

ABOUT THE COVER:

The cover illustration was made by combining three different U.S. Geological Survey digital data sets: a black and white digital orthophotograph, a digital elevation model, and a digital raster image of a topographic map. The observer viewpoint is at an altitude of 1200' above the surface, in the vicinity of Massanutten Mountain, just east of Harrisonburg, VA. The colored lines and areas from the topographic map are transparent so that when combined, the underlying imagery is visible. These data sets are then draped over a surface generated from the digital elevation data. The cover illustrates the flexibility available to the cartographer in creating graphics using computer technology and digital data sets.

JOHN WILEY & SONS, INC.
NEW YORK • CHICHESTER • BRISBANE
TORONTO • SINGAPORE

ISBN 0-471-55579-7



CONTENTS

PART I

INTRODUCTION 1

1 CARTOGRAPHY TODAY 3

CARTOGRAPHY NOW	4
CARTOGRAPHY TOMORROW	5
IMPLICATIONS	6
OUTLINE OF BOOK	7

2 NATURE OF CARTOGRAPHY 8

FORMS OF REPRESENTATION	9
NEED FOR MAPS	9
BASIC CHARACTERISTICS OF MAPS	10
PURPOSES MAPS SERVE	11
CATEGORIES OF MAPS	11
Classed by Scale	12
Classed by Function	12
Classed by Subject Matter	15
EMPHASIS ON CARTOGRAPHIC REPRESENTATION	17
THE SCOPE OF CARTOGRAPHY	18
SELECTED REFERENCES	19

3 HISTORY OF CARTOGRAPHY 20

SEQUENCE OF DEVELOPMENT	21
IMPACT OF CHANGING IDEAS	22
Concept of Representation	22
Geometry	23
Reconciling Conflicting Information	23
Globalism	24
Science and Measurement	24
Concept of Distribution	26
Systems/Ecological Thinking	27
IMPACT OF CHANGING TECHNOLOGY	28
Technical Advances	28
Integrating Technologies	36
INFORMATION AGE MAPPING	37
SELECTED REFERENCES	38

PART II

EARTH-MAP RELATIONS 39

4 BASIC GEODESY 41

SPHERICAL EARTH	42
ELLIPSOIDAL EARTH	43
GEOIDAL EARTH	44
CARTOGRAPHIC USE OF THE SPHERE, ELLIPSOID, AND GEOID	44
GEOGRAPHICAL COORDINATES	46
Latitude	46
Longitude	48
PROPERTIES OF THE GRATICULE	48
Distance on the Sphere and Great Circles	49
Direction	49
Area	51
GEODETTIC POSITION DETERMINATION	53
Geodetic Latitude and Longitude Determination	53
Horizontal Control Networks	54
Vertical Control	56
SELECTED REFERENCES	58

5 MAP PROJECTIONS 59

SCALE FACTOR AND TRANSFORMATIONS	61
DISTORTIONS RESULTING FROM MAP TRANSFORMATIONS	63
Transformation of Angles	63
Transformation of Areas	66
Transformation of Distances	66
Transformation of Directions	66
ANALYSIS AND VISUALIZATION OF DISTORTION	67
Visual Analyses	67
Quantitative Measures	68
GRAPHIC PORTRAYAL OF DISTORTIONS	68
CHOOSING A MAP PROJECTION	69
COMMONLY USED MAP PROJECTIONS	74
Conformal Projections	74

Equal-Area Projections	78
Azimuthal Projections	80
Other Systems of Map Projection	84
Polyconic Projection	85
SELECTED REFERENCES	89

6 SCALE, REFERENCE, AND COORDINATE SYSTEMS 91

MAP SCALE	92
Statements of Scale	92
Scale Factor (SF)	93
Determining the Scale of a Map	93
Transforming the Map Scale	94
REFERENCE SYSTEMS	95
COORDINATE SYSTEMS	97
Cartesian Coordinates	98
Rectangular Coordinates	99
COORDINATE SYSTEMS USED ON MAPS IN THE UNITED STATES	101
Universal Transverse Mercator (UTM) Grid System	101
Universal Polar Stereographic (UPS) Grid System	104
Modification of UTM System as Used by USGS	105
State Plane Coordinate (SPC) System	107
Public Land Survey System (PLSS)	108
CONCLUSION	110
SELECTED REFERENCES	110

