Guide to the

Geology of the I-70 Road Cut near Golden, Colorado

In Conjunction with
the PCOR Partnership Annual Meeting and Workshop

September 12, 2011

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Geologic Contact between the Lytle and Morrison Formations

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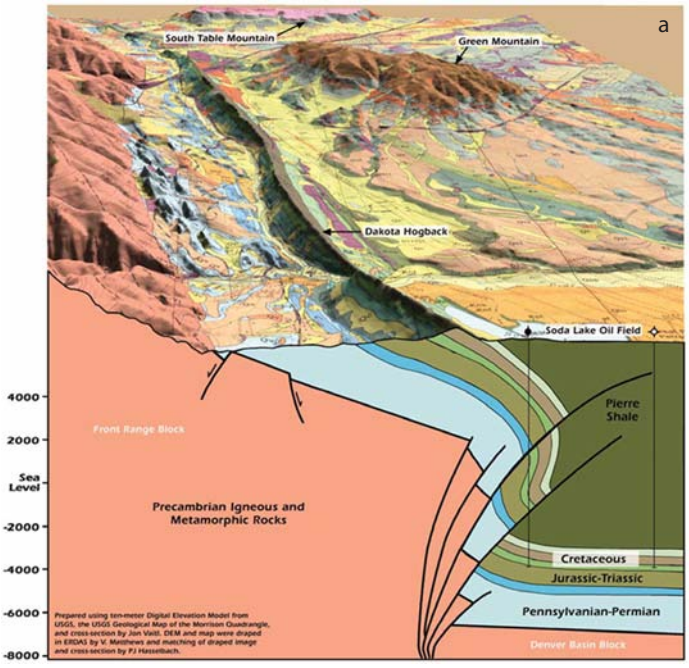
Marilyn Monroe sang that "Diamonds are a girl's best friend," but in the realm of those who study earth science, the phrase is "road cuts are a geologist's best friend." Geologists are constantly looking for ways to peer past, or infer beyond, the vegetation and soil layers that cover most of the rocks on the planet. A side benefit to the development of a national highway system is the numerous road cuts that have been sliced through the hilly and mountainous regions of the country. The geologic exposure and picturesque scenery seen in this wide and deep road cut was created between 1967 and 1969 when the interstate highway system was constructed across Colorado. From the standpoint of geologic presentation, this is one of the best road cut exposures in the United States.



The orientation of the strata at this location is the result of the uplift of the Colorado Front Range and subsequent erosion of the terrain. The Front Range of the Rockies and Colorado Plateau began uplifting approximately 70 million years ago which brought the rocks to their current position. This movement included activity in the Golden Fault which separates two blocks of Earth's crust: one pushed up and forming the mountainous areas and the other block remaining low. The fault parallels the mountain front and passes just to the east of the road cut. The oldest exposed rocks in the area include igneous and metamorphic rocks such as granite, gneiss, and schist exposed immediately to the west. These rocks are resistant to erosion and are present on the top of many nearby mountains and ridges. To the east, these same crystalline rocks are buried by a sequence of sedimentary rocks which filled the Denver Basin depression over geologic history. The deepest (and oldest) sedimentary rocks in the Denver Basin were deposited approximately 370 million years ago. The portion of this sedimentary succession deposited between 230 and 90 million years ago is revealed in the I-70 road cut. These layers were originally deposited horizontally within an ancient seaway that once covered the area. The rocks here are shown to dip to the east, toward the city of Denver where they lie approximately 12,000 feet deep beneath the city.

