

Figure 1.—Balanced rock in the Heart of Rocks area. Chiricahua National Monument is best known for its thousands of rock columns. These fanciful shapes were sculpted by wind and water from a layer of volcanic rock that is known as Rhyolite Canyon Tuff (terms in italics are defined in the pamphlet that accompanies this map). The vertical aspect of the columns resulted from erosion along vertical cracks, or joints, that formed in the volcanic rock as it cooled and contracted. The irregular profiles are the result of weathering along horizontal layers that have different degrees of hardness.

Figure 2. The principal rock of Chiricahua National Monument is Rhyolite Canyon Tuff, a volcanic rock that was deposited 26.9 million years ago by ash flows (clouds of hot ash, pumice, rock fragments, and volcanic gasses). The white streaks in the rock are blocks of pumice that were flattened, while still hot, by the weight of the overlying rock. The process of flattening is termed welding, and the resulting rock is called a welded tuff. The

first photograph (A) shows a typical vertical cliff face. The second photograph (B) features the upper (horizon-

tal) surface of a block of tuff. This three dimensional view shows that the pumice blocks were flattened into

Figure 3. The Rhyolite Canyon Tuff consists of three prominent layers that are separated by slope-forming

poorly-welded zones. The three layers are visible here, in the northern wall of Rhyolite Canyon, and they are

distinguished on the geologic map by different shades of blue. The three layers are referred to as the lower,

middle, and upper members of the Rhyolite Canyon Tuff (a formation) and they are given letter symbols as

follows: T (for Tertiary, the period of geologic time from about 65 million until about 2 million years ago), rc

(for Rhyolite Canyon), I (for lower), m (for middle), and u (for upper), or "Trcl," "Trcm," and "Trcu." The top of

Sugarloaf Mountain is dacite lava that contains large crystals of feldspar. Such a rock is called a porphyry, so the dacite lava atop Sugarloaf is symbolized here and on the map as "Tdpl" (Tertiary dacite porphyry lava).

Figure 4. This is a geological novelty that is found at the contact between the lower and middle members of the

Rhyolite Canyon Tuff. The photograph shows a thin (about 2 feet thick) welded tuff that formed from a single

ash-flow deposit (see figure 2). Light-gray, flattened pumice blocks are visible in the darker gray lower half of

the ash-flow deposit. The light-gray upper half of the deposit contains less pumice and probably was depos-

ited from the ash cloud that accompanied the flow. The overlying white layers between the middle of the

6-inch-long ruler (center of photo) and the base of the cliff above are ashy to sandy surge beds, which,

although poorly consolidated, also show microscopic evidence of welding. This entire sequence is sand-

wiched between the poorly welded top of the lower member of the Rhyolite Canyon Tuff, visible at the bottom

of the photograph, and densely welded tuff of the main part of the middle member, which forms the ledge at

heat, nor would it weigh enough, for the pumice blocks to have flattened and the deposit to have welded. Yet

it is welded. The explanation to this apparent contradiction is that the thin ash-flow deposit was compressed

and welded by the weight of the much thicker overlying tuff, a relation that indicates the overlying tuff was

The thin ash-flow deposit is unusual because such a thin deposit would not normally contain sufficient

disc-shaped masses. Large divisions on the rulers represent inches, smaller divisions are centimeters.

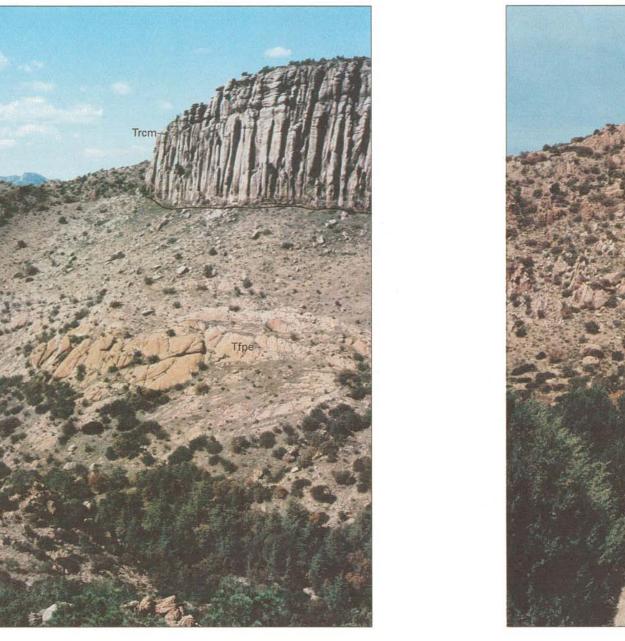


Figure 5. Rhyolite Canyon Tuff forms the cliffs north of Picket Canyon, where it overlies older rhyolite deposits of the Faraway Ranch Formation. A thin layer of black volcanic glass, or vitrophyre, is present at the base of the cliffs where the tuff was chilled against the older rocks. Prominent columnar joints visible on the ridge crest formed as tuff

contracted during cooling.

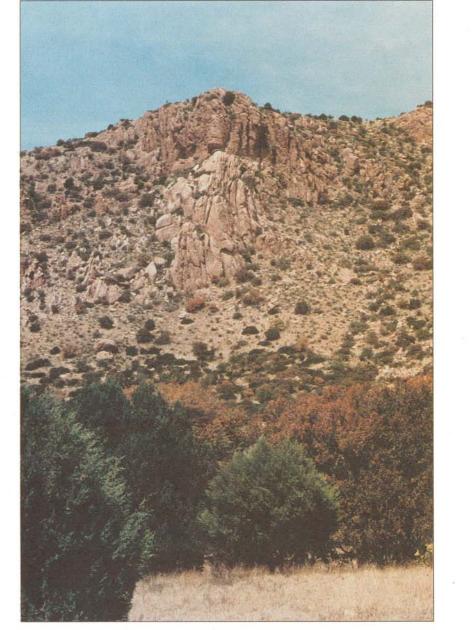


Figure 6. A vertical flow ramp forms the lower cliff face, north of the Faraway Ranch parking lot. The upper and lower cliffs are rhyolite lava of the Faraway Ranch Formation. Rhyolite lava flows tend to be extremely viscous and like cold molasses they "pile up" as upper parts of the flow override the slower moving flow front.



