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Cover

View south from Forshea Mountain showing Phonolite Hill. Phonolite Hill, a rhyolite dome, erupted 5 million years ago at the bottom of Kingston Canyon. The photographer is standing on the 8 Ma rhyolite of Forshea Mountain. The top of the gently east-dipping canyon wall across the canyon would have been a valley floor 8 million years ago. The Sevier fault is to the right of the hills at the far right of the view, west of which is a glimpse of Sevier Valley. The base of the 5 Ma rhyolite dome of Phonolite Hill is at the current canyon floor, showing here a minimum of 4000 feet (1200 m) of uplift (it would show as more if the south wall were projected out to the Sevier fault) on the Sevier fault between 8 and 5 Ma.

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Basin-Range Uplift and Canyon Cutting in 3 Million Years, Kingston Canyon, Piute County, Southwestern Utah

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ABSTRACT

The Sevier Plateau is a gently east-tilted, block-faulted range in the High Plateaus transition zone of southwestern Utah. Part of this range underwent basin-range deformation, including at least 6000 feet (1800 m) of uplift, in a 3-million-year time span. The north-south range, whose southern end is just north of Bryce Canyon National Park, was uplifted and tilted by the Sevier fault zone along the western side. Kingston Canyon is a deep, east-west antecedent canyon that cut through the range and maintained itself during uplift. The deformation took place between 8 and 5 Ma, constrained by isotopic dating of pre-uplift rhyolite flows (8 Ma), now exposed on the crest of the range, and a post-canyon-cutting rhyolite dome (5 Ma), now in the bottom of Kingston Canyon. This episode of uplift and canyon cutting represents the most closely constrained example known in the Great Basin and adjacent transition zone of main-phase uplift by basin-range faults.

INTRODUCTION

Kingston Canyon is a 4000-foot-deep (1200 m), east-west canyon that cuts entirely through the southern Sevier Plateau, Piute County, Utah (figure 1). The plateau is bounded on the west by the large, active, down-to-the-west Sevier fault zone and on the east by small, discontinuous, down-to-the-east faults, creating a gently east-tilted fault block characteristic of Utah's southern High Plateaus. Kingston Canyon was formed by the ancestral East Fork of the Sevier River, which now continues flowing west through the canyon; it is an antecedent canyon, which means that the East Fork of the Sevier River maintained itself as the Sevier Plateau was uplifted slowly along its bounding faults. The canyon is interesting and unusual for this reason alone (rivers are more commonly diverted by rising mountain blocks), but it is exceptional in that Phonolite Hill, a rhyolite dome, erupted 5 million years ago in the bottom of the canyon. This shows that the canyon existed 5 million years ago and has been little changed since then, with implications for the development of Utah's southern High Plateaus as described below.

The Sevier Plateau is a range that is about 75 miles (120 km) in north-south length and as much as 18 miles (29 km) in east-west width, from just south of Richfield on the north to just north of Bryce Canyon National Park on the south. It has relief of about 5000 feet (1500

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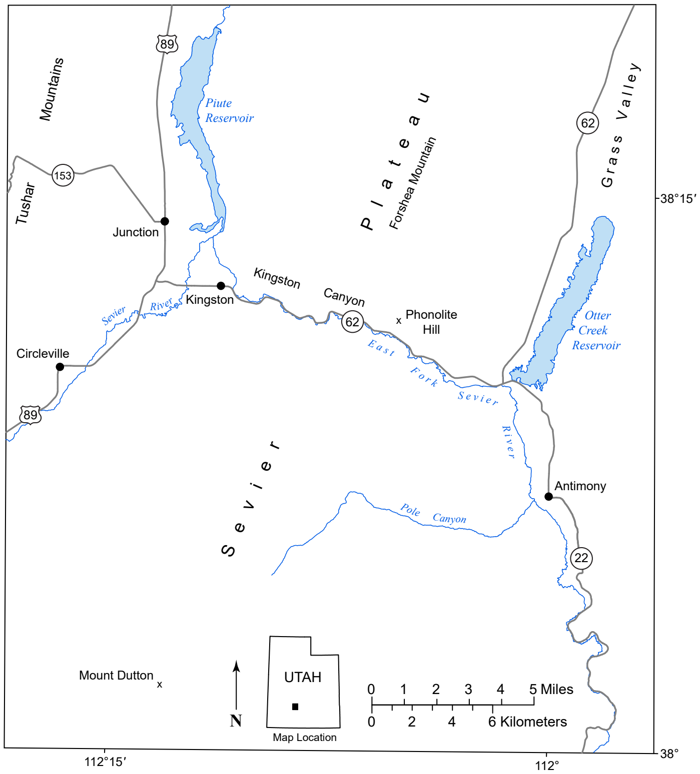