While the area that would become the Denver Basin has experienced several episodes of sea level flooding and subareal exposure, the most notable and extensive deposition occurred during the Cretaceous time period,

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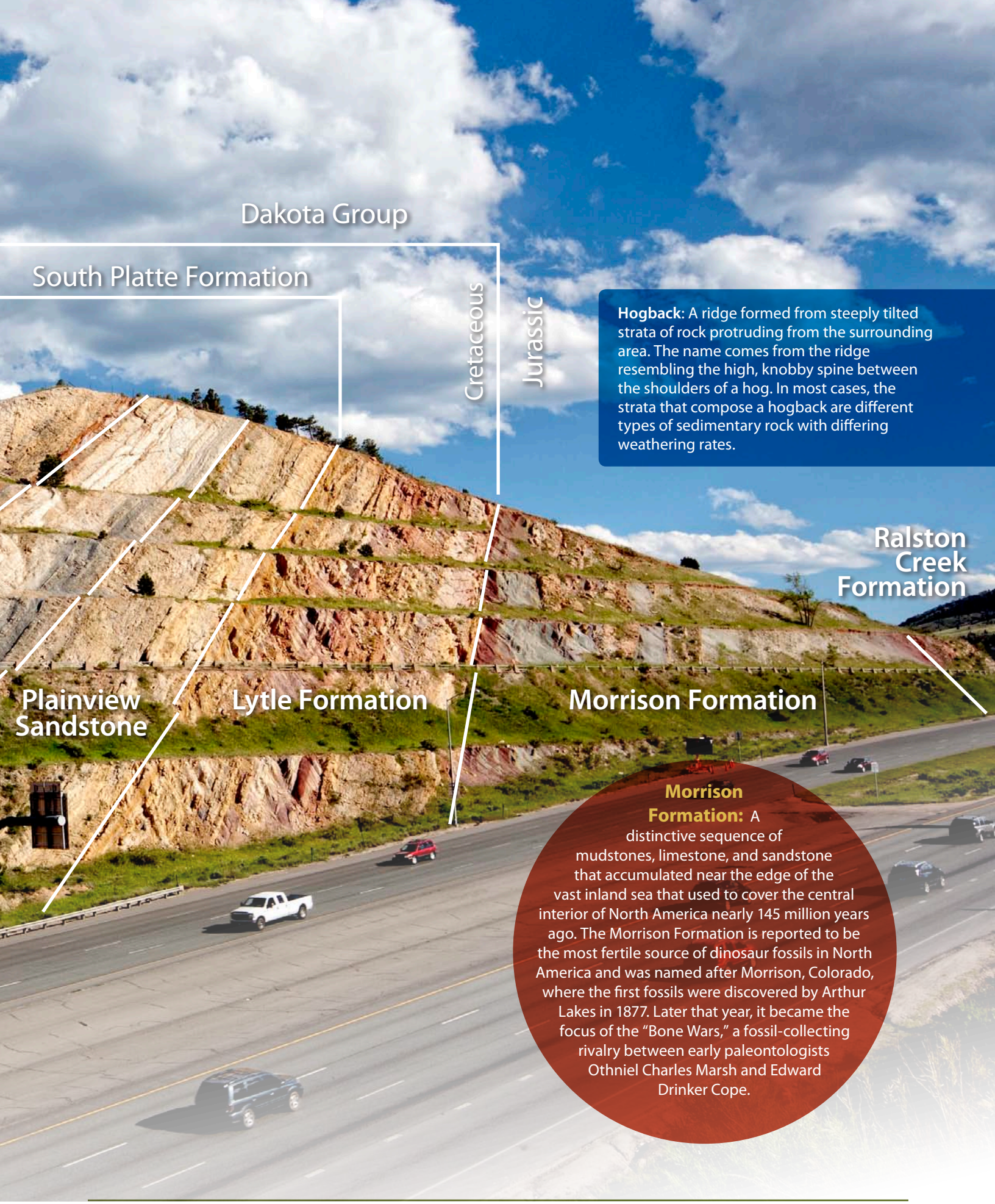
The Cretaceous Seaway as it existed over North America 85 million years ago.