Figure 7. A. The vertical trail of pits (indicated by the arrow) is a fossil fumarole pipe through which steam jetted to the surface. A number of these fossil fumaroles can be seen in the cliffs along the Sugarloaf Mountain trail. The presence of fossil fumaroles here, in the upper member of the Rhyolite Canyon Tuff, suggests that the top of the middle member was wet, possibly due to rain, prior to deposition of the upper member. As steam jetted out of the tuff it carried fine particles of ash with it, leaving coarse crystals behind. B. The "boiling pot" of a fumarole (at arrow). The concentric layers are Liesegang bands where small amounts of chemical impurities from the hot water were precipitated. The layers below are surge beds, which were deposited from horizontally directed explosive blasts of ash, crystals, and rock debris; these too are overprinted by Liesegang bands.

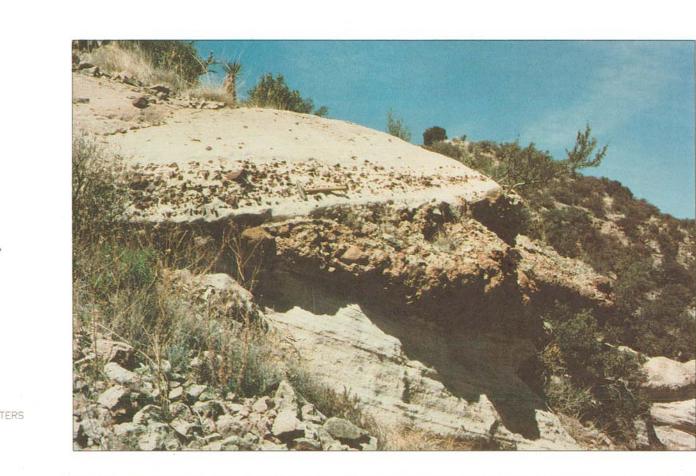


Figure 8. Marble-like rocks found along Hailstone Trail have been erroneously called "volcanic hailstones" or accretionary lapilli in the past. Water droplets that condense from a steam-rich ash cloud, or raindrops that fall into an ash cloud, can pick up concentric layers of ash to form pellets that look much like these. However, the pellets from Hailstone Trail are different. They contain crystals as well as ash, and they lack concentric layering; in fact, except for being harder, they are similar to the surrounding tuff. These features show that they are not "volcanic hailstones" at all. Instead, the marbles appear to have formed after the tuff was depos-

Figure 9. The white rhyolite ash and tan volcanic breccia shown here are part of a small volcanic cone within the rhyolite of Erickson Ridge. These pyroclastic deposits were produced by small explosive eruptions and erosion of the resulting ash cone. The rhyolite of Erickson Ridge is subdivided into two units on the geologic map: a unit dominated by pyroclastic rocks, such as shown here, and a unit dominated by lava flows, such as those illustrated in figure 6. The rhyolite of Erickson Ridge is, in turn, a member of the Faraway Ranch Formation,

a suite of volcanic rocks that are about a million years older than Rhyolite Canyon Tuff.

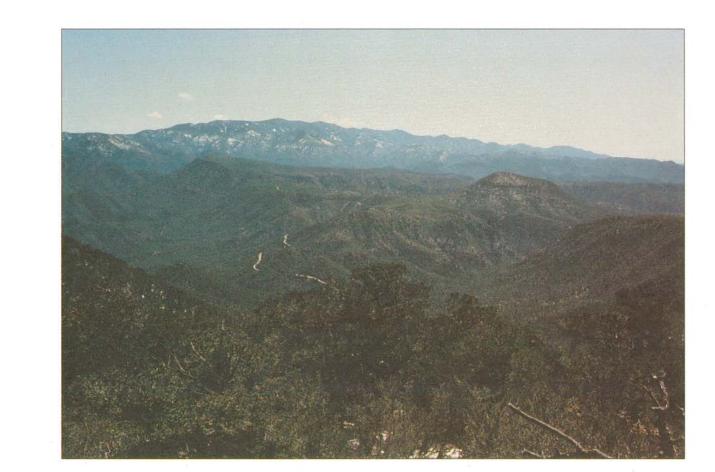
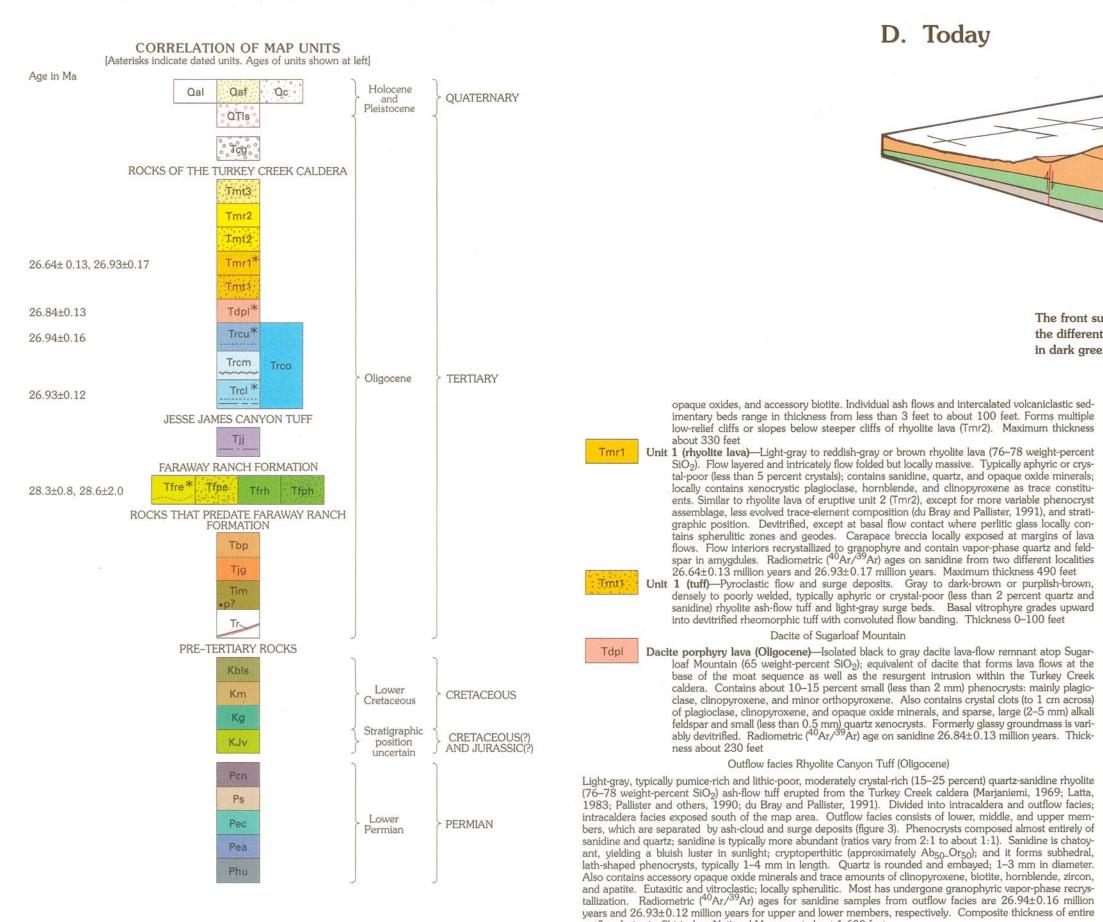