Figure 1. Location map of the Kingston Canyon area, Piute and Garfield Counties, Utah, with the Phonolite Hill geosite identified.

m), with its high points of Mount Dutton south-southeast of Circleville and of Monroe Peak northeast of Marysvale, both on the western fault scarp and just over 11,000 feet (3350 m) in elevation. Sevier Valley separates the plateau from, on the west, the Pahvant Range, Tushar Mountains, and Markagunt Plateau from north to south. On the east, Grass Valley separates the northern part of the plateau from the Fish Lake Plateau and Awapa Plateau, and Johns Valley separates the southern part from the Aquarius and Table Cliffs Plateaus. The headwaters of the East Fork Sevier River are in northern Bryce Canyon National Park, from where the river flows north through Johns Valley, then past Antimony in southern Grass Valley, where it swings west across the Sevier Plateau to join the main fork of the river, which continues northward through Sevier Valley past Richfield.

The Sevier Plateau, along with the mountains, plateaus, and valleys mentioned above, belongs to the High Plateaus subprovince of the Colorado Plateau, a transition zone between the Great Basin to the west and the main part of the Colorado Plateau to the east. The Great Basin extends from central Utah westward to easternmost California, whereas the main part of the Colorado Plateau extends from central Utah to the Grand Junction area of western Colorado. The Great Basin formed by basin-range deformation, whereby innumerable faults created alternating north-trending ranges and basins. Basin-range faults are generally normal faults that dip steeply, about 60°, and have mostly vertical, extensional motion that is down in the dip direction. The transition zone was affected by basin-range deformation but the faults are less abundant and have less throw than in the Great Basin, and their number and size decrease eastward before passing into the stable, little deformed, mostly horizontal rocks of the Colorado Plateau. Therefore, the High Plateaus subprovince also consists of north-trending ranges (horsts, commonly gently east tilted) and basins (grabens) that are bounded on both sides by faults.

The age of basin-range deformation is generally known to postdate about 20 million years old (Ma) and to be continuing today. But most of the deformation, including that which formed the present topography, appears to postdate 10 Ma (Rowley and others, 1981, 2005). The geosite described here provides the best evidence we know in the entire Great Basin and transition zone that tightly constrains, for at least part of a range, this later main phase of deformation. The geosite is in Kingston Canyon, at a mountain shown on the topographic map as Phonolite Hill. Basin-range deformation is accompanied by eruption of relatively small volumes of "bimodal" volcanic rocks of either rhyolite or basalt composition. The geosite, 5 Ma volcanic dome of Phonolite Hill, erupted in the bottom of Kingston Canyon after it was cut (Rowley and others, 1981). A volcanic dome is a relatively small edifice of rock that accumulates as short, stubby rhyolite lava flows around its vent, resulting in an upper domical surface that resembles a muffin. We contrast its age with that of a rhyolite lava flow at the top of the northern wall of the canyon that has an isotopic age of about 8 Ma. The difference between the two, about 3 million years between 8 and 5 Ma, is the interval in time during which this part of the range formed!

LOCATION

The geosite is midway through Kingston Canyon, near the central part of the Phonolite Hill 7.5-minute quadrangle, Piute County, Utah. The coordinates are: 38º11'19" N., 112º05'30" W., 8.2 miles (13.1 km) east of U.S. Highway 89 and 4.2 miles (6.7 km) west of the intersection with State Route 22.

Pull off State Highway 62 adjacent to and east of a light-gray outcrop on the north side of the road, near the edge of a volcanic crater that forms the western base of Phonolite Hill. Figure 2 is a simplified geologic map and cross section of the area.