PART III SOURCES OF DATA 113

7 GROUND SURVEY AND POSITIONING 115

PRINCIPLES OF SURVEYING	116
Angle and Distance	116
Angle-Distance-Angle	117

Distance-Distance-Distance	117
MEASUREMENT TECHNOLOGY	118
Measuring Distance	118
Measuring Direction	118
TRADITIONAL SURVEY METHODS	120
Finding Horizontal Position	120
Finding Vertical Position	122
AUTOMATED SURVEY SYSTEMS	123
Total-Station Instruments	123
Electronic Positioning	124
SIMULTANEOUS 3-D POSITIONING	125
SELECTED REFERENCES	125

8 REMOTE SENSING DATA COLLECTION 126

SOURCES OF ENERGY	127
Electromagnetic Radiation	127
Acoustical Energy	131
ENERGY RECORDING TECHNOLOGY	132
Aerial Photography	132
Electronic Imaging Devices	136
Forms of Electronic Imaging	140
Side Looking Airborne Radar	144
Sidescan Imaging Sonars	147
REMOTE SENSING PLATFORMS	148
Aircraft Remote Sensing	148
Space Remote Sensing	150
AVAILABILITY OF REMOTE SENSOR DATA	156
Public Domain Imagery	156
Commercially Available Imagery	157
Restricted Use Imagery	157
SELECTED REFERENCES	158

9 CENSUS AND SAMPLING 159

POPULATION ENUMERATIONS	160
GEOCODING	160
Entity Focus	160
Aggregation	162
SPATIAL SAMPLING	163
Size of Sample	164
Sampling Units	164
Dispersion of Sampling Units	164
Relating Sample to Distribution	165

PASSIVE DATA COLLECTION 166
SELECTED REFERENCES 166

10 DATA MODELS FOR DIGITAL CARTOGRAPHIC INFORMATION 168

MODELING GEOGRAPHIC REALITY 169
VECTOR DATA STRUCTURES 171
 Geometric Components 172
 Topological Components 173
 Feature Components 174
RASTER DATA STRUCTURES 174
MODELING SURFACES 177
MODELING SOLIDS 177
FEATURE DESCRIPTIONS 178
MODELING RELATIONSHIPS 179
MODELING TIME 181
SELECTED REFERENCES 184

11 MAP DIGITIZING 187

COLLECTING THE GEOMETRY 188
 Manual Digitizers 188
 Scanning Systems 190
ESTABLISHING A GEOGRAPHIC FRAME OF
 REFERENCE 194
ADDING ATTRIBUTES 194
EDITING DATA 195
COLLECTING METADATA 197
THE DIGITIZING PROCESS 197
SELECTED REFERENCES 198

PART IV DATA PROCESSING 199

12 IMAGE PROCESSING 201

MANUAL METHODS OF IMAGE
 INTERPRETATION 202
 Single Image 202
 Stereoscopic Images 203
DIGITAL IMAGE PROCESSING 208
 Image Rectification 209

Image Enhancement 210
Thematic Information Extraction 215
Digital Image Simplification 217
CARTOGRAPHIC PRODUCTS 218
 Mosaics 218
 Orthophotos 219
 Orthophotomaps 220
SELECTED REFERENCES 221

13 DIGITAL DATABASES 222

EARLY CARTOGRAPHIC DATABASES 223
BASE CARTOGRAPHIC DATA 224
 Defense Mapping Agency Data 225
 U.S. Geological Survey Data 225
BUREAU OF CENSUS STATISTICAL AND
 GEOGRAPHICAL DATA 226
THEMATIC DATA 229
 Soils 230
 Wetlands 230
DIGITAL ELEVATION DATA 231
DIGITAL IMAGE DATA 236
 Digital Orthophotos 236
 Government Satellite Data 237
 AVHRR 237
 Commercial Satellite Data 237
DATA EXCHANGE STANDARDS 238
 Direct Translation 239
 Switchyard Conversion 239
 Neutral Exchange Format 240
 Analysis of Standards Activities 241
SELECTED REFERENCES 244

14 GEOGRAPHIC AND CARTOGRAPHIC DATABASE CONCEPTS 246

RELATIONSHIP OF SPATIAL RESOLUTION TO
 SCALE 247
GEOGRAPHIC AND CARTOGRAPHIC
 DATABASES 249
HANDLING DATABASES OF VARYING
 SCALES 250
WHY HAVE CARTOGRAPHIC
 DATABASES? 251
SCALE LEVELS 252

