 15 chondrules was also determined and it was found that high TL chondrules tend to have Ca contents at the upper end of the range observed. These observations are consistent with the TL sensitivity variation in ordinary chondrites, which is related to metamorphism, being caused by the devitrification of glass to produce feldspar and with feldspar being the dominant TL phosphor in Dhajala. That condrules are an important TL carrier would also be consistent with primary feldspar as the TL phosphor, but petrologic observations probably make this appear unlikely.

Sugiura, N. and Strangway, D. W. (Dept. of Geology, Univ. of Toronto, Ontario, Canada): 'Magnetic Anisotropy and Porosity of Chondrites', *Geophys. Res. Letters* **10**, 83–86 (1983)

The measured magnetic anisotropy and porosity of various chondrites are found to be inversely correlated when they are considered by class of chondrites (E, H. and L + LL). For chondrites with similar porosities, the anisotropies for H and E chondrites are smaller than for L and LL chondrites, which have lower metal contents. The anisotropy and porosity are not dependent on the metamorphic grade of chandrites. K–Ar ages of strongly anisotropic and/or less porous chondrites are younger than those of less anisotropic and/or more porous chondrites. These observations suggest that impacts which reset the K–Ar ages produced the anisotropy and reduced the porosity of chondrites.

Sugiura, N. and Strangway, D. W. (Dept. of Geology, Univ. of Toronto, Toronto, Ontario, Canada): 'A Paleomagnetic Conglomerate Test Using the Abee E4 Meteorite', *Earth Planet. Sci. Letters* **62**, 169–179 (1983)

The meteorite Abee is a type 4 enstatite chondrite with many centimeter-size clasts. The paleomagnetic conglomerate test was applied to these clasts, to study the thermal and magnetic hisotry of the meteorite. The directions of magnetization in mutually oriented clasts are significantly different, suggesting the meteorite was not reheated to temperatures much above 100 °C during or after accretion. Paleonintensity estimates were made using Thellier's method. Interior samples which were probably not reheated during entry into the Earth's atmosphere show paleointensities of several oersteds. The fusion crust is also strongly magnetized, showing paleointensities up to 60 Oe.

Thiemens, M. H. and Clayton, R. N. (Enrico Fermi Inst., Univ. of Chicago, Chicago, IL 60637): 'Nitrogen Contents and Isotopic Ratios of Clasts from the Enstatie Chondrite Abee', *Earth Planet. Sci. Letters* **62**, 165–168 (1983)

Nitrogen contents and isotopic ratios have been determined for three clasts from the enstatite chondrite Abee by stepwise heating. The clasts possess a wide range in nitrogen content, ranging from 254 to 850 ppm, whereast the nitrogen isotopic ratios are nearly identical at $\delta^{15}N = -29.2 \pm 0.6‰$. A refractory inorganic nitrogen-bearing phase contains about 90% of the nitrogen which is released at temperatures of 1000 °C and above. The stepwise heating experiments suggest the possible existence of two other distinct nitrogen components, released at low (770 °C) and high (1500 °C) temperatures.

Wacker, J. F. and Marti, K. (Dept. of Planetary Sciences, Univ. of Arizona, Tucson, AZ 85721): 'Noble Gas Components in Clasts and Separates of the Abee Meteorite', *Earth Planet. Sci. Letters* **62**, 147–158 (1983)

The noble gas components and their distributions were studied in a variety of clasts and in separated phases of clast 2.2 using a detailed stepwise release program. The results show the presence of two distinct trapped components: one appears to be similar to Kenna-type gas, the other is characterized by element ratios $^{36}Ar/^{84}Kr > 370$ and $^{36}Ar/^{132}Xe \geqslant 900$ and is termed Ar-rich component. Silicate phases are identified as carriers of both components; but since they are differentially released, the results imply that multiple carrier phases are required. Unlike results from other meteorites, HF attack removes all but 15% of the xenon. Substantial amounts of trapped and, in many cases, unfractionated air were observed, apparently in reaction products of reduced and easily oxidized minerals. The ^{129}Xe release systematics imply the presence of two distinct carriers of extinct ^{129}I and suggest lithophilic behavior of I in Abee. The U/Th-^{4}He and K-^{40}Ar data are consistent with a 4.5 Gy age. Amounts of spallogenic He, Ne and Ar yield a cosmic ray exposure age of 8 My. We compare the Ar-rich component to noble gas abundances in planetary atmospheres and we discuss a suggested model of origin.

