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MODES OF FORMATION OF LUNAR LIGHT PLAINS AND THE DETECTION OF CRYPTOMARIA DEPOSITS; James W. Head, John Mustard, Irene Antonenko, Dept. of Geol. Sci., Brown Univ. Providence RI 02912 and B. Ray Hawke, SOEST, Univ. Hawaii, Honolulu, HI 96822.

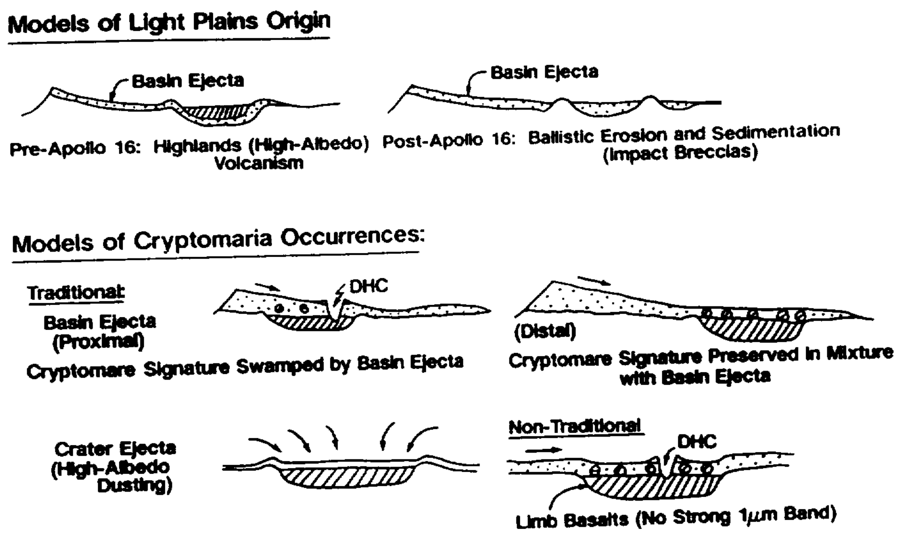
Introduction: The early volcanic and impact histories of the Moon are closely linked and the record preserved in surface morphology and samples is tightly convolved because of the interaction of the two processes. The deconvolution of the record is an important goal in order to assess early volcanic flux (1) and the mode of emplacement of large crater and basin deposits. For example, lunar light plains have been variously interpreted as volcanic (2), impact (3), and volcanic covered by impact deposits (4) [e.g., cryptomare (1)]. The development of criteria for the determination of the origin of light plains and the detection of cryptomaria is thus a key to the deconvolution of this early record. In this paper we outline the various hypotheses for the origin of, and potential modes of occurrence of light plains and cryptomaria, and develop criteria for their recognition and documentation. We use the example of the Schiller-Schickard (5) and Balmer (6) cryptomaria to illustrate the application of these techniques to the problem of light plains interpretation and cryptomaria documentation.

Modes of Occurrence and Origin of Light Plains and Cryptomaria: Prior to the Apollo 16 mission, the Cayley light plains were thought to be of volcanic origin (Fig. 1) because of their smooth nature, their filling of highland craters, and their stratigraphic and crater age placing them between the latest impact events and the earliest maria (2); thus, a significant phase of highland (high-albedo) volcanism was thought to characterize the early Imbrian history of the Moon. Astronauts John Young and Charles Duke immediately recognized that the plains at the Apollo 16 site consisted of impact breccias. Analysis of returned samples and reassessment of the impact cratering process (3,7) led to the conclusion that light plains could be produced by ballistic erosion and sedimentation processes associated with large cratering events. However, the wide range of crater ages shown by light plains led some to continue to favor a volcanic origin for many light plains deposits (8). Analysis of dark-halo craters on basin ejecta and light plains provided evidence for mare deposits that had been covered by and mixed with later basin ejecta (4). Multispectral imaging provided evidence for the regional extent of some cryptomaria and the percentage of underlying maria incorporated into the overlying ejecta deposit (5). It also showed that in cryptomaria regions proximal to basins, the contribution of primary ejecta may be so great or the vertical mixing is not thorough enough so that the percentage of underlying cryptomaria incorporated is below the detection level, and is only obvious from the direct excavation and exposure in dark halo craters (4). In addition, this study, together with crater ages (9), has shown that light plains overlying cryptomaria may form from a thin dusting of post-basin crater ejecta. Recent identification of mare basalts with a weak absorption band at 1 μm (9,10) has led to a new possibility, "non-traditional" cryptomaria (Fig. 1), where the lack of the characteristic absorption band could hinder distinction of mare contributions to mixtures with highland basin and crater ejecta. Although albedo could still be an important factor in the recognition of these types of cryptomaria, extrusive volcanic deposits (including some maria) may also exist which have relatively higher initial (mature soil) albedos. We now use the example of the Schiller-Schickard (5) and Balmer (6) cryptomaria to illustrate the application of these techniques to the problem of light plains interpretation and cryptomaria documentation.