Figure 10. This view to the south from Timber Mountain provides a useful perspective of Chiricahua National Monument and the Turkey Creek caldera, parts of which form the entire Chiricahua mountain range in the distance. From Timber Mountain it is apparent that the Rhyolite Canyon Tuff was deposited in an ancient basin within the National Monument, and that the terrane rises toward the former rim and resurgent dome of the

A similar perspective is illustrated across the face of the block diagrams to the right.

massive caldera in the distance. Sugarloaf Mountain forms the high point in the middle ground (right center).



This geologic map, perspective block diagrams, color photographs, and pamphlet illustrate and describe the volcanic geology of Chiricahua National Monument and the evolution of the Chiricahua landscape. The geology of this area is dominated by Rhyolite Canyon Tuff, a volcanic deposit derived from the 26.9 million-year-old Turkey Creek caldera, south of the National Monument. The map is designed for use by both the general public and the professional geologist. Technical information is presented in the map and description of map units. Geologic terms (shown in italics) and geologic his-

ately welded tuff. Surge beds cut by vertical fines-depleted pipes (fossil fumaroles) and overprinted by low-angle secondary Liesegang bands (figure 7). Trace augite, zircon, and biotite tend to be more common than in most samples of lower and middle members. Welded tuff contains both white fiamme and dark-gray to maroon lensoidal masses of sanidine-megatory are explained in the accompanying pamphlet. crystic rhyolite, thought to represent poorly vesiculated magma clots. Chemically equivalent to voluminous intracaldera facies Rhyolite Canyon Tuff, which contains similar megacrystic TECHNICAL DESCRIPTION OF MAP UNITS magma clots at high stratigraphic levels. Uppermost 20 feet of member is moderately to poorly welded and poorly exposed. Exposed principally as erosional outlier near top of Sug arloaf Mountain, although ash-rich zone and overlying tuff that contains sparse megacryst based on ${}^{40}\text{Ar}/{}^{39}\text{Ar}$ determinations by L.W. Snee (see Pallister and others, 1990), except where otherwise magma blebs also exposed in northwest part of map area. Thickness 80 feet at Sugarloaf noted. Geochemical data mentioned herein are presented in more detail by du Bray and Pallister (1991).]

Top of surge beds

SURFICIAL DEPOSITS Qal Alluvium (Holocene and Pleistocene)—Unconsolidated to poorly consolidated silt, sand, and gravel in valley bottoms

Alluvial-fan deposits (Holocene and Pleistocene)—Poorly sorted deposits of silt- to boulder-size material; forms aprons adjacent to topographic highlands

Colluvium (Holocene and Pleistocene)—Poorly sorted silt- to boulder-size material on slopes QTIS Landslide deposits (Quaternary or Tertiary)—Deposits formed by gravity sliding or flowage. Cuspate breakaway scarps (hachured on map) exposed at heads of some deposits. Degree of erosion and alteration, as well as proximity to Tertiary faults and to margin of Turkey Creek caldera suggest a Tertiary age for some deposits Conglomerate (Oligocene?)—Weakly indurated, poorly sorted conglomerate and gritty sandstone. Clasts are principally derived from the underlying Rhyolite Canyon Tuff ROCKS OF THE TURKEY CREEK CALDERA

Moat deposits (Oligocene)

A sequence of crystal-poor rhyolite lava flows, pyroclastic rocks, and subordinate sedimentary rocks deposited in

Cartography by Henry Williams

Manuscript approved for publication February 3, 1995

moat of Turkey Creek caldera. Divided into three eruptive units on the basis of stratigraphic position, petroraphic differences, and distinct trace-element geochemistry (du Bray and Pallister, 1991). Unit 3 (rhyolite tuff)—Lavender to reddish-gray rhyolite ash-flow tuff (76–78 weight percent SiO₂). Aphyric and lithic-poor, except near base where quartz, sanidine, and plagioclase xenocrysts and rhyolitic lithic fragments are found. Thickness 80–260 feet Unit 2 (rhyolite lava)—Light-gray to reddish-gray, phenocryst-poor rhyolite lava (76-78 weight percent SiO₂). Flow layered and intricately flow folded, locally massive. Aphyric or sparsely (0-2 percent) porphyritic or microporphyritic with small (less than 1 mm) phenocrysts of sanidine, quartz, and opaque oxide minerals; accessory biotite and zircon present in some samples. Devitrified, except at basal flow contact where black or green glassy breccia or flow-layered perlite is locally exposed. Contains secondary (vapor-phase) quartz and feldspar crystals. Forms resistant ledges and massive cliffs in exhumed moat of Turkey Creek caldera. Maximum thickness about 980 feet Unit 2 (tuff)—Ash-flow deposits and intercalated air-fall tuff and volcaniclastic sedimentary rocks. lainly light-gray to orange or pink, poorly to densely welded, crystal-poor rhyolite ash-flow tuff. Typically very sparsely porphyritic; phenocrysts (less than 1 percent) are quartz and sanidine (both less than 1 mm) and microphenocrysts of opaque oxide minerals. Similar in phenocryst assemblage and chemistry to overlying rhyolite lava (Tmr2); however, some ash

