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Surface chemistry of the Moon: New views from Chandrayaan-1 X-ray Spectrometer and future potentials

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X-ray remote sensing is an established technique for chemical mapping of atmosphere-less inner solar system bodies. Chandrayaan-1 X-ray Spectrometer (C1XS) [Grande et al, 2009], on-board the first Indian lunar mission Chandrayaan-1 [Bhandari et al, 2004], was flown with the objective [Crawford et al, 2009] of globally mapping the abundances of the major rock-forming elements Mg, Al, Si, Ca ,Ti and Fe with a spatial resolution of 25 km on the lunar surface. The instrument was developed by the Rutherford Appleton Laboratory (RAL), UK in collaboration with the Indian Space Research Organization (ISRO).
X-ray fluorescence (XRF) observations measure the abundance irrespective of the mineral structure. XRF spectral analysis can uniquely identify and quantify elemental signatures from all commonly occurring elements. C1XS is one of the first instruments to unambiguously map the abundance of elements from Na to Fe at scales of tens of kilometers. Because of the exceptionally low solar activity in 2009, the strongest solar flare observed was of C3 class and hence global mapping could not be achieved. However from the available coverage of $\sim$ 5%, we have determined elemental abundances accurately through a detailed calibration of the instrument and inversion methodology [Narendranath et al, 2010; Athiray et al, 2013]. The end-to-end capacity to derive independent and accurate global surface chemical abundances using x-ray signatures was clearly demonstrated with C1XS.
We present results from a comprehensive analysis of all data from C1XS with emphasis on the new finding of enhanced sodium in the southern lunar highlands that suggests possible new lithologies [Narendranath et al, 2011; Athiray et al, 2014]. It is generally believed that lunar highlands are mainly composed of plagioclase feldspar with lower amounts of the mafic minerals. Plagioclase in lunar samples have been found to have an anorthite content as high as An98 with the average highlands estimated to be An95. Lower anorthite content (as low as An70) plagioclase grains have been found in lunar samples but is much rarer. C1XS measurements especially of Na, Al and Ca reveal larger regions of low An than previously thought of. We provide evidence for this from quantitative estimates of elemental abundances.
Further, we present the development of Chandrayaan-2 Large Area Soft x-ray Spectrometer (CLASS) [Narendranath et al, 2014] to be flown on the second Indian lunar mission ($\sim$2018) which would continue from where C1XS left off but with a greater sensitivity and better spatial resolution.