August 21, 2024

PRL-built APXS on Pragyan Rover of Chandrayaan-3 made the First Elemental Abundance Measurements of Lunar Soil in the South Polar Region of the Moon

A team of scientists from the Physical Research Laboratory (PRL), Ahmedabad, and ISRO, has reported the first in-situ elemental abundance of lunar soil near the Southern Polar region using measurements made by the Alpha Particle X-ray Spectrometer (APXS) on the Pragyan rover of the Chandrayaan-3 mission. This study published in the journal Nature has provided evidence that supports the Lunar Magma Ocean hypothesis, which predicts that the primordial lunar crust was formed as a result of the floatation of lighter anorthite plagioclase — but, APXS also detected higher abundance of magnesium-rich minerals, suggesting contributions from deeper layer material ejected from South Pole-Aitken basin during its formation. The analysis from 23 measurements at different locations within 50-metre of the Chandrayaan-3 landing site – Shiv Shakti point – showed that the lunar regolith is uniform in elemental composition, and hence can serve as an excellent ground truth for future remote sensing missions.

The Vikram Lander of the Chandrayaan-3 mission made the historic Moon landing on the 23rd August 2023 at 18.04 Indian time at the 69.37-degree South latitude and 32.35-degree East longitude (Shiv Shakti point). The Pragyan rover deployed on lunar surface explored the near-by area by traversing about 103 meters over the next ten days. The PRL-built scientific instrument APXS (Figure 1) aboard the Pragyan rover was designed to measure the elemental composition of lunar soil at the locations of rover stops, by deploying the APXS close to lunar surface for measurements and stowing it back while moving (Figure 2). The APXS employs the techniques of X-ray Fluorescence Spectroscopy and Particle Induced X-ray Emission to detect and quantify various major and minor elements present in lunar soil, such as Si, Mg, Al, Fe, Ca, as well as Mn, Cr, Ti, Ni, K, Na, and, S etc. By irradiating the lunar surface with its Cm-244 sources, APXS recorded characteristic X-ray lines of all major and minor elements.

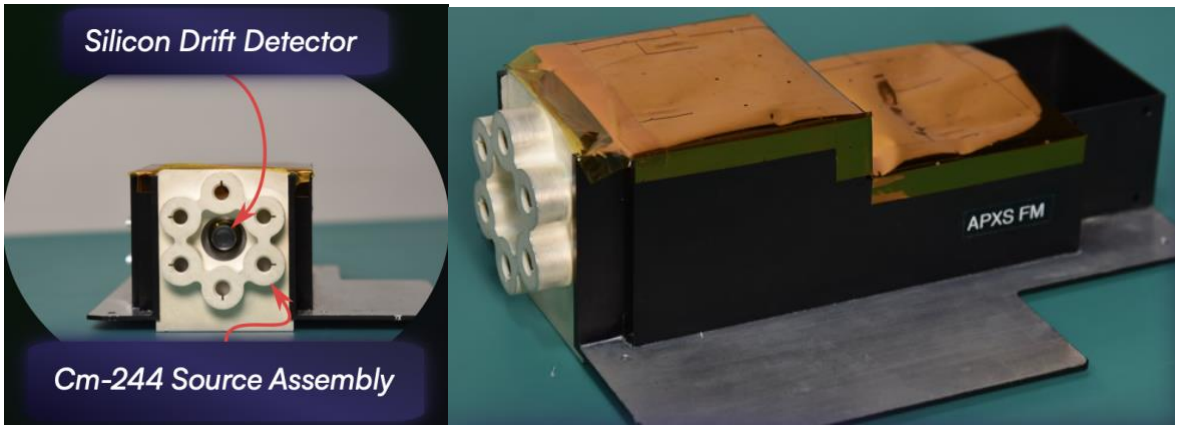

Figure 1: Photographs of the APXS instrument Flight model in Lab. The compact instrument weighs just 700 grams.