The front surface of this block diagram along B-B' represents a cross section through the National Monument along line B-B' on the geologic map, and extending off the map to the south into the adjacent Rustler Park Quadrangle (Pallister and others, 1994). Colors represent the different map units shown on the geologic map, with the following exceptions: all moat rhyolite deposits of the Turkey Creek caldera are generalized in the single color yellow, all Faraway Ranch Formation members are shown as light green, all of the Bisbee Group is shown in dark green, Tertiary volcanic rocks east of the National Monument are shown in orange. Faults are shown in red. opaque oxides, and accessory biotite. Individual ash flows and intercalated volcaniclastic sedimentary beds range in thickness from less than 3 feet to about 100 feet. Forms multiple Faraway Ranch Formation (Oligocene) assemblage of interfingering silicic lava flows, near-source pyroclastic rocks, and epiclastic sedimentary rock ow-relief cliffs or slopes below steeper cliffs of rhyolite lava (Tmr2). Maximum thickness derlie Jesse James Canyon Tuff at Erickson Ridge and near Faraway Ranch, and Rhyolite Canyon T e (Enlows, 1955; Fernandez and Enlows, 1966). Radiometric (K/Ar on biotite) ages 28.6±2.0 and Unit 1 (rhyolite lava)—Light-gray to reddish-gray or brown rhyolite lava (76-78 weight-percent).8 million years (recalculated using IUGS constants; Steiger and Jäger, 1977) for samples of rhyolite lava SiO₂). Flow layered and intricately flow folded but locally massive. Typically aphyric or crystal-poor (less than 5 percent crystals); contains sanidine, quartz, and opaque oxide minerals; sson Ridge (Tfre) (Marjaniemi, 1969) locally contains xenocrystic plagioclase, hornblende, and clinopyroxene as trace constitu-

Rhyolite of Erickson Ridge—Light-gray or red-brown (devitrified) to black (glassy) biotite rhyolite (averages 73 weight-percent SiO₂). Contains phenocrysts of plagioclase (3-7 percent) as biotite (1-2 percent). Accessory or trace sphene forms euhedral phenocrysts. Forms small lava domes and lobate flow-layered lava flows that have black glassy carapace breccias Equivalent to Faraway Ranch Formation member 7 of Fernandez and Enlows (1966). Prominent flow layering Pyroclastic flow deposits of Erickson Ridge—Light-gray to orange block-and-ash flow, ash-fall

and surge deposits, and ash-rich lahars interbedded with rhyolite of Erickson Ridge (Tfr Partly equivalent to Faraway Ranch Formation member 6 of Fernandez and Enlows (1966) Locally includes reworked volcaniclastic sedimentary deposits. Thickness 0-200 feet Trend of bedding—Varies widely as a result of steep near-vent topography Rhyolite of Hands Pass—Light-gray, quartz-sanidine rhyolite (77-78 weight-percent SiO₂). and accessory or trace biotite and opaque oxide minerals, typically in a spherulitic to granophyric devitrified groundmass. Forms a prominent lava dome overlain by Rhyolite Canyon Pyroclastic flow deposits of Hands Pass-Light-gray to orange block-and-ash-flow, ash-fall, ash-rich lahar, and volcaniclastic sedimentary deposits underlying and forming a pyroclastic apron adjacent to rhyolite of Hands Pass (Tfrh). Thickness 0–230 feet

ROCKS THAT PREDATE THE FARAWAY RANCH FORMATION

Sedimentary rocks of Bonita Park (Oligocene)—Red-weathering, poorly sorted, clast-sup-

Possible pillow basalt—Spheroidal weathering and curvilinear vesicle trains in celadonitic pla-

is typically siltstone and fine- to medium-grained volcanic sandstone, but coarse-grained

sandstone and breccia beds are near inferred volcanic centers. Metabasalt forms lava flows,

which are locally pillowed, dikes, and possibly sills in exposures to southeast. Overlies

(76-78 weight-percent SiO₂) ash-flow tuff erupted from the Turkey Creek caldera (Marjaniemi, 1969; Latta, 1983; Pallister and others, 1990; du Bray and Pallister, 1991). Divided into intracaldera and outflow facies; ported conglomerate, and interbedded volcaniclastic arenite, siltstone, and claystone; contains gypsum veinlets near Bonita Park. Graded beds and channel deposits common. intracaldera facies exposed south of the map area. Outflow facies consists of lower, middle, and upper mem-Extensively altered to clay minerals and hematite. Initially interpreted as lakebed deposits by Waller (1952). Poor sorting, hematitic alteration, and channel bedding more consistent with bers, which are separated by ash-cloud and surge deposits (figure 3). Phenocrysts composed almost entirely of sanidine and quartz; sanidine is typically more abundant (ratios vary from 2:1 to about 1:1). Sanidine is chatoy alluvial-fan deposition (Hall, 1993). Red clay-rich soil suggests that Quaternary-Tertiary col-luvium and landslide deposits, mapped in Bonita Park and west of Whitetail Pass, are under-lain by sedimentary rocks of Bonita Park. Interbedded between andesitic and rhyolitic lavas ant, yielding a bluish luster in sunlight; cryptoperthitic (approximately Ab₅₀_Or₅₀); and it forms subhedral, lath-shaped phenocrysts, typically 1-4 mm in length. Quartz is rounded and embayed; 1-3 mm in diameter. also contains accessory opaque oxide minerals and trace amounts of clinopyroxene, biotite, hornblende, zircon, of Faraway Ranch Formation about one quarter of a mile west of map boundary, north of and apatite. Eutaxitic and vitroclastic; locally spherulitic. Most has undergone granophyric vapor-phase recrystallization. Radiometric ${}^{(40}\text{Ar}/{}^{39}\text{Ar})$ ages for sanidine samples from outflow facies are 26.94 ± 0.16 million Arizona Highway 181. Thickness less than 160 feet Welded tuff of Joe Glen Ranch (Oligocene)—Gray to pink, lithic-poor (less than 10 percent years and 26.93±0.12 million years for upper and lower members, respectively. Composite thickness of entire ithics) and moderately crystal-rich (15–25 percent crystals) biotite-quartz-sanidine rhyolit low facies in Chiricahua National Monument about 1,600 feet ash-flow tuff (72-73 weight-percent SiO₂). Contains 10-15 percent sanidine, 5-7 percent quartz, 1-3 percent biotite, and about 1-2 percent plagioclase. Forms moderately weld Outflow facies, undivided-Most exposures probably equivalent to middle member remnant of outflow sheet atop ridges southwest of Riggs Spring at Pinery Creek. Strati-Outflow facies, upper member-White, ash-rich surge beds overlain by gray, densely to modergraphic assignment made on basis of similarity in mineral assemblage and chemical comp on to exposures of welded tuff of Joe Glen Ranch in the southern Chiricahua Mountain Bray and others, in press) and in the Pedregosa Mountains (Drewes and Brooks, 1988). ntermediate and mafic lava flows (Oligocene)-Interfingering lava flows, flow breccia, and near-source pyroclastic rocks that are part of a regional assemblage of intermediate and mafic rocks that underlie most rhyolitic rocks in the Chiricahua Mountains (du Bray and others, in press). In the National Monument consists of red to brown, hornblende- and piotite-bearing plagioclase porphyritic dacite that locally overlies sedimentary rocks of Bonita Park and dark-gray aphanitic to glassy, clinopyroxene-bearing andesite and basalt. Thickness greater than 400 feet locally, base not exposed in map area

