Cut, Fill, Repeat:
Slot Canyons of Dry Fork, Kane County

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Utah Geosites
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Utah Geological Association Publication 48

M. Milligan, R.F. Biek, P. Inkenbrandt, and P. Nielsen, editors

Cover Image: *Exploring a southern Utah slot canyon. Photo by Jim Elder.*

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Utah Geosites showcases some of Utah's spectacular geology, both little-known localities and sites seen by visitors to Utah's many national and state parks and monuments. The geosites reflect the interests of the many volunteers who wrote to share some of their favorite geologic sites. The list is eclectic and far from complete, and we hope that additional geosites will be added in the coming years. The Utah Geological Survey also maintains a list of geosites https://geology.utah.gov/apps/geosights/index.htm.

We thank the many authors for their geosite contributions, Utah Geological Association members who make annual UGA publications possible, and the American Association of Petroleum Geologists—Rocky Mountain Section Foundation for a generous grant for desktop publishing of these geosite papers.

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Presidents Message

I have had the pleasure of working with many different geologists from all around the world. As I have traveled around Utah for work and pleasure, many times I have observed vehicles parked alongside the road with many people climbing around an outcrop or walking up a trail in a canyon. Whether these people are from Utah or from another state or country, they all are quick to mention to me how wonderful our geology is here in Utah.

Utah is at the junction of several different geological provinces. We have the Basin and Range to the west and the Central Utah Hingeline and Thrust Belt down the middle. The Uinta Mountains have outcrops of some of the oldest sedimentary rock in Utah. Utah also has its share of young cinder cones and basaltic lava flows, and ancient laccoliths, stratovolcanoes, and plutonic rocks. The general public comes to Utah to experience our wonderful scenic geology throughout our state and national parks. Driving between our national and state parks is a breathtaking experience.

The "Utah Geosites" has been a great undertaking by many people. I wanted to involve as many people as we could in preparing this guidebook. We have had great response from authors that visit or work here in the state. Several authors have more than one site that they consider unique and want to share with the rest of us. I wanted to make the guidebook usable by geologists wanting to see outcrops and to the informed general public. The articles are well written and the editorial work on this guidebook has been top quality.

I would like to personally thank Mark Milligan, Bob Biek, and Paul Inkenbrandt for their editorial work on this guidebook. This guidebook could not have happened without their support. I would like to thank Jenny Erickson for doing the great desktop publishing and the many authors and reviewers that helped prepare the articles. Your work has been outstanding and will certainly showcase the many great places and geology of Utah. Last, but not least, Thank you to the American Association of Petroleum Geologists, Rocky Mountain Section Foundation for their financial support for this publication.

Guidebook 48 will hopefully be a dynamic document with the potential to add additional "geosites" in the future. I hope more authors will volunteer articles on their favorite sites. I would like to fill the map with locations so that a person or family looking at the map or articles will see a great location to read about and visit. Enjoy Guidebook 48 and enjoy the geology of Utah.

Peter J. Nielsen
2019 UGA President

INTRODUCTION

The slot canyons of southern Utah (figure 1) have become popular destinations for hikers, climbers, and photographers. For most of these canyons, the geology is simple: sediment carried by flowing water abrades a thick, homogeneous sandstone. As time passes, the rate of down- cutting is rapid compared to the rate of cliff retreat. End of story. The strange abundance and configuration of the slot canyons along Dry Fork Coyote (a tributary of Coyote Gulch and the Escalante River), however, have a convoluted geologic history that is climate-driven and involves canyon cutting, canyon filling, and more canyon cutting.

