“Until now, eco-tourists visiting the Great Plains faced a void of geological information. . . . [Great Plains Geology] is clearly and succinctly written by a leading geologist in a way that nongeologists will understand and appreciate.”

—James Stubbendieck, director emeritus of the Center for Great Plains Studies at the University of Nebraska–Lincoln and author of North American Wildland Plants

“Professor Diffendal has done a marvelous job of assembling information and images about the rich geological history and terrain of the Great Plains. For those who have ever lived in or spent time in the region, as I have, or been as smitten with geology as I was. . . . I highly recommend it.”

—Robert Wuthnow, professor of sociology at Princeton University and author of Remaking the Heartland: Middle America since the 1950s

“An enjoyable guide to the best geological sites in the Great Plains of Canada and the United States. Professor Diffendal’s lively writing unites geology with personal and historical references to provide a great resource for those traveling and sightseeing.”

—David Watkins, professor of earth and atmospheric sciences at the University of Nebraska–Lincoln

“From the inquisitive tourist or landowner, to the ‘wannabe’ archaeologist or dinosaur hunter, to the professional scientist or historian who seeks information in a related field, this book is a must-read. . . . [It] will quickly dispel the idea that the Great Plains are a monotonous and continuously flat region.”

—Gerald Schultz, professor of geology at West Texas A&M University
Discover the Great Plains

Series editor: Richard Edwards, Center for Great Plains Studies

Buy the Book
To my parents, who supported my undergraduate training, to Jacob Freedman of Franklin and Marshall College, who inspired me to further my education, to J. A. Fagerstrom, who nurtured me through graduate work, and especially to my wife, Anne, who has always been ready to accompany me on our adventures and to improve my manuscripts about my research and travels.
CONTENTS

List of Illustrations xi
Preface xv
Acknowledgments xvii
Introduction xix
1. What Is the Great Plains? 1
2. Geologic History of the Great Plains 13
3. Visiting the Great Plains 33

SITES IN CANADA

Site 1. Head-Smashed-In Buffalo Jump, Alberta 41
Site 2. Dinosaur Provincial Park, Alberta 43
Site 3. Cypress Hills Interprovincial Park, Alberta and Saskatchewan 46
Site 4. T. rex Discovery Centre, Saskatchewan 50
Site 5. Grasslands National Park, Saskatchewan 52
SITES IN THE UNITED STATES

MONTANA

Site 6. Giant Springs State Park  57
Site 7. Upper Missouri Breaks National Monument  59
Site 8. Pompeys Pillar National Monument  61
Site 9. Little Bighorn Battlefield National Monument  63
Site 10. Judith Mountains  64

NORTH DAKOTA

Site 11. Theodore Roosevelt National Park  67
Site 12. Fort Union Trading Post National Historic Site  69

SOUTH DAKOTA

Site 13. Slim Buttes  72
Site 14. Badlands National Park  74
Site 15. Mount Rushmore National Memorial  76
Site 16. Wind Cave National Park  78
Site 17. Jewel Cave National Monument  81
Site 18. Hot Springs Mammoth Site  83
Site 19. Petrified Forest, Black Hills  85
Site 20. Big Bend of the Missouri River  87

WYOMING

Site 21. Devils Tower National Monument  90
Site 22. Pine Bluffs Archaeological Site  92

Buy the Book
NEBRASKA
Site 23. Toadstool Geological Park 95
Site 24. Hudson-Meng Bison Kill Research Center 97
Site 25. Pine Ridge 98
Site 26. Agate Fossil Beds National Monument 100
Site 27. Scotts Bluff National Monument 103
Site 28. Chimney Rock National Historic Site 106
Site 29. Courthouse and Jail Rocks 108
Site 30. Ash Hollow State Historical Park 110
Site 31. Sand Hills Region 113
Site 32. Snake River Falls 115
Site 33. Fort Falls and Fort Niobrara National Wildlife Refuge 116
Site 34. Ashfall Fossil Beds State Historical Park 119
Site 35. Niobrara State Park 122
Site 36. Harlan County Lake 125

KANSAS
Site 37. Monument Rocks 128
Site 38. Castle Rock 130

COLORADO
Site 39. Castle Rock 132
Site 40. Section Boundary, Raton/Colorado Piedmont 135
Site 41. Comanche National Grassland 137
Site 42. El Huerfano 140
Site 43. Spanish Peaks 142

