Dinosaur Ridge and Red Rocks Field Trip

Co-Leaders:
Alan Lester, Department of Geological Sciences, CU Boulder
Val Sloan, UCAR

*The way to knowledge of natural history is to go to the fields, the mountains, the oceans, and observe, collect, identify, experiment and study.*

Reverend John Walker*, 1731-1803

*A contemporary and colleague of James Hutton (our so-called “father of geology”). Walker taught one of the first systematic courses in geology at the University of Edinburgh, 1781 to 1803. Today, even with an array of technological tools (mass spectrometers, electron microprobes, etc.) his words ring true.

Greetings!

Our intention is to showcase some interesting geology at the juncture of the Rocky Mountains and the Central Plains, to see one of the West's first and foremost dinosaur localities, and to have fun putting around and talking!

As a broad context for the field trip, we'd like to present and discuss geologic features through the lens of a key educational objective at both undergraduate- and graduate-levels—namely, the ability to distinguish between data (factual and reproducible observations) and hypotheses that serve to explain the world around us (ideas, interpretations and models).

DRIVING SOUTH TO DINOSAUR RIDGE

Notes:
1) We’re at the eastern margin of the Rocky Mountains. To the west are the foothills of the Front Range and to the east are the Central Plains—a striking contrast in topography, and one that is largely a consequence of susceptibility to erosion. The mountains are dominated by erosion resistant crystalline rocks (igneous/metamorphic) and the plains consist of much “softer” sedimentary rocks.
2) Ridge-lines, termed “hogbacks” are the result of a tilted succession of sedimentary layers, with the more resistant layers forming ridges.

3) On the drive, we’ll be on top of (and near) several extensive and markedly flat terrace-features that are linked to gravel and cobble-strewn capping sediments that sit atop, and protect, the underlying soft shales (see diagram below, e.g. “Gravel Cap on Mesa”).

STOP 1 AT DINOSAUR RIDGE

This is where we will begin our trek across the Dakota Hogback. It’s named Dinosaur Ridge due to a combination of exceptional trace fossils (i.e. track imprints, in the Cretaceous Dakota Group) on the east side and bone quarries on the west side (in the Jurassic Morrison Formation).

The parking area is located atop the Pierre Shale, a very thick unit of fine-grained marine sediments, deposited in the Late Cretaceous (approx. 70-80Ma).
The Pierre Shale was deposited during a global warm-period and an oceanic “high-stand” when the mid-continent was inundated by waters that flowed north from the Gulf of California to meet those that flowed south from the Arctic, approximately 110-70Ma.

Below is a stratigraphic column showing some of the key geologic units in this area. Note the thickness of the Pierre Shale.
From Ancient Denver,
Denver Museum of Natural History
And below is an artist’s conception of the Cretaceous-Seaway, and those who might have seen it from above!

From Ancient Denvers, Denver Museum of Natural History
http://www.dmns.org/main/minisites/ancientDenvers/landscapes.html

As we walk along the east side of the ridge, Green Mountain is clearly visible further to the east. Along the flank of Green Mountain are exposures of the Denver, Arapahoe, and Green Mountain Formations. These are flat-lying units, and their lack of tilting suggests that they were deposited shortly after the major uplift event called the Laramide Orogeny (appr. 75-45 Ma). These units contain substantial volcanic ash and stream-transported volcanic rocks. The Laramide Orogeny, in addition to being a major uplift phase (that tilted older sedimentary units, including the Dakota Formation) had substantial igneous activity associated with it! Below is an artist’s image of a pyroclastic eruption during Late Cretaceous or Early Tertiary time.
As we walk over the ridge we’ll encounter lots of interpret signs and stops. Let’s look at both the rocks and the fossils!

**ROCKS—**
1) Dakota Group + evidence for its depositional setting.
2) Morrison Formation + evidence for its depositional setting.

Note:
Just like this “little hogback ridge” which certainly won’t last *forever*, mountain ranges in general are ephemeral features on planet earth. Unless there is continued uplift, mountain ranges eventually succumb to the forces of erosion and are worn down flat! The tilting of the sedimentary layers along the eastern edge of the Front Range is a consequence of the Laramide Mountain Building Episode (or Laramide Orogeny) 75-45 Ma. The recent history of the modern Rocky Mountains is somewhat controversial, but certainly had it’s beginnings during Laramide time.
Geologists are still trying to work out if the modern ranges are a result of continuous or “renewed uplift and exhumation” (e.g. 10 Ma and younger).

FOSSILS—
Let’s consider modes of preservation (trace fossils versus bone material), habitat, ecology, and environment.

