NEW FINDINGS RELATED TO COMPOSITE BEDROCK MEGALANDSLIDES IN THE GRAND CANYON

Conor Watkins and
J. David Rogers
Department of Geological Sciences & Engineering
University of Missouri – Rolla

AEG 2005, Las Vegas, NV

New Findings

- Additional landslides were identified during the past year with most of the larger examples being located in the western Grand Canyon. Those working the canyon from the river are finishing up at this time and much of the geology in the western canyon is often overlooked.
- Other landslides were identified in the eastern Grand Canyon, including Marble Canyon. It is likely that this sliding is far more common throughout the Grand Canyon than currently realized.
- Several of these slides have dammed tributaries of the Colorado River.
- Variables common to the landsliding in Grand Canyon have been identified.
- These slides likely underwent a progressive failure caused by the strain softening of the Bright Angel Shale before catastrophic failure.

UMR

Variables Common To Landsliding

- **Although all the variables working to foment landsliding in Grand Canyon are far too complex to be adequately analyzed in a statistical model, some commonalities arise.**

-All large slides experienced basal failure in the Bright Angel Shale with the exception of possibly one.

-Jointing of the discontinuous rock mass plays a major role

-Springs and a southwesterly regional dip influence landsliding on the north side of the river in central Grand Canyon.

-Faulting seems to play a more important role in the western Grand Canyon.

-A factor common to all the slides doesn't seem to be active today. Did a wetter paleoclimate and/or other factor(s) play a role?

UMR

The Eminence Break Fault Landslide
River Mile 44, Tatahatso Point Overlook, Marble Canyon

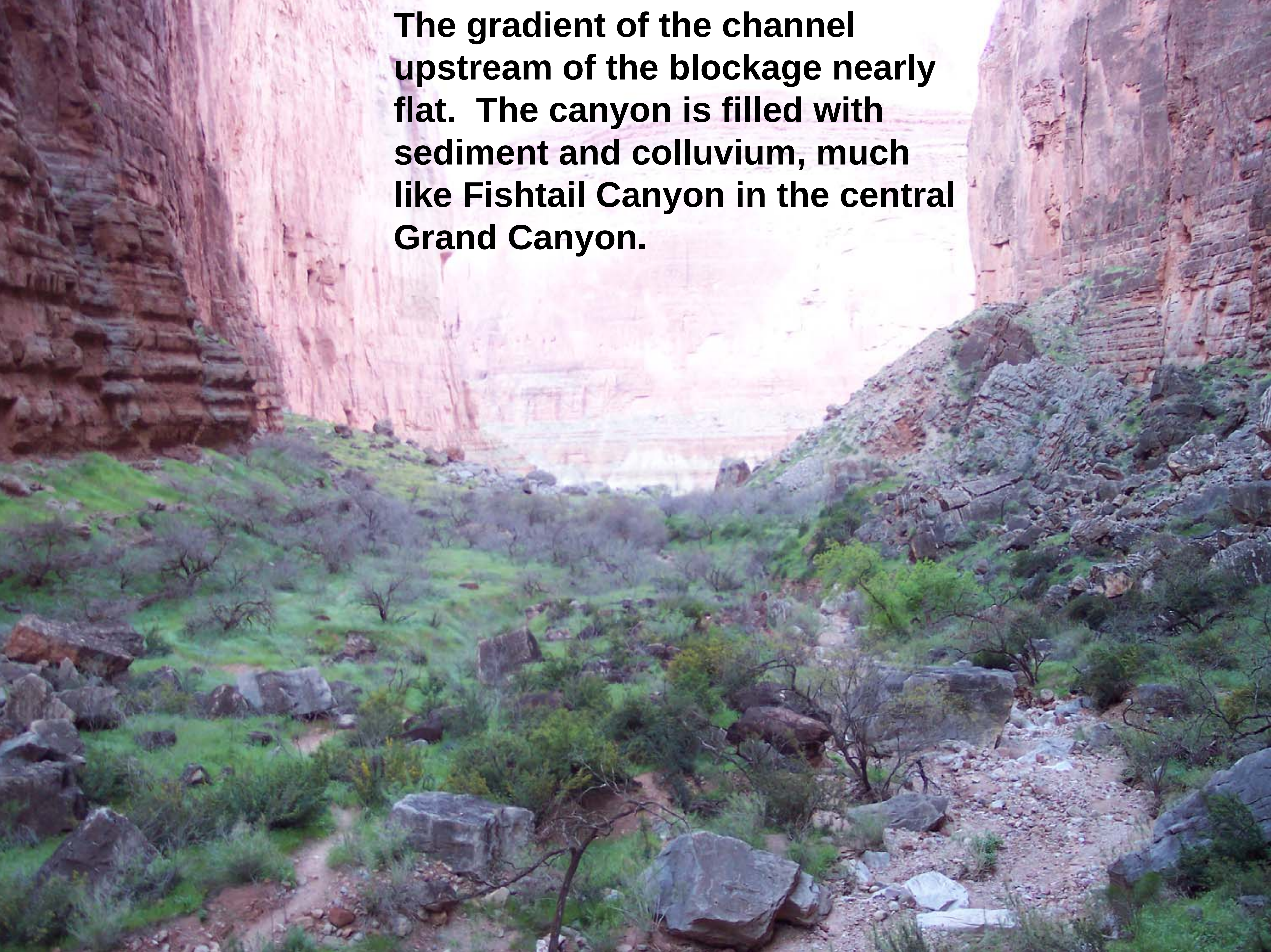
Displaced strata, part of a large slumped mass, is present along the Eminence Break Route.


The Eminence Break Fault Landslide appears
to have a scarp largely controlled by the fault.