GEOLOGIC SETTING

The Sevier Plateau lies near the eastern side of the Marysvale volcanic field, one of the largest Cenozoic volcanic fields in the West. The field is named for the small, former mining town of Marysvale, 15 miles (24 km) north of Junction (figure 1) and near the center of the 75-mile-diameter (120 km) field. The mapping study of the southern half of the Sevier Plateau, including Kingston Canyon, began with a dissertation study by the senior author (Rowley, 1968). The study showed that the Sevier Plateau is a tilt block dipping about 3º to the east and uplifted along the major Sevier fault zone on its western side. Vertical displacement on the fault zone is at least 6000 feet (1800 m), which includes not only the topographic relief of the range itself but also the amount that the bedrock beneath Sevier Valley, a graben, was downthrown (at least 1000 feet [300 m]) and filled with sediments resulting from erosion of the range. Later mapping showed that, north of the dissertation study area, relatively small down-to-the-east faults separate the eastern side of the Sevier Plateau from the graben of Grass Valley (e.g., Rowley and others, 1986a, 1986b; Biek and others, 2015a, 2015b). Therefore, the Sevier Plateau is an east-tilted horst. Many reports and geologic maps have been published about the geology of Kingston Canyon and surrounding areas, among them those by Anderson and Rowley (1975), Steven and others (1979), and Rowley and others (1981, 2005), from which the discussions below come from.

The oldest rocks in the Sevier Plateau belong to the Brian Head Formation, a light-gray, white, and light-green sedimentary sequence deposited in streams, on floodplains, and in lakes during the late Eocene and earliest Oligocene. Only the top of this unit, which is locally sheared, is exposed in the central part of Kingston Canyon (figure 2, labeled Tc on the map), although the formation is widely exposed along the flanks of the southern Sevier Plateau, where it is about 1000 feet (300 m) thick and locally on the western flank of the Awapa Plateau (Biek and others, 2015a, 2015b). The Brian Head underlies the thick volcanic rocks that make up the Marysvale volcanic field; it is rich in volcanic ash, for it represents the start of volcanism at Marysvale and in the Great Basin. This ash has weathered to smectitic clay, which is known for swelling soils and susceptibility to landsliding. Importantly, the Brian Head contains—presumably in weak clay layers—the shear planes for the Markagunt and Sevier gravity slides (Hacker and others, 2014; Biek and others, 2019). On the cross section (figure 2), the Brian Head is shown to be horizontal for simplicity, but in Pole Canyon east of Antimony (see the Pole Canyon geosite), Brian Head and many of the overlying volcanic rocks involved in the Sevier slide are deformed and are overlain unconformably by post-slide volcanic rocks, notably the Osiris Tuff, that dip east at the typical 3° (see Rowley and others, 2022).

The Brian Head Formation is overlain by the Wah Wah Springs Formation (30.5 Ma, Oligocene), one of the largest ash-flow sheets in the world (e.g., Best and others, 2013). It was derived from the Indian Peak caldera complex that spans the Utah-Nevada border more than 100 miles (160 km) to the west, so it rarely is thicker than about 50 feet (15 m) in the area. Above it, the Three Creeks Tuff Member (27 Ma) of the Bullion Canyon Volcanics is probably the largest ash-flow tuff derived from the Marysvale field. It erupted from the Three Creeks caldera in the southern Pahvant Range just north of Interstate 70 and 35 miles (55 km) northwest of Kingston Canyon, so it is commonly several hundred feet thick in the area (Rowley and others, 1994). These two tuffs, plus an overlying thin tuff, the Kingston Tuff Member of the Mount Dutton Formation, are shown on figure 2 as unit Tkcn. Stratovolcano deposits of mostly andesitic composition overlie this unit and are more than 1000 feet (300 m) thick in the Kingston Canyon area. Most of the deposits consist of volcanic mudflow

