Principal Axes of Lunar Composition. W.C. Feldman[1]; S. Maurice[2], D.J. Lawrence[1], R.C. Elphic[1], O. Gasnault[1], P.G. Lucey[3], A.B. Binder[4]; [1]Los Alamos National Laboratory, MS-D466, Los Alamos NM 87545, USA, [2]Observatoire Midi Pyrénées, 14 Avenue Edouard Belin, 31400 Toulouse, France, [3]Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu, USA, [4]Lunar Research Institute, 9040 South Rita Road, Tucson, Az 85747, USA.

Maps of several observables that provide measures of lunar composition were studied to determine their global distribution on the Moon. The mathematical formalism used to determine the principal axes of an inertia tensor was applied for this purpose. Here, $I_{kl}=\Sigma_i m_i (r_{ik}^2\mathbf{I} - \mathbf{r}_{i,k}\mathbf{r}_{i,l})$, where I_{kl} is the inertia tensor, m_i is the mass of the i^{th} volume element of an extended body, $\mathbf{r}_{i,k}$ (and $\mathbf{r}_{i,l}$) = x,y, or z for k≠l = 1,2, or 3, is the position of the i^{th} mass element of the body, and **I** is the unit diagonal dyadic. I_{kl} is a real-symmetric matrix and so can be diagonalized to determine the three axes and principal moments of the inertia tensor.

Applying this formalism to lunar composition, we define the real-symmetric matrix, $P_{kl} = \Sigma_{\theta\phi} P(\theta_i,\phi_i) (\mathbf{I} - \mathbf{r}_{i,k}\mathbf{r}_{i,l})$, where θ_i and ϕ_i are the latitudes and longitudes of a set of equal-area elements on the unit sphere (which is used here to represent the Moon), and the $P(\theta_i, \phi_i)$ are maps of; a) the albedo measured by Clementine [1], b) the abundance of Thorium, [Th] [2], c) the flux of fast neutrons [3], d) the abundance of FeO [4], and e) the ratio of thermal-to-epithermal neutrons corrected for the contribution from Gd and Sm, determined using the measured Thorium abundance [5] and the [Th]-[Sm] correlations summarized in Haskin and Warren [6]. This ratio is labeled by 'slow-neutron' in Figure 1. We also substituted the topography measured by Clementine [7] for $P(\theta_i,\phi_i)$, for comparison purposes.

The locations of all principal axes are shown in Figure 1 superimposed on an air-brush globe of the Moon. Each of the composition moments (normalized to a maximum of unity) are given underneath their respective titles at the top of the figure. Inspection of the moments shows that each of the composition triplets yields a relatively clean symmetry axis, defined here by that moment which differs markedly from the other two more nearly equal moments. Whereas the symmetry axes of the albedo and slow neutrons are given by the highest moment (given the designation 1 in Figure 1), thereby indicating an oblate spheroidal distribution of composition, those corresponding to [Th], fast neutrons, and [FeO] are given by the lowest moment (designated by 3), thereby indicating a prolate spheroidal distribution. Figure 1 shows that all symmetry axes form a tight cluster that is very close to the centers of Imbrium (marked by X) and Procellarum (marked by *). In contrast, the symmetry axis of the topography (which is moment number 1) falls between the antipode of Imbrium and the center of the South-Pole Aitken basin (marked by ◊), as might be expected because Imbrium and South Pole Aitken are the largest basins on the Moon.

Histograms of each of the measurables integrated over all longitudes in a coordinate system whose Z axis is centered on the cluster, are shown in Figure 2. Bin sizes in these histograms were chosen so that each bin contains an equal area on the unit sphere. The prolate and oblate nature of these distributions is seen clearly by the maximum and minimum value of the histogram, respectively, at zero polar angle. We note that the histograms of albedo and slow neutrons are closely similar. These histograms differ somewhat from those of [FeO] and fast neutrons, which are closely similar. And the histogram of [Th] stands by itself.

Although maps of the albedo, slow neutron, fast neutron, and [FeO] are all related through their mutual dependence on the abundance of Fe, their global distributions differ in detail (not shown here), and theoretically, the slow and fast neutron flux maps also depend importantly on the abundances of Ti and Ca. Indeed, the symmetry axis of the distribution of $[TiO_2]$ by itself [4] (not shown in Figure 1) also lies very close to the cluster shown in Figure 1. The close proximity of this cluster to the center of Procellarum is also significant because the axial enhancements and depressions of all histograms have angular half widths of about 55°, which is close to the half width of Oceanus Procellarum [8]. These observations suggest that the tight cluster of all symmetry axes shown in Figure 1 are consistent with a single formative event that structured the global composition of the lunar crust. The coincidence of this compositional symmetry with the proposed Procellarum Basin impact structure [8] suggests that giant impact is a strong and well understood candidate mechanism for producing this symmetry.