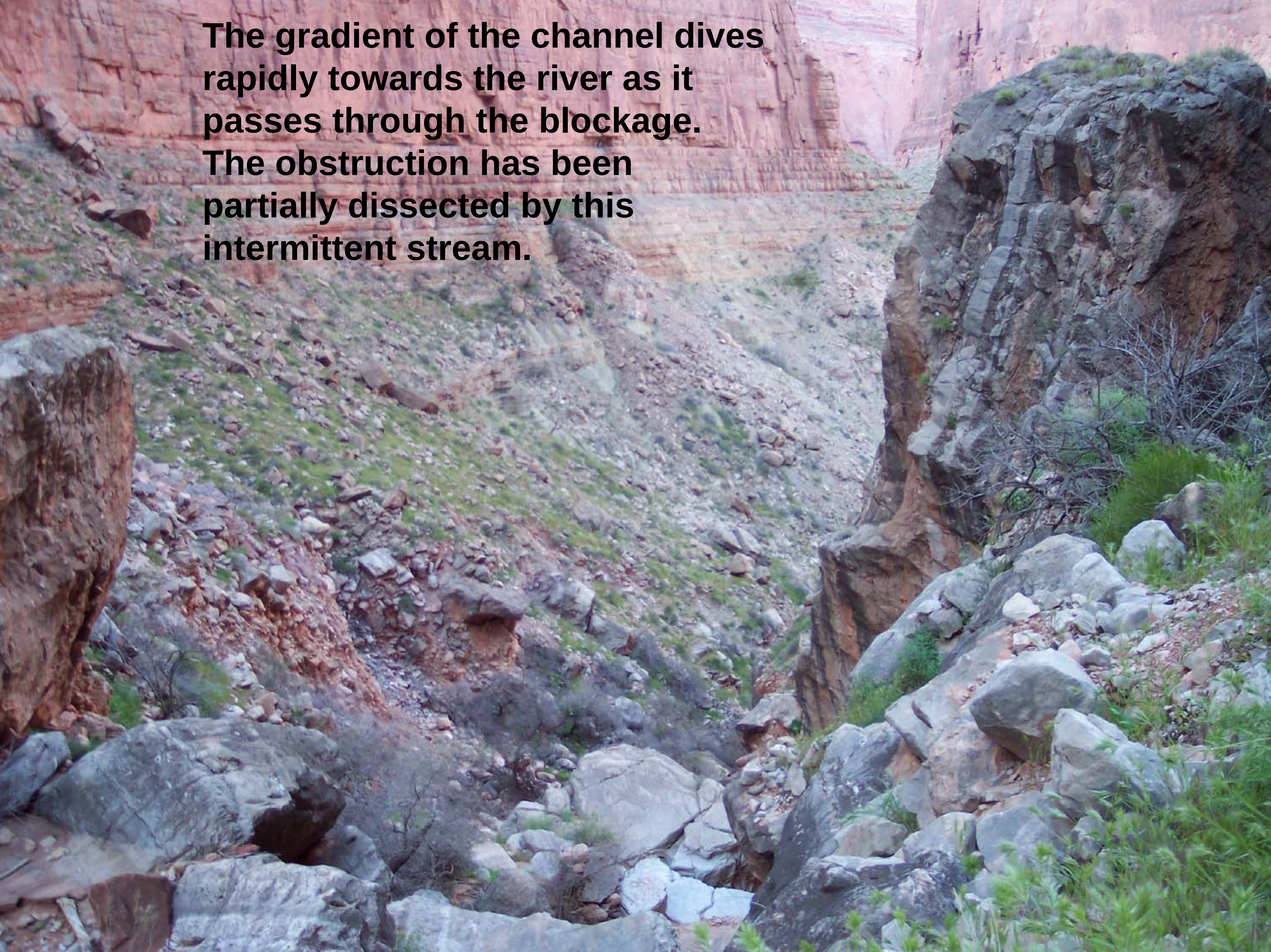
Saddle Canyon Landslide/Rockfall Dam

Rocky debris blocks the mouth of Saddle Canyon.

The gradient of the channel upstream of the blockage nearly flat. The canyon is filled with sediment and colluvium, much like Fishtail Canyon in the central Grand Canyon.



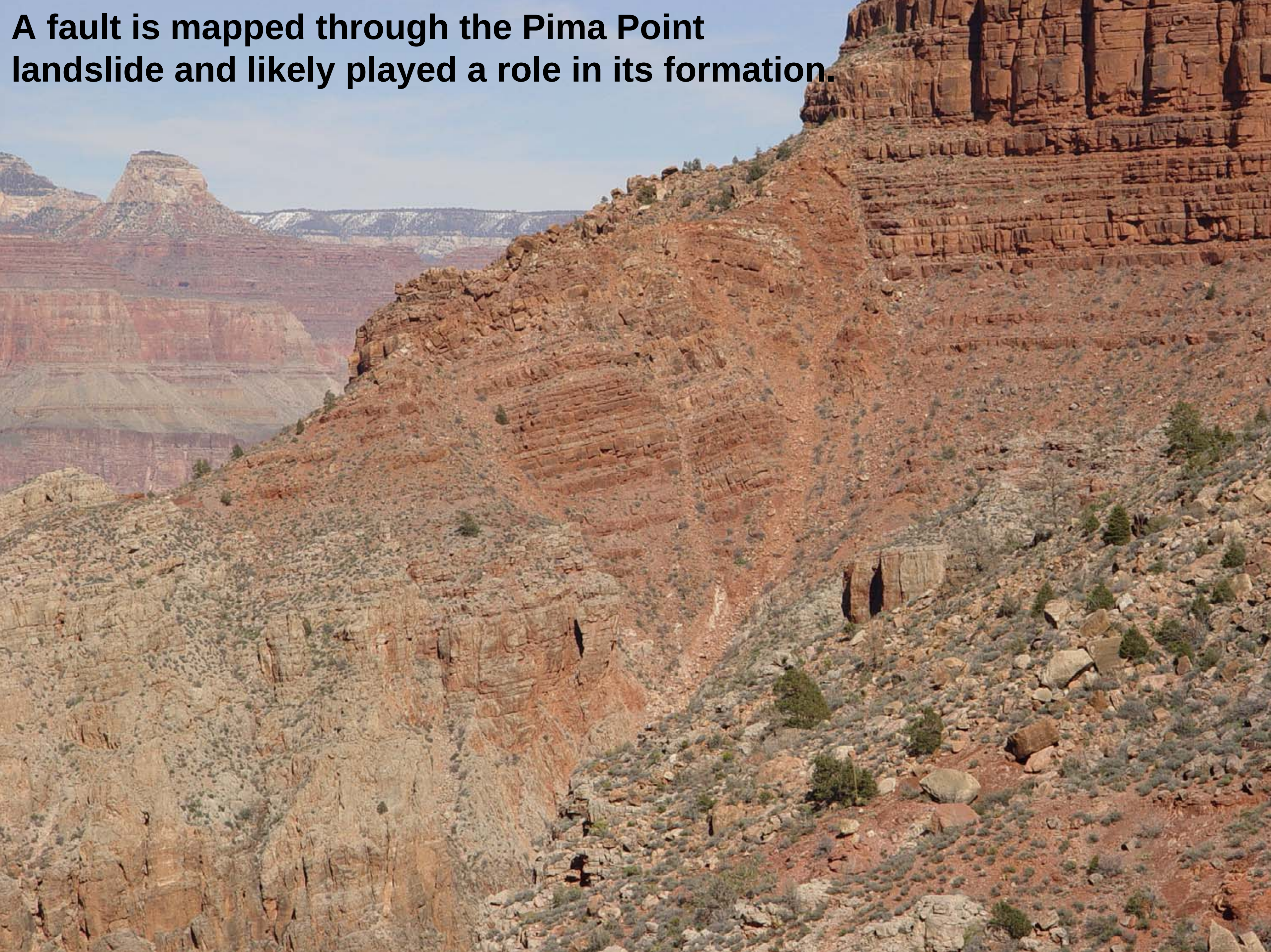
Lacustrine deposits intermixed with colluvium and debris deposits are being dissected after the Fishtail Landslide Dam breached.


The gradient of the channel dives rapidly towards the river as it passes through the blockage. The obstruction has been partially dissected by this intermittent stream.

Pima Point Landslide

Although most landslides in Grand Canyon are largely rotational in nature, some translational slides do exist. This landslide is visible from the Hermit Trail near Pima Point. It exhibits a downdropped graben and a translated passive block.

A fault is mapped through the Pima Point landslide and likely played a role in its formation.




A similar but less striking translational slide is present around river mile 215 on river left, in the western Grand Canyon.

Blacktail Canyon

Blacktail Canyon (RM 120) appears as a slot canyon in the Tapeats Sandstone when viewed at river level.

Blacktail Canyon

Blacktail Canyon (RM 120) is among the many scenic side canyons in Grand Canyon. It is noted for its narrow slot and picturesque waterfalls in the Tapeats Sandstone. Most visitors do not venture beyond the first waterfall in the canyon. Several landslides and rockfalls in the Bright Angel and Muav Formations are exposed in upper Blacktail Canyon, a portion that must be accessed via a technical climb or by hiking around the slot on its west side. The canyon widens dramatically once it enters these weaker formations.


Upper Blacktail Canyon is littered with brecciated
slide debris. These landslides
appear quite old and
are highly eroded.

The above picture shows a recent rockfall that has dammed Blacktail Canyon as viewed from downstream (note circled person for scale). For now, the course debris is allowing the intermittent flow of Blacktail Canyon to run through the blockage and the dam has not breached


Notice the ponding of fine-grained sediments behind the rockfall dam. This occurs when the flowing water in Blacktail Canyon is temporarily ponded behind the rockfall dam, allowing sediments to be deposited. The sediments will likely one day plug the voids within the debris, allowing it to retain water. Once this happens, the dam will likely overtop and breach.

Several landslide dams have blocked Blacktail Canyon, forcing it to divert around the blockages. The above pictures show an excellent exposure of a buried channel within Blacktail Canyon on its east side. These pictures were taken at the downstream end of the exposed channel fill.

