IMPORTANCE OF VENUS BULK ELEMENTAL COMPOSITION MEASUREMENTS. A. M. Parsons¹, A. W. Beck², D. J. Lawrence³, P. N. Peplowski⁴ and R. D. Starr⁵, ¹NASA Goddard Space Flight Center, Greenbelt MD (Ann.M.Parsons@nasa.gov), ²The Johns Hopkins University Applied Physics Laboratory, Laurel MD, ³The Catholic University of America, Washington DC.

Introduction: Although it is Earth’s closest neighbor, we know very little about the elemental composition and geochemistry of Venus’ surface materials [1, 2]. We have no known meteorites from Venus, and prior landed investigations lacked the ability to make sufficiently accurate, precise, and complete bulk composition measurements. The lack of detailed surface composition information inhibits the development of our understanding of Venus’ origin and evolution. The few images and chemical analyses we have from the Russian Venera and Vega landers [3, 4] show that the lowland plains are made of basaltic rock, although with some unusual and unexplained compositions. There is even less information for Venus’ highlands, central volcanoes, domes, etc., beyond what has been postulated on the basis of laboratory investigations. Venus’ atmosphere provides significant constraints on the planet’s history, but its chemical interactions with the surface materials are poorly constrained [5].

Capabilities of the Bulk Elemental Composition Analyzer (BECA): The limitations of previous Venus bulk surface composition measurements emphasize the tremendous opportunities for leaps in scientific understanding that would be achieved by sending a new mission to the surface of Venus with a state-of-the-art instrument that measures elemental composition. The Bulk Element Composition Analyzer (BECA) can provide a comprehensive characterization of Venus’ near-subsurface (10’s of cm) materials, including key elements such Na, K, Si, Al, Fe and Mg. BECA has no moving parts and can be mounted entirely within the pressure vessel. Because it utilizes high-energy neutrons and gamma rays that readily pass through the pressure vessel walls, BECA requires no windows in the pressure vessel nor does it require the ingestion of an external sample. BECA can make bulk elemental composition measurements of Venus’ surface outside the probe to high precision and accuracy within only one hour of measurement.

BECA combines an advanced Pulsed Neutron Generator (PNG) and a sensitive Gamma-Ray Spectrometer (GRS) with high-speed PNG control and GRS data processing electronics to rapidly acquire elemental composition data. The BECA PNG neutrons induce the Venus surface materials to emit gamma rays. BECA’s GRS measures these gamma rays as well as those produced by naturally radioactive elements. The energies of the gamma rays identify the elements present and their intensity determines the elemental concentration. Elemental composition information is derived from the gamma-ray measurements via iterative comparison of the data to spectral standards corresponding to specific elements. Elemental standard spectra are weighted and summed to achieve a best-fit to the gamma-ray data, from which bulk elemental composition of the surface is derived. Measurements using a BECA prototype and simulated lander-type materials were carried out at the Gamma-Ray and Neutron Test facility at Goddard Space Flight Center [6].

Importance of Gamma-Ray Measurements at Venus’ Surface: One of the fundamental uncertainties of Venus is a lack of knowledge of the igneous rock types that exist at its surface. A standard method for classifying volcanic igneous rocks is plotting the bulk concentrations of Total Alkalics (Na + K) versus Si (TAS). TAS is largely governed by the vol.% mafic versus felsic minerals (Si) and composition/abundance of feldspar, and in some case feldspathoid (total alkalis). Though mafic, intermediate, and felsic plutonic rocks are typically classified via mineral modes (i.e. vol.% QAPF), TAS can be utilized with those rocks as well since, as described above, it is sensitive to the vol.% Quartz (Q) vs. Alkali feldspar (A) vs. Plagioclase feldspar (P) vs. Feldspathoid (F).

Figure 1 shows TAS for seven suites of terrestrial volcanic rocks from [7], where we converted wt.% oxides to wt.% elements. Overlain are the compositional fields corresponding to different volcanic and plutonic igneous rocks, ranging from basalt/gabbro to rhyolite/granite, as well as more alkali-rich lithologies. Also shown are the concentrations and two-standard

![Figure 1. Plot of total alkali elemental abundances (Na+K) versus Si abundances for seven suites of terrestrial rocks [7]. Compositional fields for different rock types are outlined by boxes. Venus surface measurements and uncertainties are shown by white circles and gray error bars. Uncertainties for a BECA-type measurement are shown by black error bars.](image)
deviation (2σ) estimates for three Venus landed measurements (Venera 13, 14, Vega 2 [3, 4]). It is important to note that no measurements of Na have been made at Venus’ surface, so the Venus total alkali values shown in Figure 1 use estimates of Na based on compositional trends from Earth-analog materials. As seen, the Venera and Vega error bars (gray lines) are sufficiently large to preclude an identification of the specific rock types present on Venus. In contrast, a landed PNG-based gamma-ray measurement would measure TAS concentrations with uncertainties that are sufficiently smaller (black lines) than the Venera and Vega measurements. Such data from a new landed measurement would allow a definitive rock-type characterization.

**Importance of Neutron-absorption Measurements:** In addition to gamma rays, planetary neutron measurements are also useful for characterizing elemental concentrations, and can provide secondary information for rock-type identification [8–11]. BECA contains two 3He neutron sensors that enable the measurement of thermal-neutron absorption, a composition parameter that is dominantly controlled by the abundance of elements with large neutron-absorption cross sections. Figure 2 shows a plot of neutron absorption versus Fe abundances for the same terrestrial rock suites shown in Figure 1 (Fe is measurable by BECA at Venus’ surface). We note that these data show less spreading than the alkali versus Si plot, and thus appear to provide less ability to identify specific rock types. However, from the Venera XRF data, we calculate the surface of Venus to have an average Fe# of 52.0 (Fe# = [Fe]/(F element + Mg], where [element] = weight percent). This value is significantly lower than the Fe# of 78.3 considered for the suite of abundances of Figure 1. Thus, these terrestrial compositions have significantly more Fe than is likely present on Venus, such that the values shown in Figure 2 do not necessarily represent the actual variation of neutron absorption and Fe present on Venus. A more likely variation for Venus materials can be estimated by removing the [Fe]/[Mg] from the terrestrial basalt bulk chemistry, then re-entering those elemental concentrations based on the Venera-derived Fe# ratio. The revised variation is shown in Figure 3. In contrast to the original variation shown in Figure 2, the revised abundances show a more spread out distribution, which suggests that in addition to TAS, neutron measurements can provide a secondary yet robust rock-type characterization.

![Figure 2. Neutron absorption values versus Fe abundances for the same suite of terrestrial rocks shown in Figure 1.](image)

**Figure 3.** Neutron absorption versus Fe abundances, where the Fe abundances have been revised based on expected Fe# values on Venus. The same rock type fields shown in Figure 1 are overlain here.

**Conclusions:** While our knowledge of Venus’ elemental surface composition remains highly uncertain, surface gamma-ray and neutron measurements provide a robust and complementary means for obtaining high-precision composition measurements, thus enabling answers to key questions regarding the physics and chemistry of Venus’ surface and crustal materials.

**References:**