Buy the Book
### New Mexico

<table>
<thead>
<tr>
<th>Site</th>
<th>Location</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>44.</td>
<td>Raton Pass</td>
<td>145</td>
</tr>
<tr>
<td>45.</td>
<td>Sugarite Canyon State Park</td>
<td>146</td>
</tr>
<tr>
<td>46.</td>
<td>Capulin Volcano National Monument</td>
<td>148</td>
</tr>
<tr>
<td>47.</td>
<td>Clayton Lake State Park</td>
<td>150</td>
</tr>
<tr>
<td>48.</td>
<td>Section Boundary, Raton/Pecos Valley</td>
<td>152</td>
</tr>
<tr>
<td>49.</td>
<td>Carlsbad Caverns National Park</td>
<td>153</td>
</tr>
<tr>
<td>50.</td>
<td>Blackwater Draw Clovis Culture Site</td>
<td>156</td>
</tr>
</tbody>
</table>

### Texas

<table>
<thead>
<tr>
<th>Site</th>
<th>Location</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>51.</td>
<td>Guadalupe Mountains National Park</td>
<td>159</td>
</tr>
<tr>
<td>52.</td>
<td>Llano Estacado Escarpment</td>
<td>161</td>
</tr>
<tr>
<td>53.</td>
<td>Enchanted Rocks State Park</td>
<td>163</td>
</tr>
<tr>
<td>54.</td>
<td>Gault Archaeological Site</td>
<td>165</td>
</tr>
<tr>
<td>55.</td>
<td>Balcones Fault Zone</td>
<td>168</td>
</tr>
<tr>
<td>56.</td>
<td>Confluence of Pecos River and Rio Grande</td>
<td>170</td>
</tr>
<tr>
<td>57.</td>
<td>Seminole Canyon State Park</td>
<td>172</td>
</tr>
</tbody>
</table>

Afterword 175

Appendix 1. Geologic Subdivisions of the Great Plains 177

Appendix 2. Chronology of the Development of Some Geological Concepts 183

Appendix 3. Cautions for Travelers on the Great Plains 185

Glossary 187

Bibliography 195

Index 201
ILLUSTRATIONS

1. Geologic time scale and rock column  xviii
2. Fifty versions of the Great Plains boundary  xxi
3. J. W. Powell’s boundaries for the Great Plains and three other choices for the eastern boundary  xxii
4. Author’s boundaries for the Great Plains and its sections  4
5. Image of North America including the Great Plains area  5
6. Principal world tectonic plates  7
7. Rocky Mountain Front Range and Great Plains, Cañon City, Colorado  8
8. Bird’s-eye view of the Black Hills  8
9. Volcanic cones and lava flows near Mount Capulin, northeastern New Mexico  10
10. Synthetic-aperture radar imagery x-band of Alliance Quadrangle, Nebraska and South Dakota, showing the Sand Hills  11
11. Prairie pothole lakes on the Wisconsinan glacial plain near Wing, North Dakota  12
12. Model illustrating main geological principles  14
13. North American craton development  21
14. Paleogeographic map of Western Interior Seaway during Niobrara and Pierre times  24
15. Generalized map of Pleistocene glaciations 28
16. Probable drainage patterns of the Missouri River and some of its tributaries before onset of the oldest Pleistocene continental glaciation 30
17. Locations of geological sites described in this book: (A) northern half, (B) southern half 34
18. Escarpment, slope, and glaciated plains, Head-Smashed-In Buffalo Jump 41
19. Badlands, Dinosaur Provincial Park 43
20. Conglomerate cliffs and glaciated plains, Cypress Hills Interprovincial Park 46
21. Skull of *Tyrannosaurus rex* 50
22. Marine and coastal plain deposits, Grasslands National Park 52
23. Giant Springs, Great Falls, Montana 57
24. Dikes and sills in sandstone, Upper Missouri Breaks 59
25. Pompeys Pillar, an erosional sandstone remnant 61
26. Little Bighorn Battlefield 63
27. Judith Mountains, small uplifts deforming older strata 64
28. Coastal plain deposits, Theodore Roosevelt National Park 67
29. Missouri River terrace, Fort Union 69
30. Faulted continental deposits, Slim Buttes 72
31. Continental and marine deposits, Badlands National Park 74
32. Granite intruded into schist, Mount Rushmore 76
33. Boxwork deposits, Wind Cave National Park 78
34. Calcite spar crystals, Jewel Cave National Monument 81
35. Mammoth skeletons in place, Hot Springs Mammoth Site 83
36. Petrified tree stump, Black Hills 85

