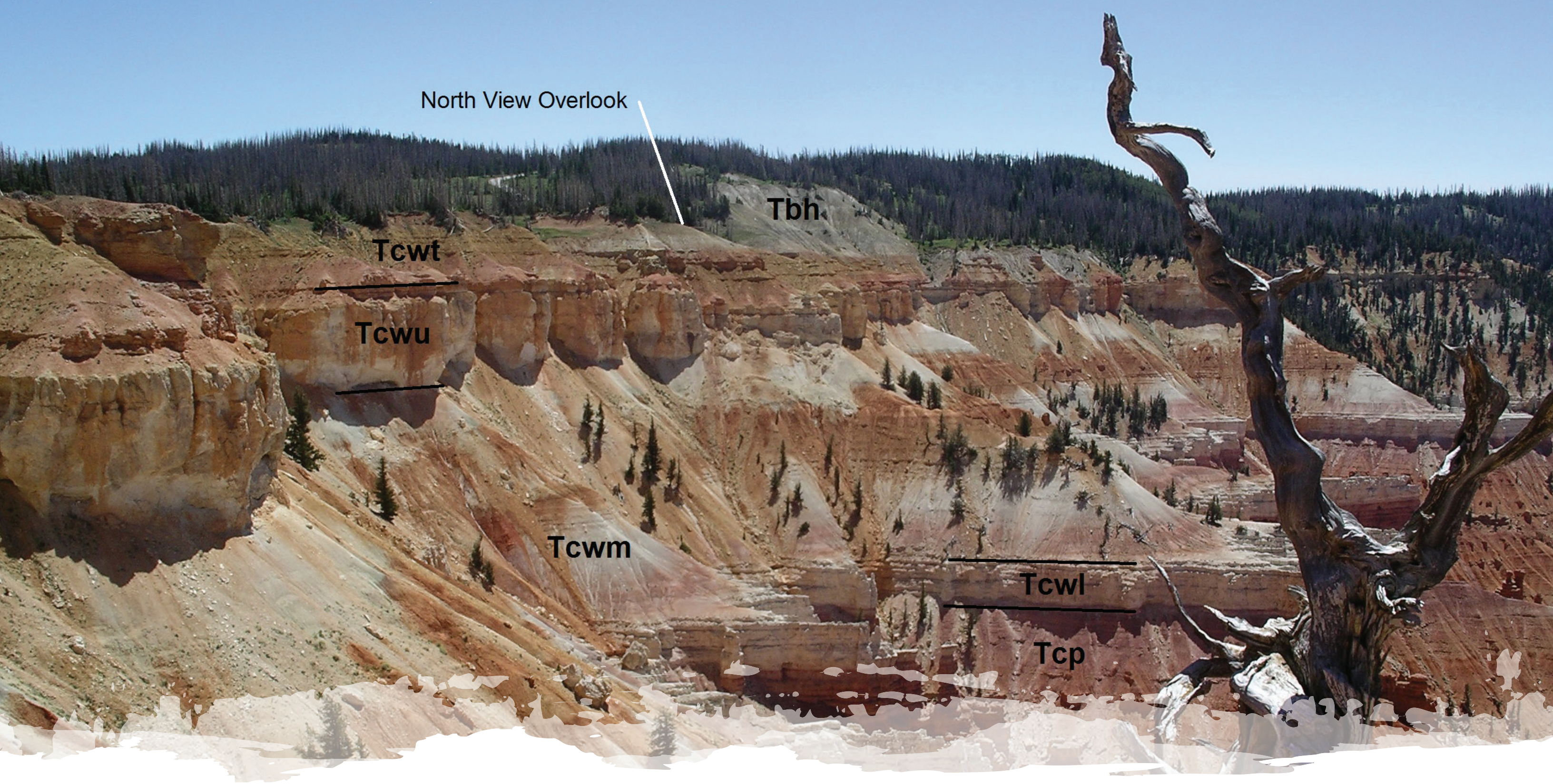

Cedar Breaks National Monument, North View Overlook

Robert F. Biek[1] and Peter D. Rowley[2]
[1]Utah Geological Survey, P.O. Box 146100, Salt Lake City, UT 84114-6100, bobbiek@utah.gov
[2]Geologic Mapping Inc., P.O. Box 651, New Harmony, UT 84757

Utah Geosites
2019
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M. Milligan, R.F. Biek, P. Inkenbrandt, and P. Nielsen, editors

Cover Image: *View east to North View Overlook at Cedar Breaks National Monument showing upper Claron and lower Brian Head strata.*

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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

Figure 1. *View west from the North View Overlook. Cedar Canyon is at left, beyond which is Cedar Valley and mountains bordering its west side.*

INTRODUCTION

Cedar Breaks National Monument straddles the western rim of the Markagunt Plateau, and, at over 10,000 feet (3050 m) in elevation, offers spectacular views westward into the adjacent Great Basin (figure 1). The heart of the monument consists of a series of overlooks along a beautiful, 4-mile-long (6 km), west-facing amphitheater that is eroded into the plateau's margin. These overlooks are adorned with a fantastic variety of hoodoos and sculpted fins eroded from alternating resistant and soft, jointed and fractured layers of the Claron Formation. Of these overlooks, the North View Overlook encapsulates the entire geologic story preserved at Cedar Breaks—a history not only of the enigmatic Claron Formation, but also of the demise of its depositional basin and eventual burial by volcanic sediments of the Brian Head Formation.