A. Pre-caldera stage, about 27-32 million years ago

B. Caldera-forming eruptions, 26.9 million years ago

C. Moat lava eruption, 26.9–26.6 million years ago

Outflow facies, middle member-Voluminous, gray, densely welded, pumiceous ash-flow tuff. Rhyolite dikes (Oligocene?)—Light-gray to pink or tan aphyric or quartz and (or) feldspar por-Prominent vertical columns (hoodoos) produced by erosion along joint planes in this memphyritic rhyolite dikes. Intrude pre-Turkey Creek caldera rocks ber. Jointing attributed primarily to contraction related to cooling (Hall, 1993). Internal Bisbee Group (Lower Cretaceous) homogeneous; however, slight variation in welding and weathering profile suggest member Mural Limestone—Tan, thin-bedded, laminated silty limestone, interbedded with siltstone and ormed from multiple ash flows that were erupted in rapid succession and cooled together Base locally marked by a 0-3-foot-thick section that consists of pumiceous ash-flow Morita Formation—Maroon-weathering siltstone, sandstone, shale, and conglomerate ash-cloud, and surge deposits that were welded as a result of emplacement of the overlying nain body of the middle member (figure 4). The middle member overlies the white, poorly Glance Conglomerate—Cobble, pebble, and boulder conglomerate composed of subrounded welded, top of lower member. Thickness 1,050 feet at Sugarloaf Mountain where top to subangular clasts of Paleozoic limestone, sandstone, and quartzite. Thickness 0-660 feet Volcaniclastic and volcanic rocks (Cretaceous? and Jurassic?)—Consists of dark-green to Vitrophyre—Black perlitic glass locally exposed at base of the middle member where it directly gray metagraywacke, meta-andesite and metabasalt. Variably metamorphosed to green overlies basement rocks of Faraway Ranch Formation in western part of Monument. Perliti schist-facies assemblages of chlorite, calcite, albite, epidote, and magnetite. Metagraywacke glass not present at base of middle member in central part of outcrop area where middle

ents. Similar to rhyolite lava of eruptive unit 2 (Tmr2), except for more variable phenocryst

graphic position. Devitrified, except at basal flow contact where perlitic glass locally con-

ains spherulitic zones and geodes. Carapace breccia locally exposed at margins of lav

par in amygdules. Radiometric (40Ar/39Ar) ages on sanidine from two different localities

64±0.13 million years and 26.93±0.17 million years. Maximum thickness 490 feet

densely to poorly welded, typically aphyric or crystal-poor (less than 2 percent quartz and sanidine) rhyolite ash-flow tuff and light-gray surge beds. Basal vitrophyre grades upward

loaf Mountain (65 weight-percent SiO₂); equivalent of dacite that forms lava flows at the

caldera. Contains about 10-15 percent small (less than 2 mm) phenocrysts: mainly plagio-

of plagioclase, clinopyroxene, and opaque oxide minerals, and sparse, large (2-5 mm) alkali

feldspar and small (less than 0.5 mm) quartz xenocrysts. Formerly glassy groundmass is variably devitrified. Radiometric (40 Ar/ 39 Ar) age on sanidine 26.84±0.13 million years. Thick-

base of the moat sequence as well as the resurgent intrusion within the Turkey Creek

clase, clinopyroxene, and minor orthopyroxene. Also contains crystal clots (to 1 cm across

into devitrified rheomorphic tuff with convoluted flow banding. Thickness 0-100 feet

Dacite of Sugarloaf Mountain

Outflow facies Rhyolite Canyon Tuff (Oligocene)

assemblage, less evolved trace-element composition (du Bray and Pallister, 1991), and strat

Lower Cretaceous Mural Formation and may be correlative with Cintura Formation of Biswelded middle zone. Middle zone grades upward into white, pumice-bearing, poorly welded bee Group (see discussions by Drewes and others, 1995). However, recent work by Lawton ash-cloud deposit. Thickness 0-600 feet; forms a wedge that thickens to south and east and Olmsted (1995) in Portal 7 1/2' quadrangle to southeast suggests a Jurassic age for at Base of ash-cloud deposit least part of unit. Contact with Mural poorly exposed and it is not known if units in this area --- Basal ash-Line denotes top of white, crystal-poor ash found locally at the base of lower are in depositional or structural contact. Thickness greater than 980 feet Paleozoic sedimentary rocks ROCKS THAT PREDATE THE TURKEY CREEK CALDERA Concha Limestone (Lower Permian)—Dark-gray, thick-bedded, fossiliferous, cherty limestone. Fossils include large productid brachiopods. Thickness 620-660 feet Scherrer Formation (Lower Permian)—Light-gray to pinkish-gray, fine-grained, nearly massive sandstone and quartzite. Thickness greater than 160 feet

Epitaph Dolomite and Colina Limestone, undivided (Lower Permian)—Dark-gray, coarse-grained, sparsely fossiliferous, slightly cherty limestone and local light-gray,

Tjj Jesse James Canyon Tuff (Oligocene)—Light-gray or pinkish-gray, typically lithic poor, modertuff from undetermined source (76-77 weight-percent SiO_2). Similar to middle and lower members of Rhyolite Canyon Tuff (Trcm, Trcl); however, distinguished by presence of trace amounts of bronze biotite and sphene, typically smaller and less abundant phenocrysts of sanidine and quartz, higher ratio of sanidine to quartz (3:1 or greater), less-evolved chemistry, and stratigraphic position. Forms a simple cooling unit; poorly welded upper zone grades downward into densely welded, eutaxitic lower zone; basal vitrophyre exposed locally. Thickness about 790 feet near Jesse James Canyon; thins to north, northwest, and Lithic-rich pyroclastic flow-Found locally at top of Jesse James Canyon Tuff. Overlain by about 5 feet of white, crystal poor, biotite-bearing ash where present

member is thick and overlies lower member. Vitrophyre typically less than 10 feet thick

ash-cloud deposit. Consists of red-brown densely welded lower zone and gray moderatel

Outflow facies, lower member-Pumiceous and locally lithophysal ash-flow tuff and related

EXPLANATION OF MAP SYMBOLS

accumulated within the caldera moat.

