On-Going Investigation of Lunar Anomalies

Mark J. Carlotto

Although our understanding of the moon has grown and become clearer from a geological standpoint, there remain mysteries that have not yet been satisfactorily explained. Laid over the impact basins and maria, the craters and rays, and other features of a clearly geologic origin are formations which geologists call "special features". Examples include narrowly spaced furrows or grooves, crater chains and other structures that repeat themselves, unusually bright regions, trenches and tubes leading into/out of craters, straight lines and other highly geometrical patterns on the surface. There are also lunar transient phenomena -- lights that appear and in some cases move across the lunar surface.

In the spring of 1994, the Clementine spacecraft [1] collected over 1 million images of the moon at an average resolution of 400 meters. Although the individual images cover smaller areas and are less detailed than most of the Lunar Orbiter and Apollo photography they provide a rich source of information to follow-up on the discoveries of unusual features reported by other investigators and to identify possible new anomalies (geological or otherwise). In this article several anomalous features identified in imagery collected during one of Clementine's 350 orbits are presented and discussed.

Methodology

First something should be said concerning the process by which a feature is detected, examined, and classified as normal or anomalous. Anomalies are, in some way, different from the background. Usually there is a structure or pattern that appears to posses some kind of organization. The organization may or may not be geometrical. For example, although the pattern of streets within an urban area is highly geometrical, at a lower resolution the pattern may be less regular but still appear organized.

Having found a possible anomaly, a search is conducted for other images taken at different sun angles and/or from different perspectives (different positions of the sensor). Images taken at different sensor positions, under some circumstances, can be combined into a stereo pair. In a stereo pair, the height of an object is converted into parallax, a shift in the apparent position of the object between the two images. This allows one to visualize the surface in three-dimensions.

If only a single image is available little can be done to assess a feature in isolation. When a collection of anomalous features are found in close proximity, analysis of spatial relationships can sometimes provide additional insights. However when multiple images exist further analysis of the feature is possible. Consider the situation where the camera positions are the same but the lighting is different. If the anomaly persists in two or more images taken under different lighting conditions it is likely that it is not an optical illusion. Another situation mentioned above is when two or more images are acquired at different sensor positions they can often be aligned to create a stereo pair. The stereo pair adds depth to the feature and allows one to examine its structure and relationship to the background in 3-D.

A feature is considered to be anomalous if it exhibits a pattern of organization within itself and/or in relation to other features, if the pattern persists (does not disappear) under different lighting conditions and sensor geometries, and does not appear to have an obvious geological explanation.

Results

Several anomalies within a 300 km strip acquired during orbit 150 have been identified. The region shown in Figure 1 is west-southwest of the crater Endymion on the near side of the moon (latitude 50° N, longitude 50° E). The craters Atlas A and D indicated in the figure are approximately 25 km. in diameter. The total region shown is about 100 x 300 km.

Faint rays can be seen over the entire area. Rays are thought to be caused by material ejected from impact craters. A prominent display of rays can be seen emanating from the crater (A) in Figure 1. Figure 2 shows this crater, which is only a few kilometers in diameter, in greater detail. The rays do not radiate in all directions. Instead there is a gap or shadow from 6 to 9 o'clock. Also the rays appear longer in certain directions than others. Another unusual aspect to this crater is the thin dark line (10 o'clock). Initially the line seems to be a vertical extension such as tower with the somewhat lighter region at 2 o'clock being its shadow. Figure 2 combines two images acquired a few seconds apart to create a stereo pair [2]. Lack of parallax differences between the two ends of the thin dark line indicates that the line is oriented more or less horizontally (i.e., it lies on the surface). It seems then that the dark line is a trench several kilometers long cut into the side of the crater.

Another unusual crater of a different sort is at the top of the mosaic (crater B). A stereo image of this crater (Figure 3) reveals that it does not appear to be a typical crater at all. Rather it seems to be a circular formation of the highlands material. In stereo the two small craters to the left of crater B are clearly depressions in the surface while crater B appears to be raised relative to the surface.

