

Contents

5.8.1	Introduction	3
5.8.1	Working Principle of Spectral Meters and Remote Sensing	3
5.8.2	Factors Affecting Spectral Resolution	3
5.8.3	Sensor Resolution	3
5.8.4	Non-Imaging Radiometers	3
5.8.1	Terminology	3
5.8.2	Working Principle of Visible-Near-Infrared Region (VNIR)	3
5.8.3	VIS-NIR Region (0.4–0.7 μm)	3
5.8.4	SWIR Region (1–3 μm)	3
5.8.5	Terahertz Region	3
5.8.6	What is an Imager?	3
5.8.7	Scanning Line Scanner (Whiskbroom)	3
5.8.8	Pushbroom Imaging	3
5.8.9	Space Imaging Mosaic	3
5.8.10	3D Imaging	3
5.8.11	Instrumentation for Stereo Viewing	3
5.8.12	Photogrammetry	3

Chapter 1: Introduction

1.1	Definition and Scope	1
1.2	Development of Remote Sensing	1
1.3	Fundamental Principle	3
1.4	Advantages and Limitations	4
1.5	A Typical Remote Sensing Programme	6
1.6	Field Data (Ground Truth)	9
1.6.1	Timing of Field Data Collection	9
1.6.2	Sampling	10
1.6.3	Types of Field Data	11
1.6.4	GPS Survey	14
1.7	Scope and Organization of this Book	16

Chapter 2: Physical Principles

2.1	The Nature of EM Radiation	19
2.2	Radiation Principles and Sources	20
2.2.1	Radiation Terminology	20
2.2.2	Blackbody Radiation Principles	20
2.2.3	Electromagnetic Spectrum	23
2.2.4	Energy Available for Sensing	24
2.3	Atmospheric Effects	24
2.3.1	Atmospheric Scattering	25
2.3.2	Atmospheric Absorption	26
2.3.3	Atmospheric Emission	28
2.4	Energy Interaction Mechanisms on the Ground	28
2.4.1	Reflection Mechanism	28
2.4.2	Transmission Mechanism	30
2.4.3	Absorption Mechanism	32
2.4.4	Earth's Emission	32

Chapter 3: Spectra of Minerals and Rocks

3.1	Introduction	33
3.2	Basic Arrangements for Laboratory Spectroscopy	34
3.3	Energy States and Transitions – Basic Concepts	36
3.3.1	Electronic Processes	36
3.3.2	Vibrational Processes	39
3.4	Spectral Features of Mineralogical Constituents	39
3.4.1	Visible and Near-Infrared Region (VNIR) (0.4–1.0 μm)	39
3.4.2	SWIR Region (1–3 μm)	39
3.4.3	Thermal-IR Region	42
3.5	Spectra of Minerals	44
3.6	Spectra of Rocks	45
3.6.1	Solar Reflection Region (VNIR + SWIR)	45
3.6.2	Thermal-Infrared Region	48
3.7	Laboratory vs. Field Spectra	49
3.8	Spectra of Other Common Objects	50
3.9	Future	52

Chapter 4: Photography

4.1	Introduction	53
4.1.1	Relative Merits and Limitations	53
4.1.2	Working Principle	54
4.2	Cameras	55
4.2.1	Single-Lens Frame Cameras	56
4.2.2	Panoramic Cameras	58
4.2.3	Strip Cameras	58
4.2.4	Multiband Cameras	58
4.3	Films	59
4.3.1	Black-and-White Films	59
4.3.2	Colour Films	64
4.4	Filters	68
4.5	Film–Filter Combinations for Spectrozonal Photography	69
4.6	Vertical and Oblique Photography	70
4.7	Ground Resolution Distance	71
4.8	Photographic Missions	72
4.8.1	Aerial Photographic Missions	72
4.8.2	Space-borne Photographic Missions	72
4.8.3	Product Media	74

Chapter 5: Multispectral Imaging Systems

5.1	Introduction	75
5.1.1	Working Principle	75
5.2	Factors Affecting Sensor Performance	78
5.2.1	Sensor Resolution	80
5.3	Non-Imaging Radiometers	81
5.3.1	Terminology	81
5.3.2	Working Principle	82
5.4	Imaging Sensors (Scanning Systems)	83
5.4.1	What is an Image?	83
5.4.2	Imaging Tube (Vidicon)	84
5.4.3	Optical-Mechanical Line Scanner (Whiskbroom Scanner)	86
5.4.4	CCD Linear Array Scanner (Pushbroom scanner)	88
5.4.5	Digital cameras (CCD-Area-Arrays)	92
5.5	Space-borne Imaging Sensors	97
5.5.1	Landsat Programme	97
5.5.2	IRS Series	105
5.5.3	SPOT Series	108
5.5.4	MOMS Series	110
5.5.5	JERS-1 (Fuyo-1) OPS	111
5.5.6	CBERS Series	112
5.5.7	RESURS-1 Series	112
5.5.8	ASTER Sensor	113
5.5.9	MTI	114
5.5.10	Space Imaging/Eosat – Ikonos	115
5.5.11	DigitalGlobe – Quickbird	115
5.5.12	Other Programmes (Past)	116
5.5.13	Planned Programmes	119
5.6	Products from Scanner Data	121

