
Furrowed and pitted terrain as mapped on the lunar east side by Wilhelms and El-Baz (1) is described as terra material of Imbrian or Nectarian age characterized by pits or furrows several kilometers long, and/or small rounded hills. Origin by emplacement of impact ejecta and origin by volcanic processes have both been proposed (1). Major occurrences of the unit are found between the Crisium and Fecunditatis basins, north of Mare Marginis, and on the floor of the Smythii basin. Furrowed and pitted material exhibits distinct morphologies in these different locales (e.g. furrows or pits may predominate). Thus, the furrowed and pitted terrain may represent more than one individual unit.

Previous work has concentrated on the Smythii basin floor. Stewart et al. (2) divided the furrowed and pitted unit, mainly on morphologic grounds, into volcanic material in the north of the basin, and impact ejecta in the south. However, Andre et al. (3) studied the X-ray fluorescence data and noted that the similar Al/Si ratios for the northern basin floor and the terra bordering it to the west made a volcanic origin unlikely. Using low altitude X-ray fluorescence data for the southern part of the basin, Maxwell et al. (4) were able to distinguish a chemical difference between the eastern and western portions of the floor, which exhibit some morphologic differences. Andre et al. (5) noted a distinct difference in chemistry between the southern floor and the terra to the west.

The area of interest for this study is the westernmost zone of furrowed and pitted material between Fecunditatis and Crisium. It is located roughly between longitudes 50-59 E and latitudes 3-8 N. Here the unit exhibits a higher albedo and more rugged texture than the Smythii material. This area was chosen for study because 1) with the exception of Smythii it has the best X-ray coverage of the furrowed and pitted sites, and 2) the Soviet Luna 20 landing site is located within it, providing sample information. The Luna 20 sample was found to be similar to the samples returned on the Apollo 16 mission, thus favoring an impact ejecta origin for the study area (6). However, a volcanic origin cannot be ruled out because 1) the Luna 20 spacecraft may not have landed on a representative portion of the unit (the texture of the site differs from the surrounding material), 2) it may have sampled the ejecta from a nearby prominent crater, and 3) a sample from a single site may not be sufficient to characterize an entire unit. (6). The material located between Crisium and Fecunditatis has been cited, along with the Smythii floor, as the most likely occurrence, if any, of the furrowed and pitted unit to be volcanic (1). Therefore, we examined the X-ray data to determine if there is evidence of a distinct compositional unit, which could indicate the existence of volcanic material amidst the highland terra.

Orbital X-ray fluorescence data provide information on lunar surface chemistry to a depth of about 20 μm (see 7). Figures 1 and 2 show the X-ray data for two revs (42 and 44) crossing the studied area. The points shown are Al/Si intensity ratios calculated using a three-point sliding average to reduce the signal-to-noise ratio.

The intensity plots indicate that the furrowed and pitted unit is clearly distinguishable from large mafic areas but appears similar to the highland material to the east. This highland material is mapped mainly as Nectarian/Pre-Nectarian partially mantled terra (1). This unit is a major component of
the eastside highlands. The nearside terra to the west of the furrowed and pitted material is composed of small patches of numerous units including plains and basin massifs (8). Therefore, the signals from this area reflect the input from several different terra units within the field-of-view. In this region the plots show an increase in the Al/Si values from the border of Mare Tranquillitatis in the west toward the furrowed and pitted material in the east. This increase with distance from Tranquillitatis is mirrored in several raves directly to the north, and may be caused by mixing of mare and terra materials, which would tend to lower the values of terra units near the mare border.

Average Al/Si intensity values were calculated for large areas where sufficient points were available well within the boundaries of each unit. For the furrowed and pitted material an average value of 1.2 was determined using 20 points from Revs 42 and 44. This was compared with the partially mantled terra which yielded a similar average Al/Si intensity of 1.3 from 17 points. Given a standard deviation of .2 for the furrowed and pitted material and .3 for the mantled terra, the small difference between the units does not appear significant. This is interesting in view of the fact that, as previously mentioned, the furrowed and pitted unit on the southern Smythii floor does exhibit a considerable chemical difference from the partially mantled terra. This supports the morphologic evidence that the study area and the Smythii floor, although both mapped as furrowed and pitted terrain, may have different origins (5).

To summarize, the X-ray data do not indicate that the furrowed and pitted material in the study area has a distinct chemical composition. Plots of Al/Si intensity and average Al/Si values show the patch of material in question cannot be distinguished compositionally from other nearby eastside terra. (Comparison with some nearside terra to the west is complicated by the presence of small diverse units and the proximity of Mare Tranquillitatis.) Therefore, a volcanic origin is unlikely. Although there was some question as to the validity of extrapolating the Luna 20 sample data to the entire unit, the X-ray data does support the sample results. The unit in this area is most likely ejecta whose furrowed and pitted morphology is the result of numerous secondary impacts, fractures, and/or deceleration structures formed during ejecta emplacement, as has been previously proposed (1,6,9). However, a volcanic origin cannot be ruled out for occurrences of furrowed and pitted material in other locales.

Acknowledgments. The authors thank C. G. Andre for many helpful discussions.

References
Figure 1. Al/Si intensity ratios for Rev 42. Terrain types are marked along X axis. M=Mare, T=Terra, F=Furrowed and Pitted, C=Crater. The westernmost segment of mare is the eastern edge of Tranquillitatis. The easternmost terra is the partially mantled terra unit.

Figure 2. Al/Si intensity ratios for Rev 44. Terrain types traversed are marked as in Figure 1.