Figure locality—Arrow indicates direction of view for photographs Point photograph locality Contact—Dashed where approximately located

EVOLUTION OF THE CHIRICAHUA LANDSCAPE

Unconformity along caldera wall, between moat deposits, and underlying Rhyolite Canyon Tuff or Faraway Ranch Formation—Hachures on downdip side; dotted where concealed High-angle fault—Dashed where approximately located; dotted where concealed. Ball and bar Landslide scarp—Hachures on downthrown side Strike and dip of bedding

-\(\phi\)- K/Ar radiometric sample locality (with age in millions of years)

Inclined Strike and dip of foliation

Horizontal Quartz vein Zones of silicification * 40Ar/39Ar radiometric sample locality (with age in millions of years)

- · - National Monument boundary

- · — · — Wilderness boundary ACKNOWLEDGMENTS Our field work was facilitated by the cooperation of Chiricahua National Monument staff. We especially thank k Armstrong, Carol Kruse, Chuck Milliken, David Moore, and Alan Whalon of the National Park Service for oviding assistance and helpful suggestions during our work in the National Monument. We thank Carol Hud-

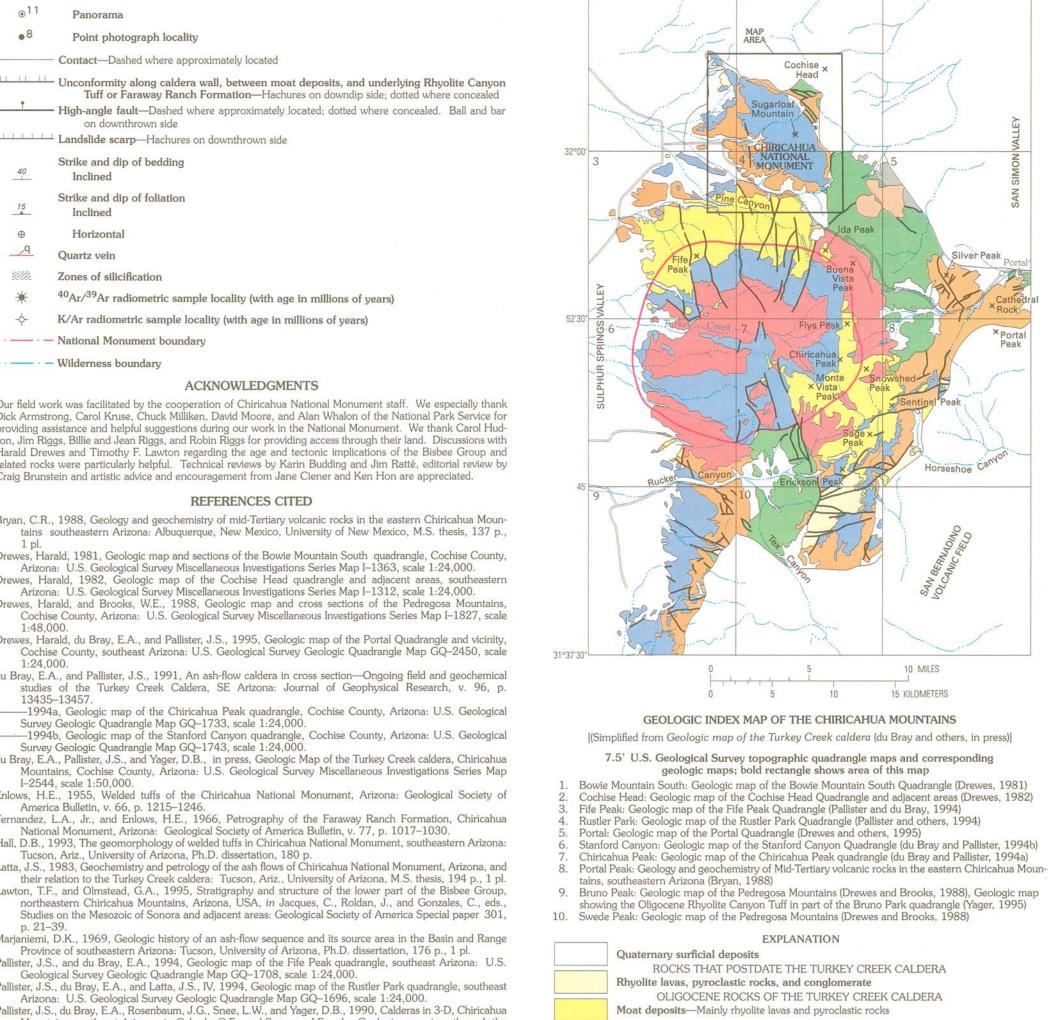
elated rocks were particularly helpful. Technical reviews by Karin Budding and Jim Ratté, editorial review by Craig Brunstein and artistic advice and encouragement from Jane Ciener and Ken Hon are appreciated. Bryan, C.R., 1988, Geology and geochemistry of mid-Tertiary volcanic rocks in the eastern Chiricahua Mountains southeastern Arizona: Albuquerque, New Mexico, University of New Mexico, M.S. thesis, 137 p.,

Drewes, Harald, 1981, Geologic map and sections of the Bowie Mountain South quadrangle, Cochise County, Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I-1363, scale 1:24,000. Drewes, Harald, 1982, Geologic map of the Cochise Head quadrangle and adjacent areas, southeastern Drewes, Harald, and Brooks, W.E., 1988, Geologic map and cross sections of the Pedregosa Mountains, Cochise County, Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I-1827, scale Drewes, Harald, du Bray, E.A., and Pallister, J.S., 1995, Geologic map of the Portal Quadrangle and vicinity, Cochise County, southeast Arizona: U.S. Geological Survey Geologic Quadrangle Map GQ-2450, scale du Bray, E.A., and Pallister, J.S., 1991, An ash-flow caldera in cross section—Ongoing field and geochemical gioclase-clinopyroxene basaltic andesite southeast of Bonita Park are suggestive of pillow studies of the Turkey Creek Caldera, SE Arizona: Journal of Geophysical Research, v. 96, p.

