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SPECTRAL STUDIES OF LUNAR EQUIVALENT ROCKS – A PRELUDE TO LUNAR MINERAL MAPPING

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ABSTRACT

Hyperspectral remote sensing technique is widely applied for geological studies including the study of extra-terrestrial rocks. Since it has many spectral bands, discrimination between rocks and minerals can be done more precisely. To perform chemical and mineralogical mapping and to study the rocks on the lunar surface, India has proposed to launch its first lunar remote sensing satellite Chandrayaan-1 in the year 2008. For mineralogical mapping, the mission will carry a Hyperspectral Imager (HySI) instrument, which operates in the VNIR region. This paper presents an attempt to study the spectral response of lunar-akin terrestrial rocks, in the VNIR region (as in the case of the proposed HySI on-board Chandrayaan-1). For this purpose, rocks similar to those present on the lunar surface were collected and their spectral response in the 64 simulated bands of HySI sensor were studied using a spectro-radiometer. Petrographic studies and modal analysis were carried out using thin sections of the rock samples. On studying the spectral response of the lunar-like rock samples in the 64 HySI bands, it is seen that there are distinct absorption features in bands 58 (923.75nm-927.5nm) and 63 (942.5nm-946.25nm) of the NIR wavelength ranges, for basalt rocks; distinct reflectance features in band 20 (590nm to 600nm) for ganmbbro: distinct reflectance features in band 19 (580nm to 590nm) and absorption in band 18 (570-580nm) for gabbroic anorthosite and distinct reflection features in band 63 (942.5nm to 946.25nm) for anorthosite. Thus, this study demonstrates the possibility of identifying the minerals and rocks on lunar surface using the hyperspectral approach and the spectral signatures of lunar-like rocks present on Earth.

Introduction

This paper presents the results of an effort to understand the spectral signatures of the lunar-like Earth rocks. The degrees of dependence of the reflectance on the mineral composition of lunar rocks, the wavelength bands in the VNIR region, have been studied. Many researchers have carried

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out studies on hyperspectral remote sensing data and its applications based on the correlation of spectral bands with the spectral reflectance of the object of interest (Perez *et al.*, 2002, Salvi *et al.*, 2002, McHugh *et al.*, 2001). There is very little literature available on the studies related to simulating spectra of lunar rocks using the spectral ranges of HySI sensor onboard Chandrayaan-1. This study is perhaps the first attempt on the reflectance studies of anorthosites and the related rocks of Tamilnadu state, which are the terrestrial equivalent of certain lunar rocks. This study is also significant as it could provide guidelines to interpret the spectral curves obtained from HySI (Hyperspectral Imager) sensor on-board Chandrayaan-1, by comparing with the spectral curves obtained from the reflectance study of the lunar-like terrestrial rocks. A source of inspiration to carry out and report this work was the articles by Bhandari (2004), wherein the author suggests that the purpose of his article was to involve the scientific community of India in formulating the best possible objectives and participating in the Chandrayaan-1 mission.

Chandrayaan-1

Chandrayaan-1 (Chandra=Moon, yaan=Ship), India's first unmanned spacecraft mission to the Moon, which will go into a polar orbit around the Moon, has the prime objective of simultaneous chemical, mineralogical and photo selenological (selenology= geology of moon) mapping of the lunar surface. In keeping with the mission objectives, Chandrayaan-1 will carry two imaging instruments working in the visible and near infrared (VNIR) spectral bands, namely- the Terrain Mapping Camera (TMC) and Hyper Spectral Imager (HySI), along with other scientific instruments. Bhandari (2004) describes the scientific reasons for undertaking the Chandrayaan-1 mission and lists some of the major scientific challenges of the mission. Earlier, Bhandari (2002) summarized the salient features of our current understanding of the moon, so that the scientific objectives of the future lunar missions can be clearly formulated. Specifically, the author discussed in the article, the desirability of a low altitude (100 km) lunar polar orbiter for simultaneous chemical, mineralogic and photogeologic mapping.

The function of TMC is to map the complete topography of Moon in both, near and far side for preparing a 3-dimensional atlas with high spatial and altitude resolution of 5m with 10 bit quantization. Such high resolution mapping of complete lunar surface will be available for the first time and will help in better understanding of the evolution process and detailed study of regions of scientific interests. Also the digital elevation model available from TMC along with the Lunar Laser Ranging Instrument (LLRI) on Chandrayaan-1 could improve upon the Moon gravity model.