xii ILLUSTRATIONS
37. Incised meander on Missouri River 87
38. Igneous intrusion, Devils Tower National Monument 90
39. Excavated materials exposed in place, Pine Bluffs Archaeological Site 92
40. Badlands, Toadstool Geological Park 95
41. Bison fossils in alluvium, Hudson-Meng Bison Kill Research Center 97
42. Pine Ridge Escarpment near Chadron, Nebraska 98
43. Rhinoceros bones in place, Agate Fossil Beds National Monument 100
44. Erosional remnant, Scotts Bluff National Monument 103
45. Erosional remnants, Chimney Rock National Historic Site 106
46. Erosional remnants, Courthouse and Jail Rocks 108
47. Aerial view of escarpment, slopes, and wagon ruts, Ash Hollow State Historical Park 110
48. Vegetated dunes and lake in Nebraska Sand Hills 113
49. Snake River Falls 115
50. Cascade, Fort Falls 116
51. Horse and rhinoceros skeletons in place, Ashfall Fossil Beds State Historical Park 119
52. Niobrara River valley, Niobrara State Park 122
53. Fault, Harlan County Lake 125
54. Erosional remnant, Monument Rocks 128
55. Erosional remnant, Castle Rock, Kansas 130
56. Erosional remnant showing “inverted topography,” Castle Rock, Colorado 132
57. Boundary between Colorado Piedmont and Raton Sections of the Great Plains 135
58. Overview of plains with Cretaceous Seaway deposits in foreground, Comanche National Grasslands 137
59. Igneous intrusion, El Huerfano 140
60. Dike near Spanish Peaks 142
61. Basalt flows capping Upper Cretaceous Seaway deposits, Sugarite Canyon State Park 146
62. Mount Capulin, Capulin Volcano National Monument 149
63. Dinosaur footprint, Clayton Lake State Park 150
64. Boundary between Raton and Pecos Valley Sections of the Great Plains 152
65. Limestone reef, Carlsbad Caverns National Park 153
66. Bones and artifacts exposed in place in lake deposits, Blackwater Draw Clovis Culture Site 156
67. El Capitan reef escarpment, Guadalupe Mountains National Park 159
68. Aerial view of Llano Estacado escarpment, surface of High Plains in background 161
69. White Caprock caliche at Llano Estacado escarpment 162
70. Exfoliated granite uplift, Enchanted Rocks State Park 163
71. Excavation pit showing stratified stream deposits, Gault Archaeological Site 165
72. Lake Austin and Balcones Fault Zone; border between Great Plains and Coastal Plain Provinces 168
73. Pecos River at its confluence with the Rio Grande; Great Plains in Mexico in background 170
74. Rock cliff undercut by erosion, Seminole Canyon State Park 172
75. Colored pictographs at Fate Bell Shelter, Seminole Canyon State Park 173
76. Grasslands on the glaciated part of the Missouri Plateau 175
This book offers my personal view of the geology of the Great Plains. It is intended for ecotourists, anyone with a broad interest in geology and some general education in science, professional geologists and geographers wanting to become more familiar with the region, and students, farmers, ranchers, and K-12 educators who want to know about the Great Plains and its geological development. Any errors of interpretation or fact in this book are solely my own.

The book is arranged in three chapters. The first two discuss the region’s boundaries and provide a brief geologic history to explain how the Great Plains came to be in its present form. The third chapter describes 57 outstanding geologic sites from Alberta and Saskatchewan, Canada, to southern Texas. Features at these sites illustrate various aspects of the geology of the Great Plains. Most of the photographs of these sites are my own.

Figure 1, the geologic time scale and rock column, follows the acknowledgments, not because you need to refer to it now, but for you to note it for later. You will find it helpful throughout this book. Use this figure to see the chronological relationships among the geological time spans and the rock units deposited in those time spans. The names of these time spans and rock units appear frequently in the book. Use this figure also to identify the occurrence of important events that
affected the Earth’s development, such as mass extinctions, glaciations and meteor impacts.