References: [1] Lucey, P.G., et al. (1994), Science, 266, 1855-1858. [2] Lawrence, D.J., et al. (1999), GRL, 26, 2681-2684. [3] Maurice, S., et al. (1999), submitted. [4] Lucey, P.J., et al. (1998), JGR, 103, 3679-3699. [5] Feldman, W.C., et al. (1999), JGR, submitted. [6] Haskin, L., and P. Warren, (1991), in 'Lunar Source Book', G. Heiken, D. Vaniman, B.M. French, eds., Cambridge U. Press, pp357-474. [7] Zuber, M.T., et al. (1994), Science, 266, 1839-1843. [8]

Wilhelms, D.E. (1987), USGS Professional Paper 1348.

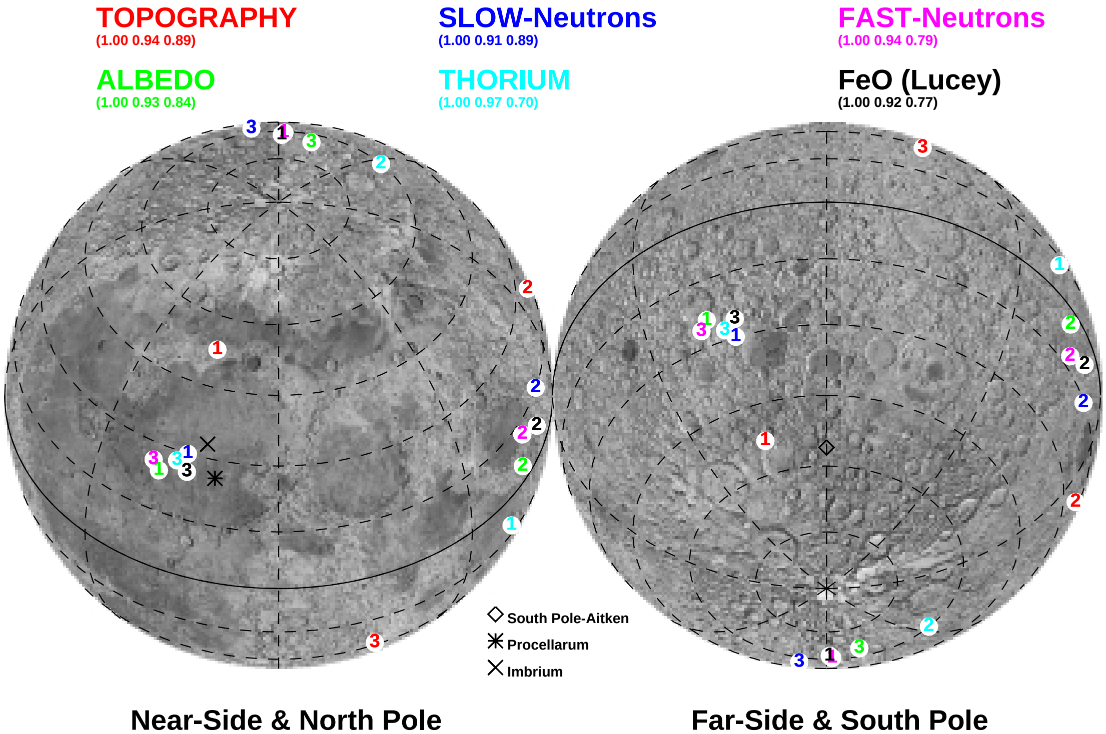

Figure 1

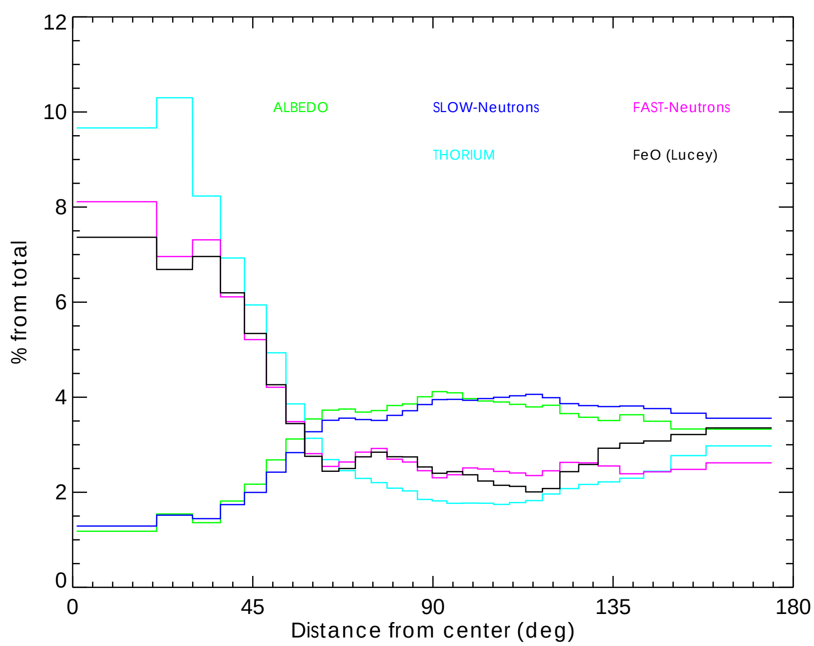

Figure 2