PROGRAM

WORKSHOP ON
SURFACE AGES AND HISTORIES:
ISSUES IN PLANETARY CHRONOLOGY

May 21–23, 2006

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Sunday, May 21, 2006

9:00 a.m.	Lecture Hall	Post Modern Flux in the Solar System
1:30 p.m.	Lecture Hall	On the Rocks
5:00 – 7:00 p.m.	Great Room	Reception

Monday, May 22, 2006

9:00 a.m.	Lecture Hall	Krater Kronology
11:15 a.m.	Great Room	Poster Session
1:30 p.m.	Lecture Hall	Secondary Redux

Tuesday, May 23, 2006

9:30 a.m.	Berkner Room	Degrading and Other Issues
1:15 p.m.		Meeting Adjourns

Sunday, May 21, 2006 (continued)

ON THE ROCKS
1:30 p.m. Lecture Hall

Chair: L. Borg

1:30 p.m. Nyquist L. E. * [INVITED]
Martian Meteorite Ages and Implications for Martian Cratering History **[#6010]**

2:00 p.m. Albarede F. * Bouvier A. Blichert-Toft J. Vervoort J. D. [INVITED]
These Good Old Shergottites **[#6003]**

2:30 p.m. Discussion

3:00 p.m. Break

3:15 p.m. Anderson F. S. * Whitaker T. Miller G. Young D. Mahoney J. Norman M. Pilger E. French G.
A Laser RIMS Instrument to Date Igneous Rocks Using Rb-Sr and Measure Elemental Chemistry **[#6032]**

3:35 p.m. Kalchgruber R. * McKeever S. W. S. Blair M. W. Deo S. Reust D. K. Gupta S. Strecker B. N.
Development of an In Situ Luminescence Dating Device for Dating of Geomorphological Features on Mars **[#6004]**

3:55 p.m. Wright S. P. * Wyatt M. B. Christensen P. R.
An Orbital Search for Bounce Rock-like Thermal Emission Spectra and Implications for Calibrating Crater Counts with Shergottite Ages **[#6027]**

4:15 p.m. Discussion

5:00 – 7:00 p.m. Reception

THESE GOOD OLD SHERGOTTITES. F. Albarède[1], A. Bouvier[1,2], J. Blichert-Toft[1], and J. D. Vervoort[3]. [1]Ecole Normale Supérieure, 69007 Lyon, France (albarede@ens-lyon.fr), [2]University of Arizona, Dept of Geosciences, Tucson, AZ 85721, USA, [3]Washington State University, Dept of Geology, Pullman, WA 99164, USA.

Introduction: It has long been recognized that a young (<1 Ga) age of Martian meteorites raises a series of issues spilling over into the fundamental understanding of the geodynamics of Mars. Early interpretations (e.g., [1, 2]) actually did accept that some shergottites may be fairly old and that the ubiquitous 180 Ma age [3] was related to impacts [4]. It was also recognized that ages based on cratering are odd and need special treatment to be reconciled with multiple rounds of ejection of ca. 180 Ma old material [5,6]. The worst conundrum, however, remains the existence of anomalies from extinct radioactive nuclides in SNCs (^{182}W and ^{142}Nd, [7]), which, if a model of young ages is adopted, has to imply very sluggish mantle convection or no convection at all. The latest results from our group re-emphasized the existence of old ages and demonstrated that a statistically significant Pb-Pb isochron at 4.0 Ga is obtained for Zagami, Shergotty, Los Angeles, and EETA 79001[8]. Although this Pb-Pb age is borne out by an independent study on Zagami [9], its significance and the conclusions we arrived at have recently been challenged both in print [9] and in abstracts [10].

Why the U-Pb Concordia should not be used in this context: All groups concur that sample leaching is necessary to remove the worst of terrestrial contamination. It has long been recognized, however, that although leaching procedures do not fractionate isotopic proportions to detectable extents, they do fractionate elemental ratios, in particular the U/Pb ratio. This can be seen in all U-Pb studies on shergottites and the reason for this, which has been discussed at length [1], is that phosphates are very easily removed upon acid leaching, however mild. Concordia arrays on Zagami and Shergotty such as those obtained by Chen and Wasserburg [1] and Borg et al. ([9], Fig. 5) run within errors through the origin. Assumption of an alignment therefore means that, once a "primordial" lead component has been removed, the ^{207}Pb*/^{206}Pb* ratios are constant and the spread of U/Pb ratios caused by the aggressive leaching procedure increases the visual feeling of a good alignment (for a similar reason, ^{40}Ar/^{36}Ar vs ^{39}Ar/^{36}Ar isochrons have now fallen into oblivion). For Zagami, this issue is clearly demonstrated by the inconsistent patterns displayed in the paired ^{235}U/^{204}Pb vs ^{207}Pb/^{204}Pb and ^{238}U/^{204}Pb vs ^{206}Pb/^{204}Pb isochron diagrams ([9], Fig. 4).

Evidence for recent addition of non-magmatic Pb to shergottites: Blichert-Toft et al. [11] made the critical observation that, once corrected to 180 Ma, all the shergottites show an excellent mixing curve (hyperbola) between their ^{238}U/^{204}Pb ratios (μ) and P contents. The low-μ component corresponds to the well-characterized Martian mantle. In contrast, the high-μ component has a high P content, information which in itself discounts terrestrial contamination, and a low Mg#. Observations in the Gusev crater [12] have demonstrated the strong correlation between P and S: our observation should be seen as nothing less than the hallmark of low- to medium-temperature water circulation in shergottites.