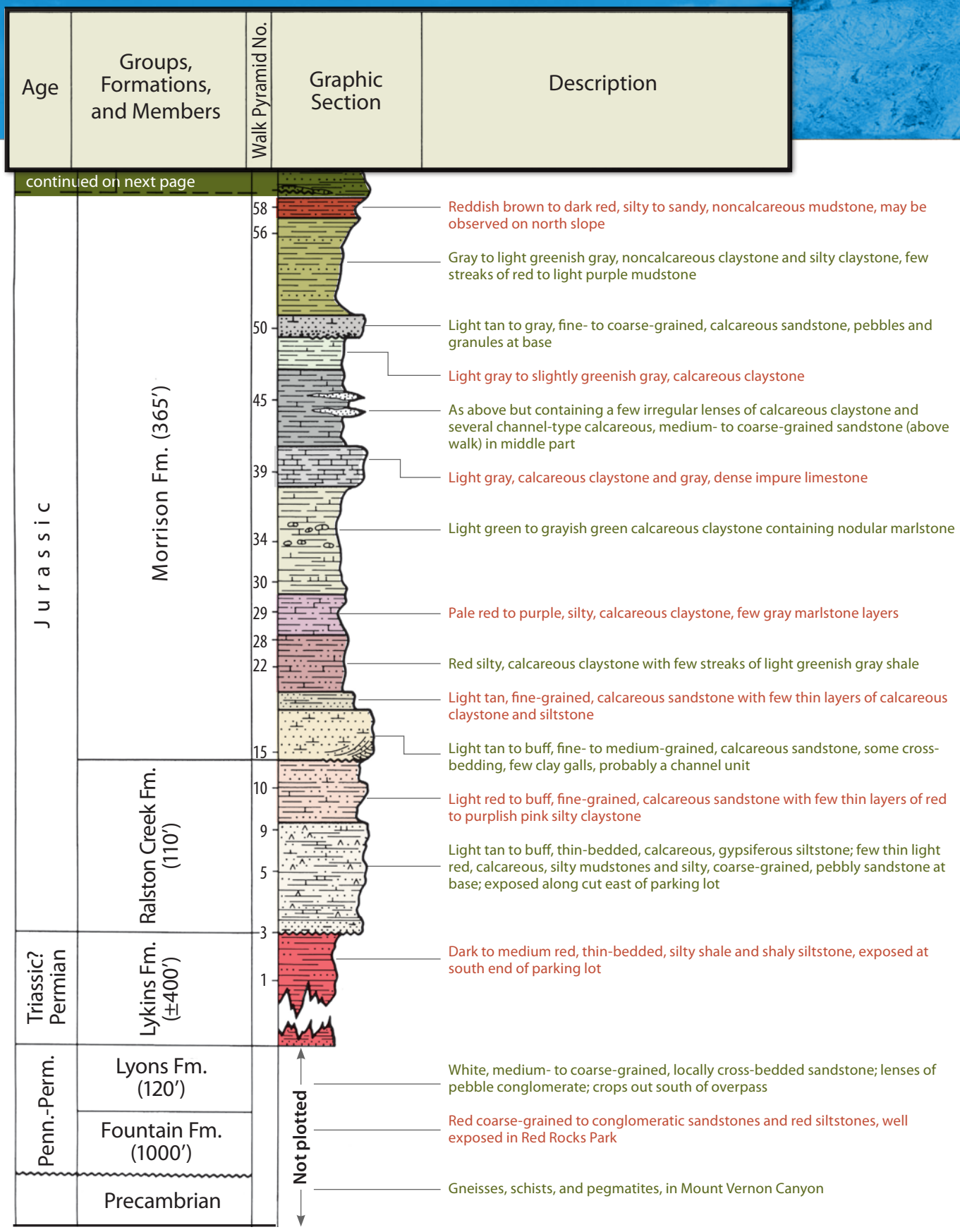
Kassler Sandstone:
Consisting of sandy, shallow marine deposits with intermittent mud flat sediments and occasional stream deposits, these strata were deposited along the shoreline of the Cretaceous Seaway. This and other sandstone units of the Dakota Group form the backbone of the prominent hogback that parallels the Front Range. Parts of this Kassler Sandstone are the primary gas production horizons in the Wattenberg Field in eastern Colorado. The Wattenberg Field is one of the largest gas-producing fields in the United States. This sandstone is also stratigraphically equivalent to the Muddy Sandstone, which is the producing horizon in the Bell Creek oil field in southeastern Montana. The Bell Creek oil field is the site of the Denbury Onshore LLC CO_2 storage and enhanced oil recovery project.