The uniqueness of the HySI will be in its capability of mapping the lunar surface in 64 contiguous bands in the VNIR region with a spectral resolution of better than 15nm and spatial resolution of 80m. The data from this instrument will help in improving the available information on mineral composition of the lunar surface. Also, the study of data in deep crater region, which represents the lower crust or upper mantle material, will help in understanding the mineralogical composition of Moon's interior (ISRO Publication, 2005).

Planetary Geology and Remote Sensing

Planetary geology is the study of surface and interior processes on solid objects in the solar system like planets, satellites, asteroids, comets, and rings. The exploration of the solar system, including the important task of characterizing the current physical, chemical, and morphologic state of planets, satellites can be satisfactorily done by spectrometry. To understand the processes on or the evolution of one solar system object, frequently the Earth's surface and objects (like rocks and minerals) are to be compared and studied. Such a study has been attempted in the hyperspectral mode and presented here.

Hyperspectral Remote Sensing

After years of research, scientists have finally made available a tool that can categorise and measure the material components of the Earth's surface. This tool is hyperspectral remote sensing (also referred to as imaging spectroscopy), which takes remote sensing from the era of 'picturing' into the era of 'measurement'. Hyperspectral remote sensing is defined as the science of acquiring digital imagery of an object in many narrow contiguous spectral bands. Hyperspectral remote sensing differs from conventional remote sensing, because it covers many narrowly defined spectral channels, where as, conventional remote sensing looks at several broadly defined spectral regions.

Imaging spectroscopy was originally developed to obtain geochemical information from inaccessible planetary surfaces within the solar system (Goetz, 1992). Hunt *et al.* (1974) studied the spectral characters of 22 basic and 6 ultrabasic terrestrial rocks in the visible and near infrared region. The authors concluded that gabbros, with strong mafic mineral content, show definite spectral signatures in iron bands. For the anorthositic gabbros, the rocks that are mainly composed of plagioclase feldspar are identified only in the weak broadband near 1.25 μm. The primary application of imaging spectroscopy technique has currently shifted towards the observation of the Earth with hyperspectral sensors, such as AVIRIS, HYMAP, Hyperion, CHRIS/PROBA, etc. Bierwirth *et al.* (1999) published an article on the high-resolution remote sensing to detect minerals associated with ore deposits in Pilbara region of Western Australia, for the visual identification of hydrothermal alteration minerals using HYMAP (airborne hyperspectral remote sensing sensor) and supported for its rapid and cost-effective exploration tool that provided valuable new information on the geology and the distribution of surface minerals. Reiterating the significance of hyperspectral remote sensing and imaging spectrometry, Sanjeevi (2003) mentioned that, studies of the reflectance properties of minerals and rocks using hyperspectral remote sensing permit a more detailed analysis of spectral features too narrow to be discriminated by coarse spectral resolution instruments. Further, the author opined that since rock spectra are composites of their constituent minerals; depending on the structure and composition of these minerals, they could be detected if they are sufficiently abundant and their spectral features are strong enough. Kruse (1997) attempted geologic mapping and mineral exploration utilizing physical characteristics of rocks and soils such as mineralogy, weathering characteristics, geochemical signatures, and landforms to determine the nature and distribution of geologic units and to determine exploration targets for metals and industrial minerals. The author utilized the technique of hyperspectral remote sensing for mineral mapping, and concluded that high-quality hyperspectral data was an ideal input for mineral mapping. Salvi *et al.* (2002) studied the *in situ* spectral reflectance measurements of geological materials in the Northern Victoria Land, Antarctica. The authors constrained the analysis and geological interpretation of remote sensing data in the 0.4-2.5μm wavelength range and carried out spectral measurement surveys in the study area and integrated the same. In another geological study, Krezhova *et al.* (2003), performed spectrometric measurements on samples of ultramafic (pyroxenite) and basic (gabbro) igneous rocks, granitoids (2 kinds of granites) and regional metamorphic rocks – serpentinite, gneiss (metagranite) and garnet bearing amphibolites. They obtained high-resolution spectral data by means of the multichannel spectrometric system 'Spectrum-256' developed for the flight of the second Bulgarian cosmonaut. Based on the spectral reflectance curves, they identified spectral subclasses belonging to a common spectral class in accordance with the mineral composition of the rock types. The results find direct application as a database of spectral library for the needs of aerial remote sensing of environment and applied geophysics. In a study related to coastal applications of hyperspectral imagery, Sanjeevi and Barnsley (2000) used the technique of spectral unmixing of the hyperspectral image data, acquired by the Compact Airborne Spectrographic Imager (CASI) to quantify sub-pixel proportions of quartz-sand and moisture in coastal dune systems.