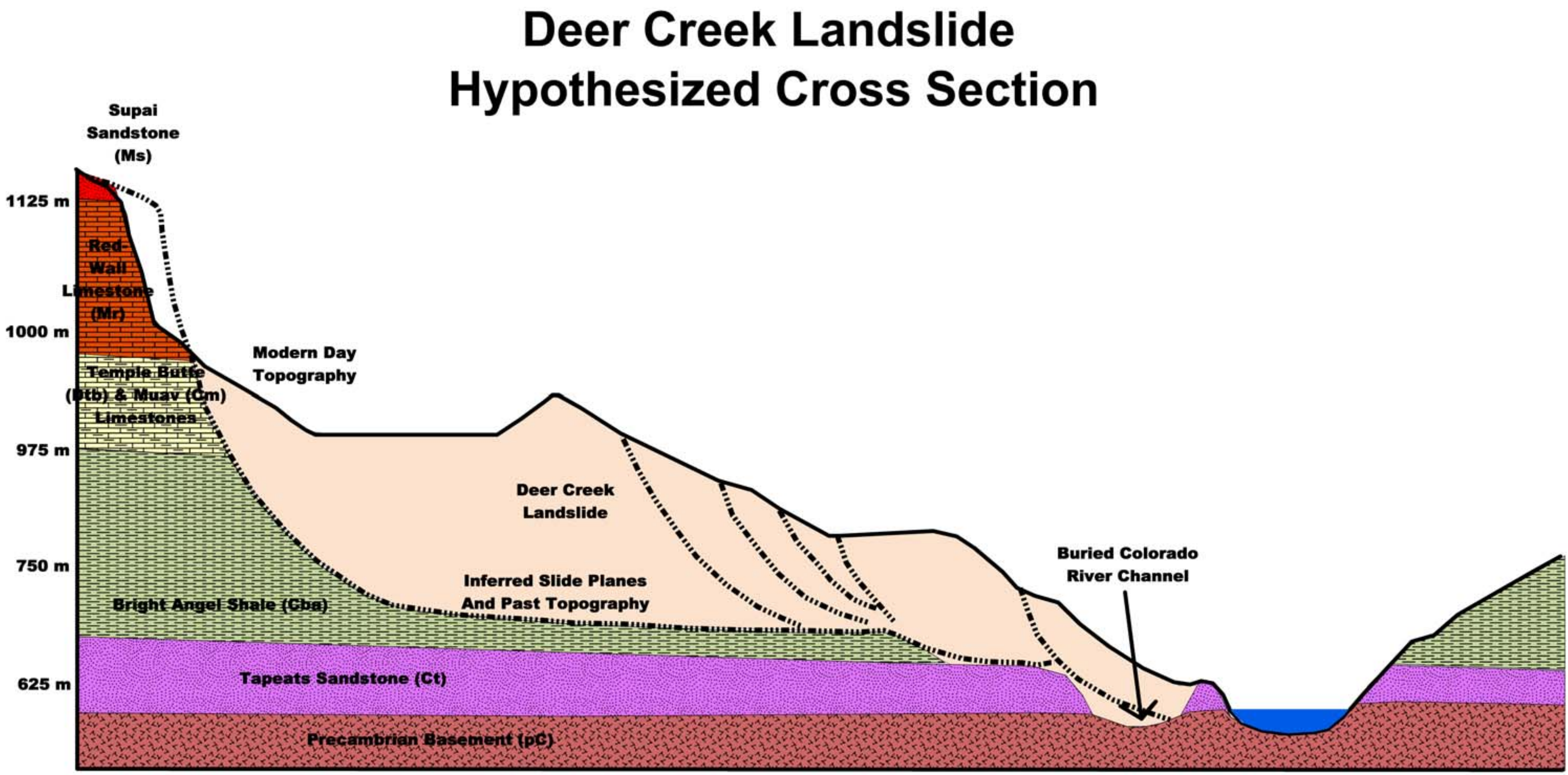
Regression of Deer Creek Landslide

- The landslide complex just west of Deer Creek appears to have undergone multiple episodes of regression.
- The modern landslide is only the latest step in what is likely a long history of landsliding at this location.
- An ancient canyon profile has been recreated by looking at the canyon profile downstream of Fishtail where the Bright Angel Shale hasn’t been incised nearly as deep and the canyon profile is much steeper.

UMR

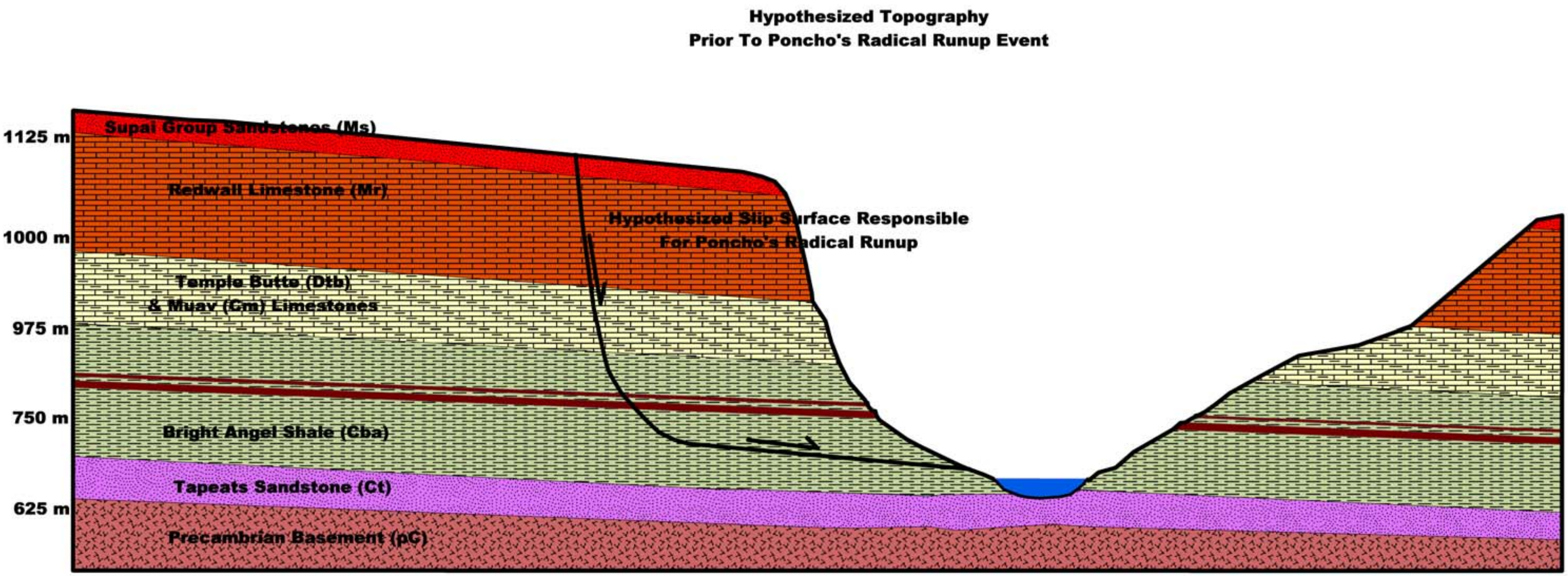
- **The Deer Creek Landslide as viewed from overhead at its eastern end. It extends along the north bank of the Colorado River for 3.7 km. Enclosed depressions are indicated by arrows.**

