EPSC Abstracts
Vol. 6, EPSC-DPS2011-1152, 2011
EPSC-DPS Joint Meeting 2011

Thermal and solar weathering of Mercury's crust

S.M. Brown and L.T. Elkins-Tanton
Department of Earth, Atmospheric, and Planetary Science, Massachusetts Institute of Technology, Massachusetts, USA (brownsm@mit.edu)

1. Abstract

We simulate space weathering by irradiating and heating minerals likely found on the surface of Mercury. Our results have implications for the formation of the Mercurian exosphere and the composition of the crust.

2. Introduction

Mercury *MESSENGER* aims to map the composition of the Mercurian crust. This composition has direct implications for the formation and evolution of the planet [4]. The instruments that will compositionally map the surface are calibrated and compared with materials in an Earth-like environment. However, minerals on the surface of Mercury are periodically exposed to the solar wind (radiation) while being heated to over 700 K and cooled to below 100 K daily [1].

The Mercurian exosphere is known to be composed of H, He, O, Na, K, Ca, and Mg [3]. The processes thought to be responsible for the species in the exosphere, which need to be continually resupplied, are solar wind sputtering, photon / electron stimulated desorption, thermal desorption, and impact vaporization. Our experiments most closely simulate thermal evaporation and solar wind sputtering. Most likely, these processes interact with each other and work together towards creating the exosphere.

To understand how these effects will change interpretations of spectra taken from *MESSENGER* and to understand interactions between the space environment and the crust we are simulating the space-weathering environment on minerals we expect to find on the surface of Mercury. We irradiate with fast neutrons and/or heat low-iron minerals that may reasonably be expected to mimic those on the surface of Mercury. We use an anorthoclase feldspar ($\mathrm{Ab_{73}Or_{22}An_{05}}$) from Mt. Franklin, Daylesford, Victoria, Australia, a diopside clinopyroxene (Mg # = 63) from Gilgit-Baltistan, Pakistan, and an enstatite orthopyroxene (Mg # = 99) from the Chandrika Wewa Reservoir, Sabaragamuwa, Sri Lanka.

We are analyzing our experiments compositionally, structurally, and spectrally. Here we present results from our compositional studies of grains irradiated (12 hours or 4 days) and/or heated (4 or 8 days).

3. Experiments

We use high-energy fast neutrons at the MIT Nuclear Reactor to simulate solar wind irradiation. We determine the relative amount of time on Mercury by comparing radiation damage based upon a non-dimensional parameter "displacement per atom" which represents the fraction of atoms displaced from their original lattice site. The average residence estimates are 5.4 days for the 12 hour irradiation and 43 days for the 4 day irradiation.

We heated the samples under vacuum for either 200 K below their melting temperatures for 4 days or 8 days at 450 K. We can determine the relative amount of time on Mercury by using the non-dimensional diffusion parameter. Considering a coarse grain size on Mercury at 700 K, our 4 day experiments correspond to $\sim$2 years on Mercury for anorthoclase (1090 K), $\sim$15 years for diopside (1430 K), and $\sim$40 years for enstatite (1590 K). Finer grain sizes and hotter surface temperatures correspond to shorter residence times.

A μm – sized grain on the Mercurian surface will remain there for on average 100 years [2]. Our residence times for both irradiation and heating are less than 100 years. Our results will be minimums for a single grain, as they are weathered longer on the Mercurian surface.

4. Results

We measured compositional changes within the grains by analyzing multiple points near the rims and cores of the grains using the electron microprobe. Table 1 represents the difference between the weighted mean core and the weighted mean rim between the weathered and unweathered samples of each element. This table allows us to see the effects of weathering while accounting for the initial concentration in the samples.

Table 1: $(\bar{x}_{core} - \bar{x}_{rim})_{weathered} - (\bar{x}_{core} - \bar{x}_{rim})_{unweathered}$, where $\bar{x}$ is the weighted mean (wt%). Error is taken as the average weighted mean of the one sigma uncertainty from the microprobe counting statistics.

		Si	Al	Fe	Ca	Na	K
Anorthoclase	Irradiated	- 0.54	- 0.15	- 0.02	0.00	0.35	0.01
	Heated	- 0.88	- 0.12	0.03	- 0.01	0.66	0.03
	Irradiated and Heated	- 0.23	0.09	- 0.03	0.03	0.23	0.01
	Average Error	0.072	0.040	0.010	0.007	0.051	0.013
		Si	Al	Fe	Mg	Ca	Na
Diopside	Irradiated	- 0.62	0.00	- 0.60	0.52	- 0.03	0.03
	Heated	1.14	0.12	0.23	- 0.61	0.37	0.12
	Irradiated and Heated	- 0.30	0.07	0.10	- 0.04	- 0.04	0.06
	Average Error	0.063	0.006	0.065	0.026	0.046	0.012
		Si	Al	Fe	Mg		
Enstatite	Unweathered	- 0.11	0.00	0.01	0.04		
	Irradiated	0.23	0.02	- 0.05	0.05		
	Average Error	0.081	0.012	0.017	0.082		

We expect the rims to lose more species as they are exposed to radiation, so a positive number in the table to the left indicates a loss of that element from the rim during weathering. A negative number indicates an increase in the concentration in the rim after processing, evidence for resorption from the exterior. A number near zero, or within the error, is considered to be unaffected. In each case the rim value is compared to the core of the same processed grain. Therefore, if the whole grain loses an element but then resorbs some onto the surface, it will obtain a negative value in Table 1 even though it has a lower concentration of that element that it did before weathering.

5. Summary and Conclusions

Loss of atoms from surface minerals through weathering may have direct application to the formation of Mercury's exosphere. Our results indicate that sodium rich feldspars have the potential to contribute sodium to the exosphere, but in order to produce potassium from the surface, more potassium rich felspars may be necessary. Calcium and magnesium are released from clinopyroxene while orthopyroxene is relatively unaffected by weathering. This may indicate more clinopyroxene than orthopyroxene in surface areas correlating to calcium and magnesium source regions. The variable space weathering effects between minerals may have important consequences in the exosphere. We also observe interactions between these processes which may help explain small scale patterns of exospheric species. We stress the need to create spectral libraries that reflect space weathering environments.

Acknowledgements

We would like to thank Lin-wen Hu, Thomas Bork, Bill McCarthy, Carl Francis, Terrence Blackburn, Nilanjan Chatterjee, Mitchell Galanek, Justin Quinn, and Noah McLean. This research was supported by a CAREER grant to Elkins-Tanton through NSF Astronomy.

References

[1] A Hale and B Hapke. A Time-Dependent Model of Radiative and Conductive Thermal Energy Transport in Planetary Regoliths with Applications to the Moon and Mercury. *Icarus*, 156(2):318–334, April 2002.

[2] R.M. Killen, Gabrielle Cremonese, Helmut Lammer, Stefano Orsini, Andrew E Potter, Ann L Sprague, Peter Wurz, Maxim L Khodachenko, Herbert I M Lichtenegger, Anna Milillo, and Alessandro Mura. Processes that Promote and Deplete the Exosphere of Mercury. *Mercury*, pages 433–509, 2007.

[3] William E McClintock, Ronald J Vervack, E Todd Bradley, Rosemary M Killen, Nelly Mouawad, Ann L Sprague, Matthew H Burger, Sean C Solomon, and Noam R Izenberg. MESSENGER observations of Mercury's exosphere: detection of magnesium and distribution of constituents. *Science*, 324(5927):610–3, May 2009.

[4] Sean C Solomon. Mercury: the enigmatic innermost planet. *Earth and Planetary Science Letters*, 216(4):441–455, December 2003.