Chapter 6: Geometric Aspects of Photographs and Images

6.1	Geometric Distortions	123
6.1.1	Distortions Related to Sensor System	125
6.1.2	Distortions Related to Sensocraft Altitude and Perturbations ...	128
6.1.3	Distortions Related to the Earth's Shape and Spin	131
6.1.4	Relief Displacement	132
6.2	Stereoscopy	136
6.2.1	Principle	136
6.2.2	Vertical Exaggeration	137
6.2.3	Aerial and Space-borne Configurations for Stereo Coverage	138
6.2.4	Photography vis-à-vis Line-Scanner Imagery for Stereoscopy ..	140
6.2.5	Instrumentation for Stereo Viewing	140
6.3	Photogrammetry	142

6.3.1	Measurements on Photographs	142
6.3.2	Measurements on Line-Scanner Images	144
6.3.3	Aerial vis-à-vis Satellite Photogrammetry	145
6.4	Transfer of Planimetric Details and Mapping	146

Chapter 7: Image Quality and Principles of Interpretation

7.1	Image Quality	147
7.1.1	Factors Affecting Image Quality	148
7.2	Handling of Photographs and Images	151
7.2.1	Indexing	151
7.2.2	Mosaic	152
7.2.3	Scale Manipulation	153
7.2.4	Stereo Viewing	153
7.2.5	Combining Multispectral Products	153
7.3	Fundamentals of Interpretation	154
7.3.1	Elements of Photo Interpretation	155
7.3.2	Geotechnical Elements	157

Chapter 8: Interpretation of Data in the Solar Reflection Region

8.1	Introduction	161
8.2	Energy Budget Considerations for Sensing in the SOR Region	162
8.2.1	Effect of Attitude of the Sun	162
8.2.2	Effect of Atmospheric Meteorological Conditions	165
8.2.3	Effect of Topographic Slope and Aspect	165
8.2.4	Effect of Sensor Look Angle	167
8.2.5	Effect of Target Reflectance	168
8.3	Acquisition and Processing of Solar Reflection Image Data	168
8.4	Interpretation	169
8.4.1	Interpretation of Panchromatic Black-and-White Products	169
8.4.2	Interpretation of Multispectral Products	174
8.4.3	Interpretation of Colour Products	177
8.5	Luminex Method	180
8.6	Scope for Geological Applications	180

Chapter 9: Interpretation of Data in the Thermal-Infrared Region

9.1	Introduction	183
9.2	Earth's Radian Energy – Basic Considerations	184
9.2.1	Surface (Kinetic) Temperature	185
9.2.2	Emissivity	190
9.3	Broad-Band Thermal-IR Sensing	190

9.3.1	Radiant Temperature and Kinetic Temperature	191
9.3.2	Acquisition of Broad-Band Thermal-IR Data	192
9.3.3	Processing of Broad-Band TIR Images	194
9.3.4	Interpretation of Thermal-IR Imagery	195
9.3.5	Thermal Inertia mapping	198
9.3.6	Scope for Geological Applications – Broad-Band Thermal Sensing	201
9.4	Temperature Estimation	206
9.4.1	Use of Landsat TM Data for Temperature Estimation	206
9.4.2	Use of Landsat-7 ETM+ Data for Temperature Estimation	209
9.5	Thermal-IR Multispectral Sensing	210
9.5.1	Multispectral Sensors in the TIR	211
9.5.2	Data Correction and Enhancement	213
9.5.3	Applications	214
9.6	LIDAR Sensing	215
9.6.1	Working Principle	215
9.6.2	Scope for Geological Applications	216
9.7	Future	216