Thus, it is seen that high-resolution spectral data obtained at narrow spectral bands, enables a reliable interpretation of the spectral signatures of the terrestrial rocks. By studying the spectral reflectance of lunar-like terrestrial rocks in the bands equivalent to the HySI bands of Chandrayaan-1, it may be possible to identify the mineralogical composition of the lunar surface rocks.

Lunar Rocks

The paper is about the only natural satellite of the planet Earth, namely the Moon. The Moon has provided a fundamental and critical testing ground for most of the currently used planetary geologic remote sensing techniques. The lunar rocks are divided into two major types based on their spatial distribution: the Highlands (bright side) and Mare - the dark side of the moon. The highlands are composed of mostly anorthosites (almost feldspars only), other rocks like norite (feldspar with pyroxene), troctolites (feldspar with olivine) are the major rocks types. The mare regions (dark side) of the moon are mainly composed mostly of basalts containing titanium (Carr *et al.*, 1984).

Terrestrial Anorthosites

Geologists have been studying rocks and minerals to understand the earth strata, the tectonic activity. Anorthosite is one such rock that constitutes marker horizons in the Precambrian terrain and throws light on defines ancient tectonic zones. To understand the origin of the Earth and the Moon, the discovery of anorthosite on the Moon understandably gave an impetus to study this rock on Earth in detail (Subramanian and Selvan, 2001).

The anorthositic complexes of Tamil Nadu state, in southern India are located in Kadavur, Oddanchatram, Sittampundi and Adaiyaur. Many authors including Leelanadam (1987), Narasimha Rao (1964), Sarkar and Bose (1978) have studied these complexes in detail and have also commented on the relationship between these anorthosites and the lunar counterparts. Of these four complexes, only three (Kadavur, Oddanchatram and Adiayur) were selected for this study since the Oddanchatram and Sittampundi complexes are similar in nature (Windley and Selvam, 1975).

Kadavur complex

Kadavur anorthosite complex located in Karur district, Tamilnadu is a massif type of anorthosite rock. It occurs within a structural basin, surrounded by ridges of sillimanite – bearing quartzite and the complex was considered to have evolved as a funnel shaped pluton, similar to the Adirondack anorthosite (Subramanian, 1956). Windley and Selvan (1975) viewed it as a relict of an Archaean layered complex. It has been compared to the Fiskenisette complex in Greenland, since both have high MgO content (Weaver *et al.*, 1981). According to Sarkar and Bose (1978), the presence of abundant mafic rocks at depth, as interpreted by geophysical studies, are the outcomes of multiple/repeated basic magmatism.

Oddanchatram anorthosite complex

The Oddanchatram complex, located west of Madurai City, has been considered to be part of a belt of anorthosite bodies in the Eastern Ghats Hill ranges. It occurs as an elliptical body measuring 16 km along its long axis maximum width of 5 km. This area is well studied by Narasimha Rao (1964) and Janardhan and Wieke (1985). The anorthostite rock is composed essentially of more than 90% plagioclase feldspar and the constituents include subordinate hornblende, minor orthopyroxene and garnet. Lenses of ilmenite and magnetite are traced within the anorthosite. Narasimha Rao (1964) was the first to study Oddanchatram anorthosite in detail. Based on petrographical studies, the author concluded it as of igneous origin with two periods of intrusion of noritic-anorthositic magma, with the first intrusion giving rise to norites and garnetiferous anorthosite, and the second intrusion giving rise to pure anorthosite rocks.