Modern Day Idealized Cross Section At Deer Creek Landslide



Poncho's Radical Runup – John Warme, Colorado School of Mines

Hypothesized Paleotopography At Deer Creek

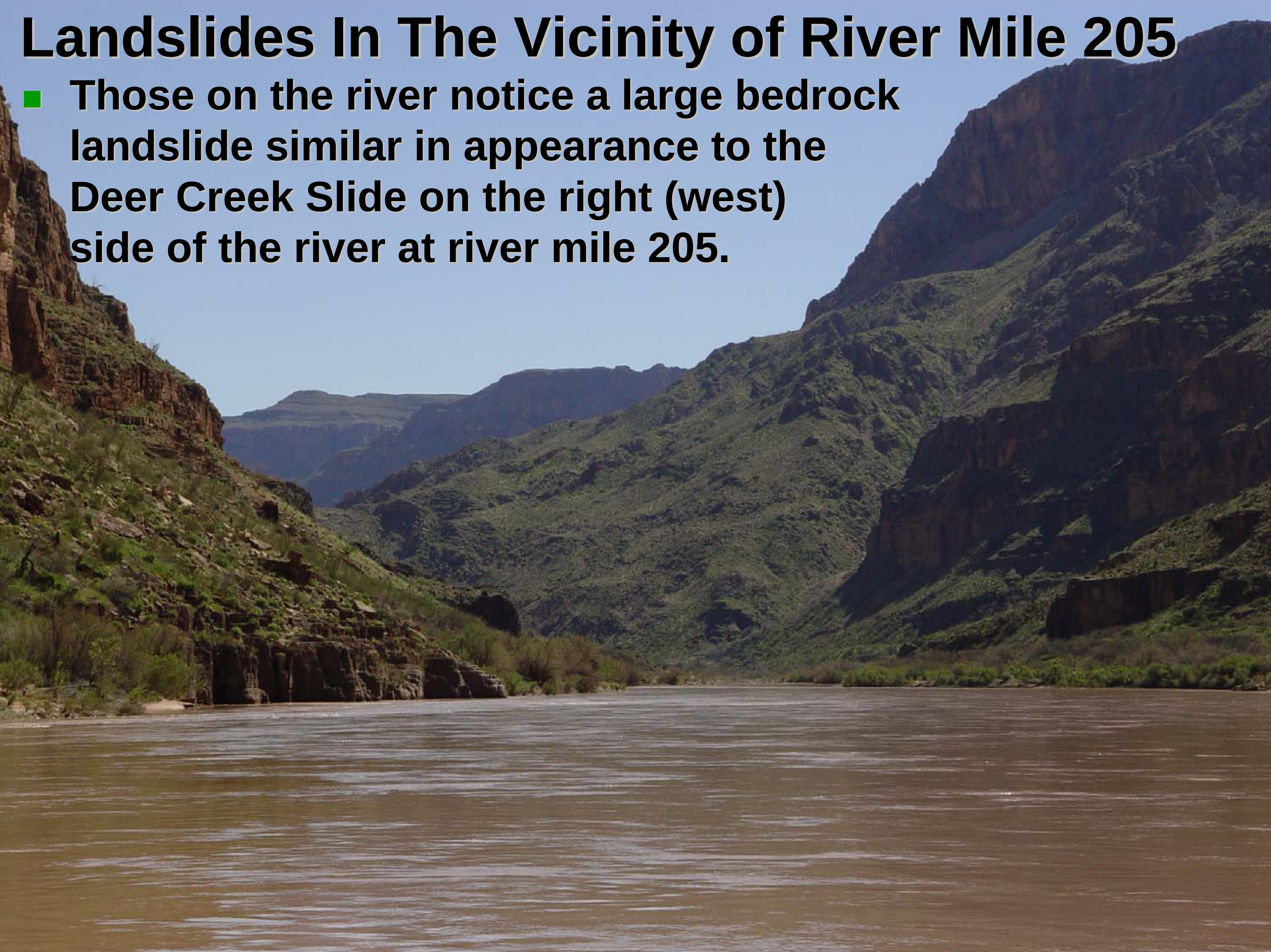


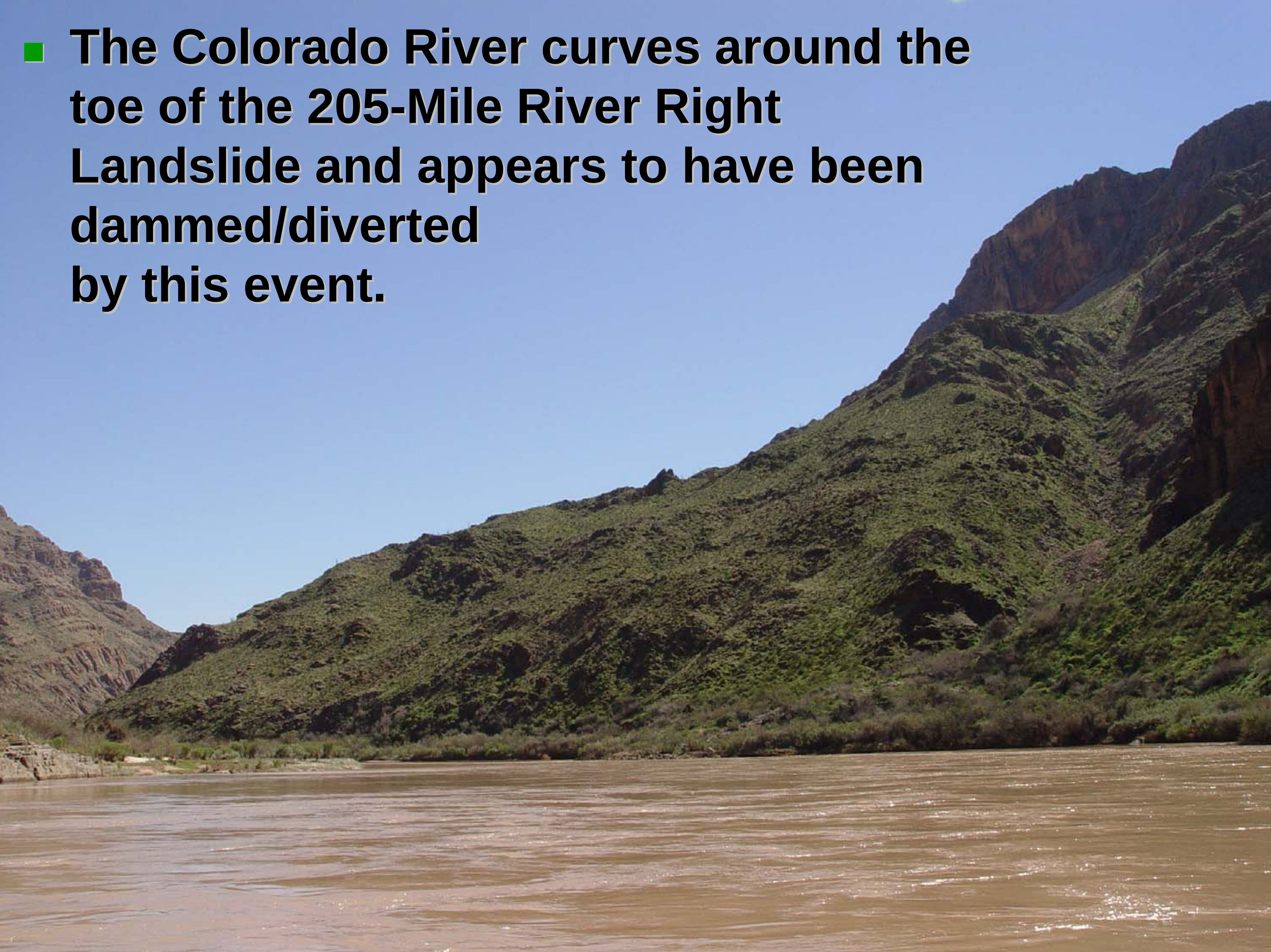
This hypothesized canyon profile is based on the topography west of Fishtail Canyon where incision into the Bright Angel is not as deep as at Deer Creek. Such a profile would allow a landslide to runup the opposite canyon wall.

UMR

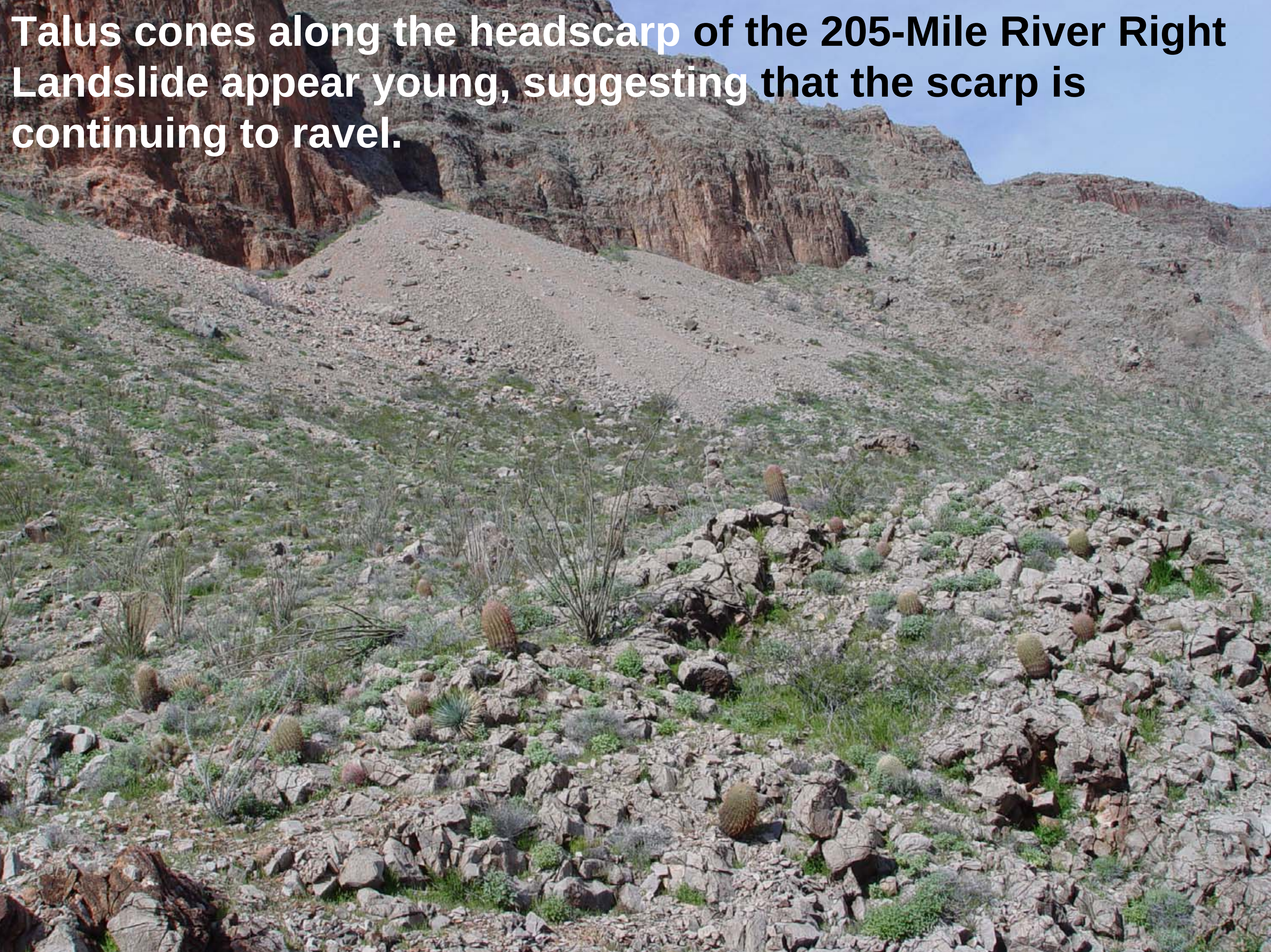
Landslides In The Vicinity of River Mile 205

