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Geologic Map of the Pahranagat Range 30′ x 60′ Quadrangle, Lincoln and Nye Counties, Nevada

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Pamphlet to accompany
Scientific Investigations Map 2904

View from Badger Mountain area looking north to Hancock Summit. Tertiary volcanic rocks unconformably overlie Cambrian and Ordovician rocks in the foreground.

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Contents

Introduction

The Pahranagat Range 30´ x 60´ quadrangle lies within an arid, sparsely populated part of Lincoln and Nye Counties, southeastern Nevada (fig. 1). Much of the area is public land that includes the Desert National Wildlife Range, the Pahranagat National Wildlife Refuge, and the Nellis Air Force Base. The topography, typical of much of the Basin and Range Province, consists of north-south-trending ranges and intervening broad alluvial valleys. Elevations range from about 1,000 to 2,900 m.

At the regional scale, the Pahranagat Range quadrangle lies within the Mesozoic and early Tertiary Sevier Fold-and-Thrust Belt (Armstrong, 1968) and the Cenozoic Basin and Range Province (Gilbert, 1874, 1928). The quadrangle is underlain by a Proterozoic to Permian miogeoclinal section, a nonmarine clastic and volcanic section of middle Oligocene or older to late Miocene age, and alluvial deposits of late Cenozoic age (Tschanz and Pampeyan, 1961, 1970; Ekren and others, 1977). The structural features that are exposed reflect relatively shallow crustal deformation. Mesozoic deformation is dominated by thrust faults and asymmetric or open folds. Cenozoic deformation is dominated by faults that dip more than 45° and domino-style tilted blocks.

At least three major tectonic events have affected the area: Mesozoic (Sevier) folding and thrust faulting, pre-middle Oligocene extensional deformation, and late Cenozoic (mainly late Miocene to Holocene) extensional deformation. Continued tectonic activity is expressed in the Pahranagat Range area by seismicity and faults having scarps that cut alluvial deposits.

Previous Work

Previous mapping and stratigraphic studies within the Pahranagat Range quadrangle (fig. 2) consist of regional geologic mapping at scales of 1:250,000 and 1:200,000, which include the geology of Lincoln County (Tschanz and Pampeyan, 1961, 1970), the geology of southern Nye County (Cornwall, 1972), and the geology of Tertiary rocks of Lincoln County (Ekren and others, 1977). Larger scale mapping at 1:24,000 scale is restricted to the westernmost part of the quadrangle, in the eastern part of the Nevada Test Site (Barnes and others, 1965; Byers and Barnes, 1967; Colton and Noble, 1967). Tertiary volcanic rocks in the northeast corner of the quadrangle were mapped by Moring (1987).

The Upper Cambrian through Mississippian stratigraphy of the Pahranagat Range was studied by Reso (1963); the upper Proterozoic through Lower Ordovician stratigraphy of the Groom Range, by Barnes and Christiansen (1967). The volcanic stratigraphy was studied by Dolgoff (1963), but much of his stratigraphic nomenclature was later revised by Ekren and others (1977), following earlier work by Cook (1965). The scant isotopic dating of volcanic rocks within the quadrangle consists of four determinations by Armstrong (1970), which are compiled in Ekren and others (1977). However, many regionally extensive ash-flow-tuff units that extend into the Pahranagat Range quadrangle have been dated (Marvin and others, 1970, 1973; Armstrong, 1970; Noble and McKee, 1972; Fleck and others, 1975).

Field work for this study was carried out in the spring and fall of 1986 and 1987, as well as in parts of 1988 and 1989. Studies consisted of field mapping at 1:24,000 scale of most the east half of the quadrangle. Areas that were inaccessible because of military restrictions, including most of the west half of the quadrangle, were mapped using aerial photography, which consisted of natural-color photos, at 1:31,680 scale, and black-and-white photos, at scales of 1:20,000, 1:40,000, and 1:60,000. Previous mapping (Barnes and others, 1965; Byers and Barnes, 1967; Colton and Noble, 1967) at 1:24,000 scale of the Nevada Test Site, part of which lies in the southwest corner of the Pahranagat Range quadrangle, was compiled without further field checking.

Stratigraphy

Quaternary and Upper Neogene Strata

Upper Neogene and Quaternary units, which underlie about one third of the Pahranagat Range quadrangle, consist predominantly of alluvium and colluvium, as well as minor eolian, lacustrine, and stream deposits. The alluvium consists predominantly of pediment gravels and large fan deposits that have filled basins and blanketed the Paleozoic and older Tertiary strata.

