PHYSICAL ENVIRONMENT OF THE LUNAR SOUTH POLE FROM *CLEMENTINE* DATA: IMPLICATIONS FOR FUTURE EXPLORATION OF THE MOON

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The polar regions of the Moon have attracted attention as possible targets of exploration for a variety of reasons, including the operationally attractive possibility of permanently shadowed areas containing water ice [1] and permanently sunlit areas [2] and the scientific potential of a polar site for lunar based astronomy [3], and the general geological exploration of the Moon [4]. Recently, international interest in lunar exploration has grown, as shown at the first International Lunar Workshop in Switzerland last year [5]. We have studied images of the south pole of the Moon obtained from the Clementine spacecraft during a single month's orbit of the Moon (late March to late April, 1994) in order to better understand the physical environment of the region. We have identified a small area near the pole (close to areas of permanent shadow) that appears to be exposed to almost constant solar illumination.

The spin axis of the Moon is inclined approximately 88.5° from the plane of the ecliptic. If the Moon were a perfectly smooth sphere, the sun at the pole would trace an arc through the sky, rising to 1.5° above the horizon during local noon and dipping 1.5° below the horizon during lunar midnight. Because the Moon has pronounced topography, areas near the pole may be either in permanent shadow, being depressed below the mean lunar radius, or in permanent sunlight, being elevated above the mean radius. The Clementine south polar mosaic shows clear evidence of large areas of shadow near the south pole of the Moon (Fig. 1), probably associated with an old, degraded basin [6] but also caused by the presence of the immense South Pole-Aitken basin [7], a 2500 km-diameter impact feature, centered on the far side of the Moon. The presence of such large areas of apparently permanent darkness led us to search for its complement, an area in permanent sunlight. If they exist, areas of permanent sunlight would be found adjacent to areas of permanent darkness; such areas would have prime operational advantages and are also of great scientific interest.

We assembled the polar images from alternate orbits (from 170 through 300), which covered the Moon for the second month of systematic mapping. These images were taken at an approximate range of 1800 km altitude and have resolution of about 600 m/pixel. The images were compiled into a movie that shows the terminator sweeping around the Moon for one lunar day (approximately 708 hours). The polar area was examined to identify zones that remain in sunlight for long periods or permanently. Near the pole is an unnamed impact crater, about 20 km in diameter. Although the pre-mission relief map shows this crater centered on the pole [8], the crater actually appears to be slightly offset, with the true pole being located just inside the rim of this feature at about the 10 o'clock position (0° longitude is the 12 o'clock position in the following discussion; Fig. 1). During winter, somewhat less than one-half of the polar area is illuminated at any one time; as the Moon rotates, the terminator sweeps anti-clockwise across the south polar region.

Large massifs associated with the South Pole-Aitken basin [6, 7] cast long shadows near the pole; these shadows create the dark areas identified by [6] and also partly mask the rim of the polar crater at various times during the month. However, a single site on the rim crest of this polar crater at the 8 o'clock position (approximate coordinates 89.6° S, 170° W) remains in sunlight during the entire near side daytime and for most of the far side daytime hours (Fig. 1). This site goes into eclipse when the solar vector (longitude of local noon) is between about 49° and 55° W, at 80° W, from 121°- 126° W, at 124° E, and at 41° E, a cumulative eclipse duration of roughly 50-60 hours. At all other times, the rim is illuminated by the sun. These images were obtained just past the southern hemisphere "winter solstice"; during the southern summer, it is likely that eclipse times are much shorter, possibly even non-existent. Thus, this site on the Moon is apparently in sunlight roughly 95% of the time. Local terrain features smaller than the image resolution (600 m) will influence the duration of shaded and sunlit periods; a statistical assessment of these effects is in progress [9].

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Several factors make this site an important target for future exploration. First, the lunar environment at this site is thermally benign, experiencing neither the blistering heat of noon nor the frigid darkness of midnight. The sun is nearly always close to the horizon, creating an average surface temperature of around 250° - 270° K. Second, the solar illumination provided by the sun can be easily collected, either with steerable solar arrays (e.g., a panel that slews 360° in azimuth, constantly tracking the sun) or with a cylindrical or conical shaped fixed array. The availability of constant solar energy and low degrees of thermal loading greatly simplifies mission and spacecraft design. The permanent shadowed areas of the pole, which appear to contain ice-like deposits [10], are within easy access of this location, either by surface roving or ballistic hops. A variety of excursions could be planned to explore and characterize these potentially important regions. Scientifically, this site offers rich possibilities for astronomy (advantages summarized in [3, 10]); the entire southern sky, where the most inviting astronomical targets are found, is visible constantly. For geoscience, results from the Clementine mission have caused us to re-evaluate the global geology of the Moon. The South Pole-Aitken basin [7] appears to be one of the most fundamental features on the Moon, responsible for a major crustal compositional province [12] as well as possibly holding the key to early lunar cratering history [13]. Geological investigations of the highlands in this area could shed light on lunar processes and history. Finally, the likely presence of significant resources, mainly water ice, near this site suggest that long-term occupation and ultimately, habitation of the Moon will be greatly facilitated from this site. A lunar outpost near the south pole could accomplish all of these scientific and technical investigations from the convenience of a single location.

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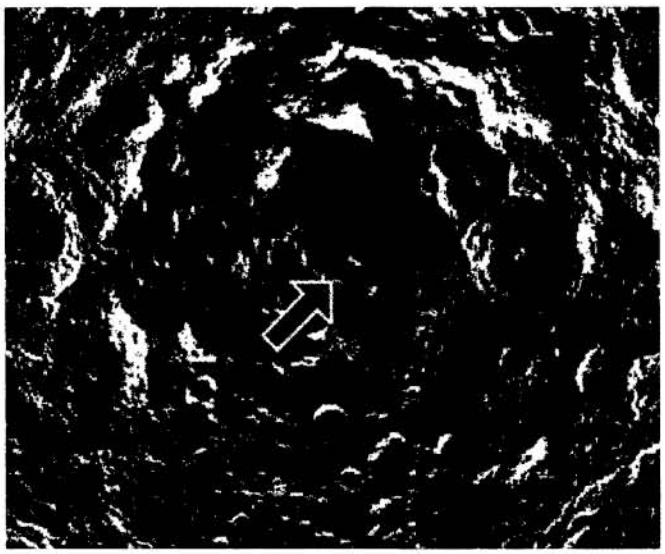

Figure 1. South Pole of the Moon from Clementine data. The 20-km diameter crater (arrow) near the pole has a site on its rim (at about the 8 o'clock position; 89.6°S, 170°W) that has near-permanent (> 90% of time) sunlight.