LOCATION

The North View Overlook is near the north end of Cedar Breaks National Monument on Utah Highway 143. The overlook itself is open year round, but for much of the year during the extended winter season, it is only accessible via Parowan Canyon or Panguitch; the park and its facilities are closed during the winter. During summer months, the overlook is also accessible from Cedar City via Utah Highways 14 and 148. The overlook is at an elevation of nearly 10,500 feet (3200 m); a short, level paved trail leads from the parking area to the overlook at latitude 37° 39' 23.6", longitude 112° 50' 0.4". Figures 2, 3, and 4 provide a geologic map, stratigraphic column, and cross section of the overlook area.

STRATIGRAPHY

Claron Formation

The Claron Formation contains some of the most visually arresting rocks in southwestern Utah—they form the Pink Cliffs, the uppermost riser and tread of the Grand Staircase, that great sequence of resistant and non-resistant sedimentary strata that steps up from the Grand Canyon northward to Bryce Canyon and Cedar Breaks. The Claron's multi-hued pink, orange, and white sandstone, siltstone, mudstone, and minor limestone were deposited in stream, floodplain, and minor lake environments in early Tertiary time. These environments were in a high-elevation basin bounded by highlands created by compressional deformation during a mountain-building event known as the Laramide orogeny. The pink member was deposited on floodplains and alluvial plains with channel conglomerates along basin margins, whereas the white member is lacustrine near the center of the basin and interbedded with alluvial-plain strata along its margins (Goldstrand, 1990, 1991, 1992, 1994; Bown and others, 1997). The formation is divided into two members, a lower pink member and a comparatively thin upper white member (figure 5). The Claron's upper white member is readily divisible into four informal parts: two, white, cliff-forming limestone units separated by intervening colorful, variegated mudstone units much like that of the underlying pink member (Rowley and others, 2013; Biek and others, 2105).