Adaiyaur anorthosite

Adaiyaur is a small village located 8 km NW of Tiruvannamalai town, Tamilnadu. The regional rock types are granites, charnockites, banded magnetite quartzite formation in Vedhiyappan malai and Goudhimalai. The Pannakkadu synclinal basin is made of the outer gabbro and anorthosite. The anorthosties are found in metamophorsed rocks with garnet. Field visits indicate that some of these anorthosites bear sapphire gemstones also.

Methodology

The three study areas (Kadavur, Oddanchatram and Adaiyaur) were chosen because they analog the rock types found on the Moon (Subaramanian,1956, Janardhan, 1985) . Both, fresh and weathered samples were collected for this study. For taking the readings in the laboratory, each sample was selected to be 1' × 1' in size. As the spectral reflectance of rocks is also governed by the grain size, fine, medium and coarse-grained samples were collected for each rock type. The collected samples were labelled with their station number and sample number.

Spectro- Radiometery

A handheld spectro-radiometer whose spectral sampling interval is 1.5nm for the regions 325-1075μm was used in this study. The standard built-in input of the instrument has a field-of-view of 25 degree full conical angle. The instrument is capable of radiometric resolution of 2.5% of reflectance. The measurement of spectral reflectance for the rock specimen is carried out after pointing the instrument at fully illuminated white reference standard (Barium plate) and collecting the reflectance, setting integration time for maximum signal and after a uniform line at 1.00 appears (this is the reflectance factor of the reference panel).

Measuring reflectance

The instrument is hand held in near- vertical position as required to study the object. The reference plate is kept below the instrument centrally and readings were taken from 325 to 1075 nm of wavelength covering Ultraviolet, Visible (blue, green, yellow, red, far red), and near infrared (NIR) regions. The operations are repeated on the rock specimens, which are kept over an absolutely dull black paper for reduction of noise from the background.

To understand the relationship between reflectance and mineralogical composition for a given wavelength, the spectral reflectance curves were plotted. Attempts have been made to understand the relationship between percentage reflectance and mineralogical composition obtained from modal analysis of the thin sections. The modal analysis was carried out by computing the percentage of each mineral in the rock sample.

Spectral averaging of wavelengths

The spectroradiometer used in this study operates in the wavelength range of 325nm to 1075nm, in 751 spectral bands. Chandrayaan-1 (proposed satellite to moon) will carry an instrument, Hyper spectral Imager (HySI) with wavelength range of 400nm to 950nm, in 64 spectral bands. Hence, the 325-1075nm wavelength range of the spectro-radiometer was spectrally averaged corresponding to the 64 bands in the 400-950 nm range of HySI sensor onboard Chandrayaan-1, keeping in view the bandwidths at various regions between 400-900nm wavelengths (Figure 1a).

Hyperspectral Imager (HySI)

The Hyper Spectral Imager is an instrument used for mineralogical mapping of the lunar surface with spectral resolution better than 15nm and spatial resolution of 80m with swath coverage of 20 km. Sun's reflected light from Moon's surface will be collected by HySI. The instrument (HySI) contains 64 bands in the spectral zone from 400nm to 950nm (ISRO Publication, 2005).

Table 1 lists the 64 convolved wavelength bands in the 400nm - 950nm range. To understand the bandwidths as the function of wavelength, a plot of bandwidth vs. center-wavelength (averaged/ convolved) was generated (Figure 1a).

Results and Discussions

Since, this study aims to understand the spectral reflectance of lunar-like terrestrial rocks such as anorthosites, gabbros and basalts, by simulating the 64 bands of the HySI instrument onboard the proposed Chandrayaan-1 satellite, samples were analysed for spectro-radiometry and petrography techniques. Fieldwork and sample

Table 1: Convolved and simulated bands of HySI sensor onboard Chandrayaan-1 (Based on 16 wavebands of HySI sensor: Source; ISRO Publication, 2005)

