

Gregory J. Retallack

Soil Grown Tall

The Epic Saga of Life
from Earth



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Cover photo: Diane Retallack on the Lint silt loam soil, a dark volcanic soil (Andisol), on the costal terrace near Yachats, Oregon.

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Dedicated to Nicholas and the quest for understanding

Preface

Soil is often overlooked and underestimated. Yet all we are, and much of what we have, came from the soil and will return there when we are done. By recycling our dead and by purifying our water, soil saves us from disease. Soil is an important carbon sink and neutralizer of weathering acids, mitigating extreme greenhouse warmings of the geological past. Past cycles of life and climate have also been cycles of soil. How such a humble substance does so much is astounding and a topic to which these pages return again and again. But additional mysteries are explored in this personal quest to understand the long geological history of soil. How did it develop over the ages, this nurturer of life, this filter of air, this political resource? Did life evolve from soil or soil evolve from life? Were forests made by forest soils or forest soils made by forests? Are nations built from or merely on their soils? Did global change alter soils or did soils cause global change? These are difficult questions, but fortunately soils have a fossil record. Fossil soils or paleosols are now recognized to be abundant among sedimentary rocks. They are especially common in colorful red beds and in grimy coal measures. This book is dedicated to the ongoing task of deciphering this long fossil record of ancient landscapes and the ecosystems they supported.

Eugene, USA

Gregory J. Retallack

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This book is a distillation of two decades of a rich and fulfilling career as a geology professor. It owes much to students and faculty of the University of Oregon and to research grants from the US National Science Foundation. They provided the means, encouragement, and stimulus to explore fundamental questions of soil evolution. Much of this book was written in tented camps in Antarctica and Kenya, providing evening diversion after days of fieldwork. I am particularly thankful to students and colleagues for advice and editorial help: Jonathan Wynn, Erick Bestland, Evelyn Krull, Helen Vallianatos, Scott Robinson, Shaun Norman, Lynn Soreghan, Christine Metzger, Carolyn Phillips, Jim Farlow, and Egbert Leigh. Last but not least, I thank my family, Diane, Nicholas, and Jeremy, for teaching me the importance of our garden.

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1

Rainbow Rocks

Paleosols, or buried soils, are widespread in multicolored badlands, and provide evidence for climate and other surface conditions between episodes of sedimentation.

We are trained to see life as clean and soil as dirty, but life and soil are not so different. Soils are born and die during catastrophic events such as floods and landslides. Many lives are lost or established by such catastrophes. Between these end points, soils develop and grow by addition of clay and organic matter from maturing populations of plants. Soils have multiple metabolic pathways, not only of their contained multitudes of microbes, but their own distinctive chemical reactions, such as weathering of feldspar to clay. Soils reproduce when wind or water scatters their clay and dust across the landscape. Thus soils can be viewed not only as nurturers of life, but as a starter system for life itself, a form of protolife. Back to the beginning the line between soil and life may have been fine enough to have been imperceptible, as the tiniest nooks and crannies of soil continued their chemical reactions, not in open intergranular spaces, but within the first isolating membranes of the earliest cells. Could it be that, after all, we are but soil grown tall?

Soils are at the nexus of life and air, and fossil soils have changed substantially over geological time as life and air evolved. Thus this book runs backward into deep time to develop an appreciation of the coevolution of life and soil over the ages that followed its origin in and as soil (Fig. 1.1). Nevertheless, the concept of a fossilized soil needs some explaining, as was made clear by Vladimir Nabokov. The opening page of his novel *Lolita* mentions paleopedology, the study of fossil soils, as the epitome of an obscure scientific interest of Humbert Humbert. So allow me to explain fossil soils, and why I

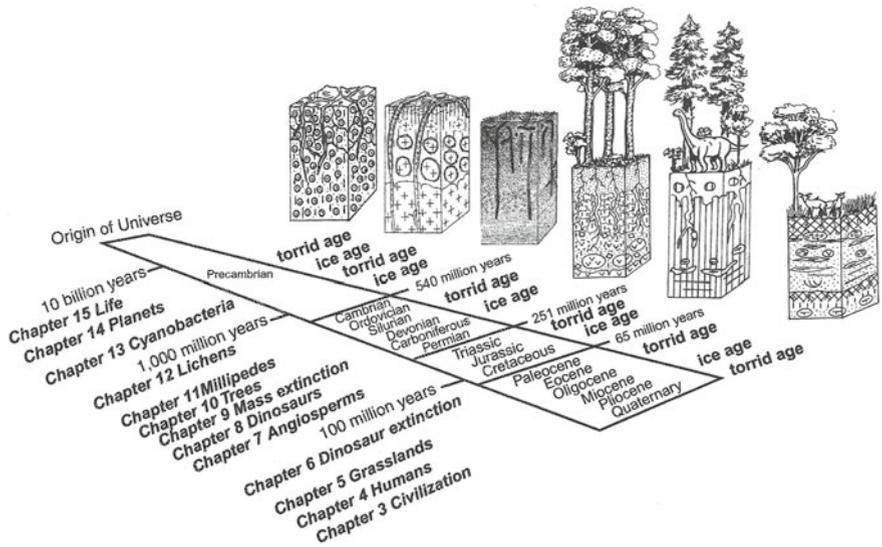


Fig. 1.1 A long view of soils and their biota backward into geological time, showing major events in atmospheric history and an outline of the chapters of this book

devoted an academic career to the study of something regarded as obscure by Nabokov.