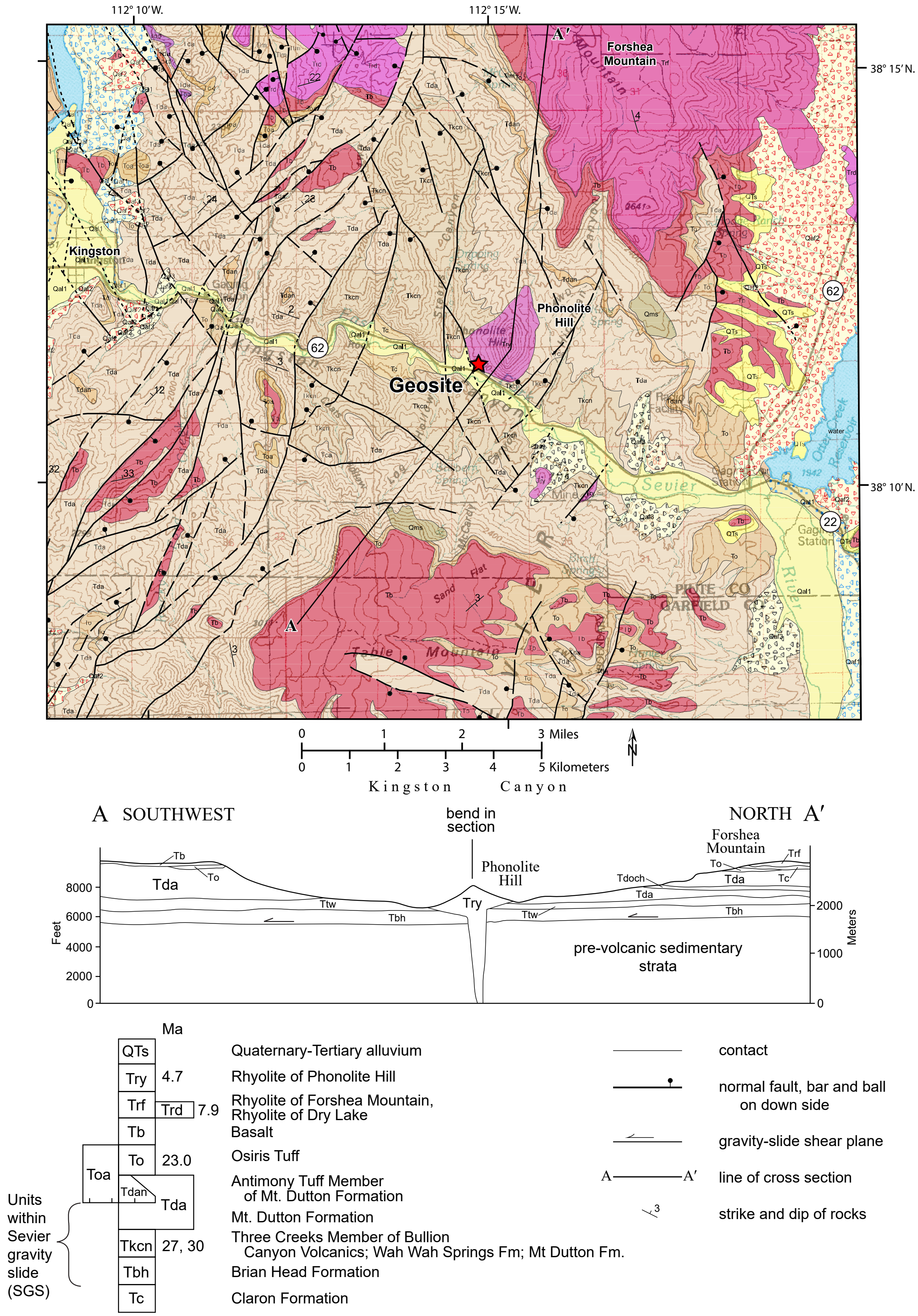

Figure 2. Geologic map and cross section of the Kingston Canyon area, Piute and Garfield Counties, Utah, showing Phonolite Hill. Cross section shows Phonolite Hill erupted at the base of Kingston Canyon. Geologic map modified from Rowley and others (2005).

breccia but interbedded lava flows are also present. Most of the volume of the Marysvale volcanic field is made up of such locally derived volcanic rocks. They are named the Mount Dutton Formation (Tda) and are as much as several thousand feet thick (1000 m); some of these mudflow deposits near Mount Dutton are older and underlie the Wah Wah Springs Formation. Near the top of the stratovolcano deposits is a thin (about 40 feet [12 m]), densely welded, crystal-poor ash-flow tuff, the Antimony Tuff Member of the Mount Dutton Formation (Tdan). Its source is unknown, but its age is about 25.1 Ma and is important for it overlies (postdates) and rests in angular unconformity on the Sevier gravity slide, showing that the slide must be older than 25.1 Ma. The Sevier gravity slide consists of all rocks that lie between the upper Brian Head Formation and the Antimony Tuff Member. Above the Antimony Tuff Member is another densely welded, crystal-poor ash-flow tuff, the Osiris Tuff (23.1 Ma, unit To), which is commonly light gray and about 50 feet (15 m) thick. The Osiris is derived from the Monroe Peak caldera, the largest in the Marysvale field, whose southern margin is about 20 miles (32 m) north of the bottom of Kingston Canyon. The Osiris locally sits directly on the Antimony, as at the eastern end of Kingston Canyon.