Figure 1. *Exploring a southern Utah slot canyon. Photo by Jim Elder.*

DRIVING AND HIKING DIRECTIONS

The Hole-in-the-Rock Road, starting 4.3 miles (7 km) east of the town of Escalante, is a graded dirt road that provides good access to the slot canyons. When dry and graded, this road is passable by passenger cars. Contact the Escalante Interagency Visitor Center (435-826-5499) for a road report and a weather forecast. From the junction of Highway 12 and Hole-in-the-Rock Road, it is 26 miles (42 km) to the turnoff to Dry Fork (figure 2; N37°27'59.7"; W111°13'13"). After turning, go 0.7 mile (1.1 km) on this rutted road (figure 2), and then take the road that branches left and go 0.8 mile (1.3 km) to the trailhead and parking area (figure 2; N37°27'59"; W111°13'26"). The trailhead provides a good view of the canyon of Dry Fork, but the slot canyons are nearly invisible from there. A cairned trail (take your time, it is somewhat difficult to follow) descends about 300 feet (90 meters) to reach the canyon floor. From there, you can choose which of seven slot canyons (if any) you want to explore. The first one—just to the left as you reach the floor of main canyon—provides a shady place to admire the walls of a slot without abrading any skin; the second one (Peekaboo; figure 4B) is more of a challenge. It is easy to lose your way in this tangle of canyons. Take a copy of figure 2 with you. The main (trunk) canyon of Dry Fork carries large volumes of gravel, sand, and mud because it drains from the Straight Cliffs. The tributaries coming in from the north carry only sand. If you get turned around, look for mud and gravel and follow it upstream; it will take you back to the place where the trail enters the canyon.

GEOLOGY

At the canyon rim, you are standing on the basal, red siltstone of the Jurassic Carmel Formation. To the north, the tan, large-scale crossbeds of the Jurassic Navajo Sandstone lie just below, and the Henry Mountains are visible in the distance. To the south are the Straight Cliffs, composed of Cretaceous and Jurassic strata (figure 3). Landslides, many of them deposited during the Ice Age, cover much of the bedrock (figure 2).

As you descend the trail into the canyon, you will see some large, dark masses of rock. These are weathered concretions (sandstone preferentially cemented by calcite--calcium carbonate; $CaCO_3$). These concretions weather dark because the crystals of calcite cementing the sand grains contain small amounts of iron. Atoms of iron are the same size and have the same (+2) charge as calcium atoms, so they fit into the calcite crystal lattice.

GEOLOGIC HISTORY

As you descend further into Dry Fork Canyon, look for a steep wall of loose, bedded sand and gravel (figure 4A). This is the first evidence that, after canyons were cut into the Navajo Sandstone, some were then filled to the rim with sediment. Streams (even those that are dry nearly all the time) can cut bedrock canyons; they can also fill them up with sediment. Climate is a major control on these processes (figure 5).

Based on optically stimulated luminescence ages from buried sand grains (Loope and others., 2014), the sediment that filled some of canyons here (the broad, older ones) was deposited during the Late Pleistocene between about 55,000 and 48,000 years ago. The slots are a younger generation of canyons—they originated during a second canyon-cutting episode (figure 4). During this second episode of canyon cutting, as the streams started to remove the fill