In the lower left corner of the mosaic (Figure 1) there are several features that together suggest a pattern of activity on the surface. Figure 4 shows the area in greater detail. The region of interest is between the two craters in the left half of the image. The pattern consists of a raised area (lower left) extending up and to the right into a small depression. To the right and below the depression is a bright area. A fissure runs from the larger crater and splits into two lines: one that runs just below the raised area, the other towards the smaller crater. Qualitatively the overall visual impression of the area is that of a complex of some kind. Figure 5 is a contrast enhanced stereo image of the complex. The bright areas in the raised portion of the complex either do not have sufficient vertical extent to cast any detectable shadows or are brighter because their albedo is higher. (The brightness of the lunar surface depends on the slope of the surface relative to the directions of the sun and the observer, and on the albedo, the ratio of the emitted to incident light). Figure 6 is a contrast enhanced stereo image of the bright area to the right of the complex. The increased brightness does not appear to be caused by a topographic effect; i.e., to appear brighter because it is sloped towards the sun. Instead the increased brightness appears to be due to a higher albedo, e.g., a debris field (large rocks) or due to recent events that have disturbed the surface exposing rock and material with a higher albedo underneath.

As a cross check, images LUA4282n, LUA4315n, and LUA4349n from orbit 283 were examined to verify the patterns seen in the orbit 150 images. In addition to confirming the above observations the somewhat higher resolution of these later images revealed an additional anomaly within the complex. The contrast enhanced stereo image in Figure 7 shows an "X" next to the larger crater in the complex. The fissure seen in the earlier images extends from this feature to the raised part of the complex (bottom of Figure 5).

Discussion

One of the many mysteries of the moon that has not been satisfactorily resolved is the origin of crater rays - the bright linear patterns that emanate from craters. The conventional explanation is that rays are material ejected from impact craters. However, not all craters have rays, those that do may only emit rays in certain directions, and not all rays begin or end in craters. And some of the smallest craters seem to have the brightest rays. (These facts have caused some to speculate that rays are tracks caused by objects moving across the lunar surface.) In this regard Crater A seems typical. However the presence of a trench cut into the crater along with other patterns of fine lines near the crater is unusual and warrants further attention. Crater B on the other hand does not appear to be typical at all. It is not a depression and thus not caused by meteoric impact. It appears to be a circular formation composed of highlands material. Perhaps it is volcanic.

The complex is the most intriguing feature in the area. Although there appears to be an overall organization, with the exception of the "X" feature, lack of higher resolution imagery limits detailed analysis of the complex. The impression that the "X" formation is a real 3-D object is strengthened by the stereo image. Perhaps higher resolution Lunar Orbiter imagery over this area exists and can shed more light on the matter.

Future Work

Other unusual features and have been detected in Clementine imagery in several other orbits. Analysis of these features is currently underway. A review of previously reported lunar anomalies (including locations of transient lunar phenomena) is also in progress in order to focus search on other potential areas of interest on the moon.

Notes:

1. Clementine was a joint project between the Strategic Defense Initiative Organization and NASA. The objective of the mission was to test sensors and spacecraft components under extended exposure to the space environment and to make scientific observations of the Moon and the near-Earth asteroid 1620 Geographos. The observations included imaging at various wavelengths including ultraviolet and infrared, laser ranging altimetry, and charged particle measurements. The Clementine mission mapped most of the lunar surface at a number of resolutions and wavelengths from UV to IR. Clementine had five different imaging systems on-board. The UV/Visible camera had a filter wheel with six different filters, ranging from 415 nm to 1000 nm, and including a broad-band filter covering 400 to 950 nm. The Near Infrared camera also had a six-filter wheel, ranging from 1100 nm to 2690 nm. The Longwave Infrared camera had a wavelength range of 8000 to 9500 nm. The Hi-Res imager had a broad-band filter from 400 to 800 nm and four other filters ranging from 415 to 750 nm. The Star Tracker camera was also used for imaging. All images presented in this article were acquired by the UV/Visible camera.

2. To view the images in stereo, look away from picture and focus at a point in the distance. Then shift your gaze to the picture. You should see three images. Concentrate (but don't focus) on the middle image and try to bring different parts of the view into correspondence. This will take some practice. If you have difficulty seeing stereo, try moving back from the page. Also, it helps if the page is flat and well lit. Finally -- be patient, it's worth it!