The youngest rocks in the Kingston Canyon area are basaltic lava flows and the overlying rhyolite of Forshea Mountain. The basaltic flows are on both walls of the canyon, whereas the younger rhyolite is only on the north wall. These rocks dip east at about 3º, as with all underlying rocks.

Rowley's 1968 dissertation study identified and mapped, at a scale of 1 inch to the mile, the rhyolite of Phonolite Hill (Try), and the rhyolite of Forshea Mountain (Trf) that caps the northern side of Kingston Canyon (figure 3). In the summer of 1970, Rowley joined the U.S. Geological Survey (USGS) to do reconaissance geologic mapping in Antarctica. From about 1975 to 1986, in between five trips to Antarctica and later in a Maryvale project, he joined two other USGS geologists, Thomas A. Steven and Charles G. (Skip) Cunningham, in detailed mapping and related studies of the Marysvale volcanic field for its mineral-resource potential. On the Fourth of July, 1978, when others had returned to their families in Denver, Tom suggested we take a break from our mapping and give Phonolite Hill a second look. They has a delightful day in which they circumnavigated the mountain, about a mile (1.6 km) in diameter and rising 1600 feet (500 m). The detailed mapping from this re-examination of Phonolite Hill showed that the rhyolite dome was sitting in a low crater of tuff and rocks ejected from the vent prior to the main eruption of the dome. Eroded pieces of the crater are exposed all around the circumference of the mountain, and the crater contains garage-size rocks of basalt that had been spit out of the vent and into the crater. Because they sit in the bottom of a canyon cut across the plateau, the crater and dome must postdate uplift of the Sevier Plateau and canyon cutting. The team collected samples for isotopic dating by potassium-argon methods, which Harald Mehnert of the USGS in Denver would do for us. A few days later Rowley collected a sample of the rhyolite of Forshea Mountain. They interpreted that the rhyolite on Forshea Mountain and its underlying rocks were deposited horizontally and predated uplift and eastern tilting of the plateau along the Sevier fault zone. Canyon cutting began as this uplift and tilting started, and the cutting continued as uplift and tilting continued. In other words, the canyon could not have been present when the rhyolite of Forshea Mountain erupted, otherwise the rhyolite would have flowed into the canyon. The results of this study were published, including a geologic map and cross section that are more detailed than those in figure 2 (Rowley and others, 1981). The K-Ar ages determined by Harald of the rhyolite of Phonolite Hill were 4.79 ± 0.23 Ma on obsidian and 5.42 ± 0.27 Ma on sanidine. Of these, K-Ar ages on the phenocryst mineral sanidine are considered more accurate. The K-Ar ages on the rhyolite of Forshea Mountain are 7.55 ± 0.44 Ma on obsidian and 7.63 ± 0.63 Ma on sanidine. The difference in sanidine ages between the two rhyolites is 2.2 million years. The team thus interpreted that the uplift of the Sevier Plateau along the Sevier fault zone had taken place during that interval. This interval, to our knowledge, is the tightest constraint in the entire Great Basin on the age of basin-range deformation of part of a major range. This conclusion is summarized in Rowley and others (1994, p. 24) and in the expanded text on the geologic framework of the Panguitch 30' x 60' quadrangle (Biek and others, 2015a, p. 131).

Figure 3. View north to the southern side of Forshea Mountain, showing a thin basalt ledge (Tb) overlain by a cliff of the rhyolite of Forshea Mountain (Trf).