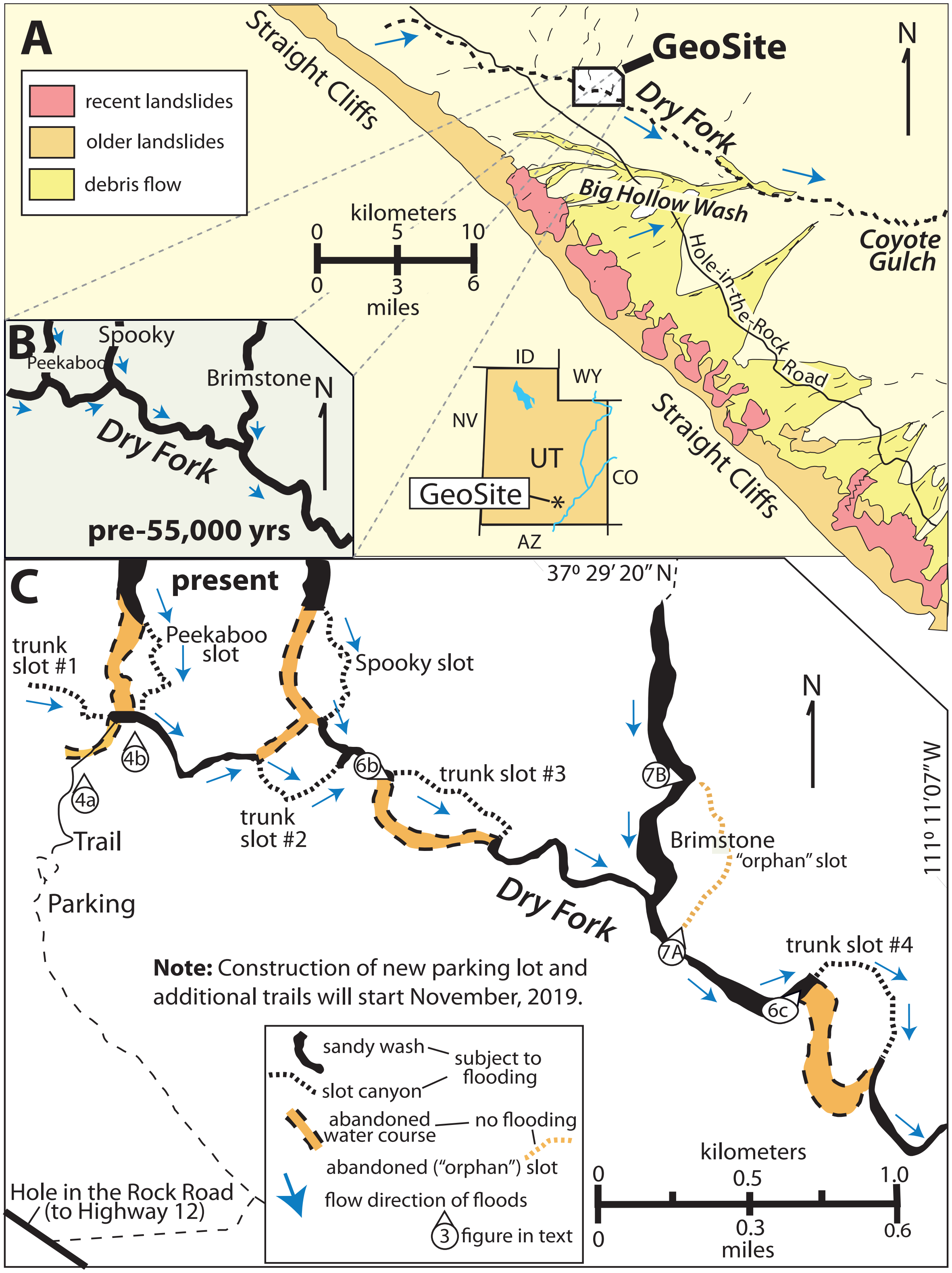

Figure 2. Three maps of the geosite and its vicinity. All water courses are dry washes; blue arrows show flow direction. **A.** *Broad setting from the surficial geologic map of Williams (1985); B and C are nested within A.* **B.** *Configuration of ancient drainages along a short portion of Dry Fork prior to filling of the canyons with sediment.* **C.** *Configuration of modern drainages, showing four slot canyons along the trunk drainage (Dry Fork), the two slot canyons (Peekaboo and Spooky) that are paired with two abandoned water-courses, and one abandoned (orphan) slot canyon paired with Brimstone Wash. Modified from Loope and others (2014).*