A meandering stream known as the “ancestral White River” (Reso, 1959) flowed through the Pahranagat Valley in late Pleistocene time. Remnants of this stream are prominent in the quadrangle. While active, the stream truncated the broad alluvial deposits that had begun to fill Pahranagat Valley. The stream bed has subsequently been invaded by local, small cone-shaped, alluvial-fan deposits. These cones are relatively stable and are covered by cultural features, indicating that they predate the present climatic regime.

Alluvial deposits within the basins of the Pahranagat Range have been cut by normal faults that form prominent scarps throughout the study area, indicating Quaternary extensional deformation.

Upper Neogene and Quaternary deposits were discriminated and mapped principally on the basis of morphologic characteristics that were evident on air photos. For example, alluvial deposits were differentiated on the basis of characteristics of dissection, such as density of drainage development, depth of incision, development of meandering on incised surface, and high topographic relief relative to nearby deposits.

Tertiary Strata

Tertiary clastic and volcanic rocks, which are exposed in about one third of the Pahranagat Range quadrangle, unconformably overlie Paleozoic strata. The volcanic rocks consist principally of ash-flow tuffs. Volcanic rocks in the southwestern part of the quadrangle are no older than early(?) Miocene in age; they are described in the section on volcanic strata of the Halfpint Range (see below). The geology of the Halfpint Range is summarized from previous 1:24,000-scale mapping (Barnes and others, 1965; Byers and Barnes, 1967; Colton and Noble, 1967) because that area, as well as the Groom Range, Jumbled Hills, and Desert Range, all presently lie within a military zone with restricted access. The eastern and northwestern parts of the quadrangle include volcanic rocks of middle Oligocene and younger age that are described in the section on Tertiary strata of the Pahranagat Range and vicinity (see below).

Volcanic Rocks of the Halfpint Range

The Tertiary section in the Halfpint Range consists of a local basal conglomerate of early or middle Miocene age that is overlain by Miocene and younger volcanic and clastic rocks (Barnes and others, 1965; Byers and Barnes, 1967; Marvin and others, 1970). The volcanic section, which ranges in age from about 15 to 11 Ma (Kistler, 1968; Marvin and others, 1970), consists of the following units: undivided tuff that lies beneath the Tub Springs Member (of the Belted Range Tuff); the peralkaline Grouse Canyon Member (of the Belted Range Tuff); the Topopah Springs Member (of the Paintbrush Tuff); and the rhyolitic to latitic rocks of the Timber Mountain Tuff. The youngest volcanic rocks are basaltic flows and dikes of late Tertiary and (or) Quaternary age (Barnes and others, 1965; Byers and Barnes, 1967). The source area for many of the ash-flow tuffs was the nearby southwest Nevada volcanic field, which includes several large caldera complexes such as Timber Mountain, 15 km west of the quadrangle (Carr and others, 1986; Christiansen and others, 1965; Byers and others, 1976; Christiansen and others, 1977).

Tertiary Strata of the Pahranagat Range and Vicinity

The Tertiary section in the Pahranagat Range area attains a thickness of one kilometer (Dolgoff, 1963). At its base is a red-weathering conglomerate that lacks volcanic detritus and consists exclusively of clasts derived from the pre-Tertiary section. The conglomerate is overlain variously by limestone or by Oligocene to middle Miocene, dacitic to rhyolitic, and peralkaline ash-flow tuffs (Ekren and others, 1977).

The Monotony Tuff is the oldest recognized volcanic unit in the map area. It is overlain by a series of densely welded, crystal-poor, felsic tuffs that include the Shingle Pass Tuff, the Leach Canyon Formation, and, very locally in the northeastern and eastern parts of the map area, the Condor Canyon Formation. The overlying Harmony Hills Tuff and Pahranagat Lakes Tuff of Williams (1967) are broadly distributed in the southeastern part of the map area; the Hiko and Kane Wash Tuffs, throughout the east half of the quadrangle. Basalt and basaltic andesite flow rocks overlie the Harmony Hills, Hiko, and Kane Wash Tuffs at various localities. The ash-flow tuffs in this area originated from several source areas. The Shingle Pass Tuff is inferred to have originated from the Quinn Canyon Range to the northwest (Sargent and Houser, 1970); the Hiko and Harmony Hills Tuffs, from the Caliente caldera to the west (Noble and McKee, 1972), the Kane Wash Tuff, from the Kane Wash caldera to the east (Noble, 1968). The stratigraphically highest basalt flow probably issued from the Kane Wash caldera to the east (Novak, 1984), whereas the lowest basaltic andesite flow may have originated within the Bald Mountain volcanic center (Ekren and others, 1977) in the northwestern part of the quadrangle. Ekren and others (1977) suggested that extrusion of basalt was tectonically controlled by activity on the Pahranagat Fault Zone, which consists of the Buckhorn, Arrowhead Mine, and Maynard Lake Faults; however, the basaltic rocks appear to be interlayered in a stratigraphic section that was disrupted significantly along the Pahranagat Fault Zone several million years after eruption of the basalt and basaltic andesite flows. In the case of the oldest basaltic rocks, the interval between emplacement and faulting amounts to about 10 m.y. The youngest basaltic unit (Tb_3) from this area, which lies at the east edge of the quadrangle, is faulted and openly folded similar to that of the underlying volcanic strata, which indicates that the basalt was deposited before extension and lateral faulting.

