Mercury Surface Composition: Integrating Petrologic Modeling and Remote Sensing Data. M. A. Riner[1], F. M. McCubbin[2], P.G. Lucey[1], G.J.Taylor[1], and J.J. Gillis-Davis[1] [1]Hawaii Institute of Geophysics and Planetology, University of Hawaii, Manoa, Honolulu, HI, [2]Geophysical Laboratory, Carnegie Institution of Washington, Washington, DC, *mariner@higp.hawaii.edu.

Introduction A significant opaque component in Mercury's crust is inferred based on albedo and spectral observations. Previous workers have favored iron-titanium bearing oxide minerals, particularly ilmenite ($FeTiO_3$), as the opaque. However, spectral observations have not detected a diagnostic 1µm absorption band and have thus limited the FeO in coexisting silicates to <2 wt%. We use equilibrium crystallization to constrain the distribution of iron between opaque oxides and silicates under a variety of environmental conditions. Due to the unknown composition and environmental conditions of Mercury, we widen the discussion of Mercury opaques beyond ilmenite or Fe-endmember oxides and survey other opaque oxides to evaluate spectral and compositional evidence in order to determine the possibility of their presence on Mercury. This work offers compositional constraints for Fe, Ti, and Mg that will be testable by various MESSENGER instrument data sets after it begins its orbital mission.

The albedo of immature impact ejecta of Mercury is lower than the albedo of immature lunar highlands [1] leading to the proposal of an ubiquitous, dark, Fe-Ti-bearing oxide mineral [1-4]. Based on the variations in albedo and spectral slope between the major crustal terrains, it has been suggested that a single opaque mineral is controlling major variations in reflectance and color on Mercury [1-4]. Denevi et al. [3] estimate 15 vol% (~20 wt%) ilmenite is required to darken the brightest materials to match the albedo and spectral slope of the intermediate terrain (similar to the global mean).

An array of remote sensing techniques have not provided definitive constraints on the FeO content of Mercury's surface. In addition to the limit on silicate FeO, the total neutron absorption measured by MESSENGER's first flyby is equivalent to a total FeO+TiO_2 content of 14-21wt%, assuming all absorption comes from iron and titanium in ilmenite ($FeTiO_3$) proportions [5].

Equilibrium Modeling: We investigate equilibrium crystallization because the geological process that produced Mercury's intermediate terrain must have occurred globally, thus requiring a common, widespread process. Though nonequilibrium processes for producing high oxide abundances on Mercury have been proposed [3], Fe:Mg exchange equilibrium is known to occur rapidly in oxides and ferromagnesian silicates at magmatic temperatures. Therefore, implicating an iron-rich end-member oxide mineral to coexist with magnesian-enriched silicates is counter-intuitive without a petrologic justification [6] for the compositional juxtaposition. Moreover, petrologic problems arise as to how wide-scale iron-enrichment, required for producing large amounts of ilmenite, can occur in a planetary body that does not produce ferromagnesian silicates with much iron (<2wt.%)

Here we test a simpler scenario in which significant Mg is allowed to substitute for Fe in the oxide mineral. We determine the proper amount of Mg-substitution, assuming the oxide is in equilibrium with coexisting silicate minerals, using the program QUILF [7].

Results: Using QUILF we explored the silicate-oxide equilibrium relationships among ferromagnesian silicates and the ilmenite-geikielite ($FeTiO_3$-$MgTiO_3$) solid solution series. In the absence of absorptions due to FeO in the near infrared, this provides a valuable constraint on the distribution of FeO between silicates and oxides.

QUILF addresses the equilibrium composition of silicate minerals but not their abundance. So we consider the silicate mineral abundances as variables and fix the oxide abundance at 20 wt%, determined by [3] for the intermediate terrain. Each composition we consider is a mixture of oxide, plagioclase and a single ferromagnesian mineral (either clinopyroxene, orthopyroxene or olivine). The maximum plagioclase content has been constrained by previous studies [3,8]. We assume plagioclase has 0 wt% FeO and the FeO of the ferromagnesian mineral is a function of oxide composition, as determined by QUILF. Figure 1 shows the total and silicate FeO abundance for the intermediate terrain as a function of plagioclase abundance and oxide composition, assuming chemical equilibrium at 800°C. The results at higher temperatures show similar qualitative relationships but require more FeO in silicates for similarly FeO-rich oxides. The 800°C results are an instructive case of minimum FeO in silicates.

If the intermediate terrain equilibrated at ~800°C or higher, endmember ilmenite cannot be the opaque oxide present because in order to keep silicate FeO low enough to explain the lack of a 1µm absorption band, the plagioclase content would have to be ≥70wt% which is too bright to match the albedo of the intermediate terrain. Mg-rich oxides have a wider range of plausible formation conditions than Fe-rich oxides and such compositions would lead to dramatically lower total iron abundance estimates.

Discussion: Based on QUILF modeling we find that the total FeO of the intermediate terrain is ≤10wt%, with lower FeO abundances favored by a wider range of conditions. High FeO abundance is only possible under a narrow range of conditions – high plagioclase abundance (70wt%) with 10wt% clinopyroxene with no olivine or orthopyroxene.

