STRUCTURES AND ACTIVITY OF A LUNAR TECTONIC ZONE

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Abstract. Most recent tectonically notable lunar surface structures, straight or arcuate rilles and mare ridges are found to form regional lineament sets which are interpreted to be manifestations of crustal zones of weakness. The activity of the zones of weakness and their different parts range over a long period of time. Some parts of these zones may have undergone similar development to those of both experimental and natural strike-slip shears. It is hypothesized that the clearly discernable surface zone, which runs from the crater Lansberg to the crater Palmieri tangential to Mare Humorum, may coincide with a major moonquake belt described by Lammlein (1977).

1. Introduction

Straight and arcuate rilles exist mainly on old lunar terra. Some close parallel linear rilles which extend through a considerable part of the terra area west and northwest of Mare Humorum determine the strike of rille set A–A (Figure 1), indicating the existence of a lunar crustal zone of weakness (Raitala, 1977). This zone evidently continues through the Oceanus Procellarum basin bedrock covered by Imbrian and Eratosthenian lavas. This extension is seen as long and narrow ridge ranges with a parallel or slightly oblique arrangement compared to the proposed zone direction (Raitala, 1978).

The rate of surface displacement remains, however, unrecorded because there is a lack of qualified markers unaffected by the zone of weakness itself. It is not possible to follow the development of both linear rille and pre-ridge fractures continuously on the large scale Apollo and Lunar Orbiter photographs.

2. Tectonic Phenomena

The southwestern part of zone A-A runs in rilles and faults through the crater Letronne rim formation and the crater Gassendi forming parallel topographic steps tangential to Mare Humorum. This fractured part of zone A-A is crossed by some other lineament sets. After the crossing of the Rima De Gasparis–Rima Palmieri system (E-E, Figure 1) to the southwest of Mare Humorum the most recent rille-forming activity of zone A-A seems gradually to vanish. The termination of the fault along the western border of Mare Humorum follows the fault termination mode given by Anderson (1951). The formation of splay rilles (Figure 2(a)) resembles that of the termination of the Hope Fault towards the Alpine Fault in New Zealand (Freund, 1974). Rilles seem to have some features of transcurrent faults, but tensional properties of rilles are also evident. According to the rille bending and splaying the sense of movement has been sinistral. In the Gassendi–Letronne area rilles form a major sinistral en echelon rille arrangement (Raitala, 1977).

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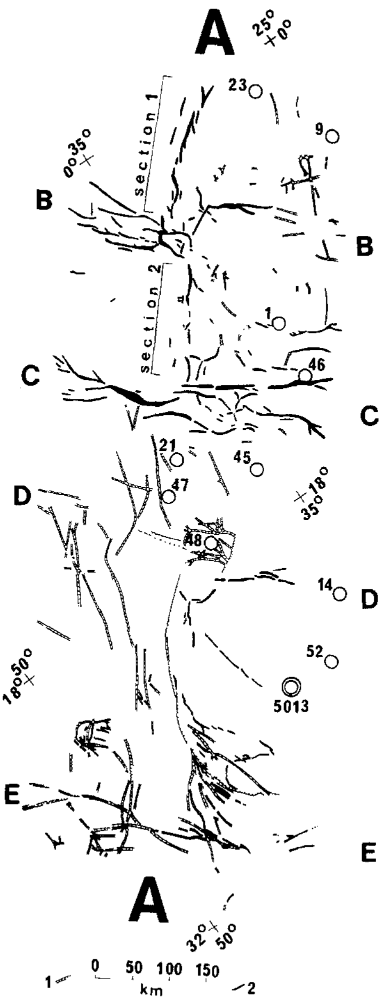

Fig. 1. Straight and arcuate rilles (1) and mare ridges (2) of the studied lineament set A-A and crossing sets B-B, C-C etc. Single circles denote deep moonquake epicentral locations and a double circle indicates a shallow moonquake epicentral location (Lammlein, 1977).

The northeastern part of zone A-A is characterized over most of its length by mare ridges. Section 1 of zone A-A (Figure 2(b)), situated to the northeast of the crossing zone B-B consists of quite narrow mare ridges with a clearly sinistral or parallel and slightly dextral arrangement. The angle between mare ridges and the zone varies but it is clearly smaller than that in the case of tension fractures. Thus the existence of sinistrally arranged Riedel shears (R-shears) joined towards the zone direction by dextrally arranged opposite Riedel shears (P-shears) may well illustrate the situation. According to Tchalenko (1970) and Freund (1974) these kinds of structures are developed during the post-peak

