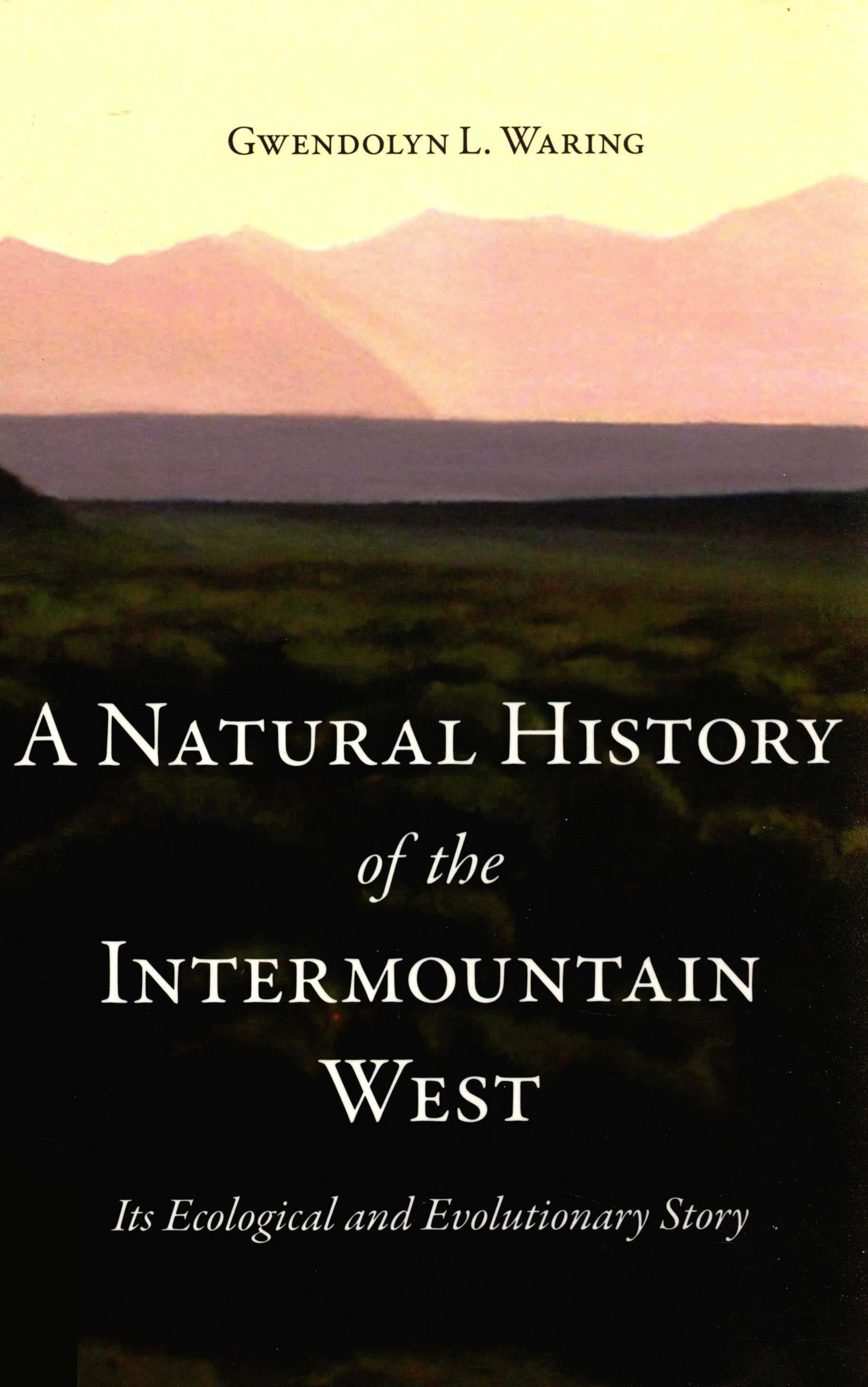

GWENDOLYN L. WARING

A NATURAL HISTORY of the INTERMOUNTAIN WEST

Its Ecological and Evolutionary Story

A Natural History of the Intermountain West

Its Ecological and Evolutionary Story

Gwendolyn L. Waring

The University of Utah Press
Salt Lake City

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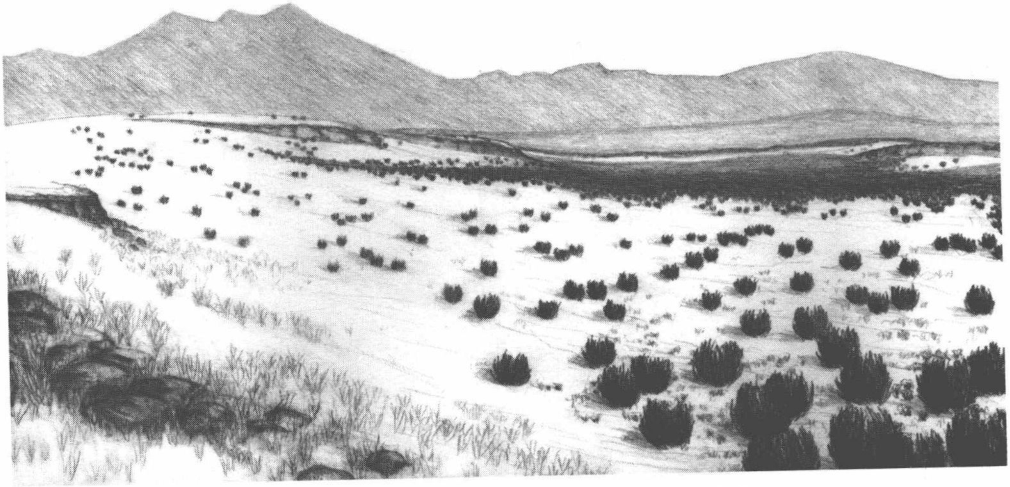
For Phoebe

A Natural History of the Intermountain West



Grasslands to mountains, northern Arizona, pencil on paper, 2004, Gwendolyn Waring.

Color Plates *(following page 72)*

Preface

This world is all about change. The plants and animals described in these chapters have been evolving and migrating endlessly through time, a fact I find somewhat comforting as we head into a pretty uncertain future. Studies indicate that some species are already migrating to higher ground, though others, such as the golden frog of Costa Rica, could not ascend high enough and have already gone extinct. As one who knows the texture of the meadows where I live—meadows that I have looked on with love for thirty years—I don't want them to change, but changing they are, and right before our eyes.

This book is a testament to natural selection and evolution, miraculous forces of the natural world that constitute a large part of my religion. It is also a testament to the tenacity of life on this planet. There are countless examples of explosions of species and subspecies, varieties and types, in every chapter of this book. Life forms are constantly arising, and each one is a wonderful experiment.

One of the most exciting aspects of writing this book has been learning about the Pleistocene, the last period of major cold and glaciation that ended only 12,000 years ago. Its effects on the land are still conspicuous because it was the most recent major climatic event. In the West we have a special record of the enormous and rapid changes that occurred in western ecosystems during the Pleistocene's last major glacial period, the Wisconsin Glacial Episode. This record is available for two reasons: because the West is so dry, and because of packrats (*Neotoma* spp.), which like so many of the species described in this book occur only in western North America and Central America. Packrats construct large nests, called middens, out of pieces of surrounding plants. The nests are thus durable records of local plant communities dating back more than 50,000 years. Thousands of packrat middens have been studied, and along with fossil pollen from lake cores, they have revealed a great deal about this region's prehistory.