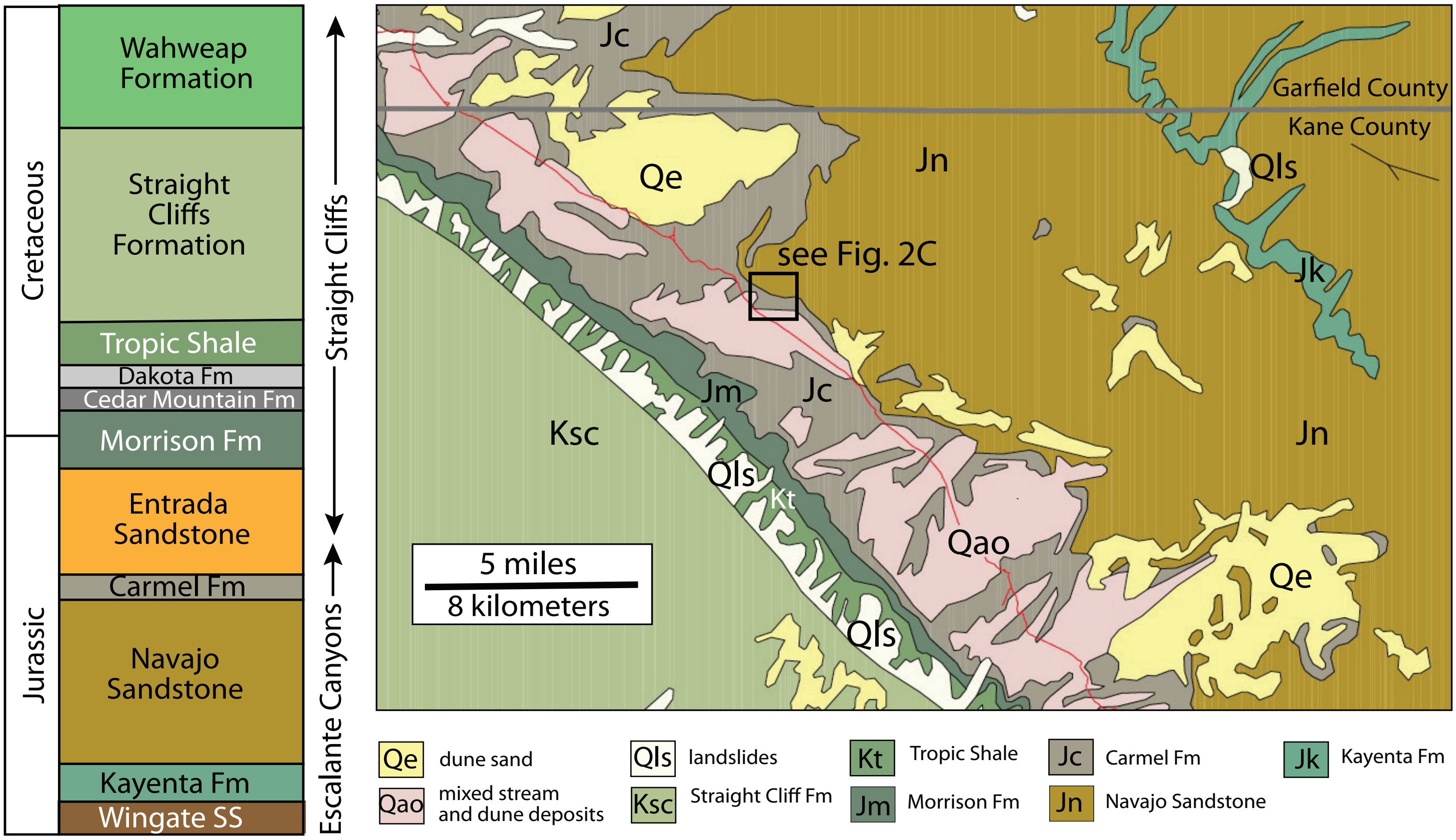

Figure 3. Stratigraphic section and geologic map for a portion of the Straight Cliffs and Escalante Canyons. Hole in the Rock Road is shown in red. From Hintze and Kowallis (2009) and Interactive Geologic Map of Utah; 1:500,000 scale (Utah Geological Survey).

of sand and gravel, they became entrapped by the rising walls of sediment. When they cut all the way through the sand and gravel, they may have reached the lowest bedrock where the old canyons were. But if they cut in places slightly different from the paths of the older canyons, they cut new canyons (figure 6). The seven slot canyons along Dry Fork lie within a very small area (1.5 square miles; 4 square kilometers) (figure 2). Four of the slots are along the main trunk of Dry Fork, the other three are tributaries from the north—Peekaboo, Spooky, and Brimstone. Each of these seven slots is paired with a segment of a wider, abandoned bedrock canyon (figure 2).

Among the three tributaries of Dry Fork, Brimstone Canyon (marked as an “orphan” on figure 2) has a unique geologic history. Unlike Peekaboo and Spooky, modern drainage at Brimstone is through a big, old, open canyon (figure 2). The mouth of the Brimstone slot looks similar to the mouths of Peekaboo and Spooky (figure 7A), but the head of the Brimstone slot is perched high on the east wall of Brimstone Canyon (figure 7B). Ever since the initial cutting of Peekaboo and Spooky, flash floods have been forced to roar through them. Not so with Brimstone. Apparently, during a major event in the distant past, flood waters were able to escape Brimstone slot and flush out the sand that once filled the last half mile of Brimstone Canyon (figure 2).

