List of figures

P.1 Born in England, Scotland or Wales – Britain 1981 (four levels each), ward map (wards are used to define most other administrative areas in this book, while maps show the distribution of some feature over an area of land) xxiv

P.2 Born in England, Scotland or Wales – Britain 1981 (four levels each), ED cartogram (ED, or enumeration district, is a small census unit with about 12 in each ward, 129 211 in Britain, while cartograms show the concentration of some feature within sections of the population) xxv

P.3 Change of residence in England and Wales 1980/81, 32 % sample ward level map xxviii

P.4 Change of residence in England and Wales 1980/81, 32 % sample ward level cartogram xxix

P.5 Childhood leukaemia in the North of England 1960s to 1980s, selection, eight maps xxx

P.6 Childhood leukaemia in the North of England 1960s to 1980s, selection, eight cartograms xxxi

P.7 Employment by occupation, sex and, if part-time, nationally in Britain, 1981–1984–1987, five pyramid glyphs xxxii

P.8 House prices by house size, type and amenities nationally in Britain 1983–1989, fourteen tree glyphs xxxiii

I.1 Two images from the Mandelbrot set of infinite complexity xxxvi

I.2 Land use Northern Britain 1980s (nine categories), 1 km squares, digital map xxxvii

I.3 Change of residence in England and Wales, 1980/81, 5.2 % sample ward level cartogram xxxix

I.4 Voting in general elections in Northern Britain, 1955–1987 (proportions), eleven constituency cartograms xl

I.5 Voting in general elections in Southern Britain, 1955–1987 (proportions), eleven constituency cartograms xli
### List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.6</td>
<td>Counties and major cities, Britain 1981. Early computer generated continuous population cartogram</td>
<td>xliv</td>
</tr>
<tr>
<td>I.7</td>
<td>Voting in the British general election 1987, constituency voting triangle</td>
<td>xlv</td>
</tr>
<tr>
<td>I.9</td>
<td>Unemployment rates in Britain 1978–1990 (grey scale), composite Amalgamated Office Area cartogram</td>
<td>xlviii</td>
</tr>
<tr>
<td>1.1</td>
<td>1980s animation with conventional polygon shading on a microcomputer, eighteen selected stills</td>
<td>2</td>
</tr>
<tr>
<td>1.2</td>
<td>1980s animation using ray-tracing on a microcomputer, eighteen selected stills</td>
<td>3</td>
</tr>
<tr>
<td>1.3</td>
<td>Ray-traced surfaces of the Mandelbrot and Julia sets, six images</td>
<td>5</td>
</tr>
<tr>
<td>1.4</td>
<td>Visualizing Fourier transforms. The art in the science, twenty-one images</td>
<td>6</td>
</tr>
<tr>
<td>1.5</td>
<td>Computer generated coloured maze shown in a low resolution, information rich image</td>
<td>8</td>
</tr>
<tr>
<td>1.6</td>
<td>Zooming down on the Mandelbrot set, fourteen images</td>
<td>9</td>
</tr>
<tr>
<td>1.7</td>
<td>Age, gender, birth place and employment in London, 1971–1981 (two levels each), eight ED cartograms</td>
<td>12</td>
</tr>
<tr>
<td>1.8</td>
<td>Colour schemes for three independent or partly related variables: cube, circle and triangle</td>
<td>15</td>
</tr>
<tr>
<td>1.9</td>
<td>Children, elderly, females and immigrants in London 1981 (four levels each), three ED cartograms</td>
<td>17</td>
</tr>
<tr>
<td>1.10</td>
<td>Born in parts of Britain, Ireland, Africa or Asia in London 1981 (four levels each), three ED cartograms</td>
<td>18</td>
</tr>
<tr>
<td>1.11</td>
<td>Employment, job status and graduates in London 1981 (four levels each), three ED cartograms</td>
<td>19</td>
</tr>
<tr>
<td>1.12</td>
<td>Broad occupational groups in Britain 1987 (dominant levels), ward cartogram</td>
<td>21</td>
</tr>
<tr>
<td>1.13</td>
<td>Change in occupational groups in Britain 1984–1987 (maximum job gains), ward cartogram</td>
<td>22</td>
</tr>
<tr>
<td>1.14</td>
<td>Change in occupational groups in Britain 1984–1987 (maximum job losses), ward cartogram</td>
<td>23</td>
</tr>
<tr>
<td>1.15</td>
<td>Occupations, hours and gender, Britain 1987 constituency (with voting), pyramid glyph cartogram</td>
<td>26</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