Figure 2: Snapshots of APXS deployment (front-side), with APXS in stowed position (left) and deployed position (right). APXS is marked in red in the images of the Pragyan Rover captured by the camera on the Vikram Lander during mission.

The APXS carried out 23 scientific observations along the rover path, shown in the Figure-3, and obtained an X-ray spectrum at each location. The observation time at each location varied from about 20 minutes (minimum) to about 3 hours (maximum), depending on the mission requirement plan; with a total observation duration of about 31 hours over the mission period of 10 days. The analysis of APXS measurements from each location have revealed that the elemental composition is fairly uniform across the area explored by the Pragyan rover. The APXS spectrum obtained by adding all the observations over 31 hours is shown in the Figure-4, where the characteristic peaks of all major and minor rock-forming elements can be seen. The average lunar soil composition near Shiv Shakti point, as measured by APXS, is shown in a pie chart (Figure-5).

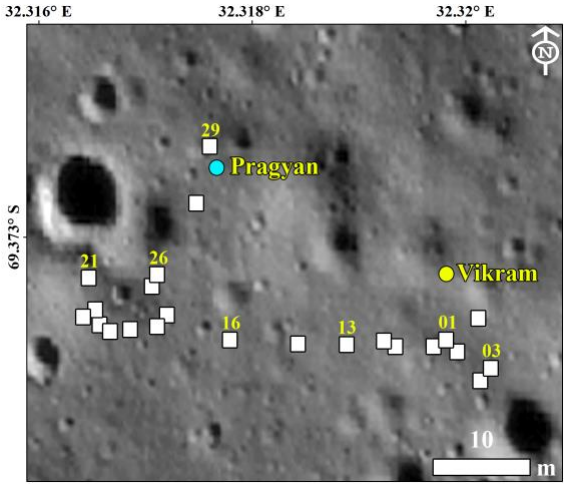

Figure 3: Locations of 23 scientific observations of APXS (marked as white squares) along the rover path overlaid on the high-resolution image of the region from Chandrayaan-2 OHRC.

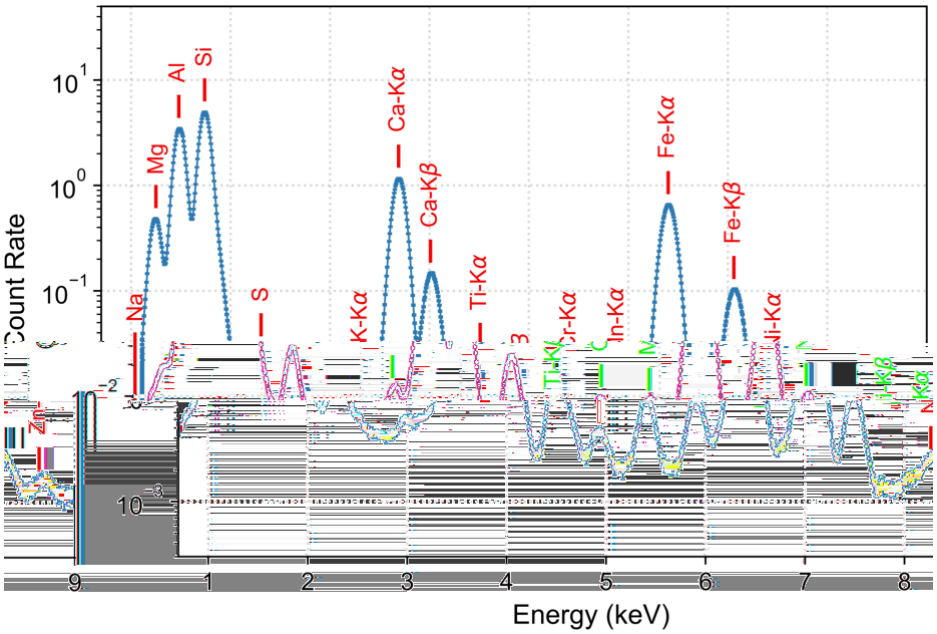

Figure 4. APXS spectrum obtained by adding data from all 23 scientific observations amounting to a total exposure of 31.34 h. An extra line of zinc (Kα) is detected in the coadded spectrum, while sodium (Na), potassium (K), and sulphur (S) are also clearly seen.

