BRYCE CANYON NATIONAL PARK & THE GRAND STAIRCASE

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THE GRAND STAIRCASE

The Grand Staircase is a series of cuestas that extend from the Kaibab Plateau, which forms the north rim of the Grand Canyon, northward to the Pink Cliffs of Bryce Canyon National Park (figures 1 and 2). In the high plateaus section, the stratigraphic units were tilted toward the north when the area was uplifted along north-south trending normal faults. Because of this northern dip the rocks become progressively younger going northward from the Grand Canyon, and the resistant beds form prominent cliffs or cuestas. On the drive between Bryce Canyon and the Grand Canyon we will stop at the Forest Service Lookout Area to get an overview of the Grand Staircase. The first series of low cuestas are the Chocolate Cliffs capped by resistant Triassic Shinarump Sandstone which occurs between the easily eroded Moenkopi and Chinle beds. The second series of cliffs are the Vermillion Cliffs held up by the Wingate Sandstone. The Jurassic Navajo sandstone which can be seen at Zion makes up the White Cliffs. The Gray Cliffs consist of Cretaceous shales and sandstones. Finally, the Pink Cliffs which top the Paunsaugunt Plateau are composed of the Tertiary Claron Formation which can be observed at Bryce Canyon.

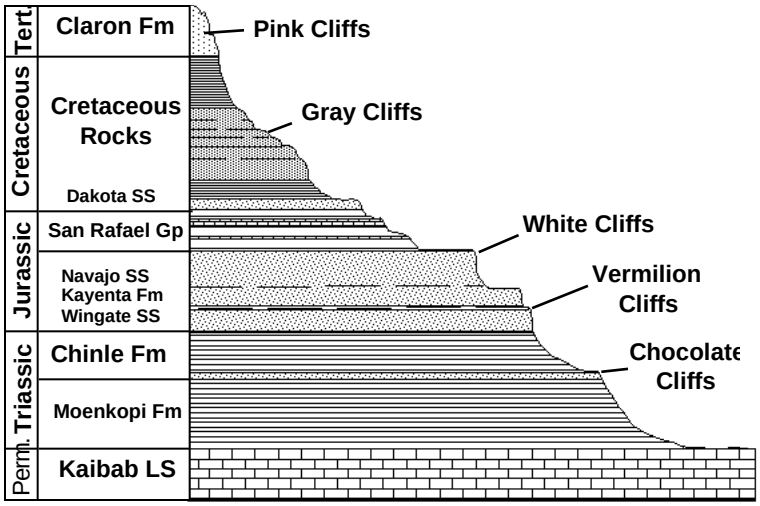

Figure 1. Stratigraphic units of the Grand Staircase.

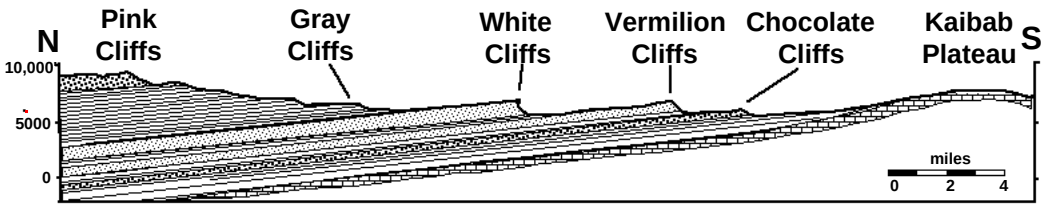

Figure 2. General north to south cross-section of the Grand Staircase.

BRYCE CANYON NATIONAL PARK

Introduction

The scenery at Bryce Canyon, with its unusual spires and hoodoos of colorful rocks, make it one of the most beautiful places on the Colorado Plateau. A descriptive Piute name for Bryce, Unka-timpe-wa-wince-pockich, means "red rocks standing like men in a bowl shaped Canyon" (Hirschmann, 1980).

Bryce Canyon is located in the high plateaus section of the Colorado Plateau, on the eastern side of the Paunsaugunt Plateau, which is bounded to the west by the Sevier Fault and east by the Paunsaugunt Fault (figure 4). Headward erosion of the fault scarp by the Paria River and its tributaries has produced the spectacular scenery of the Paria Amphitheater. Elevations range from 6,300 feet near the town of Tropic to 9,300 feet near Crawford Pass. The rim of Bryce Canyon is a drainage divide that separates tributaries to the Sevier River, which drain west into the Great Basin, from tributaries of the Paria River, which drain east to the Colorado River and Gulf of California.