Meter-thick beds of reworked tuff, conglomerate, and very local lacustrine limestone also are interbedded within the volcanic section, recording erosion and sedimentation between eruptive events. The uppermost part of the exposed Tertiary section consists of fine- to medium-grained alluvial deposits and thin (5–10 cm to 3–4 m thick) interbedded air-fall tuffs. Preliminary dating of these air-fall tuffs suggests ages as young as 7.7 Ma (Jayko, Sarna-Wojcicki, and Meyers, unpub. data, 1999). The top of the Tertiary section is not exposed and so is either faulted out or covered by alluvium.

The distribution of Tertiary rocks in the eastern part of the quadrangle suggests low-to-moderate topographic relief of a kilometer or less before deposition of the Tertiary section. The basal Oligocene unit (Ts) and Cretaceous conglomerate and lacustrine limestone (TKs) are broadly distributed in the southern part of the Pahranagat Range and northern part of the Sheep Range. These units also are common in the Jumbled Hills and Fallout Hills areas (Tschanz and Pampeyan, 1970; Ekren and others, 1977). Successively younger ash-flow tuff units onlap the Paleozoic strata north and south of the present Pahranagat Fault Zone, suggesting that a localized, east-west-trending basin occupied the area of the fault zone in the early Tertiary. East-west-trending early Tertiary paleovalleys that have a few hundred meters to a kilometer of relief have been reported farther east in eastern Nevada and southern Utah (Rowley and others, 1979; Best and others, 1987). Although some tuff units pinch out locally within the section, it appears that there was no significant disruption of Tertiary rocks of the Pahranagat Range area until after deposition of the 7.7-Ma tuff.

Paleozoic and Precambrian Rocks

The Precambrian and Paleozoic rocks consist of about 10,000 m of clastic and carbonate strata that were deposited during passive-margin sedimentation, which ranged from the

Late Proterozoic to the Permian, an interval of 400 to 450 million years (Barnes and Christiansen, 1967; Reso, 1963; Tschanz and Pampeyan, 1970). The strata of the Pahranagat Range quadrangle were deposited to the west of the continental shelf; on the shelf, the equivalent section is only one quarter the thickness (Tzchanz and Pampeyan, 1970; Stewart and Poole, 1974).

Precambrian and Lower Cambrian rocks consist dominantly of quartzite, sandstone, siltstone, and shale. The oldest exposed strata consist of the Late Proterozoic Johnnie Formation, which is found in the western part of the Groom Range and in the northern parts of the Papoose and Halfpint Ranges (Barnes and others, 1965; Barnes and Christiansen, 1967; Barnes and Christiansen, unpub. data, 1968). Upper Cambrian to Devonian rocks consist predominantly of dolomite and limestone and subordinate amounts of quartzite and shale. Mississippian and younger rocks consist predominantly of limestone and subordinate amounts of shale and minor amounts of quartzite. The youngest exposed strata consists of the Pennsylvanian and Permian Bird Spring Formation, which is found in the hills east of the Sheep Range and in the northern part of the East Pahranagat Range.

Structure

Rocks of the Pahranagat Range quadrangle were deformed by folding and thrusting during the Mesozoic and by normal faulting, strike-slip faulting, and local broad, open folding during the Cenozoic. Normal faulting began before the Oligocene and has continued intermittently but not uniformly until the present.

Mesozoic Structures

Precambrian and Paleozoic miogeoclinal strata were deformed by thrust faults and folds during the Mesozoic and early Tertiary (Tschanz and Pampeyan, 1970). The map area lies within the Sevier orogenic belt (Armstrong, 1968). Deformation associated with the Sevier orogeny has been dated elsewhere as mainly Cretaceous to early Tertiary in age (Armstrong, 1968); however, Mesozoic rocks that could constrain the timing of such deformation are not present within the Pahranagat Range quadrangle.