Wavelength range (nm)	Band width (nm)	Wavelength range (nm)	Band width (nm)	Wavelength range (nm)	Band width (nm)
400-410		640 - 648.75		820 - 830	
410-420		648.75 - 657.5		830 - 840	
420 - 430		657.5 - 666.25		840 - 850	
430 - 440		666.25 - 675	8.75	850 - 860	
440 - 450		675 - 681.25		860 - 870	10
450 - 460		681.25 - 687.5		870 - 880	
460 - 470		687.5 - 693.75		880 - 890	
470 - 480		693.75 - 700		890 - 900	
480 - 490				900 - 910	
490 - 500		700 - 705		910 - 920	
500 - 510		705 - 710	5		
510 - 520	10	710 - 715		920 - 923.75	
520 - 530		715 - 720		923.75 - 927.5	
530 - 540				927.5 - 931.25	
540 - 550		720 - 730		931.25 - 935	3.75
550 - 560		730 - 740		935 - 938.75	
560 - 570		740 - 750		938.75 - 942.5	
570 - 580		750 - 760		942.5 - 946.25	
580 - 590		760 - 770	10	946.25 - 950	
590 - 600		770 - 780			
600 - 610		780 - 790		A total of 64 bands of the HySI sensor have been simulated by convolution approach	
610 - 620		790 - 800			
620 - 630		800 - 810			
630 - 640		810 - 820			

collection was done at the anorthosite complexes of Kadavur, Oddanchatram and Adaiyur in Tamil Nadu state.

Modal Analysis

Petrography was studied by preparation of thin sections (Figure 2- a2, b2, c2, d2) of anorthosites, gabbro, gabbroic-anorthosites and basalt rocks and by examining them under the petrological microscope. The percentage of each mineral present in the thin section was computed and the modal analysis was carried out for all the rock samples.

The result of modal analysis shows that plagioclase is the predominant constituent making up to 90-95% of the anorthosite rocks. Most of the grains are polysynthetically twinned and fresh. The common mafic constituent of the anorthosite is hornblende aguite and orthopyroxene occur widely in varying proportions. The basalts are made up of olivine and pyroxene, with less plagioclase and the gabbros contain feldspars and pyroxenes. The modal composition of the rocks is listed in Table 2. The results of the modal analysis can aid in understanding of the spectral signatures of the rocks and the reflectance and absorption therein. Following is a discussion on the spectral reflectance curves.

Spectral Reflectance in the HySI Bands

The spectral reflectance curves for the rock samples are shown in Figure 1b. In general it is seen that darker rocks (such as basalts) have a low reflectance compared to the anorthosites, which are lighter in colour. The conspicuous absorption at 900nm is perhaps due to the presence of iron (ferro-magnesian minerals) in these rock samples.

The curves depicted in Figure 1b shows that it is possible to differentiate the different types of terrestrial rocks that are similar to the lunar surface rocks. Basalt can be differentiated from gabbros and anorthosites in all the 64 bands of HySI. In particular bands 57 and 62 (the NIR wavelength ranges of EMR) shows absorption whereas the other rock shows reflection.

Gabbros can be distinguished in broadbands but in band 16 (550nm to 560nm), the rocks shows spectral characters similar to basalt. Hence, this band

Table 2: Modal analysis of the sample rocks

Sample No.	Plagioclase Feldspar	Pyroxene	Quartz	Opaque	Diopside	Garnet	Rocks
1	64.44	35.56	-	-	-	-	Basalt
2	76.97	4.35	-	13.72	4.96	-	Gabbro
3	90.05	-	-	9.95	-	-	Anorthosite
4	75.59	21.69	-	-	-	-	Gabbroic anorthosite
5	84.71	11.98	3.31	-	-	-	Anorthosite
6	87.18	-	-	0.81	-	0.44	Anorthosite
7	88.46	15.46	-	-	-	-	Anorthosite
8	94.40	5.56	-	-	-	-	Anorthosite
9	80.44	-	-	-	-	19.57	Anorthosite
10	87.68	-	-	15.33	-	-	Anorthosite

