In this paper, additional numerical simulations are employed to show that solar wind ion deflection by strong lunar magnetic anomalies can produce local increases in the implantation rate of solar wind gases such as hydrogen. This may increase the resource potential of these volatiles. An example of the surface "shot pattern" produced in one such simulation is shown in the figure. The calculation includes a first-order accounting for the compression (and consequent local amplification) of crustal magnetic fields by the incident solar wind. The net effect is a slight increase in the deflection of ions as compared to that which would occur in the absence of field compression. As a nominal model of a large-amplitude, complex magnetic anomaly source region, we consider a magnetization source distribution represented by a series of dipoles with locations, orientations, and magnetic moments similar to those tabulated in [7]. The resulting magnetic anomaly fields are comparable to those measured over large anomaly sources with the Apollo subsatellite magnetometers. Surface fields are a maximum of ~3000 nT, or about 1 order of magnitude larger than that measured at the Apollo 16 landing site.

Additional simulations indicate that if water ice exists in permanently shadowed regions of the lunar poles together with locally strong magnetic fields, these fields would be capable of preventing sputter erosion losses by interplanetary and magnetospheric ion fluxes. In particular, model simulations indicate that the ability of magnetic anomalies to shield the surface from incident ions increases with the angle of incidence and, hence, for most particle sources, with selenographic latitude.

The possibility that relatively strong anomalies are capable of providing significant protection of humans and materials against major solar flare particle events has also been examined and found to be unlikely.

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MAPPING THE MOON IN SOFT X-RAYS: PROMISES AND CHALLENGES.

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Recent ROSAT images reported by Schmitt et al. [1] show that the sunlit part of the Moon is a significant source of very soft X-rays. Stimulated by these observations, Edwards et al. [2] have made an analysis of the response of the Moon to the solar soft X-ray and EUV spectrum. They argue that much of the observed emission is in the form of discrete fluorescence lines in the energy range 25 to 100 eV, and that these lines are generally much stronger than the adjacent directly scattered solar background. On this basis they suggest that soft X-ray fluorescence can be used to remotely obtain high-precision elemental maps of the lunar surface. Edwards et al. have continued to develop this idea and have suggested a system using soft X-ray telescopes in lunar orbit, which could also obtain very good spatial resolution (personal communication, 1992). This combination could be extremely valuable in furthering our understanding of lunar chemistry and potential resource distributions.

The fluorescence X-rays considered by Edwards et al. [2] all necessarily involve transitions between the valence band and very shallow core vacancies. Their energies, structures, and overall widths hence reflect the characteristics of the host matrices, and vary with valence state and coordination. In determining line structures, valence electrons derived from the fluorescing atoms' atomic states generally contribute most heavily and their weighting depends on dipole selection rules. Thus even two elements in the same compound are expected to have significantly different line shapes.

In light of the above it is clear that lunar mapping missions could best be planned using actual soft X-ray fluorescence spectra of representative lunar regolith samples, and the component minerals and glasses that make them up. Since such data are not currently available we here use our published XPS data on lunar samples [3] along with unpublished data on minerals to estimate most probable X-ray energies and allowed ranges. This is possible since both the core levels and the valence band levels are seen in the XPS data. The results are presented in Table 1.

TABLE 1. X-ray fluorescence energies and linewidths.

Element	Fluorescence Transition	Predicted Energy (eV)	Allowed Range (eV)	Reference	Samples Used
Na	$L_{23}V$	22	±6	u	Labradorite
Mg	$L_{23}V$	42	±4	u	Forsterite
		42	±7	3	Synthetic lunar glass
		42	±7	3	Lunar regolith 10084
Al	$L_{23}V$	66	±6	u	Labradorite
		67	±6	u	Synthetic lunar glass
		67	±6	u	Lunar regolith 10084
Si	$L_{23}V$	94	±6	u	Labradorite
		95	±4	u	Forsterite
		94	±7	u	Synthetic lunar glass
		96	±7	u	Lunar regolith 10084
S	$L_{23}V$	156	±8	u	FeS
		154	±7	u	ZnS
Ca	$M_{23}V$	18	±6	u	Labradorite
		19	±7	3	Synthetic lunar glass
		18	±7	3	Lunar regolith 10084
Ti	$M_{23}V$	32	±7	u	Ilmenite
		31	±7	3	Synthetic lunar glass
		30	±7	3	Lunar regolith 10084
Fe	$M_{23}V$	49	±7	u	Ilmenite
		49	±7	3	Synthetic lunar glass
		49	±7	3	Lunar regolith 10084
Zn	$M_{23}V$	80	±6	u	ZnS
		80	±6	u	ZnO

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TABLE 2. Selected X-ray escape depths (Å).