They show that the ranges of plant and animal communities have been surprisingly dynamic, with enormous forests of ponderosa pines, for instance, disappearing and then quickly reforming.

This book describes the geological formation of the West and how plants and animals have come to live in this young, rocky region, which encompasses the Great Basin, the Colorado Plateau, and the Southern Rockies. The first chapter, on geology, focuses on the complexity of landforms in the West, how they came to be, and how that complexity influences the resulting life forms. Chapter 2 focuses on the water in the West's two great drainage systems, the Great Basin and the Colorado River basin, both of which have a greater proportion of endemic fishes than any other basin in North America. Chapter 3 discusses the West's young mountain chains, which concentrate water and in some cases support alpine tundra and enormous coniferous forests. Plants and animals have traveled back and forth along these north-south-oriented mountains for millions of years as climates have changed. This is true for the nearly twenty-five alpine species found on the San Francisco Peaks of Arizona that also occur in the Arctic. Chapters 4 through 6 examine the West's forests, woodlands, and grasslands. Enormous ponderosa pine forests occur throughout the West, yet this species may have migrated or shifted its range back into its current distribution from low-elevation Pleistocene refugia only within the last 10,000 years. The pinyon-juniper woodlands also have a dynamic and somewhat enigmatic history. Grasslands arose throughout the world during the dry Miocene epoch (23 to 5 Ma), quickly leading to the evolution in North America of an astounding diversity of grazing mammals, including the horse. Although these ancient grasslands have always been assaulted by herbivores, the intense cattle-grazing practices of the last 150 years have transformed them.