Stratigraphy

Some of the youngest units we will be observing on this trip occur at Bryce Canyon where rocks range in age from Cretaceous through Pliocene (figure 5). The badlands topography of Bryce Canyon is carved into the Tertiary Claron Formation (previously called Wasatch Formation) which is assigned an age of Middle to Early Eocene. The Claron is divided into two members, the Upper White Limestone and Lower Pink Limestone. Most of the Upper White Limestone Member has been removed by erosion but it can still be observed at Bryce Point and Yovimpa Point at the south end of the park (Bowers, 1991). This cliff forming unit is more homogeneous in composition and texture than the underlying Pink Limestone Member and contains up to 90% carbonates. It contains freshwater gastropods and was deposited in a lacustrine (lake) or low energy fluvial environment.

The striking scenery at Bryce was created by differential erosion of colorful

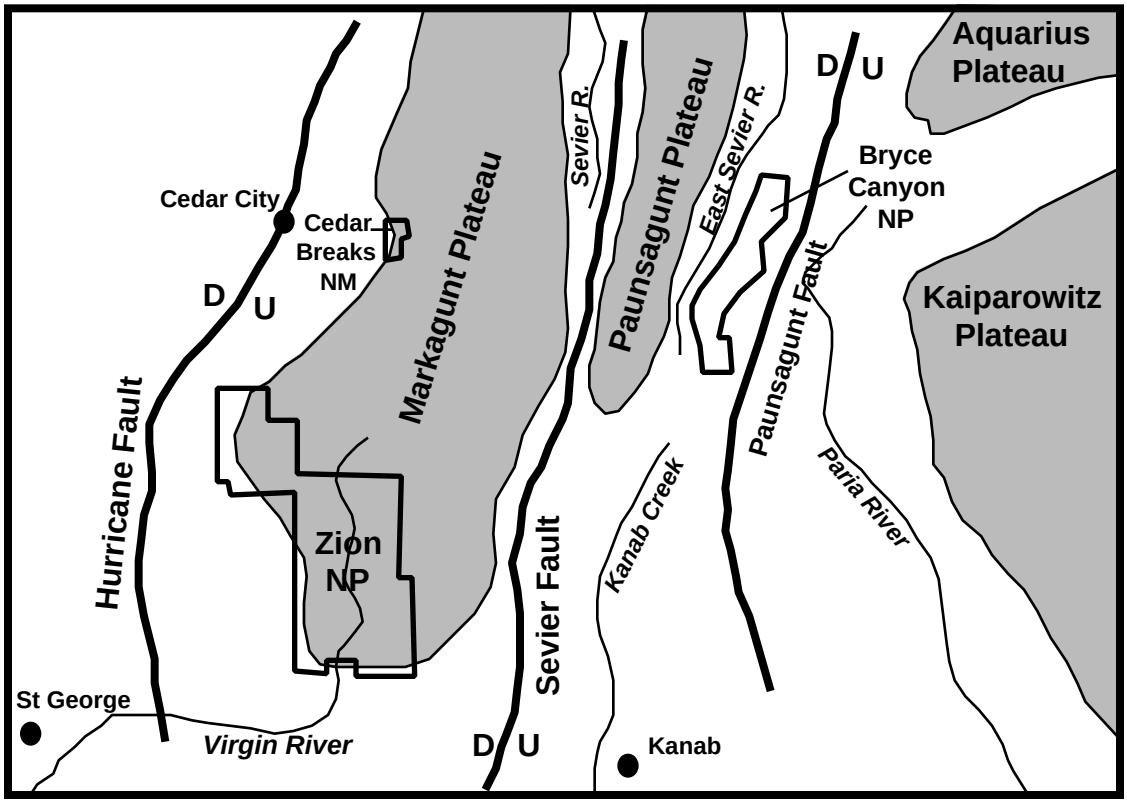

Figure 4. Map of southwestern Utah showing the major faults and plateaus (after Harris, and Tuttle, 1990).