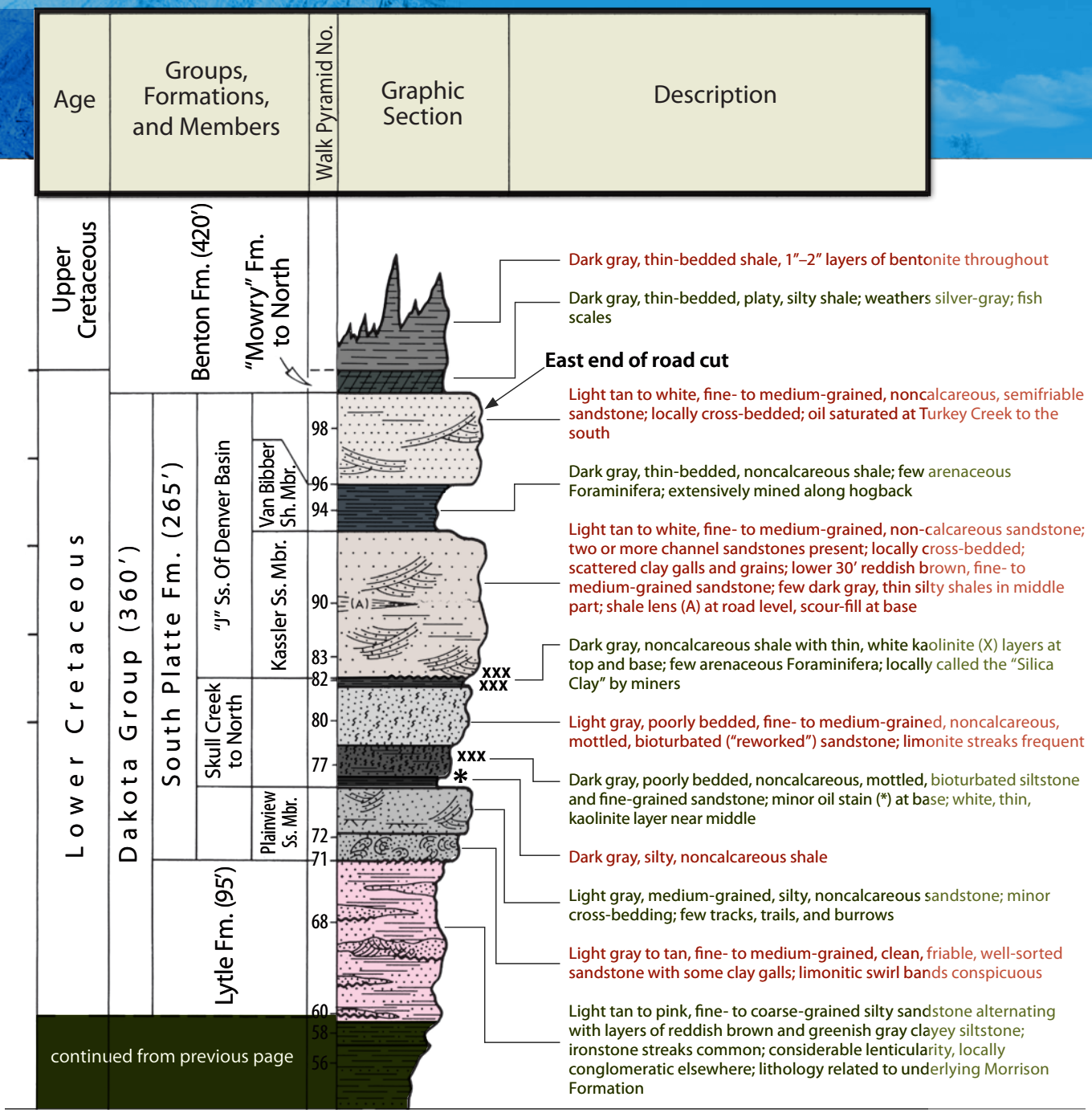
Hogback: A ridge formed from steeply tilted strata of rock protruding from the surrounding area. The name comes from the ridge resembling the high, knobby spine between the shoulders of a hog. In most cases, the strata that compose a hogback are different types of sedimentary rock with differing weathering rates.