Rb-Sr, Sm-Nd, and Lu-Hf vs Pb-Pb ages in shergottites: The first six elements behave mildly to very incompatibly during magmatic processes and therefore tend to not be hosted by silicates, but rather by inclusions and interstitial phases. This is a very general observation [13], so much so that it caused the virtual abandonment of lithophile chronometers for terrestrial plutonic rocks. Although the prime repository of these elements in shergottites is phosphate, which accounts for most of the REE budget [14], inclusions of melts, fluids, and tiny accessory phases may also carry their share of these chronometers. At first glance, the situation may appear to be similar for the U-Pb chronometer with a large fraction of young lead being removed upon leaching of shergottites [1,2]. However, plagioclase is known in every geological environment for containing abundant Pb and shergottite maskelynite is no exception. Resistance of feldspar-hosted Pb to weathering has been known for decades [15]. Once shergottite samples have been leached, their maskelynite still contains substantial quantities of Pb that were incorporated when the magmatic plagioclase precursor formed. As in terrestrial plagioclase, enough U was incorporated at the same time to cause variation in Pb isotope composition over Martian history, thereby producing our Pb-Pb isochron alignments. Analytical work on terrestrial gabbroic rocks similar to shergottites demonstrates the reliability of the Pb-Pb chronometer [16].

Terrestrial contamination: Although this point was addressed by [8], the publication in the mean time of new results on Zagami [9] provides a different perspective. The question discussed by the latter group, as well as by [17], is whether the samples may have been contaminated by either terrestrial or Martian Pb. The μ-P mixing hyperbola discussed above is already a very strong argument against this possibility. Second, Zagami is a fall and different splits were analyzed multiple times by different groups using different techniques [1, 8, 9, 17] and they all give very consistent results. Another fall, Shergotty, and two finds, Los Angeles and EETA 79001, also fall on the Zagami isochron. Because shergottites, and in particular maskelynite, are relatively rich in Pb, it was pointed out by Jagoutz [17] that if terrestrial contamination had taken place it would have had to have been massive, and to such a degree as to render this explanation improbable.

Martian contamination: Borg et al. [9] suggested that shergottites may have incorporated Pb from the Martian soil during impact. Rao et al. [18] found excesses of SO_3, K_2O, and Na_2O in maskelynite from EETA 79001, which they assumed corresponded to a "soil" component introduced during impact. We propose an alternative interpretation. First, the mineralogy of shergottites does not indicate that these rocks could have been sitting at a near enough subsurface level for an impact to have mixed them up with a soil component. Second, soils are most commonly *enriched* in the immobile element Ti, whereas maskelynite from EETA 79001 actually shows a striking 50 percent TiO_2 deficit with respect to the host rock. We prefer to interpret Rao et al.'s [18] observations as indicating that shergottites were hypabyssal plutonic rocks exposed to pervasive percolation by solutions rich in sulfate. The K/Na ratios of the observed excesses are high (>3), which, by comparison with terrestrial geothermal fields, indicates that these fluids were rather hot (~300°C). As discussed by Bouvier et al. [8], the effects of such percolation events may not be more readily detectable by mineralogical observations than what is the case for terrestrial plutonic equivalents.

A statistical caveat: With few exceptions, if any, work before [8] were incapable of producing isochrons that could pass statistical tests, regardless of the technique employed. MSWD values are conspicuouly missing from the relevant literature and scores of perfectly valid data points have been routinely disregarded to the effect of improving alignments. Applying this criterion in a terrestrial equivalent would immediately raise suspicion as to whether the core assumptions of the isochron model were fulfilled. This point in itself would be enough to wonder whether the young ages represent emplacement ages.

Conclusions: Further scrutiny of mineralogical, chemical, and isotopic data on shergottites reinforces our confidence in the 4.0 Ga age of the Pb-Pb isochron of shergottites and in our belief that it represents the age of their emplacement. As previous authors wrote 20 years ago, we consider that the ~180 Ma ages "do not represent an endogenic igneous event" [1] but rather a point in time at which they "suffered partial homogeneization of their [chronometric] systems" [2]. We now believe that the 4.0 Ga shergottite age is probably the best guess for the age of cratered terranes and that young 'ages' are related to recent dry-outs of the local Martian surface.

References: [1] Chen J. H. and Wasserburg G. J. (1986) *GCA, 50,* 955-968 [2] Jagoutz E. and Wänke H. (1986) *GCA, 50,* 939-953 [3] Nyquist L. E. et al. (2001) *Space Sci. Rev., 96,* 105-164. [4] Bogard D. D. et al. (1979) *GCA, 43,* 1047-1055 [5] Nyquist L. E. et al. (1998) *JGR, 103,* 31445-31455 [6] Hartmann W. K. and Berma, D.C. (2000) *JGR, 105,* 15011-15025 [7] Foley C. N. et al. (2005) *GCA, 69,* 4557-4571. [8] Bouvier A. et al. (2005) *EPSL, 240,* 221-233 [9] Borg L. E. et al. (2005) *GCA, 69,* 5819-5830 [10] Nyquist L. E. et al. (2006) *LPS XXXVII,* Abstract #1723 [11] Blichert-Toft J. et al. (1999) *EPSL, 173,* 25-39 [12] Gellert R. et al. (2004) *Science, 305,* 829-832 [13] Zindler A. G. and Jagoutz E. (1987) *GCA, 52,* 319-333 [14] Wadhwa M. et al. (1994) *GCA, 58,* 4213-4229 [15] Patterson C. and Tatsumoto M. (1964) *GCA, 28,* 1-22 [16] Manhes G. et al. (1980) *EPSL, 47,* 370-382 [17] Jagoutz E. et al. (2006) *LPS XXXVII,* Abstract #1577 [18] Rao M. N. et al. (1999) *GRL, 26,* 3265-3268.

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