Material	Energies (eV)			
	30.5	72.4	91.5	151.1
10084 glass	190	430	530	670
67701 glass	180	470	510	630
ZnS		380	420	660

It is also useful to know how thick a region of the lunar surface will be sampled by these soft X-rays. We have estimated mean escape depths for several energies and compositions corresponding to a mare glass, a highland glass, and ZnS using the mass attenuation coefficients of Henke et al. [4], and present them in Table 2.

High spatial resolution combined with the thin surface layer from which these soft X-rays arise suggests the exciting possibility that X-ray telescopes could map lunar volcanic volatiles from orbit. The most characteristic feature of known lunar volcanic volatile deposits is a conspicuous enrichment in sulfur and zinc on grain surfaces [5,6]. These Zn,S-rich surface films can be seen in SEM images. In XPS studies [7] we have found surface Zn concentrations higher than 5 atomic percent and have estimated a depth of at least 100 Å. Thus Apollo 17 orange glass appears to have enough Zn and S to be seen from orbit, and it would be very surprising if there are not other lunar regions much richer in volcanic volatiles.

In our XPS studies of lunar regolith fines [8] we found that a significant fraction of the iron in the outer few hundred angstroms of grain surfaces was reduced to the metallic form, presumably as a result of micrometeorite vaporization and solar wind effects. Because of the strong possibility of substantial reoxidation of lunar material during storage, sample preparation, and analysis, we cannot know what the reduced fraction was on the lunar surface, but it may have been large. The M_{23} XPS lines and $M_{23}VV$ Auger lines of Fe^{++} and Fe° have different shapes and energies, allowing them to be easily distinguished. It seems likely that the $M_{23}V$ X-ray line will also, so the oxidation state of Fe in the regolith might be mapped with properly chosen telescopes.

We thus suggest that, in addition to major-element mapping, consideration be given to volcanic volatile mapping and regolith oxidation state mapping.

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ASSESSMENT OF THE LUNAR SURFACE LAYER AND *IN SITU* MATERIALS TO SUSTAIN CONSTRUCTION-RELATED APPLICATIONS. Stewart W. Johnson[1] and Koon Meng Chua[2], [1]BDM International, Inc., 1801 Randolph Road SE, Albuquerque NM 87106, USA, [2]Department of Civil Engineering, University of New Mexico, Albuquerque NM 87131, USA.

In this paper we focus on present and future technologies to facilitate lunar composition and resource assessment with applications to lunar surface construction. We are particularly interested in the construction activity associated with lunar-based astronomy. We address, as an example, the use of ground-probing radar to help assess subsurface conditions at sites for observatories and other facilities.

We feel that a multidisciplinary effort is desirable to identify what engineering data on the lunar environment and on the lunar soil and rock should be collected and how it should be obtained. Johnson and Burns [1] have urged action to acquire the following information and resolve issues indicated: (1) topographic maps of potential observatory sites (e.g., 10-cm contours over an area 1 km in radius); (2) detailed boulder sizes and counts over the same area; (3) surveys (e.g., by radar, microwave, or other means) for subsurface boulders over critical areas where foundations and excavation are desired; (4) surveys of depth-to-bedrock (with suitable definition and characterization of bedrock); (5) trenching and bulldozing experiments to establish energy requirements and depth limitations of these operations; (6) drilling and coring experiments (with energy consumption and depth limitations clarified); (7) force-vs.-depth cone penetrometer measurements to be used for siting settlement-sensitive telescope structures; (8) trafficability measurements including establishing energy consumption, slope-climbing capabilities, and formation of ruts or depressed surfaces by repeated traverses of unprepared surfaces; and (9) electrostatic charge measurements.

This listing has grown out of discussions with Dr. W. David Carrier III of the Lunar Geotechnical Institute and others. The list will vary somewhat depending on requirements for lunar-based facilities and operations. Johnson et al. [2] have noted that it is necessary to start now to develop the concepts and technologies for the next generation of space-based telescopes. A successor for the Hubble Space Telescope could be either in high Earth orbit (HEO) or on the Moon. To properly assess the merits of these suggested future telescopes, technology development for lunar as well as HEO telescopes should now be pursued so that properly informed decisions may be made. Part of the technology development requires improved understanding of engineering properties of lunar surface and subsurface materials and dust behavior. Johnson and Wetzel [3] note that the success of a large lunar-based telescope will depend on an appropriately engineered structure, a suitable interface (foundation) with the lunar regolith, and a carefully thought-out construction process. Johnson and Burns [1] have discussed the technology development required for large lunar telescopes and lunar optical/UV/IR synthesis arrays. They encourage the community to plan early lunar-bound payloads and surface operations to advance the knowledge and understanding required for building large telescopes on the Moon after the year 2000. Examples of key technologies for large lunar observatories that we feel deserve attention early in the program to return to the Moon are