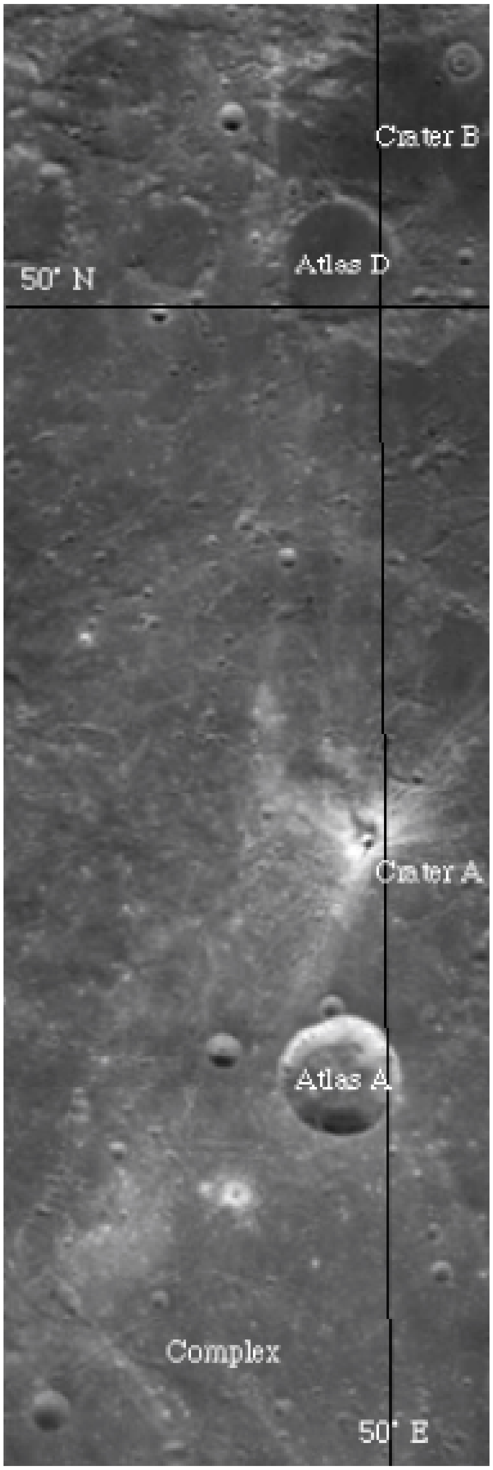

Figure 1

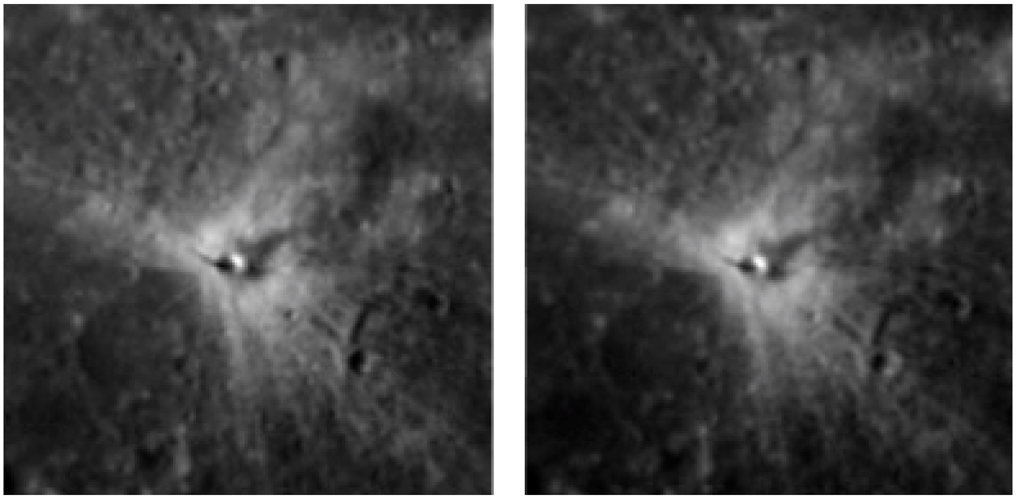
Figure 2

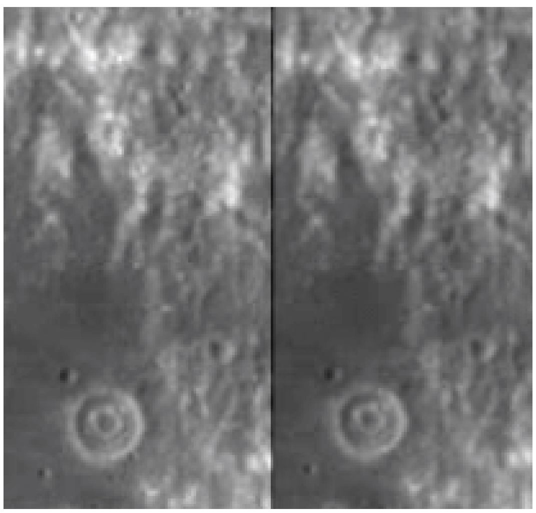
Figure 3

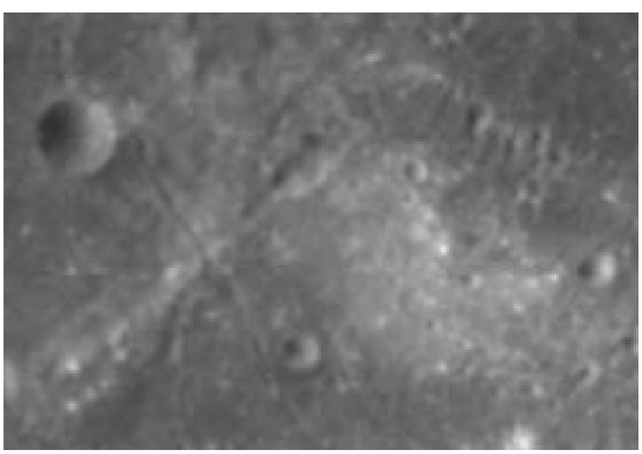