LARGE-SCALE DATA	252
SELECTED REFERENCES	254

15 MANAGING LARGE DATABASES 255

DATA ORGANIZATION	256
Partitioning	256
Spatial Indexes	258
Metadata	261
DATA COMPRESSION	263
Run-Length Encoding	263
Quadtree Encoding	267
JPEG Compression	267
Freeman Chain Codes	267
Other Compression Schemes	267
SELECTED REFERENCES	269

16 DATA MEASUREMENT AND BASIC STATISTICAL PROCESSING 270

THE NATURE OF GEOGRAPHIC PHENOMENA	271
MEASUREMENT OF GEOGRAPHICAL VARIABLES	272
Nominal Scales of Measurement	272
Ordinal Scales of Measurement	272
Interval Scales of Measurement	273
Ratio Scales of Measurement	273
BASIC STATISTICAL CONCEPTS AND PROCESSES	274
Absolute and Derived Data	275
Ratios	276
Indexes of Variation	279
SOME BASIC STATISTICAL RELATIONS	283
Regression Analysis	284
Correlation Analysis	287
SELECTED REFERENCES	290

17 GEOGRAPHIC INFORMATION SYSTEMS 291

COMPONENTS OF A GIS	292
Hardware	292
Software	293
Data	294

People or "Liveware"	298
STRUCTURE OF A GEOGRAPHIC INFORMATION SYSTEM	299
The Process Flow of a GIS	299
Stages of Maturity and Complexity	300
GIS FUNCTIONALITY	302
Graphic User Interface (GUI) Functions	302
System and Database Management Functions	302
Data Entry, Edit, and Validation Functions	304
Manipulation and Analysis Functions	307
Display and Product Creation Functions	309
THE MEANING OF GIS TO CARTOGRAPHY	310
SELECTED REFERENCES	311

PART V

PERCEPTION AND DESIGN 313

18 CARTOGRAPHIC DESIGN 315

OBJECTIVES OF MAP DESIGN	316
FUNCTIONAL DESIGN	317
SCOPE OF DESIGN	317
Design Process	318
Design Result	318
PERCEPTUAL CONSIDERATIONS	318
Graphic Elements	318
Visual Variables	319
Classes of Symbols	321
GRAPHIC COMMUNICATION	322
Perception of Graphic Complexes	323
Design Principles	324
CONTROLS ON MAP DESIGN	330
Purpose	330
Reality	330
Available Data	331
Map Scale	331
Audience	331
Conditions of Use	331
Technical Limits	331
DESIGN PLANNING	332
The Graphic Outline	332
Composition	332

Orientation and Scale	337
DESIGN EXCELLENCE	338
SELECTED REFERENCES	338

19 COLOR THEORY AND MODELS 340

THE NATURE OF COLOR	341
Spectral Color	341
Reflected Color	342
COLOR DIMENSIONS	343
Hue	343
Brightness and Value	343
Saturation and Chroma	343
THE NATURE OF COLOR VISION	345
Trichromatic Theory	345
Opponent Process Theory	346
Color Constancy	347
COLOR MODELING SYSTEMS	347
The CIE System	347
The Munsell System	351
The Natural Color System	355
COMPUTER ELECTRONIC DISPLAY COLOR MODELS	356
RGB Color Model	356
HLS Color Model	357
HVC Color Model	357
SELECTED REFERENCES	358

20 COLOR AND PATTERN CREATION AND SPECIFICATION 359

COLOR AND PATTERN FOR LITHOGRAPHIC PRINTING	360
Printing Ink Specification	360
Preprinted Tints and Patterns	360
Screen Tints	361
Moiré Avoidance	364
Links With Color Models	365
Continuous Tone Creation by Halftoning	367
Digital Screen Tints and Patterns	368
COLOR AND PATTERN FOR COMPUTER PLOTTERS AND PRINTERS	371
Line Plotter Color and Pattern Creation	371
Computer Printer Colors and Patterns	372
Electronic Color and Pattern Creation	374

