CONTRIBUTIONS OF THE CLEMENTINE MISSION TO OUR UNDERSTANDING OF THE PROCESSES AND HISTORY OF THE MOON Paul D. Spudis[1] and Paul G. Lucey[2] 1. Lunar and Planetary Institute, Houston TX 77058 2. University of Hawaii, Honolulu HI 96822

The Clementine mission [1] will provide us with an abundance of information about lunar surface morphology, topography, and composition, permitting us to infer the history of the Moon and the processes that have shaped that history. This information can be used to address fundamental questions in lunar science and allow us to make significant advances towards deciphering the complex story of the Moon. The Clementine mission will also permit a first-order global assessment of the resources of the Moon and provide a strategic base of knowledge upon which future robotic and human missions to the Moon can build.

What we want to know about the Moon Goals for the scientific exploration of the Moon have recently been articulated [2]. We need to understand the internal evolution of the Moon, including both physical and chemical effects. An intense magmatic history has resulted in a complex, heterogeneous crust and a global inventory of these compositions and their spatial distributions will permit us to determine what processes have operated and the intensities and durations of such processes. The Moon preserves a record of cosmic bombardment in Earth-Moon space and we can use the lunar surface as a natural laboratory to study physics of the impact process, the cratering flux for the last 4 Ga, and to probe the crust at depth by using large craters and basins as natural "drill-holes" into the Moon. The regolith contains information on both the underlying bedrock geology and also the irradiation history of the Moon. We can thus use the lunar regolith as a probe of solar and galactic history. All of these studies improve our understanding of global properties and processes, important constraints on modes of lunar origin.

Where does the Clementine mission fit in? The pressing need for global mapping of the Moon, by a variety of remote-sensing techniques, has been stressed repeatedly in every lunar science report for the last 20 years (e.g., [2,3]). The Clementine mission begins this task. Global mapping of the Moon is one element of a scientific strategy for lunar exploration. Such a strategy includes additional sensing from orbit, surface networks and automated rovers, reconnaissance sampling of carefully selected targets, and detailed human exploration of complicated geological sites [2]. Clementine will obtain the first global digital image data set for the Moon. The imaging sensors are equipped with a variety of filters [4] that have been selected to optimize the geologic value of the multi-spectral data. Topographic profiles derived from LIDAR laser altimetry will greatly improve our knowledge of the global figure of the Moon. Although not carrying X-ray or gamma-ray instruments for chemical mapping, significant chemical information can be obtained from multispectral imaging data (e.g., Ti abundance from ratio of 415/750 nm; [5,6]). It is important to view the Clementine mission in the proper perspective; while not completely satisfying our scientific needs for lunar global mapping, the mission is an impressive beginning towards obtaining such a data set.

Clementine will map the Moon in 11 spectral bands in the visible and near-IR [4]; although surface resolution of the image data varies because of the spacecraft's elliptical orbit, the average resolution will be about 200 m/pixel. The LIDAR instrument will take topographic profiles by taking 100 m spot ranging measurements of about 50 m precision at 2 km intervals; the 5-hour orbital period of the spacecraft ensures that adjacent orbital profiles will be spaced by about 2.5° of longitude (about 70 km at the chosen perilune latitudes of $\pm$ 30°). In addition, the LIDAR imager will obtain selected high resolution images (6-15 m/pixel), either as long contiguous strips in a single color or shorter, multi-color images, in up to 4 colors [4]. A thermal IR imager will obtain selected broadband images in the 8000-10,000 nm region at about 70 m/pixel resolution.

What will Clementine data tell us about the Moon? After the Clementine mission, we will possess the data needed to construct a global digital image model (DIM) of the Moon. These data are augmented by: 1) a set of topographic profiles (depending upon the efficacy of the ranging laser, topographic coverage may be nearly complete for the middle latitude band ($\pm$ 60°) of the Moon); and 2) a geodetic control net for the whole Moon that, when tied to the Apollo data, should permit knowledge of the true positions of lunar surface features in inertial space to within a few hundred meters. Moreover, the framing cameras take data

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sequentially and some stereo may be possible from overlapping images. Thus, maps of the Moon made from Clementine data will enable studies of regional history and permit us to decipher the processes of volcanism, tectonism, and impact that have shaped lunar history. In a supporting mode, the global DIM will serve as a base to overlay other data; the geological context of the multi-spectral data must be understood to interpret such data properly.

From the combined visible and near-IR cameras, we will have a global color map that we can interpret in terms of the distribution of rock types. At a minimum, we will be able to recognize and discriminate between the absence of mafic minerals (pure feldspar), and the presence of orthopyroxene, clinopyroxene, and olivine, as has been done for the near side of the Moon from Earth-based data (e.g., [7]). Thus, we can distinguish, on a global basis, the distribution of anorthosite, "noritic" rocks, olivine-bearing rocks (dunites and troctolites), and gabbros. For mare deposits, visible color mapping can classify the mare in terms of Ti abundance [5], an element that can be used to estimate the distribution of solar-wind hydrogen, an important lunar resource [8].

Combined with our knowledge of cratering and the use of basins as probes of the crust, these data will permit us to reconstruct the composition and petrologic structure of the crust in three dimensions. We can address the question of the existence of a magma ocean [2,9], the nature of Mg-suite magmatism, the history and extent of ancient KREEP and mare volcanism [9], the compositional diversity of mare units, and the effects of cratering on the composition of the lunar surface. Topographic data from the LIDAR ranger combined with spectral information will allow us to model and understand the dynamics of large impacts, e.g., the problem of depth of excavation for basin-sized impacts [10].

With high-resolution data from the LIDAR imager, we can study surface processes and compositions in greater detail. Many mare units display significant heterogeneity and color imaging from the Clementine LIDAR can map different color units, some of which are perhaps related to individual mare flows. Images of crater walls and central peaks can not only provide high-resolution compositional data, but permit us to better understand the geological setting and processes that have affected given regions, information that may prove critical to the proper interpretation of the regional compositional information. Finally, the high resolution imaging can be used to make detailed geological studies of areas of high scientific interest.

Conclusion The Clementine mission is a boon to the study of the geological processes and history of the Moon. Not an end unto itself, this mission is an important first step in our renewed effort to explore the fascinating and complex story of our nearest planetary neighbor.

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