Rowley and others' (1981) conclusion on the age of basin-range deformation of the Sevier Plateau, however, seems to have been ignored, perhaps because other geologists doubted that such a rapid history of faulting, uplift, and canyon cutting was possible, or perhaps they doubted the isotopic ages. Much later, Bob Biek of the Utah Geological Survey (UGS), Dave Hacker of Kent State University, other colleagues, and I (Pete Rowley) were again remapping much the same area, namely the Panguitch (Biek and others, 2015a), Loa (Biek and others, 2015b), and Beaver 30' x 60' quadrangles (Rowley and others, 2005), to determine the extent of the Markagunt and Sevier gravity slides. Because the ages of the two rhyolite masses were critical in determining the geomorphology and basin-range history of the area, and now a modern and more accurate method of dating ($^{40}Ar/^{39}Ar$) had been developed, the UGS ran samples from the two rhyolites again. The numbers are close, 4.7 ± 0.4 Ma on sanidine/plagioclase phenocrysts from the rhyolite of Phonolite Hill, and 7.89 ± 0.12 Ma on sanidine phenocrysts from the rhyolite of Forshea Mountain (UGS and NMGRL, 2019), for an interval of 3.2 million years during which time this part of the Sevier Plateau was uplifted and tilted. So the 1981 isotopic ages were essentially verified!

Corroborating evidence for this story came from the work of Skip, Tom, and colleagues at Big Rock Candy Mountain, adjacent to the Sevier River north of Marysvale. This work was done after the report by Rowley and others (1981) was published, and it was only briefly noted by Biek and others (2015a). To understand the significance of this evidence, we need to summarize the erosional history of the High Plateaus. During basin-range deformation, the ranges were uplifted along faults and the valleys (basins) were dropped down. The main drainage, the Sevier River, maintained itself as this faulting was going on. At times, especially during Pleistocene glaciations, the Sevier River and its many tributaries were large, and they eroded vigorously downward, acting like buzz saws as the underlying rocks were being uplifted. After the Sevier River exits Kingston Canyon and flows northward past Junction and Piute Reservoir, it goes through two rock obstructions, each about 5 miles (8 km) long, in the middle of Sevier Valley before it reaches Richfield. One of these is south of Circleville, and the other is north of Marysvale (including Big Rock Candy Mountain). Yet, the Sevier River did not stop at these obstructions but, as with the Sevier Plateau obstruction, it maintained itself and cut deep canyons (Circleville and Marysvale Canyons) through the obstructions. That indicates these canyons are also antecedent canyons, so the obstructions were uplifted as the river continued to flow through them.

Big Rock Candy Mountain, at the eastern edge of the Tushar Mountains in Marysvale Canyon, is a jagged, colorful, and picturesque mountain, mostly yellow with lesser tinges of orange, red, and white. It is a classic example of hydrothermally altered volcanic rock, formerly deposits of a stratovolcano. At its base is a motel, a former resort of some fame, with a café and gift shop. The café has its walls festooned with publicity photos of movie stars of the 1930s and 1940s, including John Wayne if we remember correctly, all of whom came to the resort to hunt elk and mountain lions. The mountain name came from a popular song “Big Rock Candy Mountain” first recorded in 1928 by Harry “Haywire Mac” McClintock and made famous for a second time in a 1950s sanitized children’s recording by Burl Ives. (Buskers sang bawdy versions of the song, which described a child being recruited into hobo life by tales of a “big rock candy mountain,” as early as the 1890s.) Soon after the song became popular the first time (in the 1930s), locals erected a sign “Big Rock Candy Mountain” at the base of the yellow mountain, and a nearby spring that issued from the yellow mountain became “Lemonade Springs.” The names stuck.

As part of their hunt for mineral resources in the mining districts near Marysvale, Cunningham and others (2005) studied Big Rock Candy Mountain, which is a deposit of alunite, a mineral of aluminum oxide that during World War I was mined for aluminum ore at the ghost town of Alunite, about halfway between Junction and Marysvale. The alunite at Big Rock Candy Mountain formed deep (more than a mile [>1.6 km]) below the surface about 21 million years ago when hot water from an underlying pluton altered the andesitic flows and mudflows (Cunningham and others, 2005). But much later, after deep erosion into the altered volcanic sequence by streams and the ancestral Sevier River, the alunite was exposed to the air and oxidized, weathered, and altered (in a process called supergene destruction) into natrojarosite, gypsum, and other minerals. $^{40}Ar/^{39}Ar$ ages on these minerals indicate that the start of this supergene alteration took place at about 6.6 Ma. This age is in the same timeframe as the cutting of Kingston Canyon, and because the Sevier River currently is only a couple hundred yards from the base of Big Rock Candy Mountain, it is reasonable to conclude that much of the dissection to create Marysvale Canyon was by the ancestral Sevier River, as the Tushar Mountains and the rock obstruction to Sevier Valley (beneath Marysvale Canyon) were rising along their own faults.