cannot be used to differentiate between the gabbros and basalts. Anorthosites also can be distinguished in the broadbands and most of the spectral reflectance is seen as peak in bands 63 (the red region of the EMR) and absorption in the band 47 (820-830nm). Thus, using information from one or more wavelength ranges, it may be possible to differentiate between different types of rocks such as basalt, gabbro and anorthosites (Table 3). Figure 1a is a plot of bandwidths as a function of the wavelengths of HySI onboard Chandrayaan-1. Comparison between the spectral signatures of the lunar-like rocks and the configuration of bandwidths of HySI reveals certain interesting relationships. It is observed that a bandwidth of 10nm is designed for 400nm to 640nm wavelength range; a narrow bandwidth of 5nm is designed for the 700nm to 720nm range, while a very narrow bandwidth of 3.75nm is designed for the 920nm to 950nm. Such a variation in bandwidth for different wavelength regions from 400-950nm needs an in-depth analysis. Such an in-depth analysis is facilitated by comparison of Figures 1a and 1b, ie., the bandwidths vs the spectral signature of lunar-like rocks for various wavelengths. The spectral signatures of the rock samples (Figure 1- a1, b1, c1, d1) shown in Figure 1b have characteristic plateau, peaks and troughs. The plateaus and the gently sloping portion of the curve with no kinks are seen in the 400nm-600nm regions. This implies that there is no conspicuous change in reflectance or absorption in the 400nm-600nm; thereby indicating that broadband (i.e. 10nm) sensing would suffice to study the rocks in this region of EMR.

In the 640nm to 700nm region two small peaks are observed which are widely spaced thereby justifying the use of 8.75nm bandwidths to capture these peaks and identify the rocks. The most distinct and sharp peaks and troughs, which are closely spaced, occur between 700nm-730nm, which demands that a narrow band sensing being done to capture such narrowly spaced, sharp peaks and troughs. Accordingly, a 5nm bandwidth in the 700nm to 730nm region would be useful to identify the lunar rocks.

The 730nm-825nm regions show a gentle undulation, and no appreciable peaks and troughs are observed. Hence, 10nm wide, broadband sensing would suffice to study the lunar rocks. Though a very narrow bandwidth of 3.75nm is indicated for HySI in the 920nm-950nm ranges, in Figure 1a, the radiometer used in the present study failed to indicate appreciable, closely spaced peaks and troughs. This could perhaps be due to the noise introduced by the instrument during the spectro-radiometry.

Table 3: Rocks studied and their characteristic spectral features in HySI bands

Rock	Spectral features			
	Absorption Band(s)	**Absorption wavelength (nm)**	**Reflection bands**	**Reflection Wavelength (nm)**
Basalt	57 62	920-923.75 938.75-942.5	58 63	923.75 942.5-946.25
Gabbro	20	590-600	27	657.5-666.25
Anorthosite	63	942.5-946.25	47	820-830
Gabbroic anorthosite	19	580-590	18	570-580