On the basis of 14 dated samples (Loope and others, 2014), we concluded two things about the timing of the events that generated this landscape: 1) sediment filled the older, wider canyons ~55,000 to ~48,000 years ago; and 2) all the slot canyons are younger than 48,000 years. The nature of the climate and other environmental conditions that caused burial and eventual cutting of the slots are not well known. We do know that, during the Pleistocene, a vast glacial ice sheet formed in the Hudson Bay area of Canada and repeatedly advanced deep into central United States. Mountain glaciers formed in the Rockies, and, in Utah, swelling of rivers and the cooler climate caused a water body to form in the Great Basin (Lake Bonneville) that reached a depth of 1000 feet (300 m) and an area of up to 20,000 mi^2 (52,000 km^2; https://en.wikipedia.org/wiki/Lake_Bonneville). Studies of Lake Bonneville deposits indicate that, during the last 30,000 years, Lake Bonneville’s fluctuations record glacial-interglacial cycles and accompanying changes in Northern Hemisphere storm tracks (Oviatt, 1997). Regional climate shifts, the oldest of which pre-dated the rise of Lake Bonneville, led to changes in vegetation, sediment supply, and stream power (figure 5; Blum and Tornquist, 2000) and thereby likely caused the canyon filling and canyon cutting that took place along Dry Fork.

