A Brief History of Start of Research on Lunar Samples in India Brought to Earth by Astronauts, Beginning in 1969 with the Apollo 11 Program

One of the most remarkable achievements of American astronauts and scientists was to go to the Moon six times during 1969-1972 through Apollo 11 to Apollo 17 missions. Each of these missions brought back several kilograms of rock and soil samples and provided a great deal of information about the processes in solar system. Their availability consequently provided a unique opportunity to scientists to compliment their understanding of solar system based on terrestrial systems and astrophysical observations.

Moon is unique in a variety of ways. First of all, it has no atmosphere, and receives a great variety of radiations originating from the Sun and the galaxy due to supernova explosions. Secondly the lunar surface has limited volcanic activity. This contrasts with the situation on Earth which has abundant volcanic activity that melted and re-melted the earliest rocks of the Earth. Thirdly, micrometeorites and meteoritic bodies of different sizes are directly incident on the lunar surface and have an unimpeded trajectory in the absence of atmosphere. These impacts form ‘agglutinates’ and craters of different sizes on the lunar surface. The ages of different surfaces can be determined by the distribution of craters on the lunar surface and all these inform about the temporal information of moon. According to Professor Harold Urey, the single most exciting incentive to probe lunar surface was to find the oldest rock horizons which had not been re-molten by repeated volcanic activity.

We at PRL proposed that we would look at the lunar surface and understand the effects of its exposure to all forms of radiations: solar thermal, solar wind, solar cosmic rays, galactic cosmic rays, and examine their relationships to the internal structure of meteorites of different kind. As an example, some of the so called gas-rich meteorites have regions which are rich in solar wind gases. Apparently these regions, before they were assembled as ‘gas-rich meteorites’, were irradiated with solar wind.

Fig. 1. Photo of 2 cm thick coarse layer near top of drill core sample 12028. NASA S69-23404 from Apollo 12. (Scale in cm.)

(Credit: http://curator.jsc.nasa.gov/lunar/lsc/12028.pdf)

Our studies suggested that some of the lunar materials should have been irradiated with solar cosmic radiation. This was based on large excesses of certain radio-nuclides, such as ^{10}Be, ^{26}Al, ^{53}Mn. These were produced in-situ in lunar materials as a result of irradiation by Solar Cosmic Radiation (SCR) energetic protons and He-nuclei derived from Solar flares. This offered an improvement in the information from Meteorites that are often found with records of SCR particles but loose most of it however since during their transit through the atmosphere and associated ablation that leads to incomplete SCR record that could not be used to compute the SCR fluxes.

The PRL group was amongst a few selected to receive lunar samples from the Apollo 11 mission. These were presented to us at a formal ceremony by US Ambassador to India, Mr. Keating. At PRL, we examined lunar samples from many perspectives and we found that the lunar regolith samples from different depths had prominently recorded irradiation by low energy SCR

Fig. 2. Largest (> 1 cm) particles from soil sample 12057 (from bottom of rock box) S69-60962 from Apollo 12.

(Credit: http://curator.jsc.nasa.gov/lunar/lsc/12057.pdf)

Back to Contents

Fig. 3. Six samples of Luna- 24 soil, sealed in a stainless steel box, were presented on March 3rd 1977 by Prof. Barsukov to Prof. Narendra Bhandari of the Physical Research Laboratory, Ahmedabad

radiations. This was interpreted as being a result of vertical mixing of the lunar regolith caused by micrometeorites and larger meteorites.

Using short-lived radioactivities (^{10}Be, ^{26}Al etc.), we deduced the composition of SCR radiation incident on a lunar rock. Considerable new information could be gleaned from these studies and are summarized in series of publications. This experience and our results qualified us to successfully request lunar samples from the 2nd lunar mission, the Apollo 12 lunar mission and we continued our lunar investigations until Apollo 17 lunar samples. In between, the Russians had made two successful unmanned missions bringing lunar regolith soil cores. The Russian Academy provided these samples and the results of these investigations were published by us in journals and in a special publication honoring the Luna missions.

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Meteorites: Source of Precise Information about Early Solar System

Most of us are familiar with the term 'shooting star', actually it is not a star shooting across the sky, but a small piece of solid object entering into the atmosphere called a meteoroid. During its entry, it heats up due to friction with atmosphere which results in ablation which can be seen as a brilliant flash of light. Some of these objects survive this fiery journey through atmosphere and reach to the ground. They are known as meteorites. On very rare occasions when an extremely bright meteor is observed, it is referred as a fireball. It is from these fireballs that most meteorites of recoverable size originate.

Arrival of a meteorite is a random event. When a large fireball is observed, recovery of specimens is entirely dependent upon the accounts of observers who just happen to see the event. Meteorites recovered in this manner are termed as 'falls', indicating that the specimen was observed while falling. A large fraction of meteorites is recorded as 'finds', those specimens which were not observed by falling, but collected from field in search expeditions.

Meteorites are messengers from space which help us decoding earliest history of solar system. Today most of the information we know about the early solar system processes, comes through laboratory studies of meteorites. These are left over materials which escape the planet formation and are almost unaltered since their formation at around 4.6 Ga (billion years) ago. This is possible because their parent bodies were not big enough to hold atmosphere, water (common weathering agents on terrestrial planets) and heat produced by decay of short lived nuclides and accretion energy in case of primitive undifferentiated meteorite parent body.

Classification of Meteorites: Meteorites are broadly classified into two categories: Undifferentiated and Differentiated. Undifferentiated meteorites are also known as chondrites whereas achondrites, stony iron and irons are examples of differentiated meteorites. See Fig 1 for recent classification scheme. Undifferentiated chondrites (see Fig. 2) are most primitive objects accreted very early from solar nebula and identified by presence of chondrules (mm to sub mm spherical igneous silicate balls).