The total neutron absorption measured by MESSENGER does not require high FeO abundance. In fact, the total neutron absorption of mixtures of oxide, plagioclase, olivine and pyroxene for the oxide abundances estimated for Mercury, favor Mg-rich members of the ilmenite-geikielite solid solution series. The thermal neutron absorption cross section of TiO_2 is approximately twice that of FeO. Thus for an equivalent mass fraction, geikielite has 90% the neutron absorption of ilmenite, even though the absorption due to MgO is negligible. In fact, the total neutron absorption of the intermediate terrain with 20wt% ilmenite-geikielite solid solution with variable abundances of plagioclase, pyroxene and olivine is often higher than the observed range and only geikielite-rich compositions fall within the observed range.

References: [1] Denevi and Robinson (2008) *Icarus*, 197, 239-246. [2] Robinson et al. (2008) *Science*, 321, 66-69. [3] Denevi et. (2009) *Science*, 324, 613-617. [4] Blewett et al. (2009) *EPSL*, 285, 272-282. [5] Lawrence et al. (2009) *LPS XL*, 1761. [6] Usselman et al. (1975) *LPS VI*, 835. [7] Anderson et al. (1993) *Comp & Geosci*, 19, 1333-1350. [8] Riner et al. (2009) *GRL*, 36, L02201.

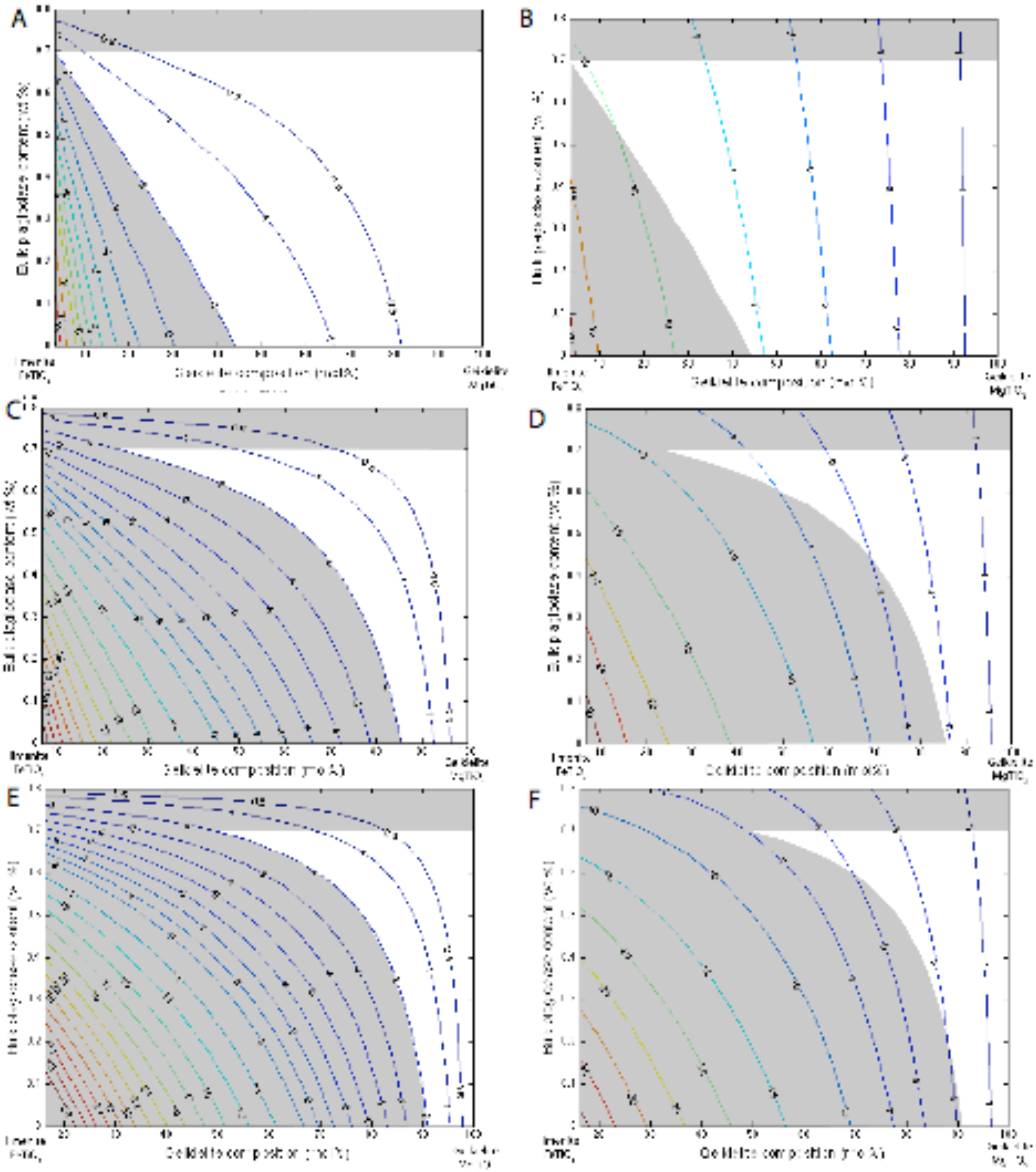

Figure 1 – Contour lines show the silicate (A,C,E) or total (B,D,F) FeO abundance for mixtures of a single ferromagnesian silicate (A-B cpx, C-D opx, E-F olivine), oxide and plagioclase. The oxide abundance is fixed at 20 wt%, determined by [3] for the intermediate terrain. The FeO content of the oxide and ferromagnesian silicates are determined by QUILF. The shaded regions are compositions that are not plausible because they would result in a 1μm band or an albedo that is too high.