I have included three appendices for background: the first on the boundaries and subdivisions of the Great Plains; the second an overview of the development of key geologic concepts; and the third a list of cautions regarding travel in the Great Plains. These are followed by a glossary of the geologic terms used in the text, a list of references, and an index.

For easier reading, I have eliminated the accepted scientific style of citing references in the text in favor of a simplified style of citing the name of the principal author of a work on some of the topics I am discussing. Please refer to that name in the references section at the end of the book to find the appropriate source.
ACKNOWLEDGMENTS

I am indebted to Richard C. (Rick) Edwards, director of the Center for Great Plains Studies at the University of Nebraska, for providing me with office space, hardware, and supplies during my research and writing. Financial support for travel and associated activities came from the University of Nebraska–Lincoln Emeriti Association and the Conservation and Survey Division of the School of Natural Resources, University of Nebraska–Lincoln. Ms. Dee Ebbeka drafted several of the figures.

To my colleagues and friends who tramped with me and talked with me about the geology of the Great Plains over the years—Mike Voorhies, Bob Hunt, Jim Swinehart, George Corner, Larry Agenbroad, Cinda Temperly, Gerry Schultz, Tex Reeves, Tom Gustavson, Dale Winkler, Jason (Jay) Lillegraven, and others—I express my gratitude for all of their help.

Thanks to Professor Wakefield Dort (University of Kansas), Shane Tucker (University of Nebraska State Museum), Kim Weide, Sheryl Cooley, Heather Lundine, Michael Forsberg, and Rick Edwards for their helpful comments that led to a very much improved manuscript. I especially thank my wife, Anne; Bridget Barry, Emily Wendell, Joeth Zucco, and other staff at the University of Nebraska Press; and the copyeditor, Joy Margheim, for offering very helpful suggestions on additions and reorganizations of several drafts of the manuscript that made it much more readable than in its original form.
Fig. 1. Geologic time scale and rock column. U.S. Geological Survey.
Like art and beauty, what constitutes the Great Plains lies in the eye of the beholder. For people who have never traveled in the American heartland, the name may conjure up images of cowboys, Indians, buffalo, prairie dogs, grasshopper swarms, cattle drives, heat, wind, dust, blizzards, tornadoes, floods, and very flat land. For those who live in the central parts of the lower 48 states, it can be some or all of these things. After hearing a college student of mine from the inner city of Chicago define a prairie as a vacant city lot, I came to better understand that our views are shaped by our experiences and differ from one another’s perceptions, often in major ways. “I know what the Great Plains region is, and this place is clearly not part of it!” one person would say and another would differ completely.

Captain William Clark thought that he saw where the plains began on the west bank as he traveled up the Missouri River near the present-day border of Kansas and Nebraska on July 10, 1804. Others have seen the beginning of the Great Plains in places to the east or to the west of that place (fig. 2).

John Wesley Powell, ethnographer, writer, explorer of the American West and second director of the U.S. Geological Survey, was, so far as I know, the first person to describe and to draw a map showing the boundaries of the major physiographic regions of the lower 48 states, including the Great Plains (fig. 3). Powell also recognized that the Great Plains
extended northward into Canada and southward into the Republic of Mexico. Later published works have varied on the size and boundaries of the Great Plains, but Powell was probably the first scholar to give the region that written name and a description. And that name has stuck both in literature and in the popular imagination.

For me, the Great Plains is a land of wide-open spaces with few trees except along watercourses or on local uplifts like the Black Hills. It is a land of big, wild, and scenic rivers, sadly now controlled to a greater or lesser extent by dams and water diversions. It is a land usually short of water, yet it includes one of the major aquifers (variously called the High Plains, Ogallala, or High Plains/Ogallala; hereafter the High Plains aquifer) in the United States. The Great Plains can look markedly different at any one place, depending on the time of day and the quality of the light; there is a mirage-like quality to the country. Plain or otherwise, it is a beautiful place, often of few people and much livestock. I love the region.
Fig. 3. J. W. Powell's boundaries for the Great Plains in the United States and some of the other possible choices proposed for the eastern boundary. The green line is the approximate 2,000-ft. contour; the blue dashed line is the approximate 20-in. precipitation line; the red line is the approximate area of alkaline and transitional soils. Solid black lines are Powell's eastern and western boundaries of the Great Plains. From Powell, “Physiographic Regions,” 98–99.