Chapter 10: Digital Image Processing of Multispectral Data

10.1	Introduction	217
10.1.1	What is Digital Imagery?	217
10.1.2	Sources of Multispectral Image Data	219
10.1.3	Storage and Supply of Digital Image Data	220
10.1.4	Image Processing Systems	220
10.1.5	Techniques of Digital Image Processing	222
10.2	Radiometric Image Correction	224
10.2.1	Correction for Atmospheric Contribution	224
10.2.2	Correction for Solar Illumination Variation	226
10.2.3	Correction for Topographic Effects	226
10.2.4	Sensor Calibration	228
10.2.5	De-striping	229
10.2.6	Correction for Periodic and Spike Noise	231
10.3	Geometric Corrections	232
10.3.1	Correction for Panoramic Distortion	232
10.3.2	Correction for Skewing Due to Earth's Rotation	232
10.3.3	Correction for Aspect Ratio Distortion	233
10.4	Registration	233
10.4.1	Definition and Importance	233
10.4.2	Principle	234
10.4.3	Procedure	235
10.5	Image Enhancement	238
10.6	Image Filtering	242
10.6.1	High-Pass Filtering (Edge Enhancement)	243

10.6.2	Image Smoothing	248
10.6.3	Fourier Filtering	248
10.7	Image Transformation	250
10.7.1	Addition and Subtraction	253
10.7.2	Principal Component Transformation	255
10.7.3	Decorrelation Stretching	258
10.7.4	Ratioing	258
10.8	Colour Enhancement	262
10.8.1	Advantages	262
10.8.2	Pseudocolour Display	263
10.8.3	Colour Display of Multiple Images – Guidelines for Image Selection	263
10.8.4	Colour Models	264
10.9	Image Fusion	267
10.9.1	Introduction	267
10.9.2	Techniques of Image Fusion	267
10.10	2.5-Dimensional Visualization	270
10.10.1	Shaded Relief Model (SRM)	271
10.10.2	Synthetic Stereo	271
10.10.3	Perspective View	272
10.11	Image Segmentation	274
10.12	Digital Image Classification	274
10.12.1	Supervised Classification	276
10.12.2	Unsupervised Classification	281
10.12.3	Fuzzy Classification	282
10.12.4	Linear Mixture Modelling (LMM)	283
10.12.5	Artificial Neural Network Classification	283
10.12.6	Classification Accuracy Assessment	284

Chapter 11: Hyperspectral Sensing

11.1	Introduction	287
11.2	Spectral Considerations	289
11.2.1	Processes Leading to Spectral Features	289
11.2.2	Continuum and Absorption Depth – Terminology	290
11.2.3	High-Resolution Spectral Features – Laboratory Data	291
11.2.4	Mixtures	294
11.2.5	Spectral Libraries	296
11.3	Hyperspectral Sensors	296
11.3.1	Working Principle of Imaging Spectrometers	297
11.3.2	Sensor Specification Characteristics	299
11.3.3	Airborne Hyperspectral Sensors	300
11.3.4	Space-borne Hyperspectral Sensors	300
11.4	Processing of Hyperspectral Data	302
11.4.1	Pre-processing	302

11.4.2	Radiance-to-Reflectance Transformation	304
11.4.3	Data Analysis for Feature Mapping	307
11.5	Applications	311

Chapter 12: Microwave Sensors

12.1	Introduction	317
12.2	Passive Microwave Sensors and Radiometry	317
12.2.1	Principle	317
12.2.2	Measurement and Interpretation	318
12.3	Active Microwave Sensors – Imaging Radars	320
12.3.1	What is a Radar?	320
12.3.2	Side-Looking Airborne Radar (SLAR) Configuration	321
12.3.3	Spatial Positioning and Ground Resolution from SLAR	325
12.3.4	SLAR System Specifications	328
12.3.5	Aerial and Space-borne SLAR Sensors	329

Chapter 13: Interpretation of SLAR Imagery

13.1	Introduction	337
13.2	SLAR Image Characteristics	337
13.2.1	Radiometric Characteristics	337
13.2.2	Geometric Characteristics	342
13.3	SLAR Stereoscopy and Radargrammetry	345
13.4	Radar Return	346
13.4.1	Radar Equation	346
13.4.2	Radar System Factors	347
13.4.3	Terrain Factors	350
13.5	Processing of SLAR Image Data	355
13.6	Polarimetry	357
13.7	Field Data (Ground Truth)	358
13.7.1	Corner Reflectors (CRs)	359
13.7.2	Scatterometers	359
13.8	Interpretation and Scope for Geological Applications	359

Chapter 14: SAR Interferometry

14.1	Introduction	367
14.2	Principle of SAR Interferometry	367
14.3	Configurations of Data Acquisition for InSAR	369
14.4	Baseline	372
14.5	Airborne and Space-borne InSAR Systems	373
14.5.1	Airborne Systems	373

14.5.2	Space-borne Systems	374
14.5.3	Ground Truth and Corner Reflectors	376
14.6	Methodology of Data Processing	377
14.7	Differential SAR Interferometry (DInSAR)	381
14.8	Factors Affecting SAR Interferometry	382
14.9	Applications	383
14.10	Future	392

