The source of the methane in Titan’s atmosphere is another mystery. Photochemical calculations show that Titan’s atmospheric methane should have been consumed (converted into ethane) over a timescale of 10-100 million years. However, methane is still the second most abundant constituent of Titan’s atmosphere, after 4.5 billion years for which the solar system has existed. What is replenishing the methane in Titan’s atmosphere?

The biggest surprise upon Cassini’s arrival at Titan was the lack of ethane oceans. Scientists had expected Titan to be covered by a global surface ocean of ethane, produced from photochemical reactions over the age of the solar system. This large expected volume of ethane cannot be accounted for by the polar lakes alone. The question of the hidden ethane is one that begs further inquiry.

The surface composition of Titan and the dominance of various surface processes over one another, in sculpting the landscape, is also a matter of current investigation. The localization of cloud systems at the 40°S latitude and at the poles has also not been explained yet. Another open-ended question is related to the possibility of formation of basic biological molecules (like amino acids) as a part of the organic chemistry on Titan.

Although the Cassini mission is still active, scientists have already begun proposing future missions to Titan. Instead of sending a lander or a rover, scientists plan to take advantage of the dense atmosphere by sending a hot-air balloon, that could cover vast distances. Another component of such futuristic missions to Titan would be landers and sample acquisition devices to study the polar lakes. Hopefully, with the help of such missions in the future, we will be able to unravel more secrets of this enigmatic satellite.

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New era of microanalysis started with the building of the first electron microprobe around 1948-1950 by Casting. Now it has become an important tool for interdisciplinary sciences. Electron Probe Micro Analyzer (EPMA) is a versatile instrument which involves non-destructive chemical composition analysis of any solid sample over a very small area.

The basic working principle of EPMA can be divided into four main parts: (i) generation, acceleration and focusing of the electron beam (ii) beam-sample interaction, (iii) detection of secondary entities formed during beam sample interaction by using various detectors (as shown in Fig. 1) (iv) conversion of electronic signals into the qualitative or quantitative compositional spectra.

EPMA (SX100- CAMECA, France) is a National Facility at PLANEX, PRL. It uses tungsten hairpin filament as an electron gun to produce electrons by thermionic emission. Electrons are then accelerated by the potential difference of 0-30 KeV (depends on sample properties) between anode and cathode (e- gun). Electron beam is focused by using the electromagnetic lenses. This reduces the beam diameter less than 1 μm before it finally impinges on the sample surface. Electrons undergo elastic and inelastic collisions with sample and produce Backscattered Electrons (BSE), Secondary Electrons (SE), X-rays, Auger electrons, Cathodo-Luminescence (CL) depending upon the energy and angle of incident electron beam and nature of sample material.

SE are detected by using Everhart-Thornley detector and BSE are detected by semiconductor detector. X-rays are detected by Gas Proportional Counter and Li drifted Silicon Detector. EDX (Energy Dispersive X-ray spectrometer) and WDX (Wavelength Dispersive X-ray spectrometer) are two mechanisms in EPMA to detect x-rays. Secondary electrons (and backscattered as well) are mainly used to get the surface morphology and to understand the features of various geological as well as biological samples. X-rays and Auger electrons are mainly used for the compositional analysis. The compositional information can be extracted from
characteristic X-rays by Wavelength Dispersion or by Energy Dispersion method.

**Wavelength Dispersion Spectrometer (WDS)**
On the basis of Bragg’s law, X-ray lines of any element can be identified and separated from each other on the basis of their wavelength. In this method a crystal and a proportional counter are used on a Rowland circle to detect a particular characteristic X-ray line.

**Energy Dispersion (EDS) Spectrometer**
The identification and separation of X-rays of an element is dependent on their characteristic energy. Generally the WDS method is used for quantitative analysis and the EDS method is used for qualitative analysis of elements.

**Applications:**

**Mineral Identification:**
Fig.2. shows a backscattered electron image of a section of Sulagiri meteorite. Grayscale varies with the change in the mineral composition. By using cracks and the boundaries it is possible to resolve different phases, change in structure, surface features etc. WDS or EDS analysis of each phase can be used to find out the chemical composition of those phases.

**Elemental Distribution:**

By rastering the beam over a selected area we can obtain the X-ray image for the elements of interest. From the X-ray images, such as the ones shown in Fig. 3 we can find the intensities of x-rays over each pixel on the selected area and get the elemental composition map of whole object.

![Fig.1. Schematic Diagram of EPMA](image)

![Fig.2. BSE Image](image)

![Fig.3. X-ray images of Ca (a) and Mg (b)](image)
**Important Results:** This facility is mainly dedicated for geological and planetary science studies. Some of the recent work is mentioned here. Using the geochemical data, various meteorites are classified on the basis of their Si and Fe, Ni and Co content. Using the chemical composition as well as the X-ray mapping, Al-rich and Fe-rich phases were identified in chondrules from undifferentiated ordinary meteorites for further isotopic study to correlate the different heat sources responsible for early metamorphism of planetesimals (*R.K. Mishra et al., APJ, (2010) 714:L217-221.*). In another study, Multi-shelled orbicular olivine gabbronorite with anorthositic rims from Leh, J&K, India have been studied for morphological details, preliminary mineralogy and petrology (Prashant Rai et al., Current Science, 97(12), 2009). The comparative geochemical study of samples from local area as well Spherules from target area of Ramgarh have revealed that local samples are mainly shale and sandstone while target sample consists of mostly SiO₉, Al₂O₃, Fe₂O₃ and MnO along with certain trace elements like Ba, Co, Zn, Ni, S, Cu and Cr in significant amount. Thus, on the basis of geochemical and petrological studies, an attempt is being made to show that Ramagarh structure was formed due to a meteoritic impact (Saumitra et al., 39th and 40th LPSC). In addition to these, spherules collected from Indian Ocean have been analysed to characterize the magnetic material and cosmic components (Shyam et al.).

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**Further Reading:**
1. SJB Reed, Electron Micro Probe Analysis.
2. K.F.J. Heinrich, Electron Microprobe Quantization.
3. Potts PJ ED Microprobe Techniques in the earth Sciences.

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**Alpha Particle X-ray Spectrometer on Chandrayaan-2 Rover for Surface Chemical Composition**

**Introduction:** Moon samples from Apollo and Luna missions have given us the first hand information on the chemical, mineral and chronological information about the Moon and led to the derivation of the average bulk composition and the evolution of the Moon. While Apollo / Luna samples represented samples from only equatorial region of Moon, lunar meteorites, ejected from random locations on Moon offered additional samples for study. Significant compositional differences between lunar meteorites and Apollo/Luna samples highlighted the need for obtaining chemical composition of more samples from other known locations of Moon in general and the polar regions in particular, in view of the importance of the South Pole Aitken (SPA) basin, representing one of the largest craters in the solar system, to better understand the compositional diversity. While orbiters provided a global coverage with a coarse resolution, in situ chemical composition determination along the traverse of a rover will offer the best way to address this aspect, until the resumption of sample return missions to Moon.

**Fig. 1. Schematic representation of the rover and various sub-systems. The position of APXS on the robotic arm is indicated.**

Alpha Particle X-ray Spectrometer (APXS) is a well proven instrument for in situ quantitative elemental analysis of planetary surfaces. Mars pathfinder rover Sojourner has first carried an APXS instrument and provided the first in situ composition data on Mars samples. Subsequently, the twin Mars exploration rovers Spirit and Opportunity have carried improved APXS instruments onboard and provided elemental composition for many surface samples. Another mars