1.16 Occupations, hours and gender, Britain 1987 constituency, pyramid glyph cartogram 27

1.17 Voting swings in Northern Britain 1955–1987 (proportions), eleven constituency arrow glyph cartograms 28

1.18 Voting swings in Southern Britain 1955–1987 (proportions), eleven constituency arrow glyph cartograms 29

2.1 General election results in Britain 1981, prototype named Parliamentary seat cartogram 33

2.2 Named Parliamentary Constituency population cartogram 35

2.3 Unemployment rate in Britain 1981 (grey scale), 17 named Level II European Regions map 36

2.4 Unemployment rate in Britain 1981 (grey scale), 64 named Counties and Scottish Regions map 37

2.5 Unemployment rate in Britain 1981 (grey scale), 97 named Family Practitioner Areas map 39

2.6 Unemployment rate in Britain 1981 (grey scale), 116 named Local Education Authorities map 42

2.7 Unemployment rate in Britain 1981 (grey scale), 136 named ‘Functional Cities’ map 43

2.8 Unemployment rate in Britain 1981 (grey scale), 280 named Local Labour Market Areas map 44

2.9 Unemployment rate in Britain 1981 (grey scale), 322 named Travel-to-Work Areas map 45

2.10 Unemployment rate in Britain 1981 (grey scale), 459 named Local Government Districts map 48

2.11 Unemployment rate in Britain 1981 (grey scale), 633 named Parliamentary Constituencies map 49

2.12 Unemployment rate in Britain 1981 (grey scale), 852 named Amalgamated Office Areas map 51

2.13 Postcode Areas, 121 coloured at random, map 53

2.14 Postcode Districts, 2649 coloured at random, map 54

2.15 Postcode Sectors, 8604 coloured at random, map 55

3.1 Counties and major cities in Britain map and three continuous area cartograms 61
LIST OF FIGURES

3.2 Named Counties in Britain showing connections that maintain ward continuity, map 62
3.3 The evolution of a population cartogram, Britain, county cartogram 64
3.4 Arrows representing topology, Britain, county cartogram 65
3.5 Local Authority Districts numbered for identification, map 68
3.6 Local Authority Districts, alphabetical indexed list 70
3.7 Local Authority Districts numbered for identification, cartogram 71
3.8 Parliamentary Constituencies numbered for identification, map 72
3.9 Parliamentary Constituencies, alphabetical indexed list 74
3.10 Parliamentary Constituencies numbered for identification, cartogram 75
3.11 Census wards and Scottish part postcode sectors (10 444), Britain 1981, ward cartogram 76
3.12 Unemployment rate in Britain 1981 (grey scale), ward map 78
3.13 Unemployment rate in Britain 1981 (grey scale), ward cartogram 79
3.14 Named Counties and Scottish Regions (individually shaded), map 82
3.15 Counties and Scottish Regions (with the same shades) on ED cartogram 83
3.16 County boundaries and named towns on ED cartogram 84
3.17 Railways. The British mainland rail network, map 86
3.18 Railways. The British mainland rail network on ED cartogram 87
3.19 Roads. The British primary road network, map 88
3.20 Roads. The British primary road network on ED cartogram 89
3.21 Grids. Equal population grid Britain 1981, map 90
3.22 Grids. The National Grid Squares in Britain 1981 on ED cartogram 91
4.1 Population change in Britain 1971–1981 (two levels), ED cartogram 96
4.2 Gender in Britain 1981 (two levels), ED cartogram 99
4.3 Young and old in Britain 1981 (two levels each), ED cartogram 101
4.4 Young, old and females in Britain 1981 (two levels each), ED cartogram 102
4.5 Young, old and females in Britain 1971 (two levels each), ED cartogram 103
LIST OF FIGURES