How widespread was the Kingston Canyon 3-million-year episode of rapid fault uplift, tilting, and canyon cutting? And how is it possible that uplift along an active fault zone such as the Sevier largely ceased at about 5 Ma, such that the East Fork Sevier River cut no further downward? To answer this question, let us look at the geology of Red Canyon, about 30 miles (50 km) south of Kingston Canyon. Here the Sevier fault zone is well exposed as a sharp, youthful (partly Pleistocene) structure, as described in the Red Canyon geosite (Biek, 2019). The Sevier fault at the western mouth of the canyon is mostly a single north-trending structure that uplifts the southern end of the Sevier Plateau and, farther south, the Paunsaugunt Plateau (Rowley, 1968; Lund and others, 2008). Total throw on the Sevier fault here is about 3000 feet (900 m), about half what it is at Kingston Canyon. But a basalt flow, with an $^{40}Ar/^{39}Ar$ age of 0.51 ± 0.02 Ma, that is exposed on both sides of the fault, is offset about 650 feet (200 m) (Lund and others, 2008). So some of the uplift is Pleistocene, unlike at Kingston Canyon. The timing and amounts of the deformation, therefore, are much different from the same fault zone at Kingston Canyon. The probable reason is segmentation of the Sevier fault zone, as described by Lund and others (2008). In other words, major faults rupture in independent seismogenic segments rather than their entire length. These segments can be identified by several methods, including map differences in the trace of the fault. Accordingly, about 4 miles (6 km) north of Red Canyon, the Sevier fault swings north-northeast and dies out into the Sevier Plateau (Lund and others, 2008, figure 2). Farther north along the north-trending range front, most bounding faults trend largely north-northeast, making an en echelon pattern of parallel faults, few of which form sharp, well-defined, youthful scarps (Rowley, 1968; Biek and others, 2015a). This pattern continues northward to Kingston Canyon, where the canyon mouth has another en echelon pattern of faults, this one trending north-northwest, that intersects the north-northeast faults (Rowley, 1968; Rowley and others, 2005). Clearly the Sevier fault at Red Canyon is a different segment than the one at Kingston Canyon, and the two segments behaved differently.

THE SITE ITSELF

As you pull off Highway 22 at the light-gray outcrop at the southwestern side of the geosite of Phonolite Hill, you will see the view shown in figure 4. The light-gray rocks closest to you are moderately consolidated sediments whose bedding planes indicate that they are dipping northward or northeastward. These sediments make up the inner part of the shallow volcanic crater, consisting of tuffaceous debris that was tossed out of a vent as rhyolite lava (magma) was moving upward in a pipelike column. The crater had an outer wall, consisting of similar sediments that dipped south and southwest here, and away from Phonolite Hill elsewhere, but this part of the crater has been removed by erosion by the Sevier River (it is preserved on the northern flank of Phonolite Hill). The debris is mostly of sand and pebble size, but some larger angular clasts (cobble- and boulder size), at least 3 feet (1 m) in diameter, are also present. Most of the clasts are white rhyolite but the larger clasts are black, consisting of basalt torn from the vent's walls. At other locations, clasts of basalt in the crater are several dozen feet in diameter, as recorded in photos given by Rowley and others (1981). If you examine the larger basaltic clasts in the crater deposits at this outcrop, you will see that the clasts sit in their own small craters. Clearly these black clasts were tossed hundreds of feet in the air during eruption, and when they fell back into wet crater sediments, they made impact craters as much as several inches deep.

Figure 4. View northeast at the volcanic dome of Phonolite Hill from the geosite parking lot. The white, left- (north-) dipping beds in the foreground are the inner part of a tuffaceous crater that surrounds the dome. Light-tan rocks just above the white, snow-covered rocks are the vertical plug (vent) of rhyolite dome rock that intrudes the crater. This rock includes a black-glass chilled margin at the intrusive contact, from where the sample was collected for K-Ar dating. Rhyolite dome rock, with generally vertical cooling joints, makes up most of the mountain.