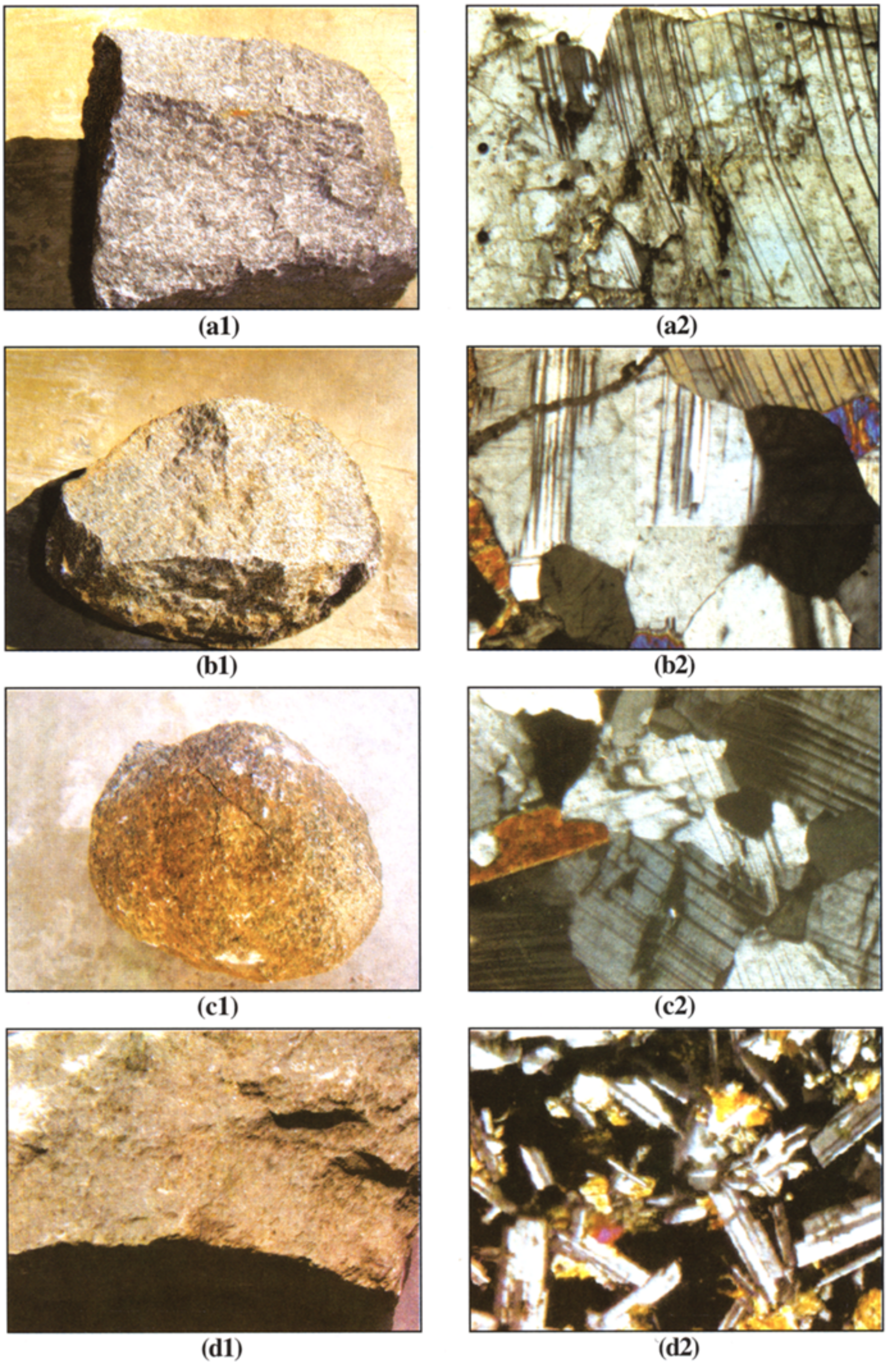

Fig. 1. Lunar equivalent, terrestrial rock samples a1, b1, c1, d1 used for spectro-radiometry and the corresponding thin-section photographs a2, b2, c2, d2 studied for petrography. (a) Anorthostie (b) Gabbroic - Anorthosite (c) Gabbro (d) Basalt.

A notable observation in this study is that, while conspicuous peaks and troughs are seen between 825nm-900nm in the spectral curves of rocks, the bandwidth, as suggested by Figure 2a is 10nm for this wavelength range. It is opined that this may not be an appropriate bandwidth, since narrower bandwidths (5nm or 3.75nm) are needed to capture such minor changes in the spectra and then identify the rocks.

Conclusions

Remote sensing technology is mainly based on the spectral response of different rocks. The mineralogical composition of the rocks has a definite influence on the reflectance characteristics in different wavelengths. An effort has been made to study the spectral reflectance characters of lunar-like terrestrial rocks in the 64 bands of HySI sensor on-board the proposed Chandrayaan-1 mission. The following are the conclusions drawn on the basis of the study carried out in the present work:

Anorthosite, basalt and gabbros have distinct reflectance in the VNIR region. While reflectance is seen in the wavelength ranges 620-630nm, 640-648.75nm, 681.52-687.5nm, 710-715nm, 750-760nm,