4.6 Young, old and females, change 1971–1981 (two levels each), ED cartogram

4.7 Irish born in Britain 1981 (two levels), ED cartogram

4.8 Born in England, Scotland or Wales – Britain 1981 (two levels each), ED cartogram

4.9 Born in Britain, Eire or Northern Ireland – Britain 1981 (four levels each), ED cartogram

4.10 Born in Africa, Ireland or Asia – Britain 1981 (four levels each), ED cartogram

4.11 Unemployed, working or inactive – Britain 1981 (four levels each), ED cartogram

4.12 Unemployed, working or inactive – Britain 1981 (four levels each), ward map

4.13 Professional, intermediate or supervised jobs – Britain 1981 (four levels each), ED cartogram

4.14 Professional, intermediate or supervised jobs – Britain 1981 (four levels each), ward map

4.15 House prices in Britain 1983 (grey scale), ward cartogram

4.16 Voting in the British general election 1987 (proportions), constituency cartogram

4.17 Voting in the British general election 1987 (proportions), constituency map

4.18 Voting in the British general election 1987, first placed parties, constituency cartogram

4.19 Voting in the British general election 1987, second placed parties, constituency cartogram

4.20 Voting in the British general election 1987, nonvoting (grey scale), constituency cartogram


5.1 Born in England, Scotland or Wales – change in Britain 1971–1981 (four levels each), ED cartogram

5.2 Born in Africa, Ireland or Asia – change in Britain 1971–1981 (four levels each), ED cartogram

5.3 Born in Africa, Ireland or Asia – change in Britain 1971–1981 (two levels each), ED cartogram
LIST OF FIGURES

5.4 Unemployed, working or inactive – change in Britain 1971–1981 (four levels each), ED cartogram 142

5.5 Unemployment rates in Britain 1978–1990 (grey scale), twelve Amalgamated Office Area cartograms 144

5.6 Unemployment rates in Britain 1978–1990 (grey scale), twelve county cartograms 145

5.7 Professional, intermediate or supervised jobs, change in Britain 1971/81, ED cartogram 146

5.8 House price inflation in Britain 1983/84 (grey scale), ward cartogram 147

5.9 House price inflation in Britain 1984/85 (grey scale), ward cartogram 149

5.10 House price inflation in Britain 1985/86 (grey scale), ward cartogram 150

5.11 House price inflation in Britain 1986/87 (grey scale), ward cartogram 151

5.12 House price inflation in Britain 1987/88 (grey scale), ward cartogram 152

5.13 House price inflation in Britain 1988/89 (grey scale), ward cartogram 153

5.14 House prices in Britain 1989 (grey scale), ward cartogram 154

5.15 Voting in the British General Election 1987, seats lost and won, constituency cartogram 156

5.16 Voting in the British General Elections 1955–1987, seats lost and won, eleven constituency cartograms 157

5.17 Voting in the British General Elections 1955–1987, first placed party, eleven constituency cartograms 158

5.18 Voting in the British General Elections 1955–1987, first placed party, eleven constituency cartograms 160

5.19 Voting in the British General Elections 1955–1987, second placed party, eleven constituency cartograms 161

5.20 Voting in the British General Election 1987, swings, constituency arrow glyph cartogram 162

5.21 Voting in the British General Elections 1955–1987, swings, ten constituency arrow glyph cartograms 163
LIST OF FIGURES xvii