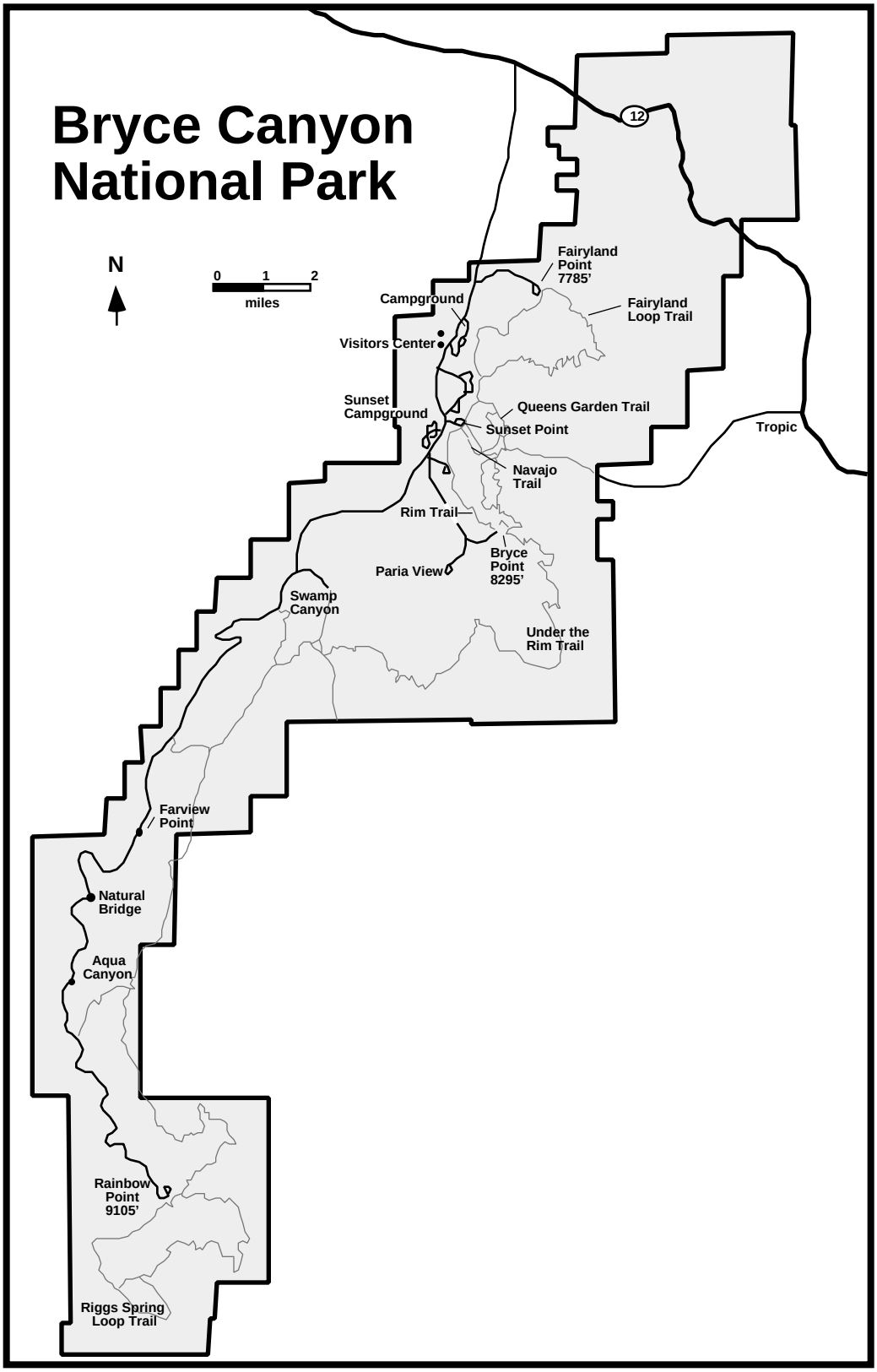

Figure 3. Map of Bryce Canyon National Park. (after National Park Service Map)