- Those on the river notice a large bedrock landslide similar in appearance to the Deer Creek Slide on the right (west) side of the river at river mile 205.



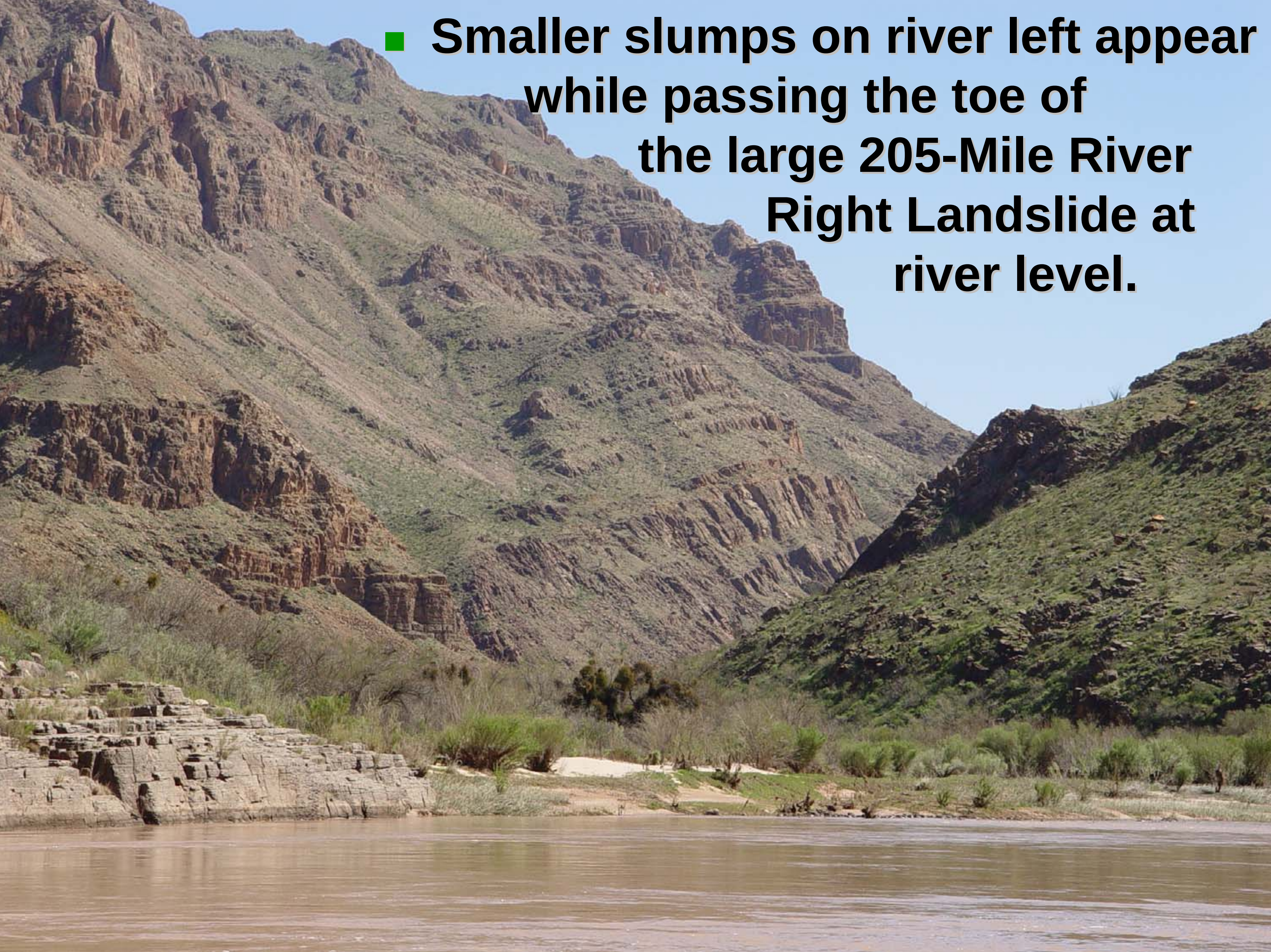

The Colorado River curves around the toe of the 205-Mile River Right Landslide and appears to have been dammed/diverted
by this event.

View of the 205-Mile River Right Slide taken from the opposite side of the canyon atop the 205-Mile River Left Landslide. Secondary retrogressive slumps line the right bank of the channel, where the toe of the main slide mass is being undercut by the Colorado River. Talus cones along the headscarp are fresh, indicating the scarp is still raveling.



Talus cones along the headscarp of the 205-Mile River Right Landslide appear young, suggesting that the scarp is continuing to ravel.


Much of the 205-Mile River Right Landslide consists of
brecciated Redwall Limestone. This texture is
common to other landslides in Grand
Canyon, including the much-studied
Deer Creek Slide.



- Smaller slumps on river left appear while passing the toe of the large 205-Mile River Right Landslide at river level.

