

Contents

Preface

Acknowledgments

List of Tables

SECTION 1 INITIATING PROJECTS

1 Project Flow and Obtaining Data

Chapter Overview

Choosing Imagery

Acquiring Imagery

References

Additional Reading

Questions to Consider

2 Photointerpretation Tools and Techniques

Chapter Overview

Tools

Image Characteristics

Interpretation Mechanics

References

Additional Reading

Questions to Consider

3 Remote Sensing Systems

Chapter Overview

Airphotos

Airborne Multispectral/Hyperspectral Scanners

Airborne Thermal Scanners

Airborne Radar

Satellite Photography

Satellite Digital Imagery

Side-Scan Sonar

Laser Altimeters

References

Additional Reading

Questions to Consider

xiii

xvii

xix

1

3

3

3

10

11

11

11

20

20

20

23

23

25

26

26

27

27

27

33

35

40

44

47

69

70

70

71

72

SECTION 2 EXPLORATION REMOTE SENSING	75
Introduction	76
Frontier Area Analysis	76
Lease Evaluation	77
4 Recognizing Rock Types	78
Chapter Overview	78
Igneous Rocks	78
Metamorphic Rocks	81
Sedimentary Rocks	81
Alteration	85
References	91
Additional Reading	92
Questions to Consider	92
5 Recognizing Structure	93
Chapter Overview	93
Undeformed Terrain	93
Recognizing Dip	93
Anticlines, Domes, and Horsts	98
Circular Features	127
Fractures	128
Interpreting the Timing of Structural Development	166
The Field Check	169
References	170
Additional Reading	172
Questions to Consider	173
6 Spectral Stratigraphy	174
Chapter Overview	174
Rock Spectra	174
Hyperspectral Imagery	179
Lithologic Mapping	184
Applications-Hydrocarbons	191
Applications-Minerals	193
References	197
Additional Reading	198
Questions to Consider	199
7 Exploration Case Histories	200
Chapter Overview	200
Frontier Petroleum Exploration: Structural Traps at Trap Springs, Nevada	200
Mature Basin Petroleum Exploration: Paradox Basin Stratigraphic Traps, Utah	203

Mature Basin Petroleum Exploration: Denver Basin Fractured Reservoirs, Colorado-Wyoming	206
Mineral Exploration: Alteration Associated with Gold at Goldfield, Nevada	210
Structural Mapping as a Guide to Porphyry Copper Deposits, Northeast China	214
Exploration for Kimberlites and Diatremes, Utah, Colorado, and Wyoming	216
Mineral Exploration in Mongolia	221
References	224
Additional Reading	224
Questions to Consider	225
SECTION 3 EXPLOITATION AND ENGINEERING REMOTE SENSING	227
Introduction	228
Exploitation Applications	228
Hydrologic Applications	229
Engineering Applications	229
8 Exploitation Remote Sensing	230
Chapter Overview	230
Choosing Infill And Stepout Well Locations	230
Bravo Dome Case History	231
Fractured Reservoirs	233
Coalbed Methane	244
Piceance Basin Coalbed Methane Case History	244
Secondary Recovery and Waterfloods	246
Cottonwood Creek Field Case History	246
Extending Known Mineral Deposits	249
Huancavelica Mining District Case History	251
Mine Safety Issues	255
References	256
Additional Reading	257
Questions to Consider	257
9 Hydrology	258
Chapter Overview	258
Locating Sources of Water	258
Monitoring Surface Water	263
Flood Control	264
Erosion	267
Geothermal Resources	269
References	270
Additional Reading	271
Questions to Consider	271

10 Logistics and Engineering	272
Chapter Overview	272
Using Appropriate Base Maps	272
Geographic Information Systems	273
Case History: Mine Management Using a Geographic Information System	274
Case History: Pipeline Routing Using Remote Sensing and a GIS	275
Reconnaissance	276
Site Selection	279
Transportation	284
Power Plants, Pipelines, Tunnels, and Dams	286
Kakrapar Atomic Power Project Site Selection Case History	287
References	287
Additional Reading	288
Questions to Consider	288
SECTION 4 ENVIRONMENTAL REMOTE SENSING	291
Introduction	292
11 Environmental Baselines and Monitoring	293
Chapter Overview	293
Environmental Audits	293
Habitat Mapping	294
Surface Disturbance and Change Detection Mapping	296
Coal Mine Fires	300
Jharia, India Coal Fire Case History	300
Mine Reclamation	301
Couer d'Alene Mine Reclamation Case History	301
Water Pollution	306
Air Pollution	316
References	318
Additional Reading	320
Questions to Consider	320
12 Environmental Hazards, Legal Aspects, and Public Relations	321
Chapter Overview	321
Landslides	321
Earthquakes	323
Floods	324
Volcanos	324
Subsidence	328
Subsidence over Abandoned Coal Mines Case History	328
Marine Hazards	331
Legal Issues	333
Public Relations	336
References	337

Additional Reading	338
Questions to Consider	338
Closing Thoughts	339
Responses to Questions to Consider	341
<i>Index</i>	355

Preface

Remote sensing technology can be traced at least to the thirteenth-century invention of eyeglasses by Roger Bacon. This technology literally got off the ground in 1858 when Gaspard Tournachon took photographs of Paris, France, from a hot air balloon in order to produce topographic maps [1]. Modern remote sensing can be traced to extensive airphoto surveys begun in the 1930s and 1940s, and with the advent of satellites and multispectral scanners the science of remote sensing has become increasingly useful in geologic exploration, engineering, and logistical planning, and environmental monitoring. The objective of this book is to show the interested reader how to interpret or extract vital information from remote sensing imagery.

Remote sensing can be defined as technologies and techniques used to obtain information about distant objects using reflected or emitted electromagnetic radiation (Fig. 1), acoustic energy, potential fields (gravity, magnetics), or geochemical measurements. We will concern ourselves only with interpreting electromagnetic, and in some cases acoustic (sonar), images. We will for the most part not discuss data that is measured at points and then contoured (geochemistry, gravity) or along profiles (lidar, aeromagnetics, seismic). Image interpretation can be defined as the process of extracting useful information from remote sensing images, whether they are digital or analog, hardcopy (paper, film) or on a computer screen. This information may be compiled as a map or report, or annotated directly on the imagery itself.

The process of interpretation draws heavily on field experience, that is, it is important for the interpreter to have observed features on the ground in order to understand what is observed on images. In geologic remote sensing this draws heavily on structural geology and geomorphology; in environmental remote sensing it is important to know about plant communities and what can affect them, wildlife behavior, weather patterns, and surface geologic and hydrologic processes; in engineering and logistics it helps to know about slope stability, soil types, etc. Whereas photogrammetry is the precise measurement or surveying of ground features from photos to make, for example, topographic maps, in image interpretation we are dealing with the study of landforms, surface cover, and cultural features to learn about both the surface and subsurface geology, environmental sensitivity, or the suitability of an area for building.

To some extent the interpretation of images also requires a knowledge of the instruments used to acquire the image and the computer processing techniques used to generate the image. This book deals with these topics only as they directly apply to interpreting imagery. For a more complete understanding of instrumentation and processing refer to the *Manual of Remote Sensing* [2] as well as books by Condit and Chavez, Drury, Gupta, Jensen, Sabins, and Siegal and Gillespie, among others [3-6]. The purpose of this book is to serve as a manual of image interpretation that shows, by example, what to look for on imagery when engaged in mineral or hydrocarbon exploration, mine and oil field development, engineering projects, and environmental monitoring.