AND, By the way—

Some of the most famous dinosaur genera (known by heart to so many school-kids) were discovered right here! *Allosaurus, Diplodocus, Stegosaurus, and Apatosaurus* (fomerly *Brontosaurus*) were all initially found and named based on fossils found right here on or near Dinosaur Ridge!

The tracks were discovered around 1930, during road construction. Not until the 1980’s were the tracks evaluated in detailed and scientific fashion. They have provided much information regarding modes of locomotion, gait, group activity, and other biological and ecological features.

The bones (in the Morrison Fm, west side of ridge) were discovered much earlier, around 1870-1880. Originally described by an early professor at Colorado School of Mines, Arthur Lakes, they quickly became part of the great “Bone Wars,” a dramatic rivalry between the reigning royalty of American paleontology, O.C. Marsh, and E.D. Cope. These guys were not nice to each other.

Marsh supposedly dynamited one of his own quarries, in order to prevent Cope from ever obtaining any of its fossils! And there are stories that Cope replaced the mailing labels on Marsh’s boxes (bound for east coast universities and museums) with his own mailing labels, such that they would end up in his hands!
The rocks of Dinosaur Ridge.

black shales— the source rock for oil and gas wells in the Denver area

unconformity

bones found in sand lenses

unconformity

from Abbott and Cook, 2012, Geology Underfoot, Colorado’s Front Range
Above diagram=> Proposed “depositional environment” for the Jurassic Morrison Formation (west side of Dinosaur Ridge). Present across the Rocky Mountain west, in Colorado, Utah, Wyoming, and Arizona, the Morrison Formation has been a major world-wide resource for dinosaur fossils. from Abbott and Cook, 2012, Geology Underfoot, Colorado’s Front Range
And, below, the fauna present near these ancient streams and rivers...
PICK UP ON WEST SIDE OF RIDGE
Bathroom stop at Dinosaur Ridge visitor center and museum.

FINAL STOP,
Upper Parking Area, Red Rocks Amphitheater
Because of the tilted nature of the strata on the eastern margin of the Colorado Front Range, all we have to do in order to find old rock layers is to simply work our way further to the west! We call this moving “down section,” in a stratigraphic sense.
See the first figure, above, labeled “Generalized Cross Section, Across the Boulder Area” (notice that the oldest layers are located to the west).
At this stop, we encounter the Great Unconformity, the boundary between the Precambrian crystalline rocks that comprise the core of the Front Range and the adjoining sedimentary units.

Notes:
1) The oldest sedimentary unit here is the Fountain Formation. It is the unit that makes up the spectacular tilted cliff-layers in which the Red Rocks concert amphitheater sits. The Fountain Formation is an arkosic (K-feldspar-rich) sandstone and conglomerate, dated at approximately 295Ma, i.e. Late Paleozoic.
Let’s take a good look at it, and discuss the rationale for its interpretation as a series of river, stream and alluvial fan deposits that flanked an ancient mountain range (the Ancestral Rocky Mountains).
As a matter of fact, the Ancestral Rocky Mountains were markedly different than the modern (Laramide) Rocky Mountains in that they rose from equatorial seas and lacked much in the way of igneous activity. This means that the only real evidence for their existence are the Late Paleozoic proximal sediments that were shed on off their flanks (including the Fountain, Cutler and Maroon Formations).
2) Precambrian Rock...

In contrast to the relatively young rocks that comprise oceanic crust (<200 Ma), the central regions of nearly all continents are floored by very ancient Precambrian rock (> 1000 Ma). Across most of North America, these old "cratonic rocks" are covered by a veneer of younger sedimentary layers and are only exposed by either deep incision (e.g. Grand Canyon) or via broad uplift and erosion, such as we have in the Rocky Mountain region.

Where visible, the boundary between the Precambrian basement rocks and the younger overlying sedimentary layers is called the Great Unconformity, referring to the lengthy periods of erosion and non-deposition that served to generate this juxtaposition.

At this, our final, stop we can literally walk up and put our fingers on the Great Unconformity and touch a rock boundary that represents approximately 1,400 million years of "missing time"— between the 1.7 Ga granite-gneiss and the Fountain Formation.

The Precambrian rocks are dominated by mid-crustal metamorphic and intrusive igneous and metamorphic rocks. They are part of a broad swath of 1.6-1-8 Ga rocks, nearly 1000 miles long and several hundred miles wide, called the Yavapai-Mazatzal crustal age province. They are a relict of North America’s deep crust during the time of continent formation.
from Abbott and Cook, 2012, Geology Underfoot, Colorado’s Front Range