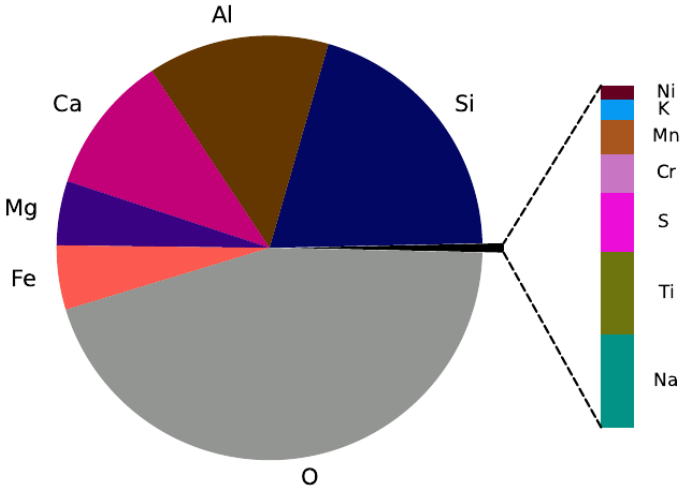

Figure 5: Elemental composition of the lunar soil as measured by APXS. Aside from the major components Si, Al, Ca, Mg, and Fe in oxide form, abundances of various minor elements are also obtained.

From the APXS-measured composition, and CIPW normative minerology computations, the PRL scientists inferred that the soil is a mixture of two types of rocks named Ferroan Anorthosite (FAN), rich in plagioclase mineral, and Magnesian Suite (Mg-suite). While the dominant mineral present is plagioclase, as expected in lunar highland terrain, other minerals, olivine and pyroxene, are higher than typically expected in the outer crust of the Moon.

According to the widely accepted hypothesis on the early evolution of the Moon, the Lunar Magma Ocean (LMO) hypothesis, the Moon was entirely an ocean of magma when it formed. As the magma cooled, heavier minerals such as olivine and pyroxene sank and formed the inner layers of the Moon, while the lighter mineral plagioclase floated and formed the outer crust of the Moon. The dominant presence of FAN in the soil observed by APXS further confirms the LMO hypothesis. However, the presence of additional Mg-rich materials suggests that the outer crustal material has been mixed with material from deeper layers of the Moon to form the soil near the Shiv Shakti point.

The South Pole Aitken (SPA) basin on the Moon, the largest known impact basin in the solar system, is believed to have been formed about 4.2–4.3 billion years ago due to an asteroid impact. This impact resulted in the excavation of Mg-rich material from deeper layers of the Moon and brought to the surrounding areas, including the Chandrayaan-3 landing site, which is about 350 km away from the rim of the SPA basin. Subsequent cratering caused the mixing of the surficial material with the material from deeper layers to form the soil with the composition seen by the APXS.

Thus, the new measurements by APXS in this never-before-explored region of the Moon indicates that the lunar soil is a mixture of two types of rocks where part of the material is excavated from deeper layers of the Moon, providing direct insight into the evolutionary history of the Moon.

The APXS instrument was designed and developed by Physical Research Laboratory, Ahmedabad (a Unit of the Department of Space), with support from SAC Ahmedabad and URSC Bangalore.

The original article entitled "***Chandrayaan-3 APXS elemental abundance measurements at lunar high latitude***", authored by Santosh V. Vadawale et al., Nature, is available at
https://doi.org/10.1038/s41586-024-07870-7
https://www.nature.com/articles/s41586-024-07870-7

Further detailed explanations of the results are available on the PRL website
https://www.prl.res.in/