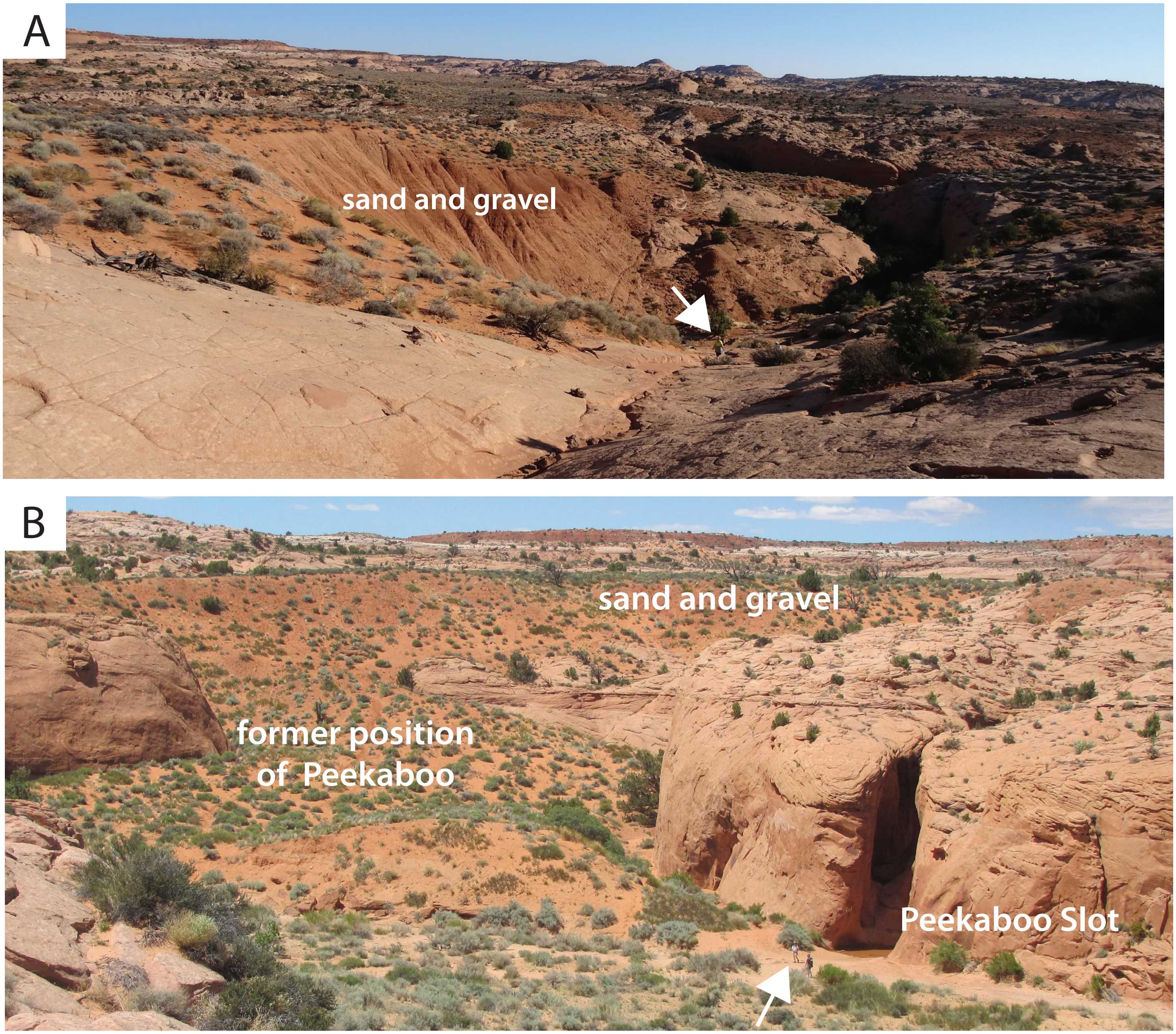

Figure 4. Alluvial fills and slot canyons. White arrows show people for scale. See figure 2 for locations. A. Northward view of thick sediment fill of the trunk of Dry Fork #1 as seen from entry trail. People are about to enter trunk slot #1. B. Northward view of the sediment-filled former course of Peekaboo and of Peekaboo Slot at its junction with Dry Fork. From Loope and others (2014).

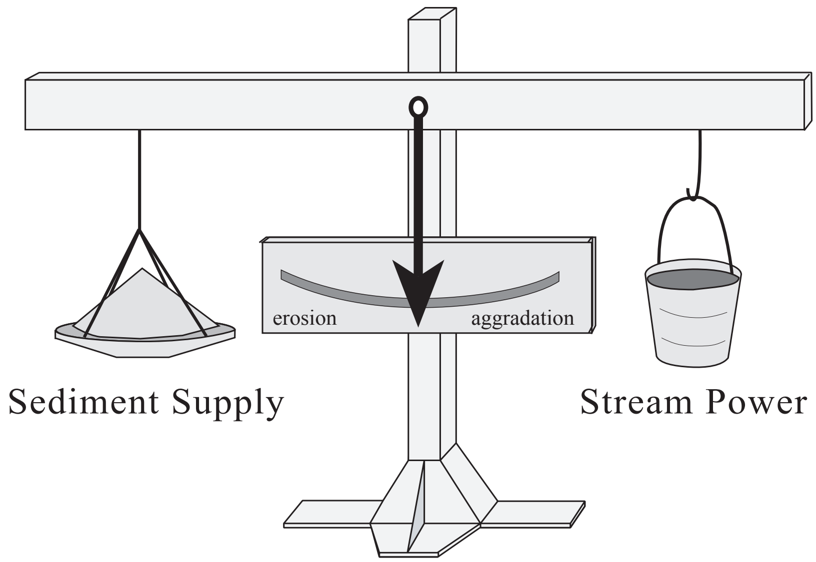

Figure 5. *Balance model for erosion (incision) and aggradation (filling) of stream channels, emphasizing changes in the relationship between stream power and sediment supply. Erosion of channels take place when the transport capacity of the water discharge (stream power) exceeds the sediment supply. With aggradation, the reverse is true. Climate and vegetation are major factors controlling both sediment supply and stream power. Modified from Blum and Tornquist (2000).*