> -1994a, Geologic map of the Chiricahua Peak quadrangle, Cochise County, Arizona: U.S. Geological Survey Geologic Quadrangle Map GQ-1733, scale 1:24,000. 1994b, Geologic map of the Stanford Canyon quadrangle, Cochise County, Arizona: U.S. Geological Survey Geologic Quadrangle Map GQ-1743, scale 1:24,000. du Bray, E.A., Pallister, J.S., and Yager, D.B., in press, Geologic Map of the Turkey Creek caldera, Chiricahua Mountains, Cochise County, Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map Enlows, H.E., 1955, Welded tuffs of the Chiricahua National Monument, Arizona: Geological Society of ernandez, L.A., Jr., and Enlows, H.E., 1966, Petrography of the Faraway Ranch Formation, Chiricahua National Monument, Arizona: Geological Society of America Bulletin, v. 77, p. 1017-1030. Hall, D.B., 1993, The geomorphology of welded tuffs in Chiricahua National Monument, southeastern Arizona: ucson, Ariz., University of Arizona, Ph.D. dissertation, 180 p. atta, J.S., 1983, Geochemistry and petrology of the ash flows of Chiricahua National Monument, Arizona, and their relation to the Turkey Creek caldera: Tucson, Ariz., University of Arizona, M.S. thesis, 194 p., 1 pl.

northeastern Chiricahua Mountains, Arizona, USA, in Jacques, C., Roldan, J., and Gonzales, C., et al., and Gonzales, and Studies on the Mesozoic of Sonora and adjacent areas: Geological Society of America Special paper 301, Marjaniemi, D.K., 1969, Geologic history of an ash-flow sequence and its source area in the Basin and Range al Survey Geologic Quadrangle Map GQ-1708, scale 1:24,000. Arizona: U.S. Geological Survey Geologic Quadrangle Map GQ-1696, scale 1:24,000. stants in geo- and cosmochronology: Earth and Planetary Science Letters, v. 36, p. 359-362.

Province of southeastern Arizona: Tucson, University of Arizona, Ph.D. dissertation, 176 p., 1 pl. 'allister, J.S., and du Bray, E.A., 1994, Geologic map of the Fife Peak quadrangle, southeast Arizona: U.S. Pallister, J.S., du Bray, E.A., and Latta, J.S., IV, 1994, Geologic map of the Rustler Park quadrangle, southeast Pallister, J.S., du Bray, E.A., Rosenbaum, J.G., Snee, L.W., and Yager, D.B., 1990, Calderas in 3-D, Chiricahua Mountains, southeast Arizona, in Gehrels, G.E., and Spencer, J.E., eds., Geologic excursions through the Sonoran Desert region, Arizona and Sonora: Arizona Geological Survey Special Paper 7, p. 31–40. Steiger, R.H., and Jäger, E., 1977, Subcomission on geochronology—Convention on the use of decay con-Waller, M.R., 1952, Lake beds in the Chiricahua National Monument: Tulsa, University of Oklahoma, M.S. Yager, D.B., 1995, Geologic map showing Oligocene Rhyolite Canyon Tuff in part of the Bruno Park quadrangle, southeastern Arizona: U.S. Geological Survey Miscellaneous Field Studies Map, MF-2292



MISCELLANEOUS INVESTIGATIONS SERIES

About 28 million years ago, before eruption of the Turkey Creek caldera, the

TURKEY CREEK CALDERA

A series of giant eruptions took place 26.9 million

years ago, as the rhyolite magma made its way to the surface

and exploded into fragments of pumice and ash. Clouds of ash blanketed a

vast area of southern Arizona and New Mexico as hot and dense clouds of pumice, ash, and

volcanic gasses roared down the flanks of the volcano and filled the Monument valley to a depth of more

Following eruption of the Rhyolite Canyon Tuff, dacite magma (shown in red) uplifted (arrows) the center

Erosion by streams, wind, and landslides has greatly changed the Chiricahua landscape

during the past 26 million years. The Turkey Creek caldera has been eroded to the point that it no

longer looks like a volcano. The high-standing caldera wall has been eroded away by Pinery Canyon. Several areas

that were once valleys or basins, like the National Monument, are now mountains. This "inversion" of topography is the result of

more rapid erosion of the older sedimentary rocks than the hard, erosion-resistant rhyolite from the caldera.

of the caldera and formed a circular valley, or moat, between the uplifted region and the eroding caldera wall. The

dacite magma also erupted and formed lava flows that flowed into the moat, as well as down an ancient channel into the Monu-

ment valley. Late during this interval, rhyolite magma erupted again, yielding ash, pumice, and viscous lava flows (shown in yellow), which also

than 1,600 feet. Three major eruptions affected the Monument; ash flows from these three eruptions deposited what

we now know as the lower, middle, and upper members of the Rhyolite Canyon Tuff (shown in shades of blue). More than 120 cubic

miles of molten rock was erupted, creating a 12-mile-diameter circular depression, or caldera, which also filled with ash and pumice. During the

eruption, the caldera floor subsided (arrows). This panel represents the waning stage of the eruptions. During the main phase, the entire region would have been

obscured from view by clouds of ash and by storms, which are known to result from volcanic addition of large volumes of ash, heat, and water vapor to the atmosphere.

northern Chiricahua Mountains consisted of uplifted masses of Paleozoic and Mesozoic sedimen-

tary rocks (shown in gray and dark green), which were overlain and surrounded by lava and ash flows from

two or more active volcanic fields. The volcanoes produced andesite, dacite, and rhyolite of the Faraway Ranch Formation

