## List of Figures

### Chapter -1

| Figure 1.1 | Laboratory schemes of spectroscopy study and resulting spectral curves. a Reflection. b Emission. c Absorption/transmission | 4 |
| Figure 1.2 | Spectral reflectance curves for jarosite, hematite and goethite showing sharp fall of reflectance in the UV-blue region due to the charge-transfer effect | 6 |
| Figure 1.3 | Reflection spectra of particulate samples of stibnite, cinnabar, realgar and sulphur, displaying sharp conduction-band absorption edge effect | 7 |
| Figure 1.4 | Crystal field effect. Reflection spectra showing ferrous-ion in selected minerals. The ferrous ion is located in an aluminium octahedral six-fold coordinated site in beryl, in a distorted octahedral six-fold co-ordinated site in olivine, in an octahedral eight fold co-ordinated site in spessartine, and in a tetrahedral site in staurolite | 9 |
| Figure 1.5 | Reflectance spectra of Calcite, Dolomite, Beryl, Gypsum, Allunite, Rectorite, Jorosite showing Vibrational bands due to OH, CO$_3$, and H$_2$O | 11 |
| Figure 1.6 | Laboratory spectra of silicate minerals | 15 |
| Figure 1.7 | Laboratory spectra of clay minerals | 15 |
| Figure 1.8 | Laboratory spectra of carbonate minerals | 16 |
| Figure 1.9 | Laboratory spectra of a) Igneous b) Sedimentary and c) Metamorphic rocks | 17 |
| Figure 1.10 | Schematic illustration of the imaging spectrometry concept. Images are acquired simultaneously of up to several hundred narrow spectral bands providing a complete reflectance spectrum for every pixel in the imaging spectrometer scene (after Vane, 1985) | 23 |
Chapter-2

Figure 2.1 Flow chart showing methodology

Figure 2.2 Ground spectroradiometric survey using GER 1500 at Sittampundi Anorthosite Complex, Tamil Nadu

Figure 2.3 Spectral measurements under controlled field condition

Figure 2.4 Stepped splice error before parabolic correction at 1000nm and 1800nm wavelength for anorthosite hand specimen

Figure 2.5 Removal of stepped splice error in reflectance spectra of anorthosites after parabolic correction

Figure 2.6 Reflectance spectra of Anorthosite hand specimens before continuum removal. Albedo ranges from 15% to 35%

Figure 2.7 Reflectance spectra of anorthosite hand specimens after continuum removal with clear absorptions at 1000nm, 1415nm, 1920nm, 2200nm and 2330nm

Chapter -3

Figure 3.1 Mumbai basaltic region: Locations of analog test sites selected for ground survey and sample collection of massive basalt

Figure 3.2 Field photograph of massive basalt outcrop, along the road to Yeoor selected for ground Spectroradiometric survey

Figure 3.3 Massive basalt in abandoned stone quarry at Gaibunder, Mumbai

Figure 3.4 Location map showing the field sites selected for spectroradiometric survey in basaltic rocks near Panvel, Maharashtra

Figure 3.5 The field photograph of vesicular basalt, near Ajvili village, Mumbai

Figure 3.6 The field photograph of vesicular basalt, near Panvel, Mumbai

Figure 3.7 Location map of Sittampundi anorthosite complex, Tamil Nadu
Figure 3.8  Geology map of Sittampundi anorthosite complex, Tamil Nadu  52
Figure 3.9  Field photograph of anorthosite outcrop Sittampundi, Tamil Nadu  54
Figure 3.10  Field photograph of anorthosite with dolerite dyke at Sittampundi, Tamil Nadu  55
Figure 3.11  Field photograph of anorthosite at Sittampundi, Tamil Nadu  55
Figure 3.12  Field photograph of weathered anorthosite, Sittampundi, Tamil Nadu  56
Figure 3.13  Analog rocks a) Gabbro b) Norite c) Pyroxinite used for spectroradiometric survey and chemical analyses  58
Figure 3.14  Analog minerals a) Olivine b) Labradorite c) Albite and d) Ilmenite used for spectroradiometric survey  59
Figure 3.15  Photomicrograph of Vesicular basalt  60
Figure 3.16  Photomicrograph of Amygdaloidal basalt  61
Figure 3.17  Photomicrograph of Massive basalt  61
Figure 3.18  Photomicrograph of anorthosite-01 collected from Sittampundi anorthosite complex, India : a- Hornblende, b- Pyroxene, c- Plagioclase  62
Figure 3.19  Photomicrograph of anorthosite-02 collected from Sittampundi anorthosite complex, India : a- Hornblende, b- Pyroxene, c- Plagioclase  63
Figure 3.20  Photomicrograph of anorthosite-03 collected from Sittampundi anorthosite complex, India : a- Hornblende, b- Pyroxene, c- Plagioclase  63
Figure 3.21  Photomicrograph of anorthosite-04 collected from Sittampundi anorthosite complex, India : a- Hornblende, b- Pyroxene, c- Plagioclase  64
Figure 3.22  Microphotograph of Norite shows the ophitic texture with plagioclase and clino pyroxene are the major minerals and biotite as minor mineral