The "cold desert" is discussed in chapter 7. This dry corridor extends from northern Arizona to British Columbia, inland from the coastal mountains that cast long rain shadows, and is so named because its winter temperatures drop below freezing. It is a land of shrubs whose populations, which extend as far as the eye can see, are well adapted to life in this beautifully spare land. Finally, a few flowers that are relatively common in the West are described in chapter 8. Their stories are improbable, and many require complex interactions with pollinators and herbivores to survive.

The scientific research on western ecosystems is exciting. The stories of plants and animals and processes are stranger than fiction. I feel very privileged to present so many of these stories in this book, and I am indebted to the scientists who talked with me about their cutting-edge research on everything from penstemon evolution to the restoration of natural conditions in western forests. There is great thinking going on here in the West, and my hat goes off to these scientists for showing us how magical this world really is.

Acknowledgments

I would especially like to thank Larry Stevens, Gerald Smith, and John Spence for their major contributions to the chapters on geology, water, and the cold desert. Special thanks also to my sister, Linda Poché, for helping to bring this book into its final form. Thanks to Winnie Taney for editing with the sharp eyes of a naturalist and a grammarian. Many, many thanks for the editorial contributions of Brad Baxter, Julio Betancourt, Ronald Blakey, William Bowman, Neil Cobb, Frank DeCourten, Jeffrey Eaton, Marylou Fairweather, Thomas Fleischner, Peter Fule, Scott Hodges, Will Moir, Nancy Morin, Ronald Lanner, Russell Monson, Michael Ort, Ken Paige, Gordon Pratt, Peter Price, Sara Rathburn, Nancy Riggs, John Paul Roccaforte, Katrina Rogers, Thomas Sisk, Michael Wagner, Justen Whittall, Andrea Wolfe, and James A. Young.

I want to thank E. Durant McArthur and James Young for expressing great faith in and hope for the future of these western ecosystems.

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Great thanks to my family, Linda, Rob, Star, Dana, and Annie, and friends. Special thanks to my mother, Gwendolyn S. Waring, for loving life so much.

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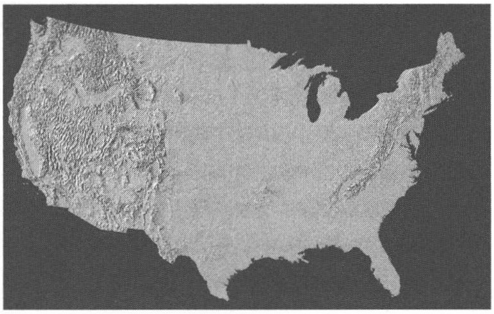
CHAPTER 1

How the Rocky West Formed and How It Shapes Western Ecosystems

GWENDOLYN WARING AND WAYNE RANNEY

Western North America acquired its mountainous shape and colorful rocks over the course of hundreds of millions, even billions, of years through a series of remarkable processes. The geologic formation of the West involved two separate and distinct episodes: a long period of deposition when its rocks were formed, and a shorter, more recent period during which they were uplifted and shaped by erosion (Fig. 1.1). These formative geological processes also shaped western life forms. This chapter describes how the various rocks were formed, how the land was shaped by tectonics and erosion, what environments once existed here, and how geology has so profoundly influenced the evolution and distribution of the plants and animals that have inhabited this land. Today the greatest levels of biological diversity in North America are found in the West.

The story begins with the formation of the West's foundation or "basement." In the Grand Tetons of Wyoming, the basement rocks are about 3 billion years old and date back to when the southern edge of the continent was located near present-day northern Colorado. About 1.75 billion years ago, two or more tectonic plates carrying chains of volcanic islands collided with North America as they drifted in from the south. These islands progressively became "sutured" onto the continent's edge, pushing some rocks deep into the crust (Ilg et al. 1996). These



1.1. Topography of the contiguous United States, 1:3,500,000, 1990. Note the pronounced geographic deformation of the West. Courtesy of the U.S. Geological Survey.