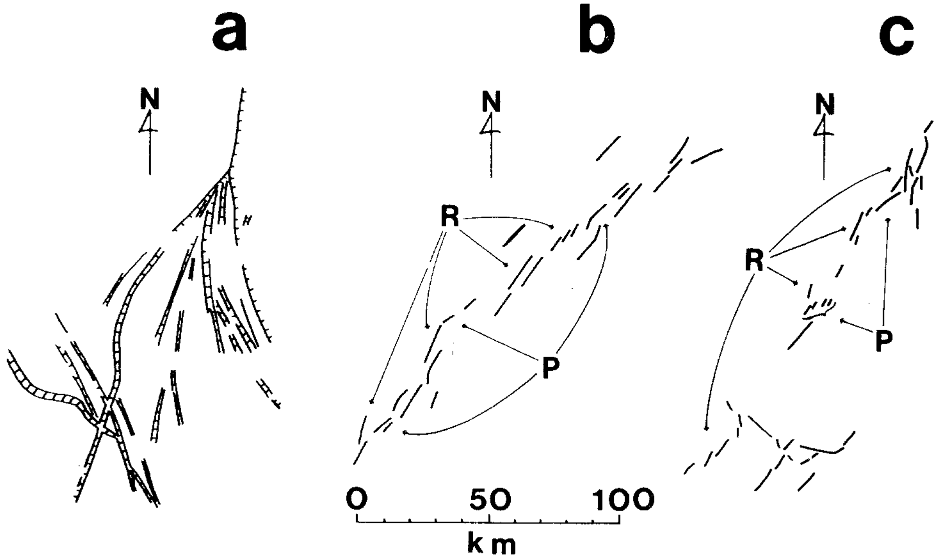

Fig. 2. The southwest termination of the Mare Humorum border fault by splaying and bending rilles (a) and ridges of the sections 1 (b) and 2 (c) with proposed R- and P-shears;

stage of deformation with a sinistral sense of movement when the conjugate Riedel shears disappear and simple shear begins to be transformed into direct shear by the bending of R-shears and their linking together by P-shears (Raitala, 1978).

Section 2 of zone A-A is situated southwest of the previous section between crossings B-B and C-C. The sinistral R-shear pattern is clearly seen but there are also some rectilinear ridges along the zone (Figure 2(c)). Also, as in Section 1, the junction between adjacent R-shears takes place through dextrally arranged P-shears. The sense of movement thus seems to be sinistral. The situation in Section 2 is further complicated by the interaction of zones B-B and C-C with each other in about the meridional direction. The crossing area of zones A-A and B-B has major elements of both zones but crossing zone C-C is much stronger than zone A-A.

Figure 1 gives the moonquake epicentres in the area of the zone under study (Lammlein, 1977). The major moonquake hypocentres lie in the lower lithosphere at a depth of 850–1020 km. One shallow moonquake hypocentre depth is about 25 km. Moonquake epicentres seem to be scattered within lunar crustal tectonic units. Three deep moonquake epicentres are located in the fractured surface zone A-A within the Gassendi–Letronne area. The others are located slightly east of this zone and connect mainly with the conjugate fracture zones. Zone A-A forms the western boundary of moonquake epicentres in this moonquake belt (Lammlein, 1977), thus indicating some possible coupling with old and recent lunar tectonic activity.

3. Discussion

Without going into volcanic phenomena, which are evidently strengthened tectonically activated structures causing positive surface reliefs (Fielder, 1965) structural similarities to small scale laboratory experiments and regional scale earthquake faults (Tchalenko, 1970) are found so that we can consider the fracture generation within mare areas as nature's own Riedel experiment with an old zone of weakness. This experiment does not suffer restrictions caused by the small scale and surrogate materials of laboratory tests. Lava slabs have evidently covered horizontally an old zone of weakness. Reactivations of this juncture zone have then given rise to fracturing of the lava slabs during horizontal shearings or jerkings. The whole crustal deformation has, however, been more complex, as seen from the existence of crossing zones of weakness (Raitala, 1978).

There have possibly been two sources of tectonic energy in the Moon. Lunar crustal tides extended by a rotational equatorial bulge which relaxed during despinning (Melosh, 1977) were possibly considerable during the period of former faster lunar rotation. Thermal energy sources were also important within the Moon during the first 1.6×10^9 yr of lunar history, as seen from widespread mare lavas. The existence of lithospheric fluids, different density layers and parts, and asthenospheric convections as well as major impacts and rotational and tidal forces has possibly favoured ancient tectonic activity and lithosphere fracturing. Lammlein (1977) has pointed out that a weak thermal convection could be the secular source of energy released during recent moonquakes (Figure 1) which are triggered by lunar tidal stresses but suppressed by the lack of recent lunar lithospheric fluids. He also postulates, however, that major moonquake belts "coincide with the regions of youngest and most active volcanic and tectonic activity".

The Moon has remained relatively static for some 3×10^9yr. Tensional properties of rilles possibly date from times of at least local lunar volcanic expansion (Raitala, 1977). The recent contraction of the Moon indicated by the thrust-faulting moonquakes (Lammlein, 1977) could be considered to be a logical continuation of lunar development. The change in tectonic character from tension to compression would be due to lunar thermal energy loss causing activity decrease and possible phase transitions. Shearing movements along the zones of weakness like these zones themselves may have arisen under the influence of global stresses coupled with old tidal and igneous forces. Thermal convection with adjoining volcanic events may have been important during the formation of tectonic structures. Tidal forces have caused small continuous relative and at least triggering movements in the lunar lithosphere. Major impacts have evidently at least activated local or even areal tectonic structures.

Some lunar sruface lineament sets with adjoining volcanic phenomena and recent moonquakes may thus indicate the evolutionary trend of lunar tectonics. On the basis of these structures it may be possible to determine some features of lunar deformation history. With regard to this aim the progress there will be conditioned by a better knowledge of development and general tectonics of other terrestrial planets. This is accepted today as having many theoretical as well as possible practical implications.

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