Figure 3.23  Microphotograph of Norite shows the ophitic texture with plagioclase and hypersthene pyroxene as major minerals

Chapter-4

Figure 4.1  Field reflectance spectra of massive basalt at Yeoer village, vesicular and amygdaloidal basalts at Panvel region, near Mumbai

Figure 4.2  Reflectance spectra of analog massive basalt under controlled field condition

Figure 4.3  Reflectance spectra of analog vesicular basalt under controlled field condition

Figure 4.4  Reflectance spectra of analog amygdaloidal basalt under controlled field condition

Figure 4.5  Reflectance spectra of analog massive basalt under lab condition

Figure 4.6  Reflectance spectra of analog vesicular basalt under lab condition

Figure 4.7  Reflectance spectra of analog amygdaloidal basalt under lab condition

Chapter-5

Figure 5.1  Field reflectance spectra of anorthosites under 350nm- 1050nm

Figure 5.2  Field reflectance spectra anorthosite conducted at Thotianatham Sittampundi with different time span

Figure 5.3  Reflectance spectra of analog anorthosite-01 under controlled field condition. The 1350nm-1425nm and 1800nm-1950nm range removed due to atmospheric noise
Figure 5.4  Reflectance spectra of analog anorthosite-02 under controlled field condition. The 1350nm-1425nm and 1800nm-1950nm range removed due to atmospheric noise.

Figure 5.5  Reflectance spectra of analog anorthosite-03 under controlled field condition. The 1350nm-1425nm and 1800nm-1950nm range removed due to atmospheric noise.

Figure 5.6  Reflectance spectra of analog anorthosite-04 under controlled field condition. The 1350nm-1425nm and 1800nm-1950nm range removed due to atmospheric noise.

Figure 5.7  Reflectance spectra of analog anorthosite-01 under laboratory condition with albedo ranges from 28% for hand specimen and 80% for finer grain size <250µm. Absorption features noticed at 385nm, 700nm, 1200nm, 1415nm, 1920nm, 2200nm and 2320nm.

Figure 5.8  Reflectance spectra of analog anorthosite-02 under laboratory condition with absorption bands at 380nm, 700-730nm, 1200nm, 1415nm, 1915nm and absorption doublets at 2250nm and 2350nm.

Figure 5.9  Reflectance spectra of analog anorthosite-03 under laboratory condition with absorptions at 700nm, 1400nm, 1930nm, 2100nm and 2315nm.

Figure 5.10 Reflectance spectra of analog anorthosite-04 under laboratory condition with absorptions at 700nm, 1000nm-1100nm, 1405nm, 1915nm, 2250nm, 2315nm and 2390nm.

Chapter-6

Figure 6.1  Reflectance spectra of Gabbro from 350nm-2500nm measured under controlled field condition. The atmospheric interferences at 1350nm-1425nm and 1800nm-1950nm region are removed.

Figure 6.2  Reflectance spectra of Gabbro from 350nm-2500nm measured under laboratory condition.

Figure 6.3  Continuum removed reflectance spectra of Gabbro under laboratory condition.
Figure 6.4  The reflectance spectra of Gabbro under 350nm - 14µm range collected from spectral library (John Hopkins University)

Figure 6.5  Reflectance spectra of Norite from 350nm-2500nm measured under controlled field condition. The atmospheric interferences at 1350nm-1425nm and 1800nm-1950nm region are removed

Figure 6.6  Reflectance spectra of Norite from 350nm-2500nm measured under lab condition

Figure 6.7  Continuum removed reflectance spectra of Norite

Figure 6.8  The reflectance spectra of Norite under 350nm - 14µm range collected from spectral library (John Hopkins University)