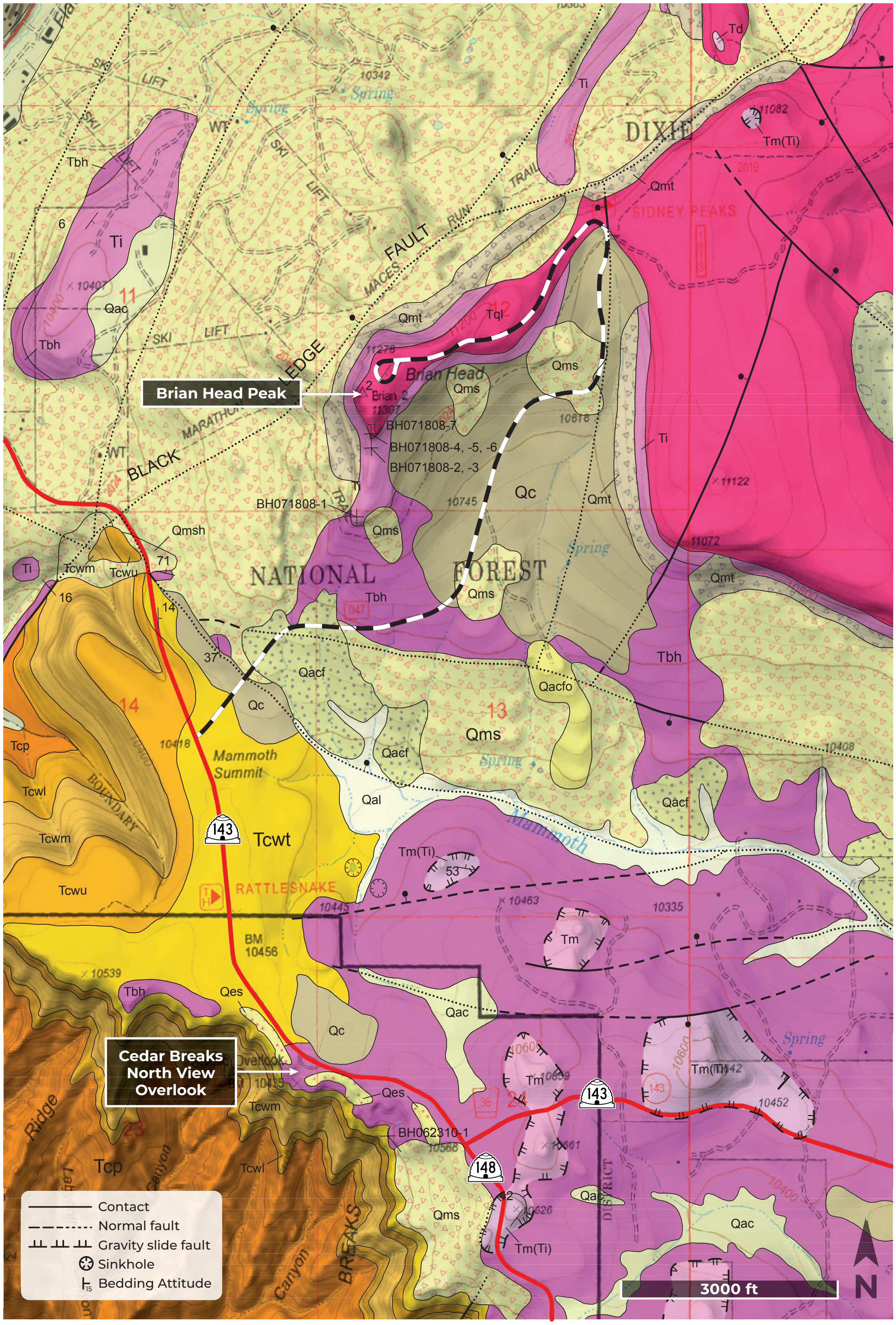

Figure 2. Geologic and location map of the overlook area. The overlook rests on the lowermost Brian Head Formation (pink on map), but it is the Claron Formation (orange and yellow on map), eroded into a vast amphitheater, that visitors come to see. Note the large area of modern landslides (yellow with red triangle pattern) that resulted from failure of the Brian Head Formation. The Brian Head ski area, and the southern end of the Yankee Meadows graben, is in the upper left part of the map. The seldom visible contact of the Brian Head and Claron Formations is well exposed in a steep, cliffy area several hundred yards southeast of the overlook. That contact marks the inception of volcanism in southwestern Utah. Map unit names are shown on figure 3. Various young surficial deposits are shown in light yellow. From Rowley and others (2013).

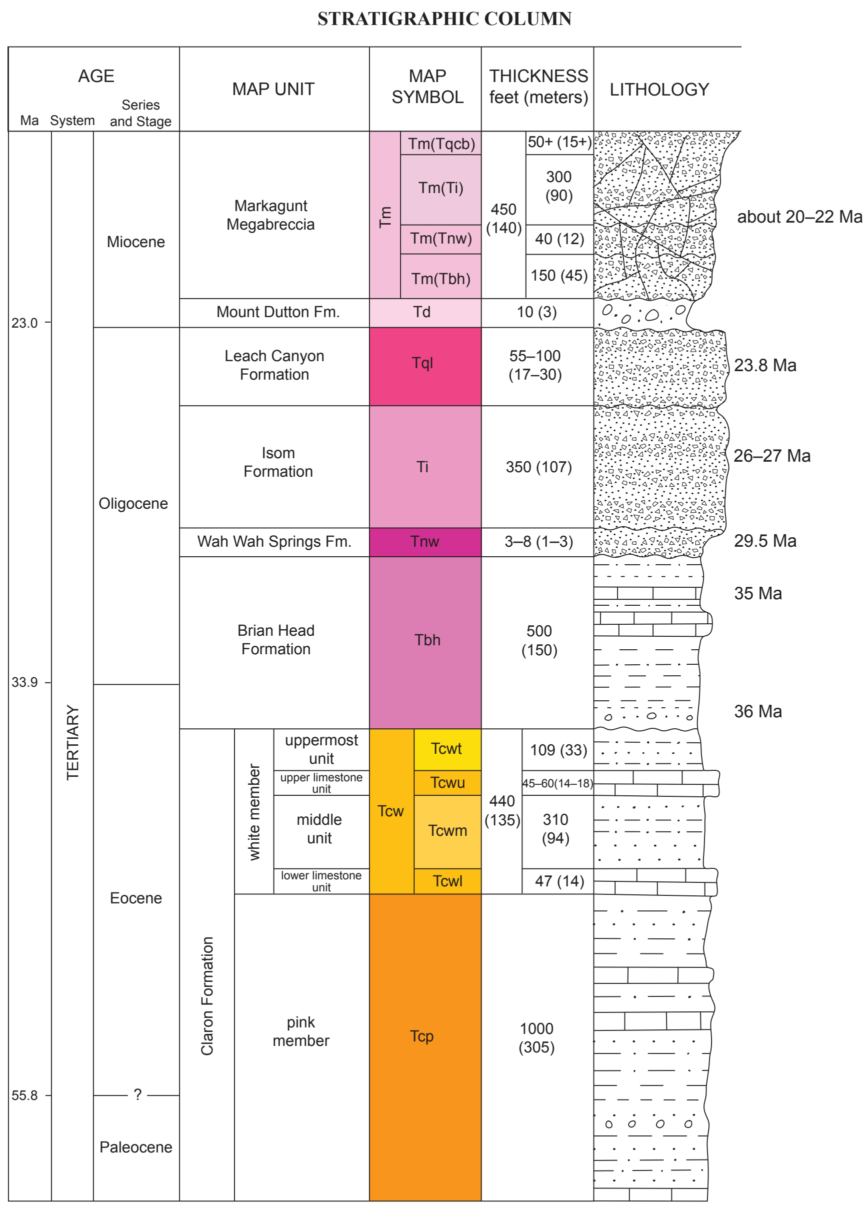

Figure 3. Stratigraphic column showing rock units of the overlook area. The Markagunt Megabreccia is the deposit of the Markagunt gravity slide. From Rowley and others (2013).