You have seen many fossil soils, even if you did not recognize them, in the rainbow-colored landscapes of western movies. The enduring appeal of westerns derives in part from the freedom of time and space that is everywhere apparent in the wide, open landscapes of the North American West. The Bighorn Basin of northwestern Wyoming, for example, is a dusty rangeland of sagebrush rimmed with furrowed badlands of crumbling clay. The badlands are “bad” because they defy the efforts of ranchers to use them for pasture or grain, or of pioneers to cross them in wagons. The untamed badlands are a law unto themselves, a metaphor for the Old West itself. The badlands clays are a riot of red, green, orange, brown, and yellow bands and splotches. The beauty and fascination of Wyoming badlands was well expressed by Christina, the four-year-old daughter of geologist Mary Kraus, who has returned to Wyoming year after year to study these colorful rock exposures. “Those are mommy’s rainbow rocks!” Christina once exclaimed. Her remark echoes Navajo Native Americans, who call comparably colorful rocks of Capitol Reef, Utah, “land of the sleeping rainbow.” Navajo elders sensed what modern science has confirmed. The badlands are a record of events and environments of the deep past. There is a common thread to these colorful rocks and others like them in Bryce Canyon National Park, the Badlands of South Dakota,



Color Photo 1.1 Early Cretaceous (112 million years), Alag (grey-purple Inceptisol), Boro (red Inceptisol), and Mulani (Entisol) paleosols in the Zhonggou Formation at Zanyue Danxia Geopark, Gansu, China

Arizona's Grand Canyon, the Flaming Cliffs of Mongolia, Olduvai Gorge of Tanzania, the Ischigualasto badlands in Argentina, or the Flinders Ranges of South Australia (Color Photos 1.1, 1.2). They include buried landscapes of the past, represented by numerous fossil soils, or paleosols.

A paleosol is clay, silt, sand, gravel, or rock that was formed as a soil at the Earth's surface, and then was preserved, usually by burial, as a record of a former landscape and its life. Between times of flooding and volcanic eruption, grasses, trees, worms, and rabbits rooted and burrowed the freshly created ground and worked it into productive soil. The product of this concentrated biological work over long periods of time can include red, blocky clays, or white, hard nodules, or black seams of coal. Each of these materials form very distinct horizons in otherwise ordinary shales, sandstones and conglomerates. Life and soil have had a long and intimate relationship. When fossils are not preserved, paleosols may be the only records of past life.

The concept of paleosols can give surprising answers to what otherwise would be complete mysteries, and my own appreciation of paleosols grew slowly from childhood to adolescence. When I was a child, I lived in the dirt, not in front of a computer screen, and my mother often urged me to "Go play outside!" From the age of five I was fascinated with enigmatic, dark, red, rocklike lumps in brown soils near Sydney, Australia. What on earth



Color Photo 1.2 Oligocene (32 million years) Luca paleosols (red Alfisols) in the Big Basin member of the John Day Formation in the Painted Hills, central Oregon

were they? These dark red nodules and concretions are difficult to characterize succinctly because of their great variety. Their size ranges from that of peas to tennis balls. In shape, they vary from spheres to misshapen lumps, like small figurines that allow ample scope for childish imagination. Some are hard, heavy and polished. Others are hollow and partially filled with dusty, yellow ocher, a distinctive form called a paint-pot concretion (Fig. 1.2). Selected nodules were prizes of my childhood rock collection arranged on cotton wool in cigar boxes, or within the small compartments of boxes designed for fishing tackle.

The nodules and concretions are widespread around Sydney, as I found in moving between suburbs and schools, and that is one clue to their origin. It does not seem to matter whether the soil containing them is gray and sticky, brown and crumbly, or orange and hard. The hard, red lumps are in, on, and under these very different soils. As the soils vary, so do their vegetation, but soils under woodland, heath and meadow all contain similar nodules. Thus it seems unlikely that the nodules were formed by any particular kind of soil or vegetation. Nor does local bedrock seem to matter. They were not in any particular rock layer, nor along faults or joints. Each excavation for building foundations or roads in sandstone, shale, claystone or dolerite brings up a new crop of dark reddish lumps. Unlike their surrounding shales that weather to