Figure 6.9  Reflectance spectra of Pyroxinite from 350nm-2500nm measured under controlled field condition. The atmospheric interferences at 1350nm-1425nm and 1800nm-1950nm region are removed

Figure 6.10  Reflectance spectra of Pyroxinite from 350nm-2500nm measured under lab condition

Figure 6.11  Reflectance spectra of Olivine from 350nm-2500nm measured under controlled field condition. The atmospheric interferences at 1350nm-1425nm and 1800nm-1950nm region are removed

Figure 6.12  Reflectance spectra of Olivine from 350nm-2500nm measured under laboratory condition

Figure 6.13  Reflectance spectra of Labradorite from 350nm-2500nm measured under controlled field condition. The atmospheric interferences 1350nm-1425nm and 1800nm-1950nm are removed

Figure 6.14  Reflectance spectra of Labradorite from 350nm-2500nm measured under lab condition

Figure 6.15  Reflectance spectra of Ilmenite from 350nm-2500nm measured under controlled field condition. The atmospheric interferences at 1350nm-1425nm and 1800nm-1950nm region are removed
Figure 6.16 Reflectance spectra of Ilemenite from 350nm-2500nm measured under lab condition

Figure 6.17 Reflectance spectra of Diopside from 350nm-2500nm measured under controlled field condition. The atmospheric interferences at 1350nm-1425nm and 1800nm-1950nm region are removed

Figure 6.18 Reflectance spectra of Diopside from 350nm-2500nm measured under lab condition

Figure 6.19 Reflectance spectra of Albite from 350nm-2500nm measured under controlled field condition. The atmospheric interferences at 1350nm-1425nm and 1800nm-1950nm region are removed

Figure 6.20 Reflectance spectra of Albite from 350nm-2500nm measured under lab condition

Chapter - 7

Figure 7.1 True color composite image generated using the band 3,2,1 in red, green, blue filters and it has given contrast for anorthosite in bluish white color

Figure 7.2 False Color Composite (FCC), generated using 4, 3, 2 bands were assigned as Red, Green and Blue colors

Figure 7.3 Pseudo Color Composite image generated using bands 5, 4, 2

Figure 7.4 Band combination with 1, 2, 3 bands under red, green and blue filters anorthosite enhanced in purple tint color

Figure 7.5 Band combination of 2, 3, 1 (Green, Blue, Red) anorthosite enhanced in purple tint color

Figure 7.6 Contrast stretched FCC (4 3 2) using histogram equalization

Figure 7.7 Principal Component Analysis of Sittampundi Anorthosite Complex (a) PC1, (b) PC2
Figure 7.8 Spectral profile of the Sittampundi Anorthosite Complex (analog test site) 124

Figure 7.9 Spectral profiles of pure anorthosite and mixed anorthosite pixel for Sittampundi Anorthosite Complex 124

Chapter - 8

Figure 8.1 Model spectra from Clementine images of central peaks (after Tompkins, 1998) 129

Figure 8.2 Laboratory spectra of Massive basalt coincides with Tompkins spectra of Troctolite composition 131

Figure 8.3 Laboratory spectra of Vesicular basalt spectrum matches with Tompkins spectra of Tractolite composition 131

Figure 8.4 The spectrum obtained for Aristarchus Central peak is matching with analog rock spectra (after Evans, 2008) 132

Figure 8.5 Laboratory spectra of Amygdaloidal basalt coincide with the tractolite (olivine rich) of Tompkins classification indicates the presence of olivine in Amygdaloidal basalt 133

Figure 8.6 The analog anorthosite-01 has more plagioclase feldspar and almost matches with anorthositic gabbro (AG) of the Tompkins classification 133

Figure 8.7 The analog anorthosite-02 has more plagioclase feldspar and almost matches with anorthositic gabbro (AG) of the Tompkins classification 134

Figure 8.8 The corundum anorthosite spectral profile is match with gabbroic noritic tractolitic anorthosite 2 (GNTA2) of the Tompkins classification 134

Figure 8.9 Spectral curvature of the Anorthite, Olivine, Low-Calcic pyroxene and High-Calcic pyroxene (after Tompkins and Pieters 1997) 136

Figure 8.10 Spectral Curvature of the analog anorthosites 137
Figure 8.11  Clementine raw band 1 (415nm) for Theophilus crater, lunar nearside region

Figure 8.12  Clementine raw band 2 (750nm) for Theophilus crater, lunar nearside region