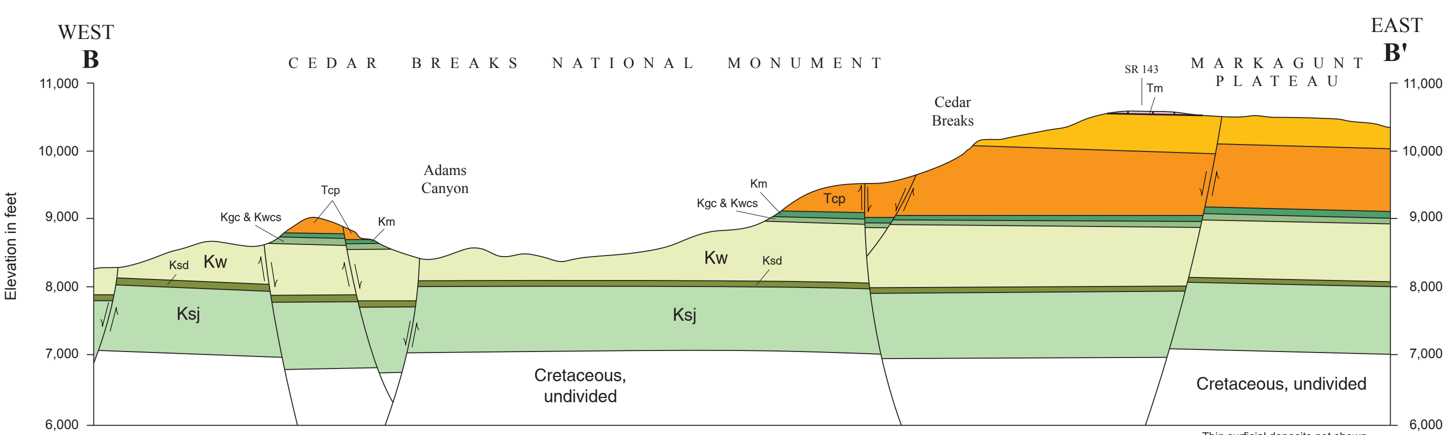

Figure 4. Cross section through Cedar Breaks National Monument from Rowley and others (2013). Note that line of cross section lies just south of and covers a wider area than that shown in figure 2. Cretaceous strata: Ksj = John Henry Member and Ksd = Drip Tank Member of Straight Cliffs Formation; Kw = Wahweap Formation, Kgc and Kwcs = Grand Castle Formation and capping sandstone member of Wahweap Formation; Km = Cretaceous strata on Markagunt Plateau. Tertiary strata: Tcp = pink member and Tcw = white member of Claron Formation; Tm = Markagunt gravity slide.