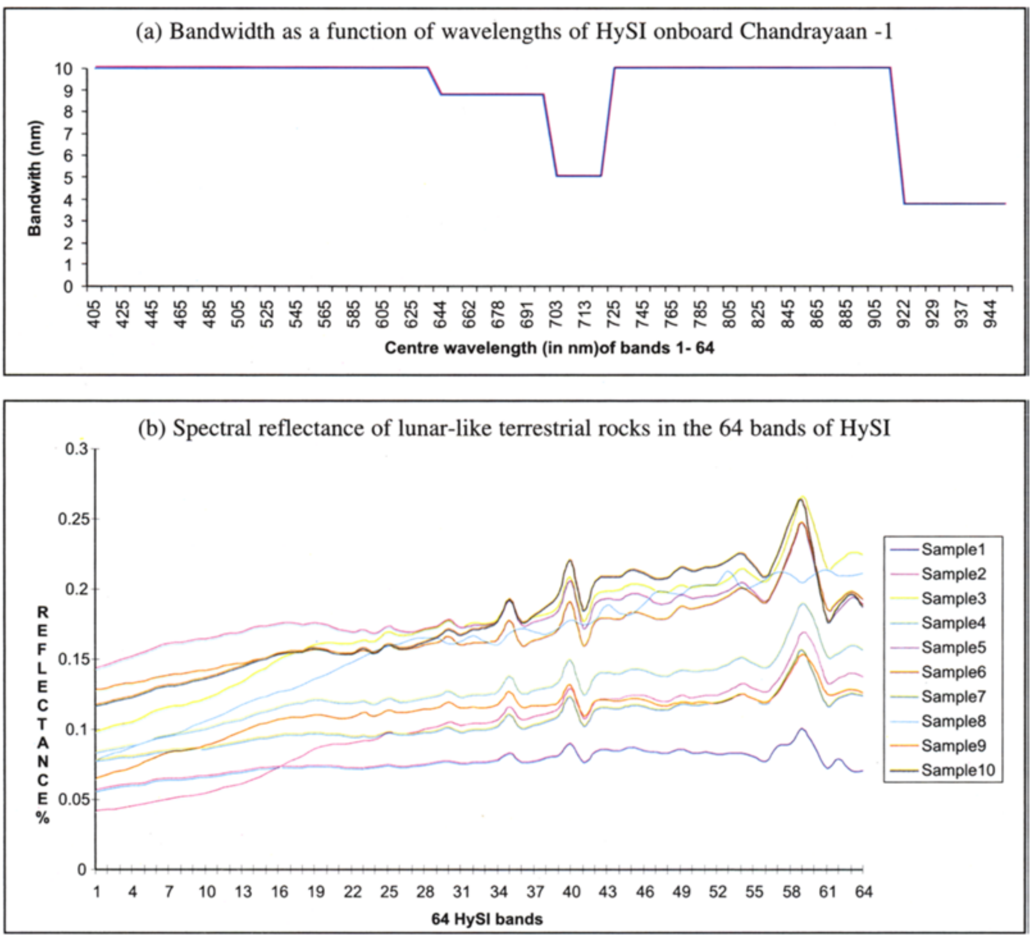

Fig. 2. (a) HySI bandwidth as a function of wavelength.
(b) Spectral reflectance of selected samples of lunar-like terrestrial rocks in the 64 bands of HySI.

800-810nm, 840-850nm, 890-900nm, 920-923.75nm, absorption is seen in the wavelength ranges: 630-640nm, 760-770nm and 830-840nm, 870-880nm, 910-920nm, 935-938.75nm. Hence, it is believed that the HySI sensor on the onboard Chandrayaan-1 will be able to discriminate between the different rock (anorthosites, gabbros and basalt) found on the lunar-surface. Due to the specific absorption and reflection (troughs and peaks) observed in certain of the 64 bands of HySI, it will be possible to identify approximate mineralogical comosition of the lunar surface. A few illustrations are:

a. Band 57 (920nm to 923.75nm), with a bandwidth of 3.75nm shows distinct reflection and band 63 (942.5nm to 946.25nm) with a bandwidth of 3.75nm shows distinct absorption, which is typical of basalt.

b. Band 20 (590nm to600nm) shows distinct reflectance, indicating the rock as gabbro.

c. Band 19 (580nm-590nm) has a distinct reflectance, indicating the gabbroic anorthositic rock.

d. Band 63 (942.5nm to 946.25nm) has a distinct reflectance character, which is typical of anorthosites.

It may be concluded that the spectral data obtained at hyperspectral mode enables a reliable interpretation of the spectral signatures of the lunar-like terrestrial rocks. The results also indicate appreciable correlation between the mineral composition and the spectral reflectance characters of the rocks. The spectral response curves generated in this study can also serve as a significant component of the spectral signature bank of terrestrial minerals and rocks that can be used for comparison with the HySI-generated spectra. Thus, it may be concluded that the spectral reflectance measured in the HySI bands of Chandrayaan-1 will provide the opportunity to identify the minerals and rocks on the lunar surface. It is also opined that the operational use of HySI sensor can be a precursor to future hyperspectral satellite missions of India to map minerals and rocks on the Earth.

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