Morrison Formation: A distinctive sequence of mudstones, limestone, and sandstone that accumulated near the edge of the vast inland sea that used to cover the central interior of North America nearly 145 million years ago. The Morrison Formation is reported to be the most fertile source of dinosaur fossils in North America and was named after Morrison, Colorado, where the first fossils were discovered by Arthur Lakes in 1877. Later that year, it became the focus of the "Bone Wars," a fossil-collecting rivalry between early paleontologists Othniel Charles Marsh and Edward Drinker Cope.

Stratigraphic Section of South Exposure of Road Cut



Stratigraphic Section of South Exposure of Road Cut (continued)



The stratigraphic section shown on these pages represents the succession of strata from oldest (on the bottom, or to the west on the outcrop) upward to the youngest (east end of the outcrop). The weathering profile on the right edge of the column represents the relative resistance that each horizon has to weathering. The sandstones and well-cemented siltstone will stand out more prominently along the outcrop, whereas the shales and claystones are less resistant to weathering and erode more easily.

The pyramid numbers indicated in the stratigraphic column refer to the concrete pyramids that hold the railing in place along the walkway. The numbering starts from the parking lot and provides a helpful indicator for correlating your place on the walkway to the stratigraphic column.

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100 to 65 million years ago. During this time, a major seaway connected the proto-Caribbean Sea and the Arctic Ocean over a wide swath of North America. Although the seaway was geologically short-lived (only several million years), the volume of sedimentary rock collected was immense. As the seaway retreated, continental sediments continued to accumulate and erode within the Denver Basin.

The bright coloration of the rocks exposed in this road cut is a by-product of oxidation of iron compounds in the sedimentary layers. Without the exposure to air, the rocks are typically gray, black, or greenish in color. Colorful purple, red, and green rocks of the Morrison Formation on the west end of the exposure are a famous source of many dinosaur bones. The dinosaur monument in Utah is based on this same formation. Not far to the south of this location dinosaur footprints can be seen on the bedding surfaces in the Morrison Formation.

The sandstones of the Dakota Group exposed on the eastern end of the road cut are productive oil and gas reservoir rocks in eastern Colorado and western Nebraska. The Dakota sandstones are also an extensive and important source of groundwater at shallower depths across the Great Plains.

Although dramatically tilted in this exposure, the rock layers do provide a good representation of an arrangement of strata that occurs deeper in many sedimentary basins. The sandstones of the Dakota Group are a great representation of strata that would make for an ideal CO_2 storage target. And although too thin at this location to be an excellent seal, the shales of the Skull Creek Formation provide an opportunity to see a cap rock lithology in context with surrounding rock.

[a] Geologic map and cross-section image from Aber, S.W., 2009, Field geology 2009—exploring the Raton Basin and Southern Rockies of Colorado: www.geospectra.net/fieldgeology/coloradorocks.htm (accessed August 18, 2011).

[b] Image of Interpreted Early Cretaceous North America from Blakey, R., 2011, Paleogeography and geologic evolution of North America: www2.nau.edu/~rcb7/nam.html (accessed August 18, 2011).

Concretions: Hard masses of sedimentary rock that form by the preferential precipitation of minerals (cementation) in localized portions of the rock. Concretions form within layers of sedimentary strata that have already been deposited, but early in the burial history of the sediment, before the rest of the sediment is hardened into rock. They're commonly subspherical but frequently form a variety of other shapes, including disks, grapelike aggregates, and complex shapes. Concretions are often noticeable features because they have strikingly different color and/or hardness than the rest of the rock.

The Plains CO_2 Reduction (PCOR) Partnership is a group of public and private sector stakeholders working together to better understand the technical and economic feasibility of sequestering CO_2 emissions from stationary sources in the central interior of North America. The PCOR Partnership is led by the Energy & Environmental Research Center (EERC) at the University of North Dakota and is one of seven regional partnerships under the U.S. Department of Energy's National Energy Technology Laboratory Regional Carbon Sequestration Partnership Initiative. To learn more, contact:

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Visit the PCOR Partnership Web site at www.undeerc.org/PCOR. New members are welcome.

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