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Measuring Surface Bulk Elemental Composition on Venus

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Abstract

The extreme surface environment (462 ˚C, 93 bars pressure) of Venus makes subsurface measurements of its bulk elemental composition extremely challenging. Instruments landed on the surface of Venus must be enclosed in a pressure vessel. The high surface temperatures also require a thermal control system to keep the instrumentation temperatures within their operational range for as long as possible. Since Venus surface probes can currently operate for only a few hours, it is crucial that the lander instrumentation be able to make statistically significant measurements in a short time. An instrument is described that can achieve such a measurement over a volume of thousands of cubic centimeters of material by using high energy penetrating neutron and gamma radiation. The instrument consists of a Pulsed Neutron Generator (PNG) and a Gamma-Ray Spectrometer (GRS). The PNG emits isotropic pulses of 14.1 MeV neutrons that penetrate the pressure vessel walls, the dense atmosphere and the surface rock. The neutrons induce nuclear reactions in the rock to produce gamma rays with energies specific to the element and nuclear process involved. Thus the energies of the detected gamma rays identify the elements present and their intensities provide the abundance of each element. The GRS spectra are analyzed to determine the Venus elemental composition from the spectral signature of individual major, minor, and trace radioactive elements. As a test of such an instrument, a Schlumberger Litho Scanner† oil well logging tool was used in a series of experiments at NASA's Goddard Space Flight Center. The Litho Scanner tool was mounted

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above large (1.8 m x 1.8 m x .9 m) granite and basalt monuments and made a series of one-hour elemental composition measurements in a planar geometry more similar to a planetary lander measurement. Initial analysis of the results shows good agreement with target elemental assays.

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Keywords: Elemental analysis: Venus; pulsed neutron generator; gamma ray spectrometer

1. Introduction

The Bulk Elemental Composition Analyzer (BECA) instrument uses high-energy neutrons and gamma rays to penetrate an object's surface and measure the bulk elemental composition over a large volume beneath a landed probe (up to 30 cm depth and about a 50 cm radius lateral distribution). This elemental composition provides bulk geochemistry information. Currently, Venus surface probes can operate for only a few hours, making it crucial that the lander instrumentation can make statistically significant measurements in a short period of time.

The harsh Venusian surface environment makes the operation of external mechanisms extremely challenging. For example, it is currently impractical to operate a rover on the surface of Venus. Sample handling systems are difficult to use and pressure vessel windows present design limitations. BECA is well suited for Venus surface measurements as it will be located completely inside the Venus lander. The instrument has no moving parts and since neutrons and gamma rays can penetrate the pressure vessel walls, BECA does not require sample manipulation or a pressure vessel window.

Little is known about the bulk composition of the near surface of Venus. Although surface x-ray fluorescence measurements were made by the Venera and Vega missions in the 1970s-80s, gamma-ray bulk composition measurements were limited to the naturally radioactive elements (Surkov *et al.*, 1984; Surkov *et al.*, 1986). With the addition of a pulsed neutron generator, BECA provides a significant improvement over previous Venus bulk composition studies.

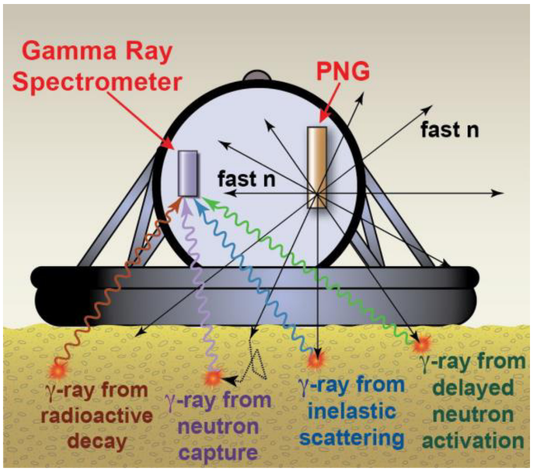

Fig. 1. BECA's PNG excites the nuclei in the surface material resulting in the emission of characteristic gamma rays. The detection of these gamma rays by the GRS yields the elemental composition.