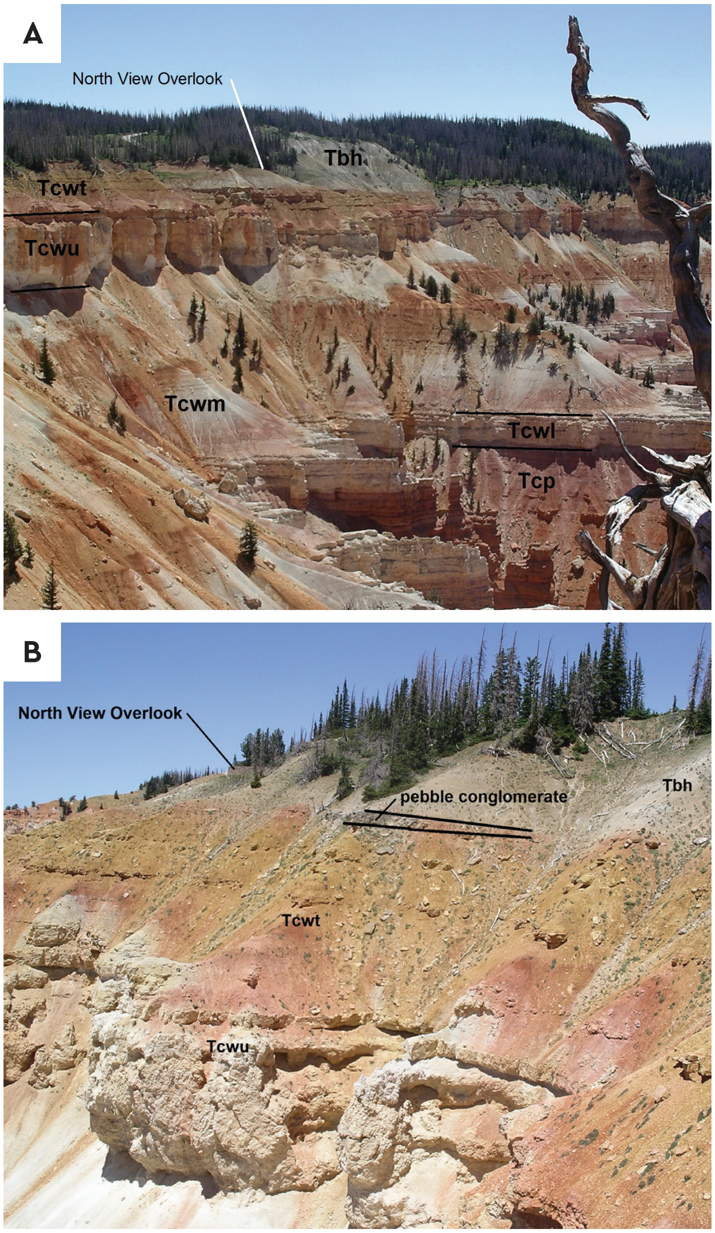

***Figure 5. A.** View east to North View Overlook at Cedar Breaks National Monument showing upper Claron and lower Brian Head strata. The North View Overlook is on basal strata of the gray volcaniclastic unit of the Brian Head Formation (Tbh). **B.** View northwest to overlook, showing variegated uppermost Claron strata (Tcwt) and contact with Brian Head Formation (Tbh). The top of the Claron is marked by a thin, calcareous, pebbly conglomerate that lacks volcanic clasts and thus predates volcanism in the region; this conglomerate marks an unconformity, a surface of erosion and therefore a gap in geologic time where no strata are preserved that might record past environments. Tcp = pink member; Tcwl = lower limestone unit of the white member, Tcwm = middle white unit, Tcwu = upper limestone unit, Tcwt = variegated, nontuffaceous mudstone, siltstone, and minor sandstone and pebble conglomerate unit of the Claron Formation.*

What makes the Claron so interesting is that most of its fine-grained floodplain and stream deposits were extensively modified by soil-forming processes such that it now represents a stacked sequence of paleosols (ancient soils) (Mullett and others, 1988a, 1988b; Mullett, 1989; Davis and Pollock, 2010). The formation locally contains abundant crayfish burrows and trace fossils of ants, wasps, and bees that record nest activity during soil formation (Bown and others, 1995a, 1995b, 1997). Crayfish burrows (figure 6) in Claron strata of the Markagunt Plateau record a relatively deep and highly fluctuating water table in the pink member, and a relatively shallow water table in alluvial parts of the white member (Hasiotis and Bown, 1997).

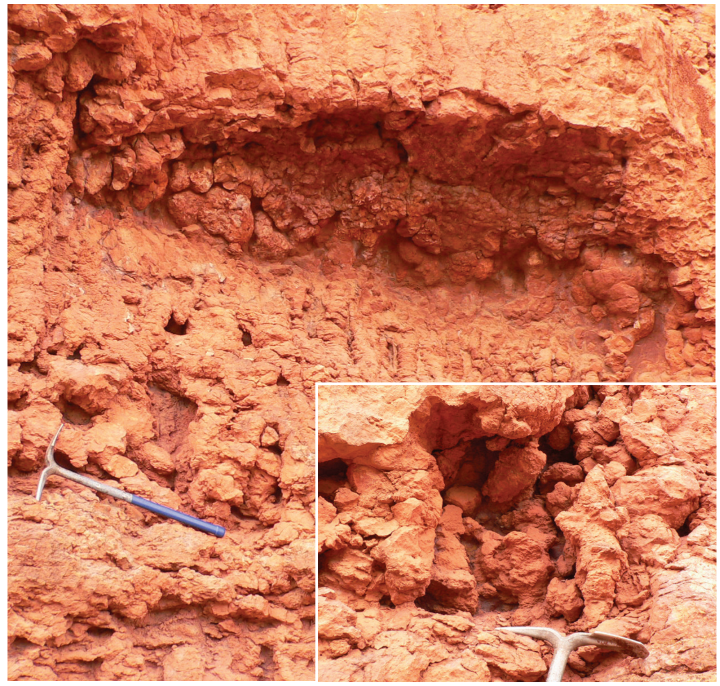

***Figure 6.** Intensely bioturbated (burrowed) lower part of the pink member of the Claron Formation at the west edge of the Markagunt Plateau in First Left Hand Canyon, north of Cedar Breaks. Inset shows close-up of closely packed crayfish burrows.*

But as renowned as the Claron is for its spectacular scenery, it is equally known among geologists for being frustratingly unfossiliferous (apart from trace fossils such as burrows) and devoid of datable volcanic ash or age-constraining detrital zircons (a hard, resistant mineral that contains trace amounts of uranium and thorium, making it amenable to radiometric dating). The lack of fossils is disheartening in that the formation was deposited during a period of abrupt mammalian diversity that accompanied a gradual 6-million-year-long global warming trend culminating in the Eocene Climatic Optimum (see, for example, Röhl and others, 2000). Oxidation, burrowing, and weathering associated with the formation of paleosols doubtless led to the destruction of what otherwise may have been highly fossiliferous beds. The lack of volcanic ash stems directly from the near cessation of volcanism that accompanied relatively rapid, “flat-slab” subduction at the western margin of North America during the Paleocene to early Eocene (65 to 45 million years ago), when the Claron was deposited (see, for example, Dickinson, 2006, and Humphreys, 2009).