5.22 Voting in the British General Elections 1955–1987, nonvoting (grey scale), eleven constituency cartograms 164

6.1 Change of residence between all European Regions in Britain 1976, ordered flows 169

6.2 Change of residence between Regions in Britain 1976. Attempts at coping with the complexity 170

6.3 Journey to work flows of over 1000 people between wards, map 172

6.4 Journey to work flows of over 700 people between wards, map 173

6.5 Journey to work flows of over 200 people between wards, map 175

6.6 Journey to work flows of over 100 people between wards, map 176

6.7 Daily Commuting between wards, 31.7% of all flows shown, England and Wales, map 178

6.8 Daily Commuting between wards, 31.7% of all flows shown, England and Wales, cartogram 179

6.9 Daily Commuting between wards, 43.6% of all flows shown, England and Wales, cartogram 180

6.10 Daily Commuting between wards, 56.5% of all flows shown, England and Wales, cartogram 181

6.11 Daily Commuting from wards, 50% of all flows shown, England and Wales, map 186

6.12 Daily Commuting from wards, 50% of all flows shown, England and Wales, cartogram 187

6.13 Daily Commuting as a proportion of destination employees, England and Wales, cartogram 188

6.14 Daily Commuting as a proportion of destination residents, England and Wales, cartogram 189

6.15 Daily Commuting from wards, 50% shown with job status, England and Wales, map 190

6.16 Daily Commuting from wards, 50% shown with job status, England and Wales, cartogram 191

6.17 Change of residence between family practitioner areas in Britain 1975–1976, FPC level cartogram 193

6.18 Change of residence between wards with job status, England and Wales, 1980/81, map 196
xviii LIST OF FIGURES

6.19 Change of residence between wards with job status, England and Wales, 1980/81, cartogram 197

7.1 Contours and colour used to depict surface height 200

7.2 Contours without colour used to depict surface height 201

7.3 Voting in British general elections, 1955–1987, eleven voting triangles 204

7.4 Voting in County Council elections in England 1981, voting triangle 206

7.5 Voting in County Council elections in England 1985, voting triangle 207

7.6 Voting in County Council elections in England 1989, voting triangle 208

7.7 Voting and votes in County Council elections in England 1981, composite voting triangle 211

7.8 Voting and votes in County Council elections in England 1985, composite voting triangle 212


7.10 Voting and votes in County Council elections in England 1989, composite voting triangle 215

7.11 Change in voting and votes in council elections in England 1981/85, composite voting triangle 216


7.13 Unemployment numbers in Britain 1981 as surface height on ward cartogram 218

8.1 Unemployment rates in Britain, yearly 1978–1990 (grey scale), composite county cartogram 229

8.2 Employment by detailed occupation, sex and, if part-time, nationally in Britain 1981, pyramid glyph 231

8.3 Employment by detailed occupation, sex and, if part-time, change in Britain 1981–1984, pyramid glyph 232

8.4 Employment by detailed occupation, sex and, if part-time, change in Britain 1984–1987, pyramid glyph 233

8.5 Employment by occupation, sex and, if part-time, change in Britain 1987, constituency pyramid glyph cartogram 234

8.6 Employment by occupation, sex and, if part-time, change 1984–1987, pyramid glyph cartogram 235
8.7 Chernoff faces showing all permutations of five levels of cheeks, eyes, nose and mouth 241
8.8 House price, nonvoting and employments with voting colour 1983, constituency faces cartogram 244
8.9 House price, nonvoting, employment and service workers 1983, constituency faces cartogram 245
8.10 House price, nonvoting and employments with voting colour 1987, constituency faces cartogram 246
8.11 House price, nonvoting, employment and service workers 1987, constituency faces cartogram 247
8.12 House price, nonvoting and employments with voting colour, changes 1983–1987, faces cartogram 248
8.13 House price, nonvoting, employment and service workers, changes 1983–1987, faces cartogram 249
9.1 Population in Britain 1981, ‘snooker table’ county cartogram 253
9.3 Unemployment rates in Britain, yearly 1978–1990 (grey scale), three-dimensional county cartogram 256
9.4 Unemployment rates in Britain, yearly 1978–1990 (grey scale), superimposed county cartograms 257
9.5 House price inflation, highest year, in Britain 1983–1989 (grey scale), ward cartogram 258
9.6 Childhood leukaemia in Britain 1966–1983, smoothed surface ED cartogram 260
9.7 Childhood leukaemia cases in Northern England 1966–1986, six views of population time cube 263
9.8 Childhood cancers; key to different types shown by spheres in the next six figures 264
xx LIST OF FIGURES

9.12 Childhood cancers in Teeside 1968–1991 (three views from East and future), three-dimensional cartogram with time 268
9.13 Childhood cancers in Teeside 1968–1991 (three views from West and past), three-dimensional cartogram with time 269
9.14 Voting in District Elections in Scotland 1988, six views of a voting tetrahedron 272
9.15 Voting. A schematic representation of four-party voting using a voting tetrahedron 273
9.16 Voting in District Elections in Scotland 1988, unfolded voting tetrahedron 274
9.17 Voting in District Elections in Scotland 1988 (four views), multiple voting tetrahedra 276
9.18 Voting in District Elections in Scotland 1988, ray-traced multiple voting tetrahedra 277
10.1 The ward cartogram transformed using Thiessen polygons 284
10.2 Voting in the British general election 1987 (proportions), continuous area constituency cartogram 286
10.3 Voting in the British general election in Northern Britain 1987 (six views), from a map to a cartogram 288
10.4 Voting in the British general election in Southern Britain 1987 (six views), from a map to a cartogram 289
10.5 Voting in the British general election 1987, nonvoting (grey scale), election triangle 290
10.6 Voting in British general elections, 1955–1987, nonvoting (grey scale), eleven election triangles 291
10.7 Professional, intermediate or supervised jobs – Britain 1981 (four levels each), smoothed ED cartogram 294
List of text boxes

1.1 Creating the graphics 10
1.2 Printing in colour 14
1.3 Recording the places 25
2.1 Drawing the maps 34
2.2 Storing the geometry 40
2.3 The areal hierarchy 47
3.1 The Mercator projection 63
3.2 The algorithm at work 73
3.3 Deriving a constant 80
3.4 Many-dimensional cartograms 92
4.1 Storing the census 98
4.2 Working definitions 115
4.3 Two-dimensional smoothing 119
5.1 Linking the censuses 133
5.2 How closely connected? 135
5.3 Measuring the changes 137
6.1 Storing the flows 168
6.2 A significant flow 182
6.3 Drawing overlapping arrows 183
7.1 The electoral triangle 205
7.2 The perspective projection 210
7.3 Travel time surface 221
## LIST OF TEXT BOXES

8.1 Areal interpolation 226  
8.2 Trees and pyramids 236  
8.3 Constructing face glyphs 240  
9.1 Three-dimensional smoothing 261  
9.2 The electoral tetrahedron 270  
9.3 Three-dimensional structure 278