SURFACE COMPOSITIONAL INFORMATION DERIVED FROM SIMULATED HIGH-ENERGY GAMMA RAYS FOR THE PSYCHE GAMMA-RAY AND NEUTRON SPECTROMETER. Insoo Jun[1], D. J. Lawrence[2], P. N. Peplowski[2], L. T. Elkins-Tanton[3], J. Goldsten[2], S. Marchi[4], T.McCoy[5], T. H. Prettyman[6], C. A. Polanskey[1], C.T. Russell[7], and the Psyche Science Team. [1]Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA, USA (Insoo.jun@jpl.nasa.gov); [2]APL; [3]ASU; [4]SwRI, [5]Smisonian, [6]PSI, [7]UCLA.

Introduction: The baseline science payload for a planned NASA Discovery mission to the asteroid (16) Psyche includes an instrument called Gamma-Ray and Neutron Spectrometer (GRNS). The Psyche GRNS is designed to measure elemental compositional distributions on the surface of Psyche. Psyche is thought to be an exposed core of a differentiated primordial body mainly composed of iron and nickel, possibly mixed with silicates. It is also possible that Psyche could be primordial material, never melted or differentiated, but accreted very early from reduced, metal rich material [1]. The Psyche GRNS provides clues about the origin of Psyche by measuring: (1) the bulk Ni concentration, (2) the contribution to the major element chemistry from silicates, and (3) the light element (H, C, O) concentration [2,3].

The Psyche GRNS consists of two subsystems: a MESSENEGR heritage gamma-ray spectrometer (GRS) and a Lunar Prospector heritage neutron spectrometer (NS). The GRS provides data that can be used to derive near-surface (10's cm) bulk elemental composition, and the NS data will be used to complement the GRS data by providing qualitative composition parameters such as distributions of neutron absorbing elements, hydrogen concentration, and average atomic mass [3,4]. These types of spectrometers have been used successfully in many previous planetary science missions where measurements of bulk elemental compositions were important to achieve each mission's science goal, e.g., the Moon [5], Mars [6], Vesta [7], Mercury [8], and Ceres [9].

Bulk surface elemental composition can be estimated by analyzing distinct single gamma peak(s), which are characteristics of a particular element. For example, [2] described how the 1.454 MeV peak will be used to derive the Ni concentration for Psyche. While these characteristic gamma-lines located at specific energies are most often used to derive the elemental compositions, it has been demonstrated using gamma-ray data from the Moon, Vesta, and Ceres [10–12] that the high-energy gamma ray (HEGR) flux defined between 8 MeV and ~9 MeV can provide additional compositional information. Specifically, HEGRs provide a measure of average atomic mass <A>, which is complementary to element-specific gamma-ray measurements and compositional parameters derived from neutron data. Here, we briefly describe some results for the HEGR portion of simulated gamma-ray spectra for Psyche-like materials, with the goal to understand what additional information HEGRs could reveal about Psyche surface compositions.

Simulations: All simulations were performed using a Monte Carlo radiation transport code, MCNPX [e.g., see 12-15], to simulate gamma-ray emissions from Psyche. Calculations were made for a range of metal compositions (10-100 metal vol%). For example, 10% metal volume fraction means the remaining 90% is pyroxene or 100 % metal volume fraction means there is no pyroxene in the modeled Psyche composition. Nickel composition was varied from 2 to 30 wt% within the modeled metal volume fraction. In addition, hydrogen concentration was varied from 0 ppm to 500 ppm for each modeled metal/pyroxene composition to simulate possible exogenic contamination by hydrogen-bearing impactors, similar to that observed at Vesta [7]. Leakage gamma-ray spectra were tallied and analyzed to investigate general trends of the HEGR flux variation as functions of different compositional combinations.

Results and Discussion: In the following discussion, the total gamma-ray fluxes summed between 8 MeV and 9 MeV are used to illustrate variation of HEGR fluxes as functions of different combinations of the modeled Psyche surface compositions. The main purpose of the HEGR flux analysis is not to provide accurate estimate of the Ni concentration of Psyche. Rather the Ni concentration will be estimated by using the main Ni inelastic peak at 1.454 MeV. The HEGR fluxes would provide additional information that can be used to constraint the Ni and/or hydrogen concentration.

A few salient features of the results are summarized in Figure 1, which illustrates the HEGR flux variations as functions of pyroxene vol % (thus correspondingly metal vol %) and nickel wt% within metal and for different hydrogen contents. For a given pyroxene fraction, both nickel and hydrogen content significantly affect the HEGR flux. In general, the higher the nickel concentration, the higher the HEGR flux, which is consistent with prior observations that HEGRs scale with average atomic mass. However, small amounts of added hydrogen result in higher HEGR fluxes. The gamma-ray spectra shown in Figure

2 for three different compositions provide a clue that may explain these behaviors.