Cedar Breaks National Monument is justly famous for its hoodoos that adorn the western escarpment of the Markagunt Plateau. Hoodoos form by relatively rapid erosion of alternating resistant and less-resistant beds in combination with pervasive jointing, high precipitation rates, and some 200 freeze-thaw cycles per year. Freeze-thaw cycles loosen rock, whereas summer thunderstorms work to wash it away. Importantly however, new research shows that it is the local stress field that gives rise to the hoodoos; erosional processes act within that stress field to create these fantastic forms (Bruthan and others, 2014). The vertical stress imparted by the weight of a resistant caprock holds grains together; as erosion removes some grains, the stress between the remaining grains increases, holding them more tightly together and making it harder to erode the sides of the hoodoos. Erosion is thus slowed and the hoodoos tend to "grow" taller over time. In addition, much of the precipitation that falls on the hoodoos quickly evaporates, leaving behind any cement that the water started to dissolve and thus making the rind of the hoodoos more resistant (called case hardening).

Sinkholes are common in the pink member in the central Markagunt Plateau (figure 7) (Moore and others, 2004; Hatfield and others, 2010; Biek and others, 2011; Rowley and others, 2013). They form due to the region's abundant precipitation and susceptible rocks—slightly acidic rain and snowmelt serves to dissolve carbonate cement in Claron strata, creating karst topography with interconnected open fractures and caves. Large sinkholes visible on 1:20,000-scale aerial photographs are plotted on the regional geologic map of Biek and others (2015), and doubtless many smaller sinkholes are present. These sinkholes capture local runoff and serve to shunt shallow groundwater rapidly down dip where it emerges as springs, including the large Mammoth, Asay, and Cascade Springs (Wilson and Thomas, 1964; Spangler, 2010; Weaver, 2010). Karst terrain developed in the pink member of the Claron Formation makes the groundwater of the Markagunt Plateau particularly susceptible to contamination.

Figure 7. Sinkhole on the southeast flank of Blowhard Mountain, immediately west of Utah Highway 148. The sinkhole formed by dissolution of carbonate cement in the pink member of the Claron Formation and here propagated upward through overlying Markagunt gravity slide residuum.

Conglomerate at Boat Mesa

Claron deposition ended by the latest middle Eocene, about 38 million years ago, with deposition of the conglomerate at Boat Mesa above an erosionally beveled surface. At Cedar Breaks and elsewhere on the Markagunt Plateau, this conglomerate is thin, 1 to 10 feet (0.3–1 m) thick; still, it marks a widespread unconformity in the Claron basin (Biek and others, 2015). Farther east on the Paunsaugunt Plateau where the conglomerate is best developed and as much as 100 feet (30 m) thick, this unconformity cuts gently down section from north to south. This pebbly conglomerate contains rounded clasts of chert, quartzite, and Claron limestone, but lacks volcanic or intrusive clasts. The lack of igneous clasts suggests that the conglomerate predates the inception of volcanism in this part of southwest Utah. Still, the conglomerate contains a robust suite of late Eocene detrital zircons that yielded a U-Pb detrital age of 37.97 +1.78/-2.70 Ma (Biek and others, 2015). The conglomerate at Boat Mesa represents deposits of braided-stream channels and minor floodplains incised into the Claron Formation.

Brian Head Formation

The North View Overlook itself rests on the lowermost Brian Head Formation, named for poor exposures of white volcaniclastic mudstone, siltstone, sandstone, volcanic ash, micritic limestone, and minor conglomerate and multi-hued chalcedony at its type area of Brian Head peak, visible just 1.5 miles (2.5 km) north of the overlook (see Brian Head peak geosite). These strata, rich in volcanic ash, were deposited in low-relief fluvial, floodplain, and lacustrine environments (Sable and Maldonado, 1997).

The contact of Brian Head and Claron strata is visible and well exposed a few hundred yards east of the overlook, where a thin, 35.77 ± 0.28 Ma rhyolitic air-fall tuff marks the base of the Brian Head Formation (figure 8). Several additional radiometric ages from Brian Head strata from across the region show that it was deposited from about 37 to 30 million years ago (Biek and others, 2015). The formation is thus mostly late Eocene in age, reaching into the lower Oligocene to which it was previously assigned; it forms the base of the volcanic section in southwestern Utah.

Figure 8. *Basal Brian Head strata just southeast of the North View Overlook at Cedar Breaks National Monument (see figure 3 for location). Utah Geological Survey paleontologist Don DeBlieux (standing) and Gary Hunt (former UGS geologist) are at contact with underlying Claron Formation. Inset shows thin rhyolitic ash (the upper part of which is a deep reddish brown) at base of the Brian Head Formation that yielded a radiometric age on zircon of about 36 million years.*

The Brian Head Formation is known for abundant trace fossils, including possible crayfish burrows and root traces (Golder and Wizevich, 2009; Golder and others, 2009), but aside from its basal variegated interval it is surprisingly unfossiliferous. It is also known for its colorful beds of chalcedony in various shades of white, gray, yellow, red, black, and brown, all typically with a white weathering rind. The chalcedony, probably derived from remobilization of silica in glass shards from the tuff beds, forms resistant beds commonly 1 to 3 feet (0.3–1 m) thick but locally as much as 8 feet (2.5 m) thick, and may have resulted from silicification of limestone beds (Maldonado, 1995; Sable and Maldonado, 1997; Schinkel, 2012). Being resistant, the chalcedony commonly litters slopes developed on Brian Head strata, and it was commonly used for tools and arrowheads by early Native Americans.