The lower part of the rhyolite rock (dome) itself is a vertical feeder pipe that cuts the crater deposits about 600 feet (200 m) to the northeast (figure 4). The rhyolite at the contact is black glass (obsidian) about 3 feet (1 m) thick, a chilled margin that cooled fast and did not devitrify like the white rock. The rhyolite was warped into small flow folds as it oozed past the contact. Presumably the upper part of the dome flared outward, but this part has been removed by erosion. Rhyolite magma is viscous and flows like bread dough, quite unlike runny basalt flows. Some domes, therefore, are intruded as subvertical spines called tholoids, and this tall mountain that towers above may have been such a feature.

If you look south, you will see the caprock of basalt and Osiris Tuff that defines the top of the southern wall of Kingston Canyon (figure 5). The northern wall of the canyon, however, is difficult to see because it is blocked by rocks lower on the wall, including Phonolite Hill, but the northern canyon rim is capped by the rhyolite of

Figure 5. View south from Forshea Mountain showing Phonolite Hill. Phonolite Hill, a rhyolite dome, erupted 5 million years ago at the bottom of Kingston Canyon. The photographer is standing on the 8 Ma rhyolite of Forshea Mountain. The top of the gently east-dipping canyon wall across the canyon would have been a valley floor 8 million years ago. The Sevier fault is to the right of the hills at the far right of the view, west of which is a glimpse of Sevier Valley. The base of the 5 Ma rhyolite dome of Phonolite Hill is at the current canyon floor, showing here a minimum of 4000 feet (1200 m) of uplift (it would show as more if the south wall were projected out to the Sevier fault) on the Sevier fault between 8 and 5 Ma.

Forshea Mountain. The rhyolite of Forshea Mountain was interpreted to have been deposited horizontally, like the beds below it, and only later was the Sevier Plateau uplifted along the Sevier fault zone and tilted east. Figure 5 shows the view from Forshea Mountain; figure 6 gives a glimpse of the northern wall, along with Phonolite Hill itself.

The significance of the Kingston Canyon geosite is it constrains the main phase of basin-range deformation in this part of a range in the Great Basin–Colorado Plateau transition zone to between 8 and 5 Ma. This 3-million-year span is the tightest constraint we know of, across the entire Great Basin and its transition zone, for uplift of a range by basin-range faults. It might be argued that this short span of time for the uplift by basin-range faulting may pertain to only a single range, the Sevier Plateau. Yet this time span fits with what we know about the main period of basin-range deformation across much of these provinces. Although basin-range deformation began more than 20 million years ago, the post-10 Ma interval produced the greatest deformation and thus most of the present topography. And Kingston Canyon shows that along some segments of major fault zones, uplift and deformation was more rapid than has been documented before.

Figure 6. View west-northwest at Phonolite Hill. The top of Forshea Mountain in the northern wall of Kingston Canyon is capped by the 8-million-year-old rhyolite of Forshea Mountain, barely visible as the farthest hill on the right. The mesa at the left skyline consists of the 27-million-year-old Three Creeks Tuff Member of the Bullion Canyon Volcanics.

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This short report has an unusual amount of history behind it, and great indebtedness. The late Professor J. Hoover Mackin of the University of Texas supervised Rowley's dissertation. The late Professor John J. Anderson of Kent State University participated with Rowley in working on the volcanic stratigraphy of the southern Marysvale field. The late Paul L. Williams of the USGS first found and named the Osiris Tuff and served on Rowley's dissertation committee. The late Thomas A. Steven of the USGS is partly responsible for the study of the Marysvale field and suggested that the rhyolite of Phonolite Hill was worth mapping in detail. The late Charles G. Cunningham of the USGS was another close colleague who was key to unraveling the Marysvale field. Harald H. Mehnert of the USGS, probably the best K-Ar geochronologist in the business, determined many of the ages of volcanic rocks in the Marysvale field, including the initial ages in Kingston Canyon. Lisa Peters of the New Mexico Institute of Mining and Technology did the argon ages. We thank Grant Willis, Stephanie Carney, and Mike Hylland (UGS) for technical review of the manuscript, and Lori Steadman for drafting the figures.

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