Warner, J. L., Ashwal, L. D., Bergman, S. C., Gibson, E. K. Jr., Henry, D. J., Lee-Berman, R., Roedder, E., and Belkin, H. E. (NASA Johnson Space Center, Houston, TX 77058): 'Fluid Inclusions in Stony Meteorites', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A731–A735 (1983)

We describe fluid inclusions in five stony meteorites: diogenite ALHA 77256 and chondrites Bjurbole (H4), Faith (H5), Holbrook (L4), and Jilin (H5). This brings to seven the number of stony meteorites in which fluid inclusions have been confirmed. The fluid inclusions in diogenite ALHA 77256 display a vapor bubble that decreases in volume from $-180\,^{\circ}C$, the lowest temperature attainable in our microthermometruc runs, to homogenization of liquid plus vapor to liquid. Homogenization temperatures are reproducible in each inclusion, and range from $25\,^{\circ}C$ to over $225\,^{\circ}C$; some vapor plus liquid inclusions remain at $225\,^{\circ}C$, the highest temperature in our microthermetric experiments. On cooling, the fluid in some inclusions apparently freezes, as indicated by deformation and immobilization of the vapor bubble at low temperatures. However, temperatures of melting are difficult to observe and are not reproducible. Preliminary laser Raman spectroscopy shows symmetric and antisymmetric stretch bands characteristic of H_2O. Microthermometric data suggest that the fluid in diogenite ALHA 77256 is aqueous with a high solute content. Fluid inclusions discovered in four chondrites have similar properties.

Westphal, M. and Whitechurch, H. (Institut de Physique du Globe, 5 Rue Descartes, F-67084, Strasbourg Cedex France): 'Magnetic Properties and Paleointensity Determination of Seven H-Group Chondrites', *Phys. Earth Planet. Interiors* **31**, 1–9 (1983)

Seven H-group meteorites were studied for paleointensity determination. The method used was the Thellier and Thellier double step heating method. The reliability of the results was estimated from the demagnetization behaviour and from the shape of the pTRM/NRM curve. The best values are obtained for Prairie Dog Creek (H3: 1.4 Oe), Mooresfort (H5: 0.7 Oe) and Oakley Stone (H6: 1.2 Oe). Less reliable results are obtained for Bath (H4: 1.7 Oe), Ochansk (H4: 1.3 Oe), Pultusk (H5: 0.5 Oe) and Indio Rico (H6: 0.8 Oe).

4. Cosmic Dust, Other Particles, etc.

Ahrens, T. J. and O'Keefe, J. D. (Seismological Lab., California Inst. of Tech., Pasadena, CA 91125): 'Impact of an Asteroid or Comet in the Ocean and Extinction of Terrestrial Life', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A799–A806 (1983)

Finite difference calculations describing the impact mechanics associated with a 10 to 30 km diameter silicate or water object impacting a 5 km deep ocean overlying a silicate solid planet at $30\,km\,s^{-1}$ demonstrate that from 12 to 15% of the bolide energy resides in the water. In the gravity field of the Earth some 10 to 30 times the impactor mass of water is launched on trajectories which would take it to altitudes of 10 km or higher. This ejecta launched on trajectories which can acheive stratospheric heights is 10^1 to 10^2 projectile masses, similar to that resulting from impact of objects on an ocean-free silicate half-space (continent). As in the case of impact directly onto a continent, only the ejecta composed of impactor material, launched on trajectories which would carry it to stratospheric heights, matches the fraction (10^{-2} to 10^{-1}) of bolide (extraterrestrial) material found in the platinum-metal-rich Cretaceous-Tertiary and Eocene-Oligocene boundary layers. Oceanic impact results in impulsive-like giant tsunamis initially having amplitudes of ~ 4 km, representing the solitary waterwave stability limit in the deep ocean, and containing 10^{-2} to 10^{-1} of the energy of the impact. Using the constraint of no observed turbidites in marine sediments in the Cretaceous-Tertiary and Eocene-Oligocene boundary materials (claculated maximum water-sediment interface particle velocity $\sim 10^{0}\,m\,s^{-1}$) implies a maximum impactor energy of $\sim 10^{28}$ to $\sim 10^{29}$ erg corresponding to a maximum diameter for a silicate impactor of ~ 2 km (at 11 km/sec). Minimal global tsunami run-up heights on the continents corresponding to impacts of this energy are 300–400 m. We speculate that such waves would inundate all low altitude continental areas and strip and silt over virtually all vegetation. As a result, the terrestrial animal food chain would be seriously perturbed. This, in turn, could have caused extinction of large terrestrial animals including the archosaurs.