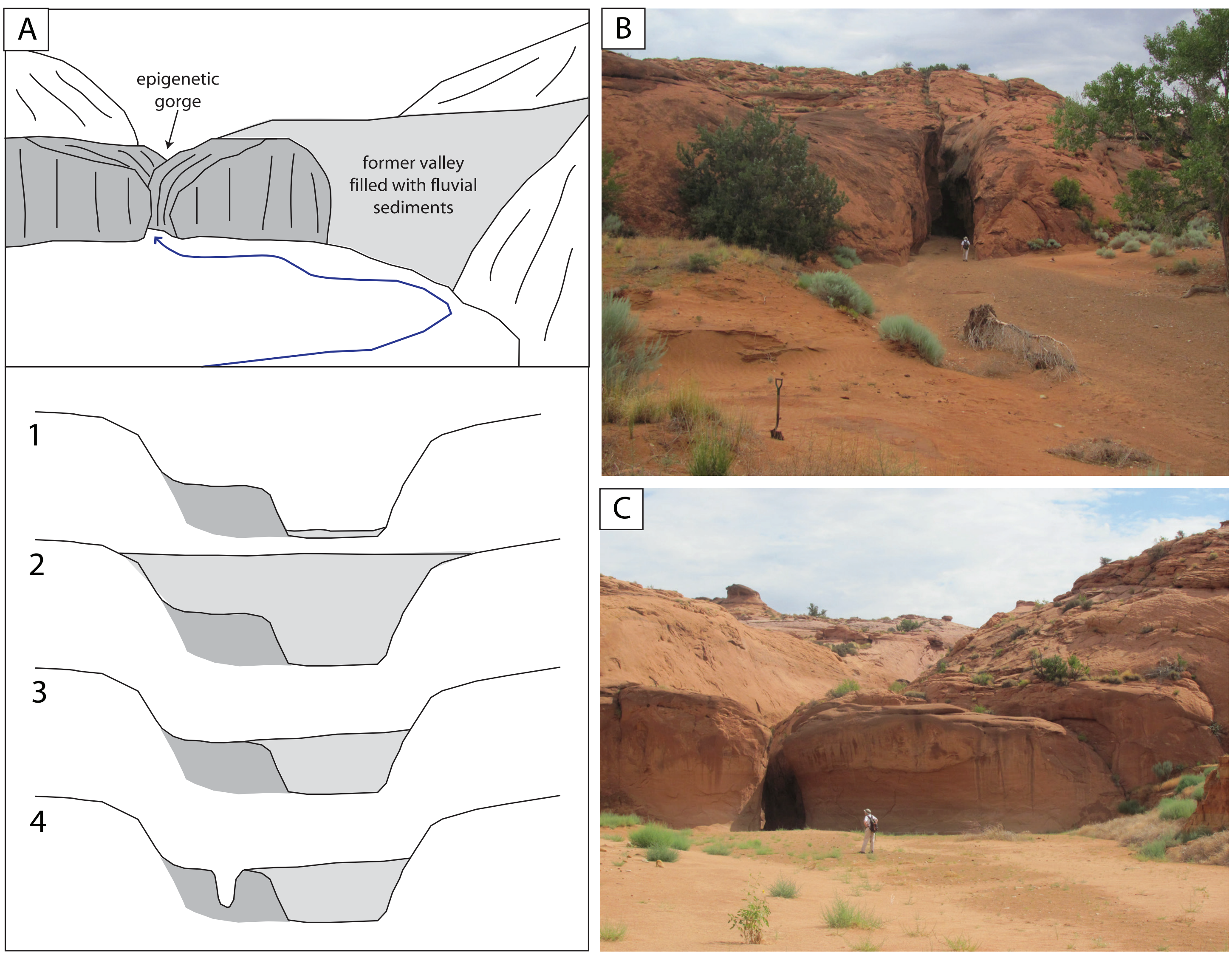

Figure 6. *Cutting and filling of canyons. See figure 2 for locations of photos.* ***A.*** *Stages of evolution involving a bedrock spur (dark gray), burial, and cutting of a young, narrow canyon (from Ouimet and others, 2008).* ***B.*** *Upstream entrance to trunk slot #3;* ***C.*** *Upstream entrance to trunk slot #4. In both B and C, the sediment-filled, broader canyon lies to the right (south) of the slot canyon. From Loope and others (2014).*