LINKS BETWEEN ELECTRONIC AND HARDCOPY COLOR	377
SELECTED REFERENCES	379

21 COLOR AND PATTERN USE 380

FUNCTIONS OF COLOR AND PATTERN IN MAP DESIGN	381
Symbolizing Qualitative Features	381
Symbolizing Quantitative Features	387
ENHANCING DESIGN EFFECTIVENESS	397
Increasing Visual Acuity	397
Promoting Figure-Ground	398
Promoting Map Aesthetics	399
SPECIAL COLOR DESIGN PROBLEMS	400
Special Illumination Conditions	400
Designing for Color-Deficient Vision	400
SELECTED REFERENCES	401

22 TYPOGRAPHY AND LETTERING THE MAP 403

HISTORY OF MAP LETTERING	404
FUNCTIONS OF LETTERING	406
NATURE OF TYPOGRAPHY	407
Elements of Typographic Design	407
Forming the Letters	414
LETTERING THE MAP	416
Positioning Guidelines	416
Methods of Lettering	419
GEOGRAPHICAL NAMES	421
Naming Conventions	422
Databases	422
SELECTED REFERENCES	423

23 MAP COMPILATION 425

THE COMPILATION PROCESS	426
The Worksheet	426
Source Data and Map Scale	426
Thematic Data	427
Base Data on Thematic Maps	428
ANALOG COMPILATION WORKSHEET	431
Base Materials	431
Forming the Guide Image	432
Separations	432
Registry	432
Image Geometry	434

Scale	434
Use of the Analog Worksheet	439
DIGITAL COMPILATION WORKSHEET	439
Sources of Digital Data	439
Projections and Coordinate Systems	440
Preparing the Worksheet	441
Using the Digital Worksheet	441
ACCURACY AND RELIABILITY	442
RIGHTS AND RESPONSIBILITIES	443
Sources and Credits	443
Copyright	444
Liability Issues	445
SELECTED REFERENCES	446

PART VI

CARTOGRAPHIC ABSTRACTION 447

24 SELECTION AND GENERALIZATION PRINCIPLES 449

SELECTION	450
GENERALIZATION CONCEPTS	451
The Elements of Generalization	451
The Controls of Generalization	458
CLASSIFICATION, SIMPLIFICATION, AND EXAGGERATION MANIPULATIONS	460
Classification Manipulations	460
Simplification Manipulations	462
Exaggeration Manipulations	472
SELECTED REFERENCES	472

25 SYMBOLIZATION: FEATURE ATTRIBUTES AT POINTS, LINES, AND AREAS 474

THE SYMBOLIZATION PROBLEM	475
Measurement Level	475
Feature Dimensionality	476
Visual Variables in Symbolization	476
Summary of the Symbolization Problem	477
SYMBOLIZING GEOGRAPHIC FEATURES	478
Mapping Features Conceived as Points	478

Mapping Features Conceived as Lines	483
Mapping Features Conceived as Areas	484
Summary of Symbolizing Geographic Features	486
SELECTED REFERENCES	492

26 SYMBOLIZATION: FEATURE ATTRIBUTE VOLUMES 493

CONCEPT OF A STATISTICAL SURFACE	494
MAPPING THE STATISTICAL SURFACE WITH POINT SYMBOLS	497
Dot Map	497
Choosing Dot Size and Unit Value	498
Choosing Dot Location	498
MAPPING THE STATISTICAL SURFACE WITH LINE SYMBOLS	501
Hachures	502
Profiles	503
Oblique Traces	504
Isarithmic Mapping	505
MAPPING THE STATISTICAL SURFACE WITH AREA SYMBOLS	515
Choroplethic Mapping	515
Dasymetric Mapping	519
MAPPING THE STATISTICAL SURFACE WITH LINE AND AREA SYMBOLS	525
Shaded Isarithms	525
Shaded Classless Choropleths	525
SELECTED REFERENCES	526

27 PORTRAYING THE LAND-SURFACE FORM 527

HISTORICAL BACKGROUND	528
VISUALIZATION METHODS	531
Perspective Pictorial Maps	532
Morphometric Maps	536
Terrain Unit Maps	537
Hachures	537
Contouring	538
Hill Shading	543
SELECTED REFERENCES	548

28 MULTIVARIATE MAPPING AND MODELING 549

SUPERIMPOSITION OF FEATURES	550
SEGMENTED SYMBOLS	550
CROSS-VARIABLE MAPPING	552
COMPOSITE INDEXES	553
Choice of Variables	553
Variable Weighting	554
Links Between Weighted Variables	555
FIDELITY OF CARTOGRAPHIC MODELING	555
READABILITY OF MULTIVARIATE MAPS	556
SELECTED REFERENCES	556