Age	Thick. (ft)		Description
Quaternary		**Q**	Unconsolidated alluvium (**Qal**), colluvium of slopewash or mass-wasting debris (**Qc**), landslide deposits (**Qls**), older alluvium and colluvium (**Qoac**), Pleistocene pediment deposits (**Qp**)
Pliocene	**0-80**	**QTsr**	**Sevier River Formation** Tan to light-gray, moderately sorted, conglomeratic sandstone and conglomerate with clasts of volcanic rocks.
Oligocene	**0-100**	**Tbm**	**Boat Mesa Conglomerate** Light-brown, tan and gray calcareous sandstone and conglomerate and light-gray to white limestone and conglomeratic limestone.
Eocene			**Claron Formation**, divided into the White Limestone Member (**Tcw**) and Pink Limestone Member (**Tcp**)
	0-300	**Tcw**	**White Limestone Member** White, light-gray, or tan, fine grained to microcrystalline, thick-bedded to massive, cliff-forming limestone with local thin bedded purplish-gray mudstone interbeds.
	400-700	**Tcp**	**Pink Limestone Member** Pale-pink, red, pale-orange, and tan, very fine-grained, thin- to thick-bedded limestone, argillaceous limestone, and dolomitic limestone with sparse thin interbeds of gray or tan calcareous mudstone and a basal conglomerate locally. Forms fluted cliffs, columns, spires, hoodoos and steep slopes.
Cretaceous	**0-700**	**Tw**	**Wahweap Formation** Upper 50-100 feet consist of light-gray to white, fine- to coarse-grained, cross-bedded sandstone and conglomeratic sandstone. Lower 600 feet is buff to light-brown, hard, fine-grained, lenticular sandstone interbedded with gray to tan mudstone, thin beds of light-gray or white, siltstone and very fine-grained sandstone.
Cretaceous	**1200-1700**	**Ks**	**Straight Cliffs Formation** White to light-gray, thick-bedded, massive, fine- to coarse-grained cross-bedded sandstone containing lenses of conglomerate, buff, tan and light-brown, very fine- to fine-grained sandstone with interbedded gray to tan mudstone, carbonaceous shale and thin coal.
Cretaceous	**700-1000**	**Kt**	**Tropic Shale** Gray to olive-gray marine shale with thin, very fine-grained sandstone beds, thin beds of tan bentonitic clay and a basal limestone concretion zone, contains marine fossils.
Cretaceous	**180-300**	**Kd**	**Dakota Sandstone** Interbedded buff to light brown sandstone, gray to tan mudstone, dark carbonaceous mudstone and coal.

Figure 5. Description of Stratigraphic Units at Bryce Canyon National Park (from Bowers, 1991)

sedimentary rocks of the Pink Limestone Member. This unit consist of interbedded very fine-grained limestone, calcareous mudstone and fine-grained sandstone and the color is variable including pale pink to red, pale orange, tan, and white. The beds are variable in texture and composition and the bedding features are often indistinct. At Bryce most of the exposures are covered with a layer of clay that has washed down from overlying beds, known as a stucco, which obscures the bedding and sedimentary structures. The less resistant beds contain greater amounts of clay and silt and the resistant beds contain a significant amount of dolomite. The Pink Limestone Member was deposited in a low energy fluvial and lacustrine environment. The indistinct bedding has resulted from destruction of sedimentary structures by pedogenic (soil forming) processes. Pedogenesis can impart a vertical internal fabric on the rocks which may be a contributing factor to the vertical erosion observed at Bryce.

An Unconformity separates the Claron Formation from the underlying Cretaceous units. The Wahweap and Straight Cliffs Formations are dominantly sandstones, with interbedded mudstones and conglomerates. They were deposited in fluvial or flood plain environments. Below the Straight Cliffs Formation is the Tropic Shale, a fossiliferous, marine unit composed of gray shale and fine grained sandstones.

Structure

The Paunsaugunt Fault, a north striking normal fault, marks the eastern limit of the Paunsaugunt Plateau (figure 6). The fault dips 60 to 75^{o} to the west and has from a few hundred to 1,400 feet of displacement. The high angle Basin and Range type faulting of the High Plateaus occurred during late Miocene between 8 and 5 million years ago. The east-facing escarpment of the plateau occurs on the down dropped side of the fault because of more rapid erosion of the rocks exposed on the upthrown block. Westward retreat of the escarpment has left little topographic expression of the fault.

An east-west trending thrust fault, known as the Rubys Inn Fault, occurs in the northern end of the park. Evidence for the fault includes; limestone beds of the Claron that are repeated by thrusting, Cretaceous rocks that have been thrust over vertical and overturned beds of Claron, plus striae and grooves on fault surfaces within the Claron Formation. The thrusting post-dates deposition of the Claron Formation and most likely occurred between middle Eocene and Oligocene (Bowers, 1991). The thrust faults are similar to other compressional structures of southern Utah which formed during the Sevier orogeny. However, the Rubys Inn Thrust is younger than the Sevier structures which are middle to late Cretaceous. Lundin (1987) suggest that thrusting originated during the Sevier Orogeny and was reactivated after deposition of the Claron Formation.