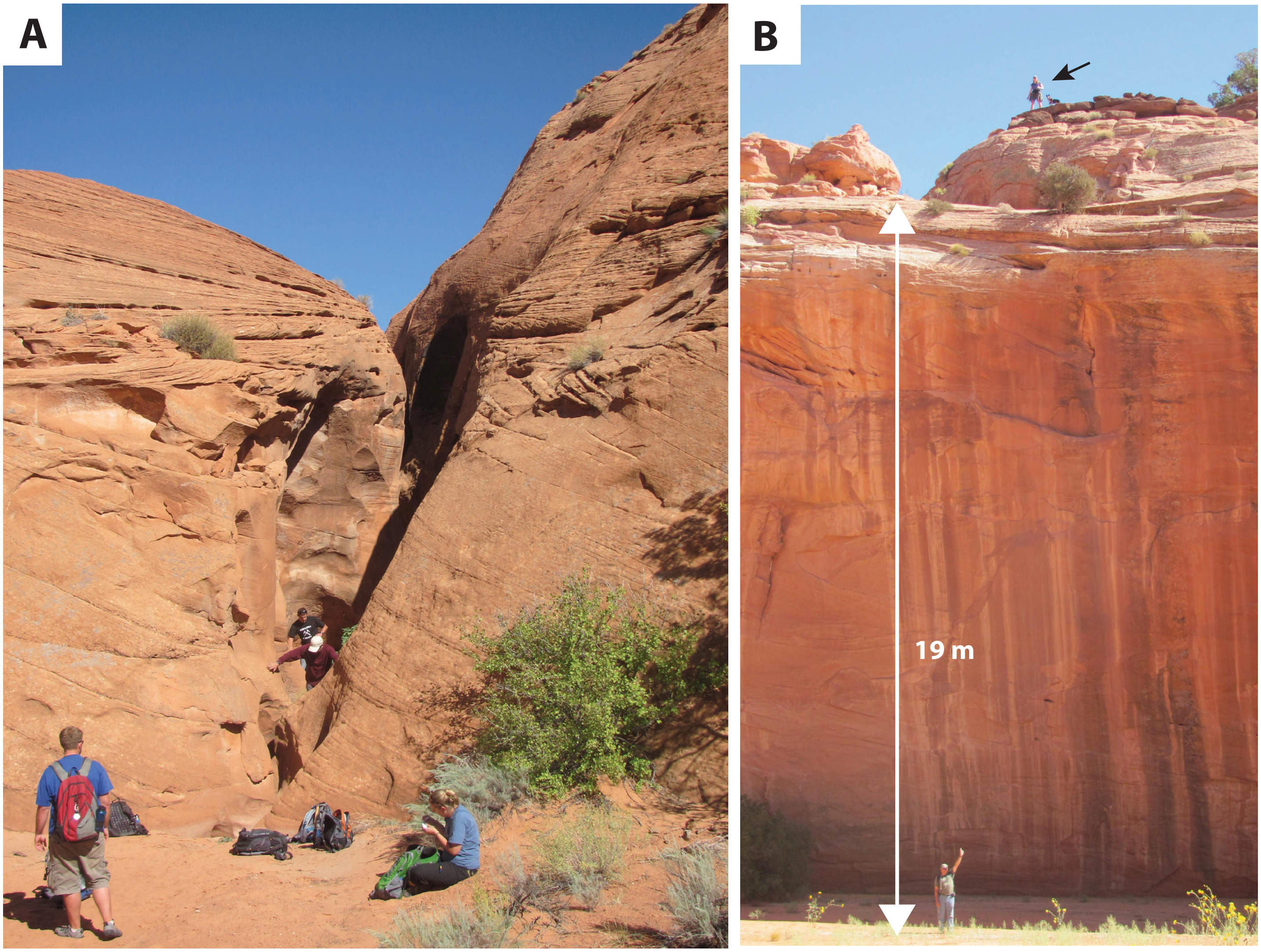

*Figure 7. **A.** Mouth of Brimstone slot at its confluence with Dry Fork. **B.** Head of the slot canyon is at tip of upper white arrow, 60 feet (19 m) above the floor of Brimstone Wash. Black arrow points to person for scale. Stream incised some of its fill and then cut the slot before abandoning it when it overflowed its (west) bank and reoccupied the broad canyon. It then rapidly excavated the remaining 60 feet (19 m) of fill in that canyon, leaving an "orphan slot" high, dry, and open. From Loope and others (2014).*

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