29 DYNAMIC/INTERACTIVE MAPPING 557

ANIMATION	558
Fixed-Sequence	559
User-Specified Sequence	561
NAVIGATION SYSTEMS	562
SIMULATION	563
INTERACTIVE CARTOGRAPHY	565
MAP AS INTERFACE	566
SELECTED REFERENCES	566

PART VII MAP EXECUTION AND DISSEMINATION 567

30 MAP REPRODUCTION 569

REPRODUCTION GUIDES PRODUCTION	570
METHODS FOR A FEW COPIES	570
Reflection Original	571
Transmission Original	573
Digital Original	577
METHODS FOR MANY COPIES	578
Lithography	579
Platemaking	582
Presswork	583
TRENDS IN MAP REPRODUCTION	583
SELECTED REFERENCES	584

31 MAP PRODUCTION 585

FORM OF MAP ARTWORK	586
---------------------	-----

Electronic Display Screens	588
CONSTRUCTION METHOD	589
Clip-Art Maps	589
Database/Algorithm Mapping	589
Maps from Scratch	594
Desktop Publishing	596
OUTPUT OPTIONS	597
Raster Devices	598
Vector Plotters	602
DIGITAL PRODUCTION PROBLEMS	603
Mixed-Media Degradation	604
Scale Issues	604
COMPOSITING SEPARATIONS	605
Composite to Film	605
Composite to Plate	605
PROOFING	606
Digital Check-Plots	606
Photo-Mechanical Proofs	607
Involving the Printer	607
SELECTED REFERENCES	607

APPENDIX

A FEDERAL GEOGRAPHIC DIGITAL DATA PRODUCTS 609

SOURCES OF DIGITAL DATA	610
U.S. Department of Agriculture (USDA)	610
U.S. Department of Commerce (USDC)	610
National Oceanic and Atmospheric Administration (NOAA)	611
U.S. Department of the Interior	612
ELECTRONIC ACCESS	613

B DATA AND GRAPHIC FILE FORMATS 614

DATA FORMATS	615
ASCII	615
Binary	615
GRAPHIC FILE FORMATS	617
Vector File Formats	618
Raster File Formats	626

COMPUTER GRAPHICS STANDARDS 628
SELECTED REFERENCES 629

C SELECTED LIST OF MAPPING SOFTWARE VENDORS 630

CLIP-ART 631
GEOGRAPHIC INFORMATION SYSTEMS 631
IMAGE PROCESSING 632
STATISTICAL MAPPING 632
PROJECTIONS 632
COMPUTER AIDED DESIGN (CAD) 632
ILLUSTRATION 633
PAINT 633
IMAGE EDITORS 634

D GRAPHIC ARTS PHOTOGRAPHY 635

RECORDING MEDIUM 636
Color Sensitivity 636
Contrast 638
EXPOSURE CONTROL 640
Projection Copying 640
Contact Copying 640
Electronic Imaging System 641
FILM REGISTRATION 642
Camera Work 642
Contact Work 643
LIGHT SOURCES 643
Flood Sources 643
Laser Sources 644
PROCESSING PHOTOGRAPHIC MATERIALS 644
RETOUCHING AND ALTERATIONS 645
SELECTED REFERENCES 646

E USEFUL ADDRESSES FOR REMOTE SENSING PRODUCTS 647

Governmental Aerial Photography, Orthophotoquads, Human Spacecraft Photography, Landsat Imagery and Digital Data 648
High Altitude Aerial Photography, SLAR Imagery, Human Spacecraft Photography, Landsat Imagery and Digital Data 648
ACSC, USFS, and SCS Photography 648
Space Shuttle Large Format Camera Photography 648
Historical Aerial Photography 648
Canadian Aerial Photography 648
Sidescan Sonar Imagery 648
Landsat Imagery and Digital Data 649
Spot Imagery and Digital Data, Soyuzkarta Imagery 649
Weather Satellite Imagery and Data, Passive Microwave Imagery 649

F PHOTO-MECHANICAL MAP PRODUCTION 650

DRAFTING 651
SCRIBING 652
Guide Image 652
Image Orientation 653
Scribing Instruments 654
Scribing Techniques 655
COMPLEX ARTWORK 656
Open-Window Negatives 656
Negative Screens 657
Positive Masks 661
SELECTED REFERENCES 663

INDEX 664