The rocks at Bryce contain numerous joints and fractures. Joints differ from faults in that there is no movement or displacement of the rocks on either side of the fracture. The joints are near vertical and occur in parallel groups, or sets forming a complex system trending N 30^{o}W and N21^{o}E (Bezy, 1991). The joints formed either as a result of strain generated by large-scale crustal movement, or the release of pressure by erosion and removal of overlying sediments.

Badlands Formation

Badlands is a name for highly gullied landscapes that occur throughout the west, where easily eroded rocks are highly dissected. The badlands of Bryce are unique with labyrinths of box canyons, sheer walls, mazes of fin-like ridges, fluted columns, and pedestals (Bezy, 1991). The landscapes of Bryce are distinctive because of a very special combination of factors such as rock type, geographic position and climate. Bryce Canyon is not a true canyon but a series of amphitheater shaped basins formed by headward erosion along the Paunsaugunt fault scarp. The rates of weathering and erosion at Bryce are very rapid, with the rim retreating 1.5 feet (.5 m) every 100 years. Tributaries coming off the rim drop 500-1500 ft in less than 1 mile. This very steep gradient means large quantities of material can be carried away by streams during flash floods. Protective soils and vegetation cannot develop on the steep slopes, further enhancing the erosive power of running water. Bryce Canyon