TABLE 1.1. GEOLOGICAL TIME LINE FOR THE WESTERN UNITED STATES

Period	Epoch	Beginning of Interval	Events
Quaternary	Holocene	10,000 years ago	Δ Ponderosa pine and other plants migrate back to higher elevations and latitudes. Δ Warming, drying trend. Δ Euro-Americans settle in the West.
	Pleistocene	1.6 Ma	Δ Major glaciation worldwide, causing plant and animal migrations and flooding. Δ Humans evolve.
Tertiary	Pliocene	5 Ma	~ 3 Ma, the south-north American land bridge allows intercontinental floral and faunal interchange.
	Miocene	22 Ma	Δ Grasslands spread throughout the world during a warm, dry climate, followed by an explosion of grazing mammals, including horses. Δ Sierra Nevada, Cascades, and Great Basin form, contributing to drying of the Intermountain West. Δ Colorado Plateau uplifts. Δ Upper and lower Colorado River basins connected.
	Oligocene	34 Ma	Δ ~30 Ma, change from shortening to extension of western North American plate, causing further extension of the Great Basin.
	Eocene	55.8 Ma	Δ Warming climate; subtropical flora makes it to Alaska. Δ Earliest ponderosa pine, British Columbia.
	Paleocene	66 Ma	Δ Age of mammals.
Cretaceous-Tertiary Boundary		65.5 Ma	Δ Extinction of dinosaurs. Δ Laramide Orogeny produces the Rocky Mountains... again.

became the Southwest's basement rocks and so extended the size of the continent. These crystalline rocks underlie most of Utah, Colorado, New Mexico, and Arizona, but they are exposed only in the bottoms of the deepest canyons, such as Arizona's Grand Canyon (Plate 1), Westwater Canyon in Utah, and the Black Canyon of the Gunnison in Colorado. These oldest rocks include metamorphic schist and gneiss, and igneous granite. Where exposed, their hardness makes river canyons narrow and steep, and few plants can colonize their sheer walls and rocky slopes.

These tectonic collisions also warped the western landscape into an ancient mountain range that existed for several hundred million years. But by 750 million years ago (Ma), a great rifting or splitting event affected the entire West. By about 525 Ma, rifting and erosion had lowered the American Southwest to near sea level, and sediment of mostly marine origin accumulated in the area for the next 210 million

TABLE 1.1. CONTINUED

Cretaceous	144 Ma	Δ Sevier (Nevada) Orogeny. Δ Evolution of flowering plants and pollinators; age of dinosaurs.
Jurassic	213 Ma	Δ Age of reptiles. Δ Morrison Formation forms from floodplain sediments.
Triassic	251 Ma	Δ Continental deposits form, including Chinle Formation from rivers, and Navajo Sandstone from dunes. Δ Earliest dinosaurs. Δ Formation of deserts. Δ Breakup of Pangea into Gondwanaland and Laurasia, and then into modern continents. Δ Evolution of pines before breakup of Laurasia.
Permian	299 Ma	Δ Formation of red beds. Δ Frequent western orogeny.
Mississippian	360 Ma	Δ ~350–250 Ma, the Ancestral Rocky Mountains form.
Devonian	416 Ma	Δ Antler Orogeny; subduction along Pacific coast.
Silurian	440 Ma	Δ First land plants and insects.
Cambrian	544 Ma	Δ ~525 Ma, lowering of western North America leads to several hundred million years of deposition of marine and coastal sediments.
Precambrian	4600 Ma	Δ ~1175 Ma, portion of western North America attaches south of present-day Wyoming. Δ ~ 3950 Ma, oldest sedimentary rocks form; first single-celled organisms.

Source: Geological Society of America website, http://www.geosociety.org/science/timescale

years (Plate 2). The seas left resistant layers of coastal sandstone and offshore limestone and dolomite that can be found across much of the West today. The Redwall Limestone is 500 feet thick in the Grand Canyon (Middleton and Elliott 2003) and is present in the Northern Rockies as well (where it is known as the Madison Limestone). The Tapeats Sandstone in the Southwest (called the Flathead Sandstone up north) formed along a beach in a nearshore environment (Table 1.1). All totaled, between 2,500 and 5,000 feet of marine and coastal deposits (and even more in the Great Basin) were laid down over this immense amount of time. Limestone is especially durable in the modern arid environment and forms the backbone of many mountain ranges in the Great Basin. As with the basement rocks, canyons cut into limestone are generally narrow and steep, which limits the development of riparian plant communities.

By about 315 Ma, the long period of marine sedimentation ended as the crust of