

SURFACE FLUORINE ON LUNAR SAMPLES\*, R. H. Goldberg, D. A. Leich,<sup>†</sup>  
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The possibility of surface deposits of volatile elements on lunar samples produced by impact, and conceivably volcanic events, has motivated us to study the distribution of F in the outer micron of lunar samples. In this regard the high (~ 2500 ppm) surface F concentrations reported by the in-situ Surveyor VII analysis (1) are of particular interest. We have used the nuclear reaction  $^{19}\text{F}(p, \alpha\gamma)^{16}\text{O}$ , for which the yield of  $\gamma$ -rays as a function of beam energy can be directly converted to F concentration vs. depth with a resolution of 0.05  $\mu\text{m}$ . Previously, we reported F surface concentrations (up to 2000 ppm) on several Apollo 16 samples which were much larger than those of bulk analyses of rocks (< 50 ppm) or soils (50-100 ppm) (2). The critical question, which we were unable to answer previously, was the level of F contamination. This is of particular concern because F-rich materials (Teflon, Freon, etc.) have been used extensively both in the mission and post-mission handling of lunar samples. Our recent work has indicated that F contamination is present — making the study of lunar surface F very difficult.

There are two features of our data which are not easily explained by contamination: (A) High F concentrations are observed even at depths of 1  $\mu\text{m}$ . This is illustrated in Fig. 1 for the case of 66044,8, a crystalline anorthosite 4-10 mm coarse-fine particle which has the highest surface-averaged F content we have measured. The F concentrations are high on two surfaces and uniform at depths from 0.2 to at least 1  $\mu\text{m}$ . Table 1 indicates the range of F contents in the depth intervals 0-0.5 and 0.5-1.0  $\mu\text{m}$  for some of the samples we have studied. Our experience in H depth studies has shown the contamination is usually manifested as a surface film which is less than ~ 0.1  $\mu\text{m}$  thick. Previously, we had observed relatively sharp peaks in the F distributions which were at apparent depths down to ~ 0.2  $\mu\text{m}$ . Electrostatic charging of the sample surfaces which produces beam deceleration and a shift in the depth scale was a possible explanation for these results and this has been confirmed by subsequent studies. We now correct for surface charging by measuring the shift in the  $^{21}\text{Al}(p, \gamma)^{28}\text{Si}$  resonance at 0.992 MeV, assuming that the Al content is relatively uniform with depth. The range of surface potentials observed, 2-14 kV, indicate that all the observed peaks are actually on the surface, consistent with contamination. (B) F contents are always much higher on the lunar exterior surface of rock chips than on the interior surface. The samples studied to date were allocated primarily for the purpose of H studies; in order to provide a dry  $\text{N}_2$  atmosphere and to protect against surface abrasion during shipping, the samples were sealed in Teflon bags. The interior surfaces produced by chipping in Houston provide a control on F contamination from the packaging process. However, all rocks returned on Apollos 15-17 were contained in fluorocarbon bags cleaned in Freon, which could provide additional F contamination on lunar exterior surfaces.

In order to measure the contamination due to Teflon packaging, we

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cleaned and baked quartz glass discs and found, after this procedure, a fluorine level of  $< 20$  ppm. Two of these discs were transported to the curatorial facility where they were heat sealed in Teflon bags in the same way as lunar samples. Subsequent measurements showed a surface fluorine peak ( $\sim 200$  ppm) which at a depth of 1 micron had not yet reached zero ( $< 20$  ppm) concentration (Fig. 2). The discs which remained here as controls had  $< 20$  ppm fluorine as before. Figure 2 shows that readily measurable amounts of F were produced either by the heat sealing or by abrasion; however, the amounts are much lower (by a factor of 5-10) than on lunar exterior surfaces. Conceivably, the rough surface of a rock is much more susceptible to contamination than the discs. However, the lunar interior samples packaged in Teflon tend to show concentrations no higher than those found on the discs. It is also clear from Fig. 2 that contamination is present to depths as great as  $1 \mu\text{m}$ , implying that the high F at this depth in lunar samples (item A) could also be contamination.

If the surface F contents represent contamination from the mission packaging materials, it is somewhat surprising that the most contaminated sample should be a coarse-fine fragment, because 66044,8 was transported to earth as part of a soil sample and statistically, should have been protected. To check that 66044,8 was not an anomalously F-rich lunar rock it was cleaved in half in our laboratory and F measured on the interior surface. As shown in Fig. 1, the average F content at  $0.5\text{-}1.0 \mu\text{m}$  is  $\leq 40$  ppm, consistent with bulk F measurements (2).

Although we have not ruled out a lunar origin for the surface F, we now have experimental evidence that the original arguments against contamination may not be valid. It may be that no lunar sample is sufficiently uncontaminated for the purposes of our experiment and perhaps other surface property experiments (like carbon) as well. The only possibility would be samples from surface indentations, e. g. vesicles, which have been protected from abrasion.

## REFERENCES

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TABLE 1

Sample	Surface-averaged F Content (ppm)		Surface Peak	
	0-0.5 $\mu\text{m}$	0.5-1.0 $\mu\text{m}$	position ( $\mu\text{m}$ )	FWHM ( $\mu\text{m}$ )
65315,6	1000	480	0.10	0.17
65315,6 interior	100	50	0.12	0.30
68124,3-A	410	50	0.13	0.13
68124,3-B	850	120	0.12	0.13
66044,8-A	820	540	0.10	0.04
66044,8-B	1900	1400	0.03	0.08
66044,8 interior	75	40	0.02	0.15

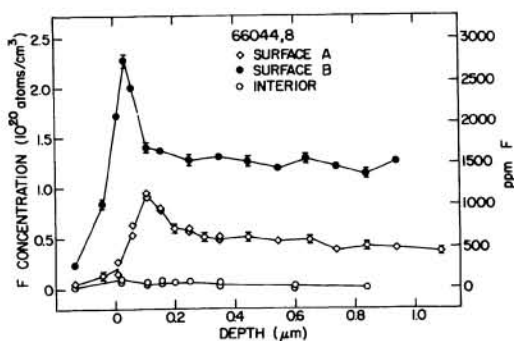


Fig. 1: Fluorine concentration versus depth for sample 66044,8. Surfaces A and B were exterior surfaces; the interior surface was exposed by our cleaning the sample.

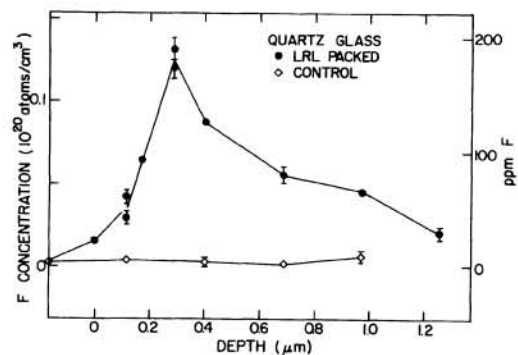


Fig. 2: Fluorine concentration versus depth for quartz glass discs: solid points corresponds to one that was packaged in Teflon at LRL; open points to an identical disc that served as a control.