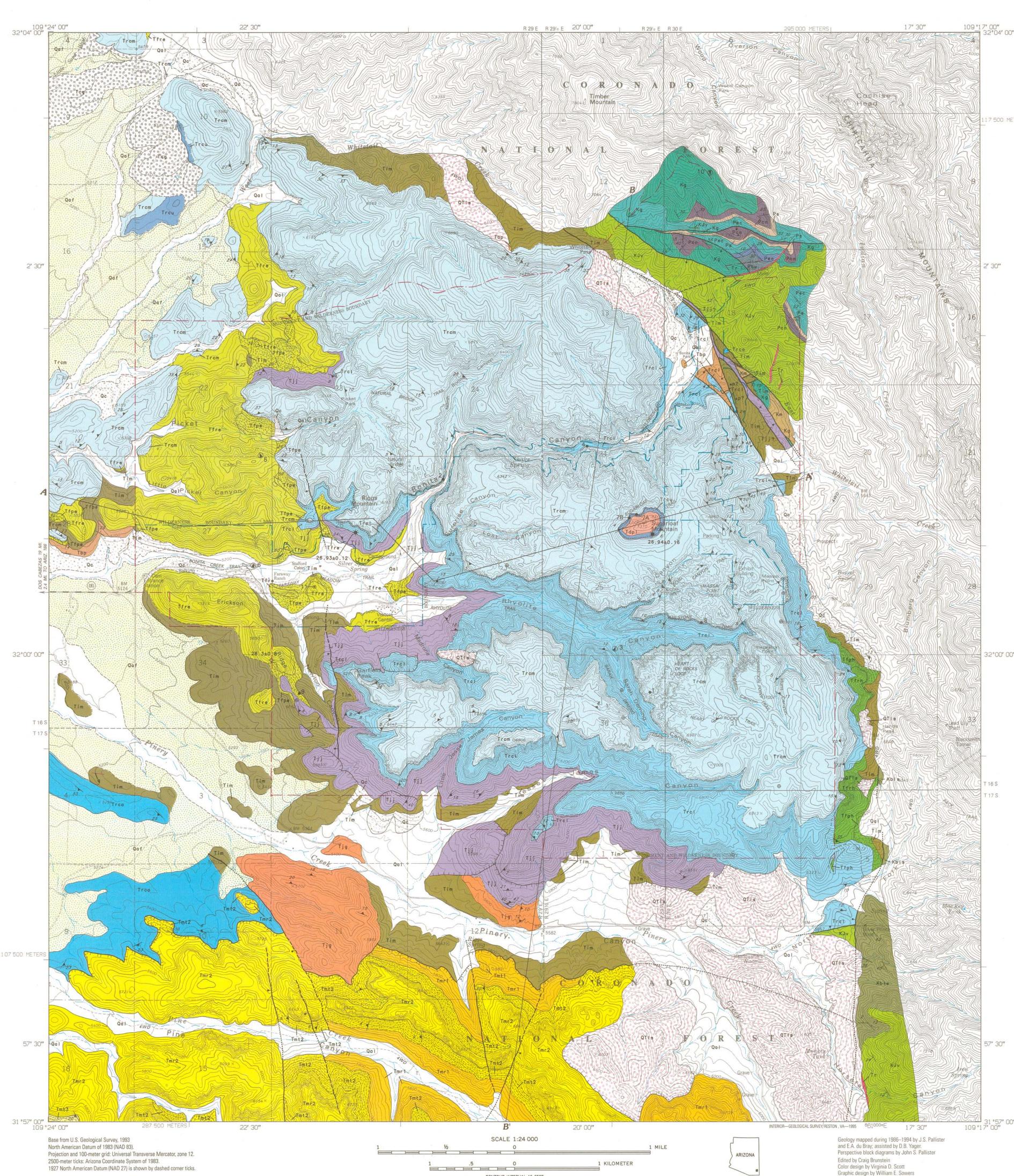
(shown in light green) as well as similar volcanic rocks north of the National Monument (shown in orange). About 27 million years ago,

a large body of rhyolite magma (shown in blue) accumulated beneath and uplifted (arrows) the area south of the National Monument.

Pamphlet accompanies map

fine-grained, limy dolomite. Fossils include large echinoid spines and gastropods. Thickness Earp Formation (Lower Permian)—Pale-red siltstone and argillaceous limestone; interbedded with light-gray to yellowish-gray limestone. Thickness greater than 1,000 feet Horquilla Limestone, upper member (Lower Permian)—Light-gray, thin- to thick-bedded, ne-grained calcilutite, coarse-grained bioclastic and fossiliferous cherty limestone, and interbedded pink siltstone. Thickness about 1,300 feet Thin surficial units not shown. Thin dotted lines show bedding or flow trends; thicker dotted lines in units Trou and Trol are explained in technical description of map un

Figure 12. West to east geologic cross section through Riggs and Sugarloaf Mountains (see figure 11 and map) that shows the distribution of rock layers in the subsurface.



INTERPRETIVE MAP AND GUIDE TO THE VOLCANIC GEOLOGY OF CHIRICAHUA NATIONAL MONUMENT AND VICINITY, COCHISE COUNTY, ARIZONA

CONTOUR INTERVAL 40 FEET NATIONAL GEODETIC VERTICAL DATUM OF 1929

John S. Pallister and Edward A. du Bray

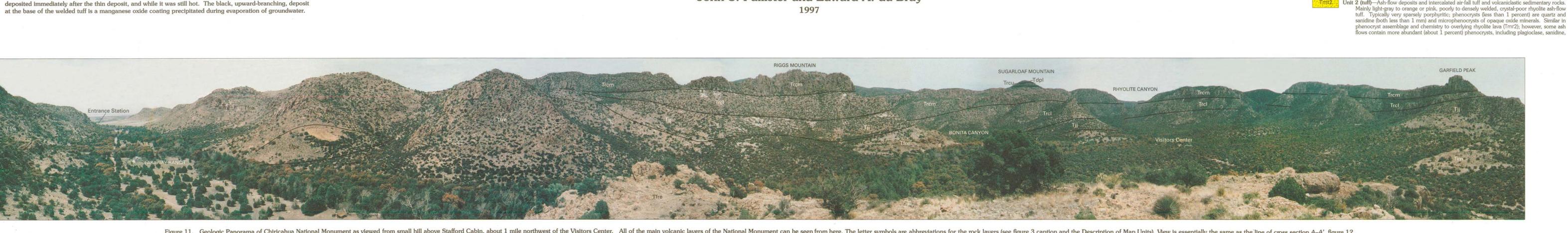


Figure 11. Geologic Panorama of Chiricahua National Monument as viewed from small hill above Stafford Cabin, about 1 mile northwest of the Visitors Center. All of the main volcanic layers of the National Monument can be seen from here. The letter symbols are abbreviations for the rock layers (see figure 3 caption and the Description of Map Units). View is essentially the same as the line of cross section A-A', figure 12.