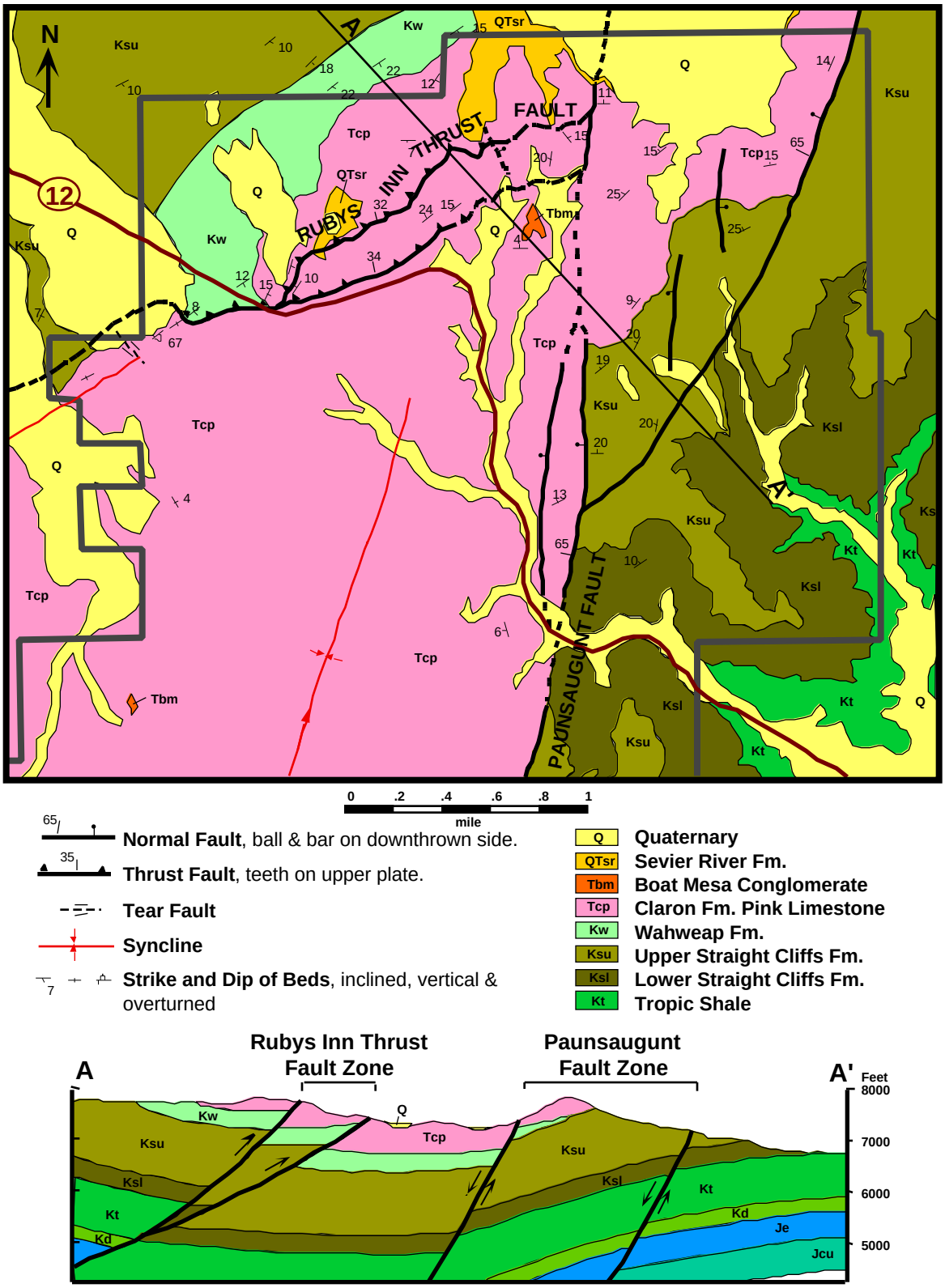

Figure 6. Geologic map and cross section of the northern corner of Bryce Canyon National Park (modified from Bowers, 1991).

experiences up to 275 freeze-thaw days per year, making frost wedging an important weathering process in this area. Frost wedging occurs when water within the rocks freezes and expands, breaking the rocks apart. Repeated melting and freezing of the water accentuates this process. South facing slopes experience more freeze-thaw cycles than north facing slopes, resulting in preferential weathering and the asymmetric appearance of many of the landforms.

A gridwork of horizontal bedding planes cut by vertical joints determines the pattern, shape and detail of the badlands. Water flow is focused along joints accentuating weathering and erosion of these planes of weakness. Eventually the joints are enlarged, forming deep slots, leaving behind vertical walls of rock. Windows and arches can form within these walls of rock. Further dissection causes the roofs of arches to collapse, resulting in vertical pillars known as hoodoos.

The Pink Limestone Member of the Claron Formation is composed of rocks with varying degrees of hardness and resistance to weathering. Alternating beds of carbonate-rich and carbonate-poor rocks gives the canyon walls their characteristic horizontal grooves and protrusions. The massive layers consisting of freshwater limestone and dolomite resist erosion, whereas, the bedded clay and silt rich layers readily give way to erosion. The massive carbonate rich units often form pedestals of protective cap rocks that shield the softer, underlying beds from erosion.

Alluvial Fans

Alluvial fans are cone shaped deposits that form where a stream confined to a narrow canyon suddenly flow into a flat valley and are common along fault scarps. The sudden decrease in stream gradient and velocity, lowers the stream capacity (ability to transport sediment) resulting in deposition and accumulation of sediment. As Bryce Creek flows from the rim out onto the floor of the amphitheater its gradient decreases from 1500 to 200 feet/mile. This dramatic decrease in gradient along with the rapid erosion and abundant source of sediment, has resulted in the accumulation of an alluvial fan along Bryce Creek. Sediment of alluvial fans is transported in three ways: stream flow, debris flow and mudflow (Prothero, 1990). In arid regions the stream flow occurs in flash floods. The streams, chocked with sediment, form a braided stream pattern with each flood cutting a new channel leaving older channels to be filled with gravel. The stream deposits are sorted, well stratified and consist of cross bedded sandstones and lag conglomerates. In contrast the debris and mud flow deposits are very poorly sorted, consisting of a chaotic jumble of boulders, cobbles, pebbles, sand, silt, and clay. The grain size of alluvial fan deposits ranges from boulders down to clay size with a particle size decrease down fan. In the rock record alluvial fans are preserved as coarsening upwards sequences of cross-bedded sandstone, conglomerates and unsorted debris flow deposits.

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Exercises

Faults

1) We will stop to observe the Paunsaugunt and Rubys Inn Faults along highway 12 (see figure 6). For each fault describe the outcrop or surface expression of the fault. What stratigraphic units are exposed? What is the strike and dip of the beds? are any small scale structures present?

Paunsaugunt Fault

Rubys Inn Fault

Bryce Canyon Alluvial Fan

1) Observe the characteristics of the alluvial deposits on the trail to Tropic. Record your observations and locate the sites where you made them on the topographic map. At each site observe features such as grain size, sorting and sedimentary structures. Be sure to make observations at proximal, mid-fan and distal sites.