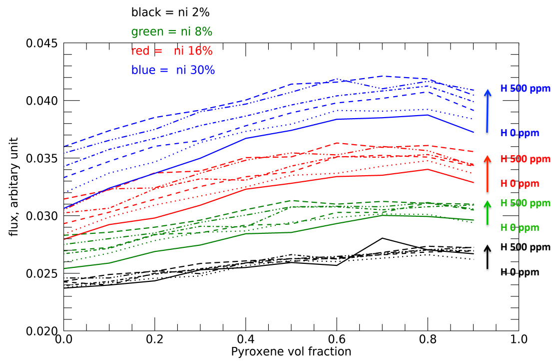

Figure 1. Variation of HEGR fluxes for different pyroxene/metal/nickel/hydrogen concentrations. Here, the Ni fractions given for each color are the Ni weight % within each metal fraction. For example, the blue lines for the 20 vol% pyroxene means that the Ni is 30 wt% within the 80 vol% metal.

Figure 2 indicates that the HEGR fluxes are rather strongly dependent on the intensities of the 8.119, 8.532, and 8.997 MeV peaks. These three gamma-ray peaks are from neutron capture reactions with nickel [16]. More hydrogen means more slowing-down of neutrons, which means more capture reactions. It is also possible that the simulated peak and continuum contributions can be separated to show how the line/continuum or line/total-HEGR varies with added H, which is a future study topic. Higher HEGR fluxes for higher Ni fractions at given H concentrations are simply because there are more nickel atoms available for the capture reaction in the modeled composition. It is also observed from Figure 2 that the HEGR flux flattens out or rolls off at very high pyroxene fractions. This behavior may be explained by the fact that the decreased Ni concentrations at high pyroxene fractions result in lower <A> and less capture reactions. Complex dependencies likely exist for different nickel, metal, and hydrogen concentrations. Further investigation will follow: including the efficiency and energy resolution in future studies will help better understand any final result. However, it is clear the HEGR flux from the Psyche GRS can provide additional data to infer Psyche's composition, including information about Ni concentrations to complement other nuclear spectroscopy measurements [2].

References: [1] L. T. Elkins-Tanton et al., LPSC, Abstract #1632, 2015; [2] P. Peplowski et al., LPSC, Abstract #1394, 2016; [3] D. Lawrence et al., LPSC, Abstract #1622, 2016;[4] T. H. Prettyman et al., Space Sci. Rev., 163, 371, 2011; [5] T. H. Prettyman et al., JGR, 111, E12007, 2006; [6] W. V. Boynton et al., Science, 297, 78, 2002;

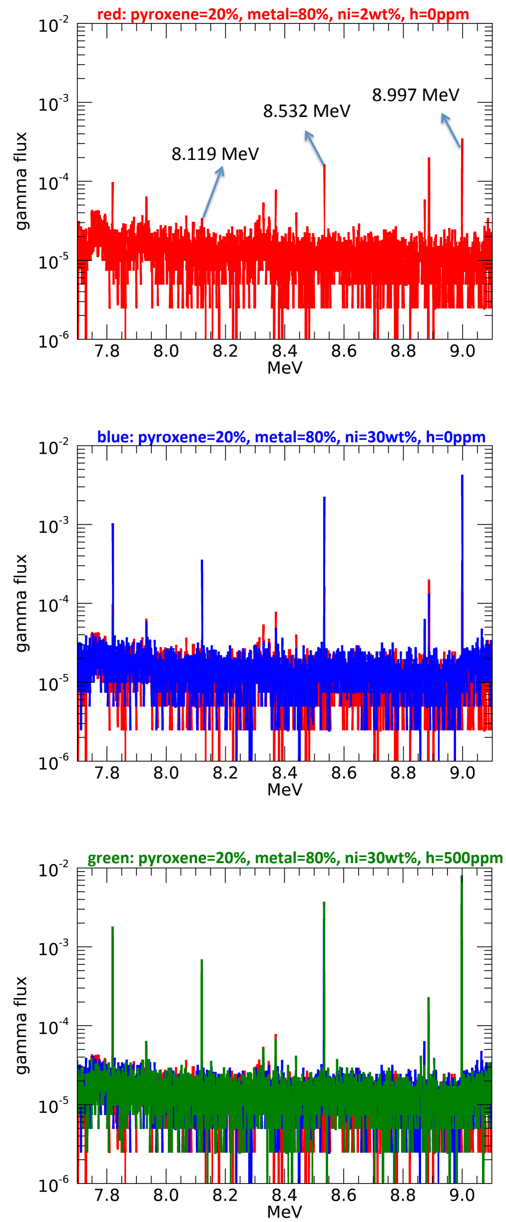

Figure 2. Examples of HEGR spectra for three different combinations of the modeled Psyche composition.

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