Above all, however, because of its abundant smectitic clay derived from weathered volcanic ash, the Brian Head Formation is known for its swelling soils and for its susceptibility to landsliding. Nearly all exposures on steep hillsides form large landslide complexes, the largest of which fills the 15-mile (24 km) length of Yankee Meadows graben just north of Cedar Breaks National Monument. The non-resistant, clay-rich Brian Head Formation was also the principal detachment surface for the early Miocene (23 to 21 million-year-old) Markagunt gravity slide (Hacker and others, 2014; see Sidney Peaks geosite).

STRUCTURE

Cedar Breaks National Monument lies at the western edge of the Markagunt Plateau, on the southwestern margin of Utah's High Plateau's physiographic province. This region is a structural and stratigraphic transition zone between the highly extended Great Basin to the west and the colorful, mostly flat-lying strata of the Colorado Plateau to the east. The plateau itself is a gently east-tilted fault block bounded on the west by the active Hurricane fault (on the east side of Cedar City) and the Parowan and Paragonah faults (on the south and east sides of Parowan Valley) (figure 9).

Between Cedar City and Parowan, the western margin of the Markagunt Plateau is cut by high-angle normal faults that create a series of horsts (fault blocks that are uplifted) and grabens (fault blocks that are downthrown) that step down from the plateau to the adjacent Great Basin (figure 10) (Maldonado and others, 1997; Biek and others, 2015). The most prominent of these faults is the active Hurricane fault at the base of the plateau east of Cedar City, which has a down-to-the-west vertical displacement of at least 6000 feet (1800 m) (Hurlow, 2002; Lund and others, 2007). Overall, the collection of horsts and grabens forms a highly faulted relay ramp between the Paragonah fault and the Hurricane fault (figure 11).

Cedar Breaks, as with Bryce Canyon National Park to the east, is dominated by beautiful and starkly contrasting pink and white sedimentary rocks of the Claron Formation eroded into pictur-

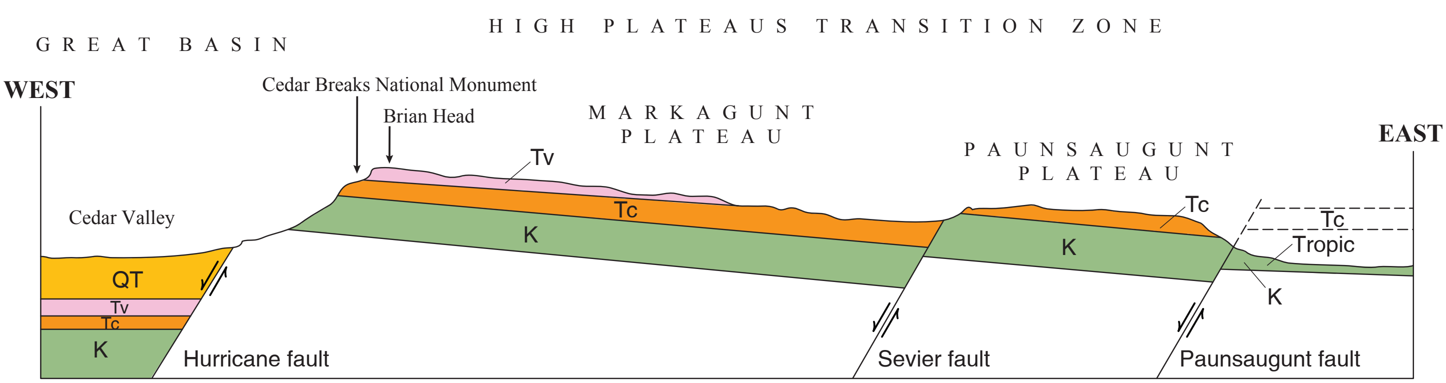

Figure 9. *Schematic west-to-east cross section through the central Markagunt and Paunsaugunt Plateaus. Note gentle east dip of strata in the plateaus, which are bounded by the Hurricane, Sevier, and Paunsaugunt faults. CBNM = Cedar Breaks National Monument. QT = Quaternary-Tertiary basin fill, Tv = Tertiary volcanic rocks, Tc = Claron Formation, K = Cretaceous strata.*