2) How do the sediments change as you go down Bryce Canyon?

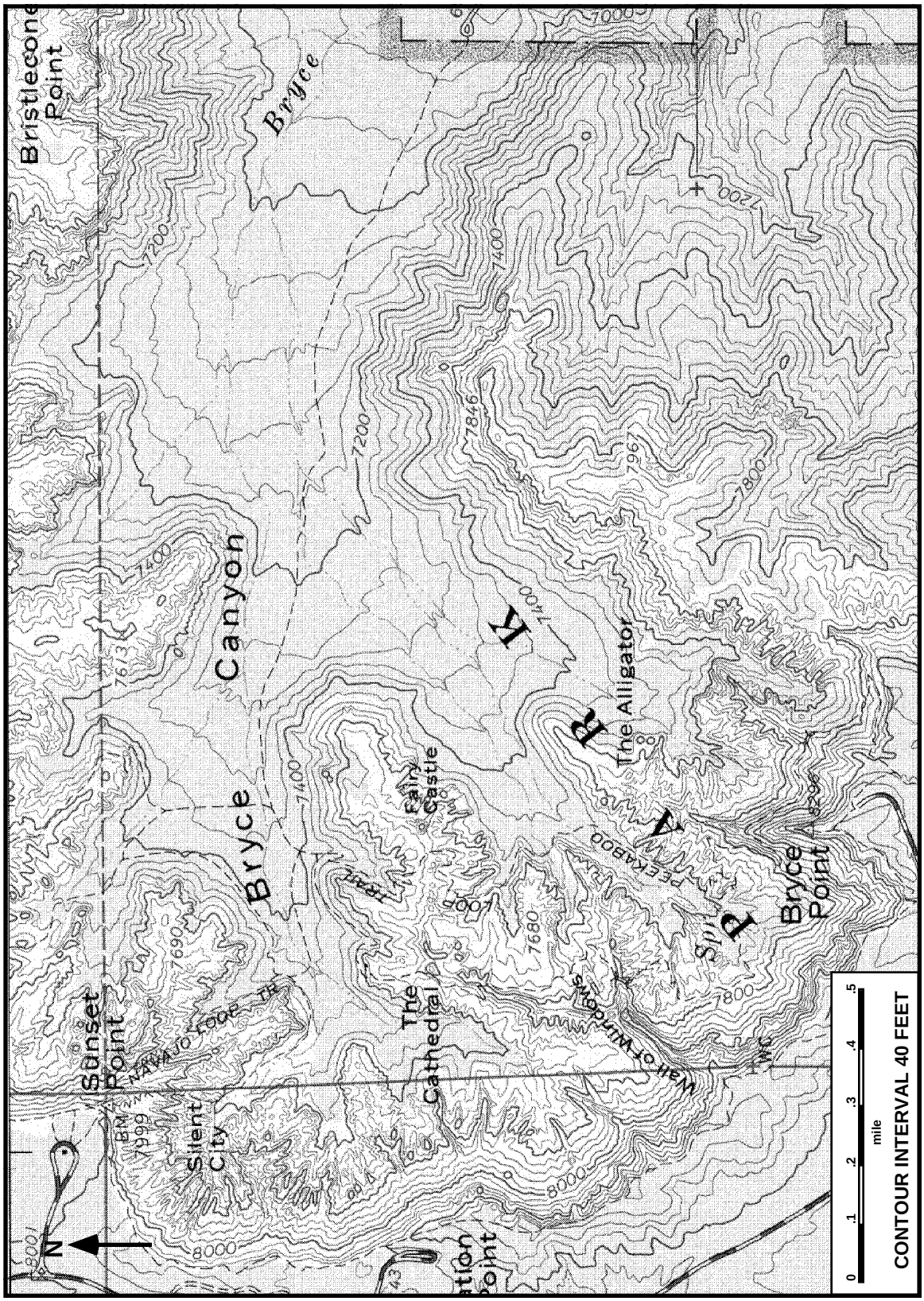

Figure 7. Topographic map of Bryce Canyon.

Definitions

Define the following terms and give examples of each feature.

Alluvial fan

Badlands

Cuesta

Frost wedging

Hoodoo

Joint

Intermittent stream

Natural stucco

Normal fault

Thrust fault