Figure 8.13  Clementine raw band 3 (900nm) for Theophilus crater, lunar nearside region

Figure 8.14  Clementine raw band (950nm) for Theophilus crater, lunar nearside region

Figure 8.15  Clementine raw band 5 (1000nm) for Theophilus crater, lunar nearside region

Figure 8.16  FeO concentration image of Theophilus crater generated with help of Clementine ratioed image

Figure 8.17  TiO2 concentration image of Theophilus crater generated with help of Clementine ratioed image

Figure 8.18  The ratio of 750nm/950nm show brighter signature of mafic rocks at central peak and mafic flow in the upper left part of the Theophilus crater, near side of moon

Figure 8.19  The ratio of 750nm/415nm gives darker signature for mafic rocks and brighter signature for rest of the Theophilus crater, nearside of moon

Figure 8.20  Standard Band ratio (red = 750nm/415nm, green = 750nm/950 nm, blue = 415 nm/750 nm) image of the Theophilus crater, nearside of moon

Figure 8.21  Pseudo-true color image is created by combining the 950nm, 750nm, and 415nm filters in the red, green, and blue channels of the Theophilus crater, nearside of moon

Figure 8.22  Absolute (a) and normalized (b) Clementine spectra of central peak of Theophilus crater

Figure 8.23  Absolute (a) and normalized (b) Clementine spectra of mafic floor of the Theophilus crater
Figure 8.24  Absolute (a) and normalized (b) Clementine spectra of melt and slumped wall units

Figure 8.25  Absolute (a) and normalized (b) Clementine spectra of feldspathic floor of the Theophilus crater

Figure 8.26  Absolute (a) and normalized (b) Clementine spectra of the Theophilus crater
### List of Tables

<table>
<thead>
<tr>
<th>Table No.</th>
<th>Title</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1.1</td>
<td>Major and minor phases of lunar minerals</td>
<td>22</td>
</tr>
<tr>
<td>Table 2.1</td>
<td>Developments in Lunar geological studies</td>
<td>26</td>
</tr>
<tr>
<td>Table 2.2</td>
<td>Specification of Spectroradiometer GER 1500</td>
<td>31</td>
</tr>
<tr>
<td>Table 2.3</td>
<td>Specification of Field Spec®3 spectroradiometer</td>
<td>33</td>
</tr>
<tr>
<td>Table 3.1</td>
<td>Lunar analog rocks and minerals</td>
<td>43</td>
</tr>
<tr>
<td>Table 3.2</td>
<td>Chemical composition of terrestrial and lunar basalts</td>
<td>45</td>
</tr>
<tr>
<td>Table 3.3</td>
<td>Mineralogy of Terrestrial vs Lunar basalts</td>
<td>45</td>
</tr>
<tr>
<td>Table 3.4</td>
<td>Major chemical elements of analog anorthosites vs lunar highland anorthosites</td>
<td>53</td>
</tr>
<tr>
<td>Table 3.5</td>
<td>The percentage of major and minor minerals of anorthosite samples collected from Sittampundi anorthosite complex, India</td>
<td>54</td>
</tr>
<tr>
<td>Table 3.6</td>
<td>Major chemical elements of analog gabbro and norite rocks vs lunar rocks</td>
<td>69</td>
</tr>
<tr>
<td>Table 3.7</td>
<td>The percentage of major minor minerals of analog gabbro and norite vs lunar gabbro and norite</td>
<td>70</td>
</tr>
<tr>
<td>Table 7.1</td>
<td>Specification of Landsat ETM+ Sensor</td>
<td>113</td>
</tr>
<tr>
<td>Table 7.2</td>
<td>Comparison of spectral characteristics of Image spectra, Field spectra and Lab spectra</td>
<td>125</td>
</tr>
<tr>
<td>Table 9.1</td>
<td>Spectral characteristics of analog basalts in controlled field condition</td>
<td>159</td>
</tr>
<tr>
<td>Table 9.2</td>
<td>Spectral characteristics of analog basalts in laboratory condition</td>
<td>162</td>
</tr>
<tr>
<td>Table 9.3</td>
<td>Laboratory reflectance spectra and diagnostic spectral characteristics of analog anorthosites</td>
<td>165</td>
</tr>
</tbody>
</table>
Table 9.4  Absorption band depths for lunar analog rock; gabbro and norite under 350nm-2500nm wavelength region

Table 9.5  Absorption band depth in analog basalts under 350nm-2500nm wavelength region