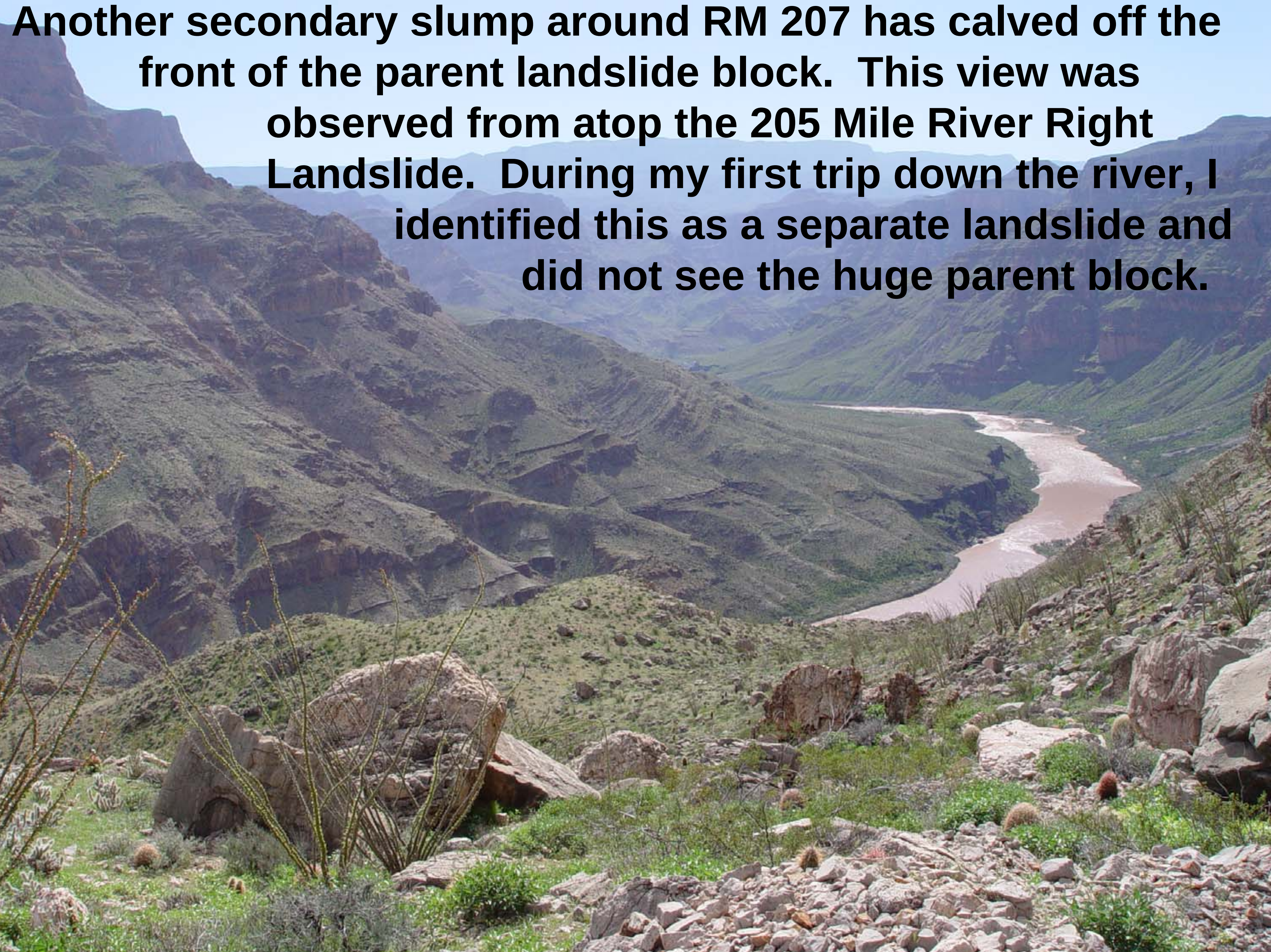

These landslide events are distractions
preventing the observer from recognizing
the “BIG ONE” from the river.

The “BIG ONE”

A short walk up 205-Mile Canyon gives a side view of the massive 205-Mile River Left Landslide. Only then does the whole scope of the landsliding in this area begin to show. The bedrock slumps visible from the river are secondary failures off of this enormous backrotated block.

This view of the 205-Mile River Left Landslide was taken from atop the 205-Mile River Right Landslide. This enormous landslide block spans more than two miles and is outlined here in red.

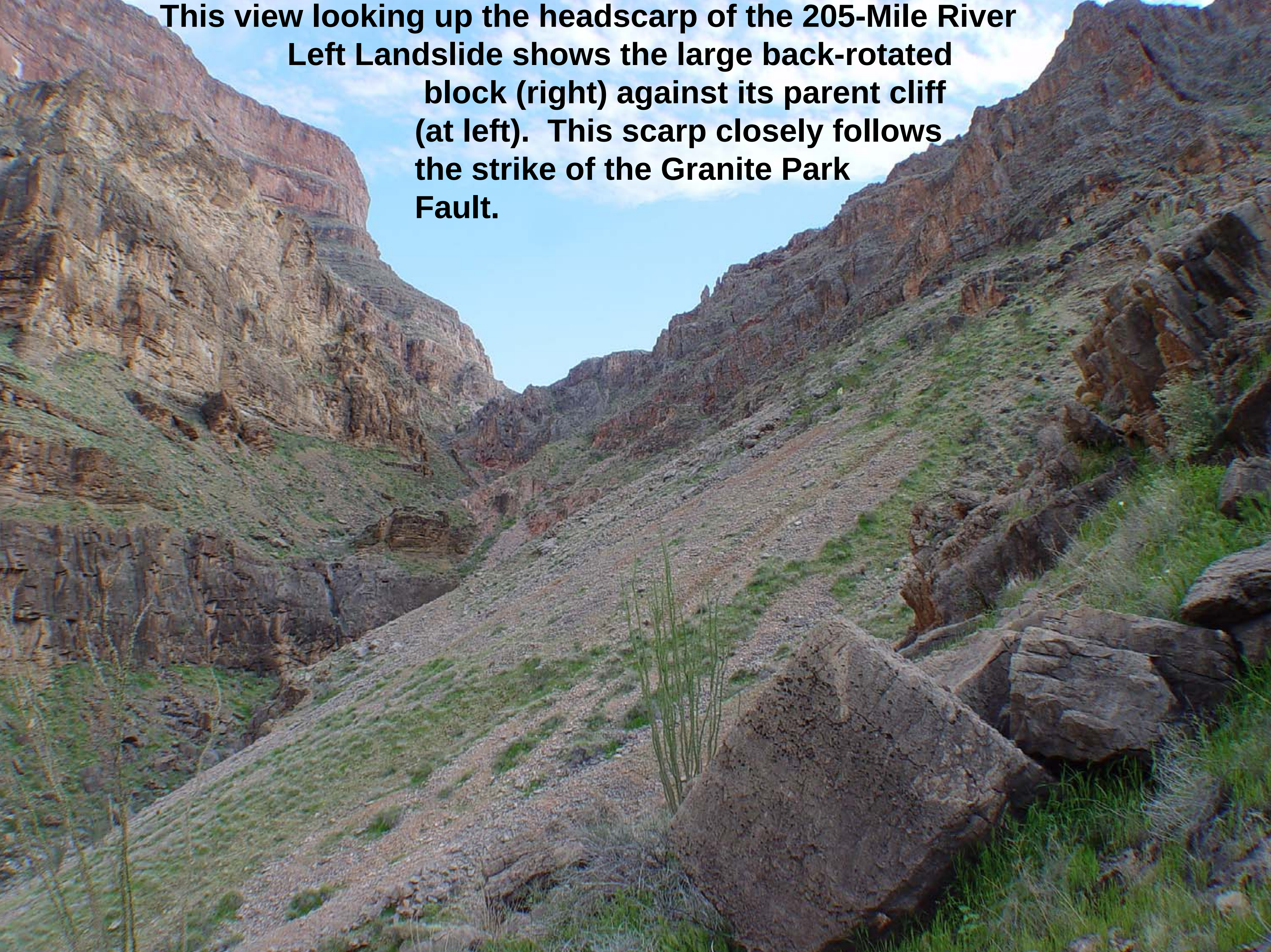
The large secondary slump off the 205-Mile River Left Slide is fairly easy to discern from atop the River Right Slide.


Another secondary slump around RM 207 has calved off the front of the parent landslide block. This view was observed from atop the 205 Mile River Right Landslide. During my first trip down the river, I identified this as a separate landslide and did not see the huge parent block.

The “BIG ONE”

- Although erosion has dissected the slide mass, estimates put the original volume at about ½ cubic mile. This equates to TWO BILLION CUBIC METERS.
- Its gargantuan size prevents almost anyone from fully appreciating the feature from river level. One must explore the slide from 205-Mile Canyon, climb the landslide on river right, and/or view the area from the air to fully understand the size of this landslide.
- This is not only the largest identified single landslide blocks in Grand Canyon, but likely one of the largest in North America.
- Although the landslides near Deer Creek and Surprise Valley are impressive and have been analyzed by many researchers, this even larger landslide has so far escaped major studies.
- Other major landslides are present throughout the western Grand Canyon, all the way to the Grand Wash Cliffs. These slides, many of which appear to be related to faulting, have not been extensively studied.

The River Mile 205 Left Landslide as viewed from the air on Southwest Flt 2272 en-route to Las Vegas on 9-19-2005 at approx 6:45 p.m. looking NNE.



This view looking up the headscarp of the 205-Mile River Left Landslide shows the large back-rotated block (right) against its parent cliff (at left). This scarp closely follows the strike of the Granite Park Fault.

The Granite Park Fault and a zone of clayey gouge is clearly exposed in 205-Mile Canyon. Faults usually create low permeability zones with low shear strength, promoting secondary displacements that occur in response to surface processes and loading. Visually, this gouge resembles the Bright Angel Shale, but further analysis will be required to verify this observation.