Alvarez, L. W. (Lawrence Berkeley Lab., Univ. of California, Berkeley, CA 94720): 'Experimental Evidence that an Asteroid Impact Led to The Extinction of Many Species 65 Million Years ago', *Proceedings of the National Academy of Sciences* **80**, 627–642 (1983)

Blanco, A., Falcicchia, G., and Merico, F. (Gruppo Astrofisico, Dipartimento di Fisica, Universita di Lecce, Italy): 'Planck Mean Absorption Efficiency for Amorphous Carbon and Graphite Grains', *Astrophys. Space Sci.* **89**, 163–168 (1983)

Planck mean absorption efficiency factors for amorphous carbon and graphite grains have been computed using experimentally determined optical properties. The effective temperature used in calculating these means ranges from 10 to 1800 K.

Bradley, J. P., Brownlee, D. E., and Veblen, D. R. (Univ. of Washington, Dept. of Astronomy, Seattle, WA 98195): 'Pyroxene Whiskers and Platelets in Interplanetary Dust: Evidence of Vapour Phase Growth', *Nature* **301**, 473–477 (1983)

Enstatite ($MgSiO_3$) whiskers and platelets have been observed in interplanetary dust particles collected from the stratosphere. Their unique crystal morphologies and microsctructures, such as axial screw dislocations, strongly suggest that they are primary vapour phase condensates which could have formed either in the solar nebula ro in presolar environments.

Chen, A.: 'Crystal Whiskers of Interplanetary Dust', *Science News* **123**, 119 (1983)

The study of grains of enstatite that were detected in micrometeorites by Brandley and Brownlee is reported.

Enever, J. E. (Ingatestone, Essex, England): 'When Explosions Collide', *Griffith Observer* **47**(1) 2–11 (1983)

Some of you may remember a classic article, 'Giant Meteor Impact', on the catastrophic effects of an ocean collision of a minor plant with the earth. It appeared in the March, 1966 issue of *Analog*, and I remember it well. It was written by J. E. Enever. A year ago, in the January, 1981, issue of *Analog*, J. E. Enever jolted his readers with violent collision once again. This time he smashed the planet Mercury with a 155 mile wide cannonball of interplanetary rock and left the planet with an 800 mile wide target for future bombs: the Caloris Basin. Most would argue that most things that bump planets in the night are debris that already belonged to the solar system. Fair enough. Most of it is. But here Mr. Enever adds the unsettling thought that some of these felons are note even in the family. They are the interstellar orphans of colliding explosions.

Here, then, is an astronomical speculation to be taken seriously but to be read critically. Are there really asteroid-sized muggers out there beyond the rim of the solar system?

Fisher,: 'How Science Traced the Killer Asteroid' *Popular Science* **222**(2) 36, 39–40 (1983)

Alvarez's asteroid hypothesis is outlined.

Nuth, J. A. and Donn, B. (NASA Goddard Space Flight Center Lab. for Extraterrestrial Physics, Greenbelt, MD 20771): 'Laboratory Studies of the Condensation and properties of Amorphous Silicate Smokes', Proceedings of the Thirteenth Lunar and Planetary Science Conference, Part 2, *J. Geophys. Res.* **88**, Suppl. A847–A852 (1983)

As part of an investigation of cosmic grains, we have measured the critical partial pressure of SiO necessary to initiate nucleation from SiO-H_2 and Mg-SiO-H_2 vapors as a function of the temperatures of the ambient gas (750 K < T < 1010 K). Although the presence of magnesium vapor lowers the critical partial pressure of SiO at ambient temperatures less than ~ 925 K when compared to the pure SiO-H_2 system, it does not effect the onset of nucleation at higher temperatures. The infrared psectra of particles collected from our system, and of those particles which have subsequently been annealed, are quite similar to spectra of the circumstellar shells of oxygen rich stars. To a lesser extent, the

spectra of these particles also resemble the spectra of some individual chondritic strasospheric dust particles and the matrix material of some carbonaceous chandrites. Determination of the temperature dependent rate of recrystallization our our synthetic materials could elucidate the temperature histories of similar 'cosmic' grains.