Figure 4

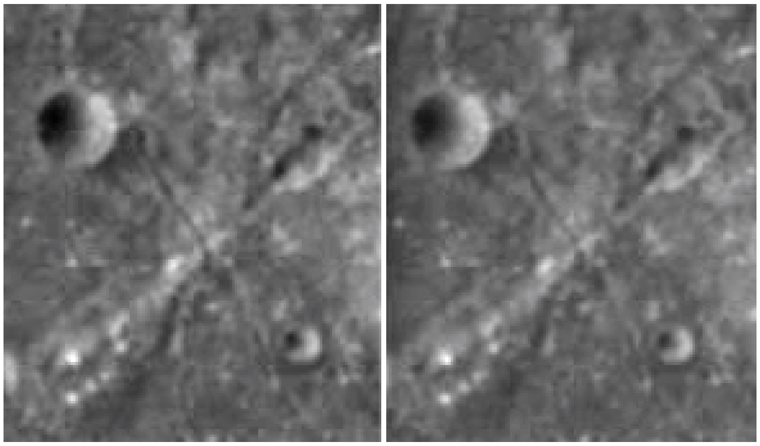
Figure 5

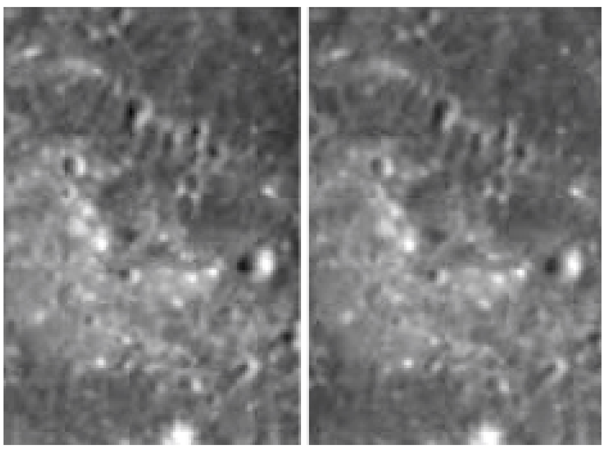
Figure 6

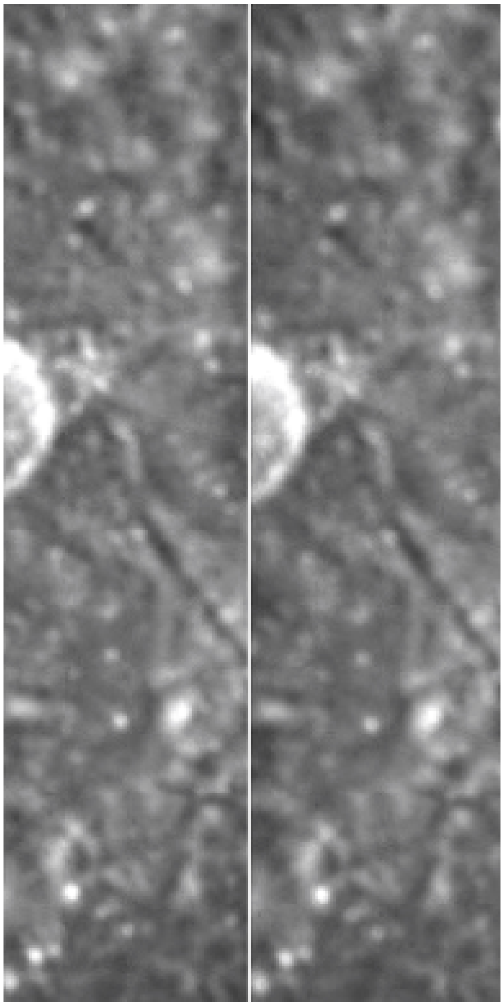

Figure 7