A small thrust has been preserved in a large Muav boulder in the narrows of 205-Mile Canyon, just downstream (west) of the Granite Park Fault.

The Granite Park Fault and/or the 205-Mile River Left Landslide appears to have altered the course of 205-Mile Canyon. The canyon has carved a striking narrows through the Muav Limestone on the downdropped (west) side of the fault, but is much wider on the uplifted (east) side developed in the more resistant Tapeats Sandstone. This suggests the Muav Narrows are a geologically young feature. This side canyon also follows the Granite Park Fault until the narrows, where it turns abruptly to the west. Some reddish sediments are preserved upstream of the narrows. Most of these appear to be debris flow related, but some fine lenses may represent lacustrine deposition that were collected behind a landslide dam.

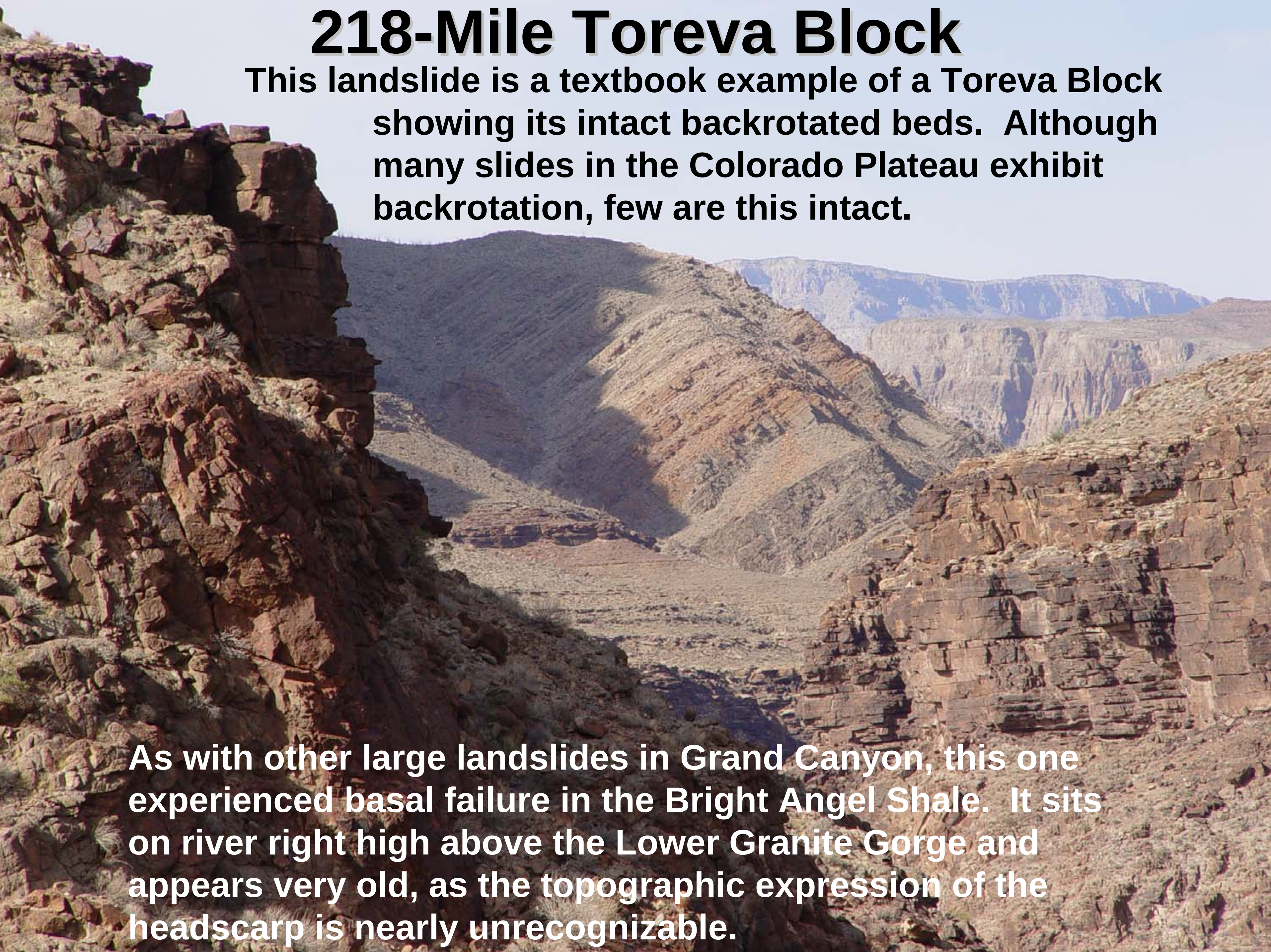
205-Mile Canyon opens up and becomes much wider east of the Granite Park Fault. This part of the canyon is developed in more resistant Tapeats Sandstone, so it is likely much older than the Muav Narrows.

Since the formation of the Muav Narrows in 205-Mile Canyon, displacement on the Granite Park Fault seems to have continued. The mouth of 205-Mile Canyon appears aggraded and choked with sediment to an unknown depth.


The toe of the 205 Mile River Left landslide is experiencing continual regression along the river channel. The oxidized color of the parent slide debris suggest an old age, likely Pleistocene.

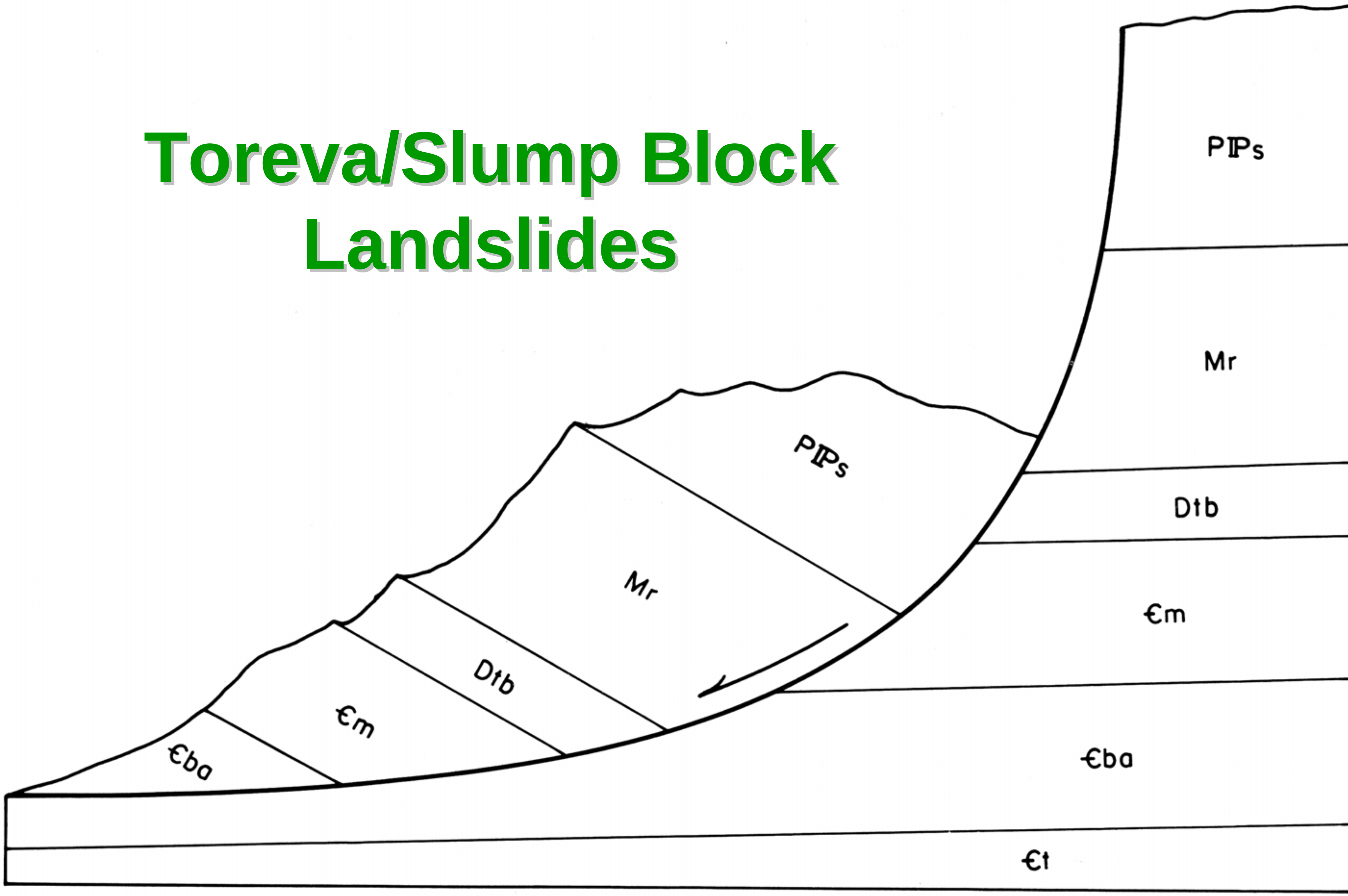
218-Mile Toreva Block

This landslide is a textbook example of a Toreva Block showing its intact backrotated beds. Although many slides in the Colorado Plateau exhibit backrotation, few are this intact.