The Schiller-Schickard Example: This cryptomaria (4,5) is located about 900 km to the southeast of the Orientale basin in the transition zone of radially textured ejecta, plains, and secondary craters; its presence is shown by dark-halo craters with mare basalt-like spectra (4) and its extent is indicated by mixing-model calculations (5). A mare fraction image (5) shows the details of cryptomare distribution; abundance values are density-sliced into discrete levels, with a lower bound of 25% chosen to mark the lower limit of confidence for an unambiguous mare signal. Patches of cryptomaria that are smaller, thinner, or closer to the basin might not be detected with this lower bound. The two zones of high abundance on the floor of the Schickard impact crater correspond to the previously known small patches of post-Orientale mare; the rest of the floor shows moderate to low abundance. The east, south, and west walls of Shickard show an absence of mare indicating a surface dominated by highland components. This illustrates the fact that many cryptomaria will be difficult to detect because they are patchy and infilling crater floors. Most of the light plains and discontinuous facies of the Hevelius Formation within and between the Schickard and Schiller craters, and in the northern half of the Schiller-Zucchius Basin, also exhibit moderate to low mare abundances. On the basis of crater counts (5) some of the light plains within Schiller-Zucchius apparently post-date the emplacement of the Hevelius Formation and may be post-Orientale maria that have been covered by bright ejecta from nearby craters such as Zucchius. This shows that dusting by post-basin crater ejecta can at least locally produce higher albedo plains. The mare fraction map (5) shows that a minimum areal extent of pre-Orientale mare is $\approx 3\text{-}4 \times 10^5$ km^2. However, evidence from dark halo craters suggests that additional mare patches are buried by the continuous facies of the Hevelius formation west of this main area (4). These areas are not detected in this analysis (because they have mare abundances less than the 25% cutoff) and may be covered by a greater thickness of ejecta, or be smaller than the spatial resolution of the instrument. Thus, in this case, crater probes (dark-halo craters) help to detect the presence of cryptomaria where they are being swamped by basin ejecta. The sizes of the cryptomare outlined here are comparable to several post-basin maria (e.g., Humorum, Nectaris, Vaporum, Orientale); however, it is also clear that additional deposits exist closer to the basin but are swamped by ejecta deposits.

The Balmer Basin Example: The interior of this basin is the site of geochemically anomalous (11) light plains of Imbrian-Nectarian age interpreted to be mare basalts underlying a veneer of bright material (5,11); however, no major basin in the vicinity appears to be capable of providing a substantial post-plains ejecta deposit. Instead, the bright veneer is interpreted to be due to the presence of five large impact craters within a distance of 250 km from the plains (5) providing a veneer of highlands crater ejecta to obscure the cryptomare (Fig. 1). Another possible explanation, potentially supported by the geochemical data (11), is that these plains represent volcanic deposits that have an initially higher albedo than typical mare deposits (Fig. 1).

Conclusions: On the basis of these analyses, it is clear that multiple approaches and data sets must be used to determine the potential modes of origin of light plains and cryptomaria. In some cases, ancient cryptomaria deposits may never be detected if they are beneath proximal basin ejecta, while in other cases, it is clear that the judicious use of global orbital spectral reflectance, imaging, and geochemical data will reveal a range of anomalies and occurrences well beyond our current knowledge. In this analysis, we are continuing to develop criteria for their recognition and documentation.



References: 1) J. Head and L. Wilson (1992) *G&CA*, 56, 2155; 2) D. Wilhelms (1970) *USGS PP 599F*; 3) V. Oberbeck *et al.* (1974) *PLSC 5*, 111; (1975) *Moon*, 12, 19; 4) P. Schultz and P. Spudis (1979) *PLPSC 10*, 2899; B. Hawke and J. Bell (1981) *PLPSC 12*, 665; 5) J. Mustard *et al.* (1992) *LPSC 23*, 957; J. Head *et al.* (1992) Lunar impact basins: New data for the western limb and farside (Orientale and South Pole-Aitken basins) from the first Galileo flyby, subm. to *JGR*; 6) B. Hawke *et al.* (1985) *EMP*, 32, 257; 7) V. Oberbeck (1975) *RGSP*, 13, 337; 8) G. Neukum (1977) *Moon*, 17, 383; 9) R. Greeley *et al.* (1992) Galileo imaging observations of lunar maria and related deposits, *JGR*, in review; 10) C. Pieters *et al.* (1992) Crustal and mantle diversity: Compositional analysis of SSI Moon data, *JGR*, in review; 11) T. Maxwell and C. Andre (1981) *PLPSC 12*, 715.