Chapter 15: Integrating Remote Sensing Data with Other Geodata (GIS Approach)

15.1	Integrated Multidisciplinary Geo-investigations	393
15.1.1	Introduction	393
15.1.2	Scope of the Present Discussion	395
15.2	Geographic Information System (GIS) – Basics	395
15.2.1	What is GIS?	395
15.2.2	GIS Data Base	397
15.2.3	Continuous vs. Categorical Data	398
15.2.4	Basic Data Structures in GIS	399
15.2.5	Main Segments of GIS	400
15.3	Data Acquisition (Sources of Geo-data in a GIS)	400
15.3.1	Remote Sensing Data	400
15.3.2	Geophysical Data	400
15.3.3	Gamma Radiation Data	403
15.3.4	Geochemical Data	404
15.3.5	Geological Data	404
15.3.6	Topographical Data	404
15.3.7	Other Thematic Data	405
15.4	Pre-processing	405
15.5	Data Management	413
15.6	Data Manipulation and Analysis	413
15.6.1	Image Processing Operations	413
15.6.2	Classification	416
15.6.3	GIS Analysis	420
15.7	Applications	424

Chapter 16: Geological Applications

16.1	Introduction	429
16.2	Geomorphology	431
16.2.1	Tectonic Landforms	433
16.2.2	Volcanic Landforms	434
16.2.3	Fluvial Landforms	435
16.2.4	Coastal and Deltaic Landforms	441

16.2.5	Aeolian Landforms	442
16.2.6	Glacial Landforms	444
16.3	Structure	445
16.3.1	Bedding and Simple-Dipping Strata	448
16.3.2	Folds	450
16.3.3	Faults	456
16.3.4	Neovolcanic Rift Zone	460
16.3.5	Lineaments	460
16.3.6	Circular Features	477
16.3.7	Intrusives	480
16.3.8	Unconformity	480
16.4	Lithology	481
16.4.1	Mapping of Broad-Scale Lithologic Units – General	481
16.4.2	Sedimentary Rocks	482
16.4.3	Igneous Rocks	486
16.4.4	Metamorphic Rocks	490
16.4.5	Identification of Mineral Assemblages	493
16.5	Stratigraphy	497
16.6	Mineral Exploration	498
16.6.1	Remote Sensing in Mineral Exploration	498
16.6.2	Main Types of Mineral Deposits and their Surface Indications	501
16.6.3	Stratigraphical–Lithological Guides	502
16.6.4	Geomorphological Guides	502
16.6.5	Structural Guides	503
16.6.6	Guides Formed by Rock Alteration	505
16.6.7	Geobotanical Guides	515
16.7	Hydrocarbon Exploration	519
16.8	Groundwater Investigations	523
16.8.1	Factors Affecting Groundwater Occurrence	524
16.8.2	Indicators for Groundwater on Remote Sensing Images	526
16.8.3	Application Examples	526
16.9	Engineering Geological Investigations	536
16.9.1	River Valley Projects – Dams and Reservoirs	536
16.9.2	Landslides	539
16.9.3	Route Location (Highways and Railroads) and Canal and Pipeline Alignments	542
16.10	Neotectonism, Seismic Hazard and Damage Assessment	542
16.10.1	Neotectonism	543
16.10.2	Local Ground Conditions	551
16.10.3	Disaster Assessment	555
16.11	Volcanic and Geothermal Energy Applications	555
16.11.1	Volcano Mapping and Monitoring	555
16.11.2	Geothermal Energy	560
16.12	Coal Fires	563

16.13	Environmental Applications	571
16.13.1	Vegetation	572
16.13.2	Land Use	573
16.13.3	Soil Erosion	575
16.13.4	Oil Spills	576
16.13.5	Smoke from Oil Well Fires	581
16.13.6	Atmospheric Pollution	583
16.14	Future	583
Chapter 15: Integrating Remote Sensing Data with Other Geospatial Data (GIS Approach)		
Appendices		585
References		593
Illustrations – Location Index		623
Subject Index		627
Chapter 16: Geological Applications		
16.1	Introduction	1.0
16.2	Geomorphology	1.01
16.3	Tectonic Landforms	1.1
16.4	Volcanic Landforms	1.11
16.5	Ephemeral Landforms	1.12
16.6	Coastal and Deltaic Landforms	1.15
16.7	Assessment	1.01.1
16.8	Near-surface Geological Hazards and Dams	1.01.2
16.9	Dam Safety Assessment	1.01.3
16.10	Volcanoes and Geological Hazards	1.13
16.11	Aquatic Management and Monitoring	1.11.1
16.12	Geological Hazards	1.11.2
16.13	Coastal Hazards	1.15