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Geochemistry of Venus: Progress, Prospects and New Missions

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Available geochemical data on Venus' surface materials are limited and of poor precision. Those data were obtained by the Venera and VEGA lander missions, which were engineering and scientific triumphs of their days. However, their chemical analyses of the Venus surface do not permit detailed geochemical interpretations, such as are routine for terrestrial analyses and MER APXS rover analyses from Mars. In particular, the Venera and VEGA analyses of major elements (by XRF) did not return abundances of Na, and their data on Mg and Al are little more than detections at the 2s level. Their analyses for K, U, and Th (by gamma rays) are imprecise, except for one (Venera 8) with extremely high K contents ($\tilde{4}$% K2O) and one (Venera 9) with a non-chondritic U/Th abundance ratio. In addition, the Venera and VEGA landers sampled only materials from the Venus lowlands – they did not target sites in any of the highland areas: shield volcanoes, tesserae, nor the unique plateau construct of Ishtar Terra. The Virtis imaging spectrometer on Venus Express has provided new global data of likely geochemical importance – maps of surface emittance at near 1.2 μm – but it remains unclear just what causes its observed variations in emittance.

The limitations of the available data on Venus' surface rock compositions and mineralogy highlight the huge opportunities in additional chemical and mineralogical analyses of Venus' surface. In geochemistry, currently available instruments could provide much more precise analyses for major and minor elements, even within the engineering constraints of the Venera / VEGA lander systems. Such precise analyses would be welcome for basalts of Venus' lowland plains, but would be especially desirable for the highland tesserae and for Ishtar Terra. The tesserae may well represent ancient crust that predates the most recent volcanic resurfacing event and so provide a geochemical look into Venus' distant past. Ishtar Terra may be composed (at least in part) of granitic rocks like Earth's continental crust, which required abundant water to form. So, Ishtar Terra could possibly yield evidence on whether Venus once had an ocean, and thus the possibility of life. The mineralogy of Venus' surface materials will reflect not only its rocks, but also their chemical weathering in the hot, dense, corrosive Venus atmosphere. Mineralogical instruments at the Venus surface (like XRD or Raman) could test various theories of surface atmosphere interactions, like carbonate buffering of atmospheric CO2, sulfide/sulfate buffering of SO2, and origin of Venus' low emissivity highlands as iron sulfide or as metallic tellurium frost.

The geochemistry of Venus' surface would be learned best in lander missions, which are under consideration from several agencies. Current mission concepts are severely limited durations at Venus' surface before they succumb to its high temperature. However, high-temperature electronics and power systems are under development. Surface-atmosphere interactions, and hence surface mineralogy, can be constrained indirectly by probes of Venus' lower atmosphere (with or without soft landing). And improved radar imagery and altimetry can provide crucial indirect constraints on surface mineralogy and geology via emissivity and geophysical constraints (e.g., whether Ishtar Terra could be a granitic continent).