As with other large landslides in Grand Canyon, this one experienced basal failure in the Bright Angel Shale. It sits on river right high above the Lower Granite Gorge and appears very old, as the topographic expression of the headscarp is nearly unrecognizable.

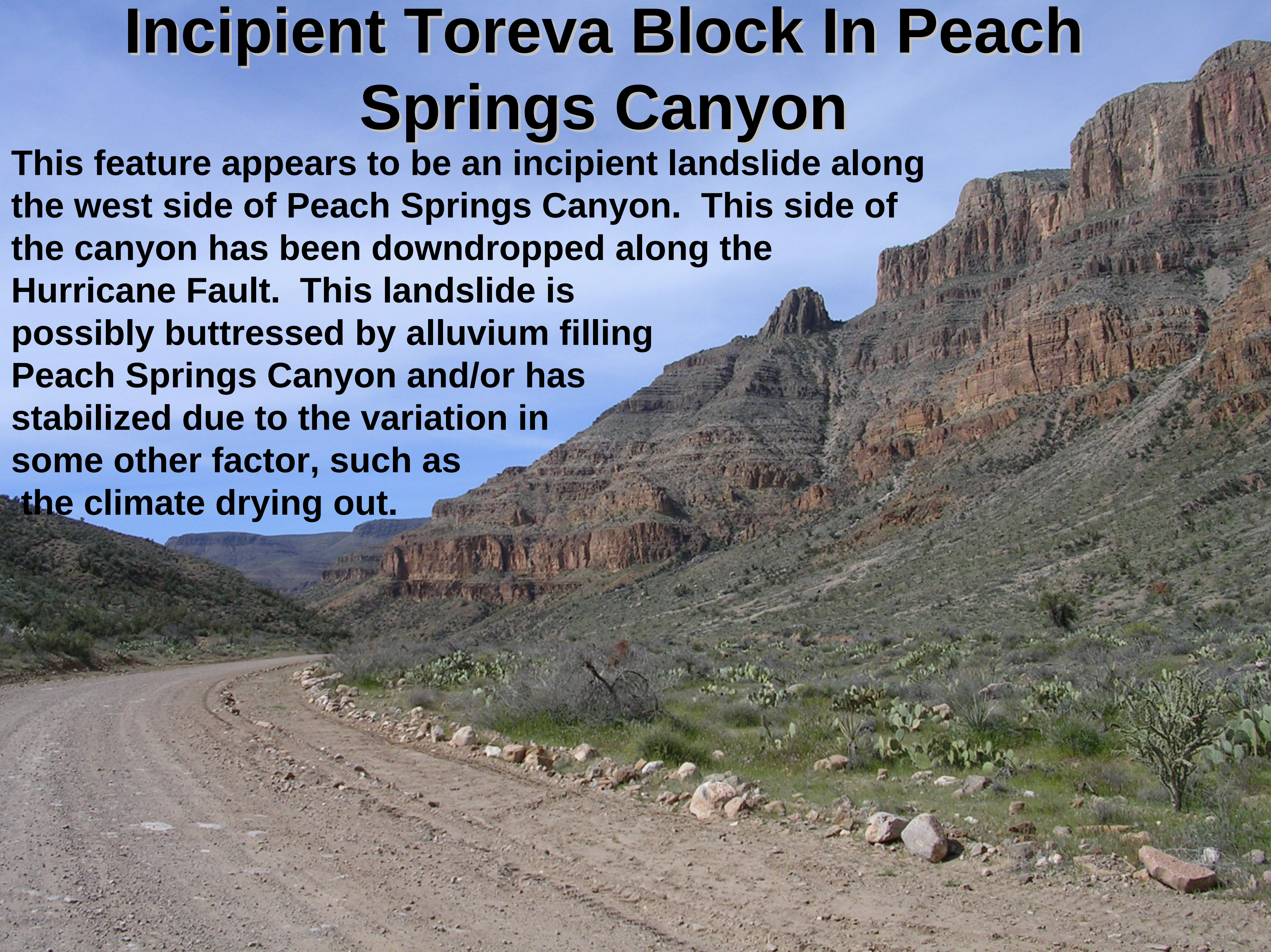
Toreva/Slump Block Landslides



Schematic of a simple Toreva or slump block typical of Surprise Valley in Grand Canyon (from Huntoon, 1978). This type of landslide exhibits rotational motion during movement.

Incipient Toreva Block In Peach Springs Canyon

This feature appears to be an incipient landslide along the west side of Peach Springs Canyon. This side of the canyon has been downdropped along the Hurricane Fault. This landslide is possibly buttressed by alluvium filling Peach Springs Canyon and/or has stabilized due to the variation in some other factor, such as the climate drying out.



Where We Want To Go From Here

- We are looking to unravel potential causes of the landsliding by coming up with rough dates and indicators of the paleoclimate at the time.
- Landslide surfaces remain active long after the main event, giving a young bias to cosmogenic dates.
- Sedimentary (mostly lacustrine) deposits are preserved in several landslide headscarp grabens and behind landslide dams.
- So far, OSL dating complemented by palynology seems to be the most foolproof method for younger sediments.
- Some debris and lava flows have been deposited atop landslides, making cosmogenic dating useful to establish constraints.
- We are open to suggestions as how to best study this material.

The main headscarp graben of the Deer Creek Landslide formed a closed basin that has been accumulating lacustrine sediments and talus since its formation. The deposits may be 100 + meters thick. In order to date the landslide one would need to obtain samples from the lower horizons of this deposit.

Fine-grained lacustrine deposits in Surprise Valley have yielded 18 types of spores, fungal hyphae, and pollen, including that of freshwater algae. Although these deposits appear red and oxidized, their parent materials (mainly Hermit and Supai Formations) are red in color.

CONTENTS IDENTIFIED IN SURPRISE VALLEY LACUSTRINE SEDIMENT

- 1) <u>Pollen and spores</u>:
- *Ambrosia* (ragweed)
- *Anemopsis californica* (Saururaceae)
- Annoniaceae?
- Bryophyte spore
- *Chrysoplenium* (dominant pollen)
- Cruciferaceae
- *Dodocatheon*? (Primulaceae)
- *Ephedra fragilis* (Ephedraceae)
- *Equisetum*
- *Mitella?* (Saxifragaceae)
- *Picea* (spruce)
- *Pinus* (pine)
- Podocarpaceae (specimens similar to fossil *Zonalapollenites*)
- *Quercus* (oak)
- *Saxifraga* (Saxifragaceae)
- *Sequioia* (Taxodiaceae)
- Solaniaceae
- *Taxodium* and one unidentified genus of Taxodiaceae
- 2) <u>Freshwater algae</u>: *Botryococcus* and algal clusters are the dominant palynomorphs in
- both samples.
- 3) <u>Fungi</u>: Fungal hyphae are present.

UMR

Conclusions

- Although the geology of Grand Canyon has been studied in great detail, there are still many unanswered questions.
- Although multiple factors seem to play a role, joints in the bedrock seems to overwhelmingly allow failure in finite element models.
- We have been having trouble finding a program to adequately model the complex situations at hand and are open to suggestions as to what would work best in our case.

UMR

Conclusions (cont)

- It is unlikely that palynology would provide us with any exact dates. Instead, it will likely complement cosmogenic and/or OSL dates recovered from the landslides by providing a picture of vegetation and thus possible climate at the time of landsliding.

UMR

?