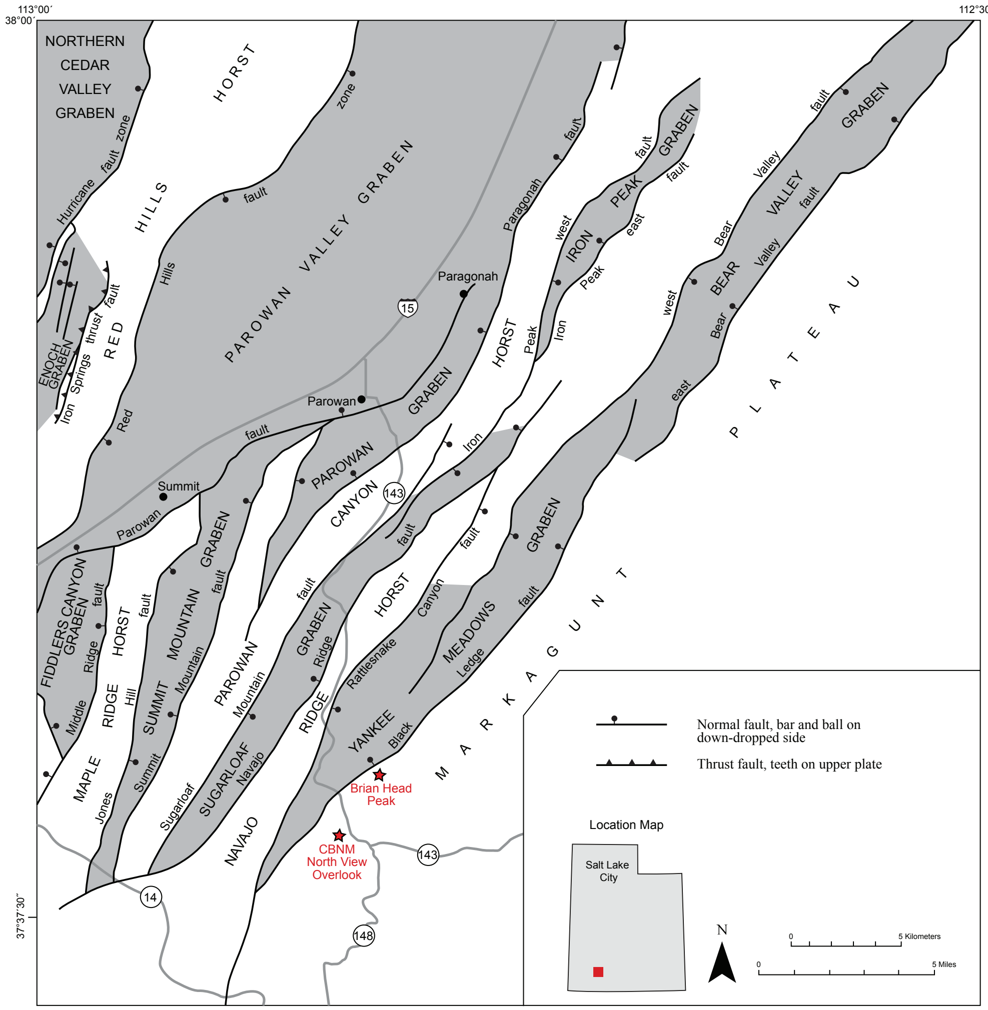

Figure 10. Major faults of the western Markagunt Plateau and Red Hills, and named grabens (shaded) and horsts. CBNM = Cedar Breaks National Monument. From Biek and others (2015).

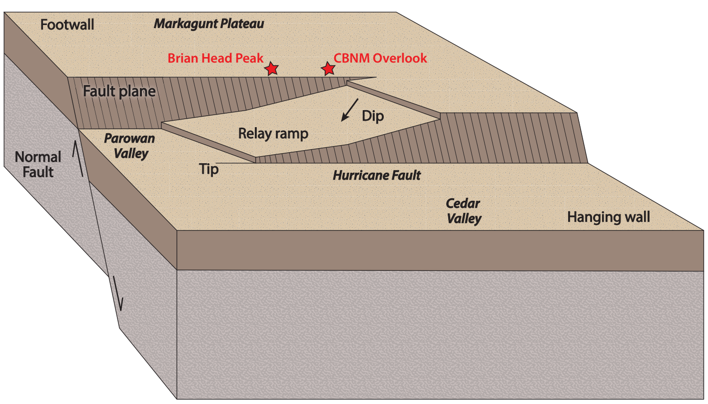

Figure 11. Diagram of a relay ramp between parallel strands of a fault zone. The ramp links displacement between the faults. CBNM = Cedar Breaks National Monument.

esque hoodoos and fins. The uplift by large normal faults of the Markagunt Plateau resulted in the erosion that is evident today. The North View Overlook provides the opportunity to examine and learn how some of the most colorful, beautiful, and famous sedimentary rocks in Utah formed during the Eocene, and why they subsequently weathered the way they did.

ACKNOWLEDGMENTS

Our knowledge of southwestern Utah geology comes from combined decades of geologic mapping supported largely by the Utah Geological Survey and U.S. Geological Survey. As the acknowledgments of our many published geologic maps attest, we are indebted to a great many people for their help over the years. Thanks to Grant Willis, Stephanie Carney, and Mike Hylland (all with the Utah Geological Survey) for their insightful reviews, and to Jenny Erickson (UGS) for drafting the figures.

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