At least two and probably three structural levels are exposed in the map area. The lowest level consists of rocks underlying the Gass Peak Thrust Fault, which are mapped only in the southeast corner of the quadrangle. The intermediate level consists of the Gass Peak plate (Tschanz and Pampeyan, 1970), which underlies most of the quadrangle. The highest level consists of rocks that are the upper plate of the Spotted Range Thrust Fault, which have been down-dropped along normal faults against rocks of the Gass Peak plate. This upper plate is only exposed in the southwestern part of the quadrangle east of Chert Ridge, where undivided Proterozoic and Cambrian rocks are faulted against upper Devonian and Mississippian strata. The Gass Peak Thrust Fault is not exposed north of the Pahranagat Fault Zone; it may die out northward into the East Pahranagat Syncline, or it may be offset along a hidden Mesozoic transfer fault that parallels the Tertiary Pahranagat Fault Zone.

Folds and small-scale thrust faults are present in upper Paleozoic strata that underlie the Gass Peak Thrust Fault east of the Sheep Range, as well as in Mississippian strata that may underlie the Spotted Range Thrust Fault on Chert Ridge. Small-scale folds and thrust faults also are present in the upper part of the Cambrian section—in particular, within the Bonanza King Formation. A large-scale, east-verging regional fold is present in the East Pahranagat Range.

Cenozoic Basin-Range Structures

Extensional faulting predates Oligocene ash-flow tuffs in the eastern part of the quadrangle and middle Miocene tuffs in the western part. The eastern part of the quadrangle was relatively stable between the Oligocene and latest Miocene, but extensional deformation affected the entire map area from the late Miocene or Pliocene to the present.

Low-angle normal faults (mapped as thrust faults by Barnes and others, 1965) cut moderately dipping Paleozoic strata of the Halfpint Range and are covered by middle Tertiary ash-flow tuffs. These faults revert to a configuration of moderately to steeply east-dipping normal faults when the dips of the moderately tilted Paleozoic strata are restored to more gentle dips, which suggests that extreme extension affected this area before the middle Miocene.

Late Cenozoic structures include abundant north-striking, east- and west-dipping, high-angle normal faults; northeast-striking normal and strike-slip faults; and rollovers, monoclinal flexures, drag folds, and large basins. Northeast-striking, generally synclinal drag folds are prominent within the Pahranagat Fault Zone, which lies within a zone of dominantly left-lateral displacement (Tschanz and Pampeyan, 1970). Less obvious rollovers and monoclinal flexures are present along some of the north-striking high-angle faults.

Pahranagat Fault Zone

The Pahranagat Fault Zone (Pahranagat Shear System of Tschanz and Pampeyan, 1970), which strikes about N. 50º E. and is about 12.5 km wide and 40 km long, continues to the east of the Pahranagat Range quadrangle. Liggett and Ehrenspeck (1974) and Wernicke and others (1984) suggested that the Pahranagat Fault Zone is a tear fault that connects the faults in the Desert Valley with large, normal faults in the Dry Lake Valley, about 15 km to the southeast, and the Delamar Valley, 10 km to the east.

Three major N. 50º E.-striking faults constitute the Pahranagat Fault Zone in the Pahranagat Range quadrangle. From south to north, these are the Maynard Lake, Buckhorn, and Arrowhead Mine Faults (Tschanz and Pampeyan, 1970, p. 83). All dip steeply to the northwest, and they all show oblique slip that contains a major component of dip-slip in addition to left-lateral strike-slip displacement (Tschanz and Pampeyan, 1970; Ekren and others, 1977). Tschanz and Pampeyan (1970), as well as Liggett and Ehrenspeck (1974), estimated a total of 9 to 16 km of displacement on the fault zone. South-southeast of the Pahranagat Valley, Tertiary strata are rotated to gentle, southerly dips into the major splays of the Pahranagat Fault Zone, suggesting that the faults are listric to the north.

These three major faults of the Pahranagat Fault Zone terminate just east of the Desert Range. Although a few east-striking faults are present in the Desert Hills, none have significant lateral displacement. No evidence exists which shows that the Arrowhead Mine, Buckhorn, or Maynard Lake Faults continue to the west into the Paleozoic strata of the Desert Range or northern Pintwater Range. The Spotted Range Fold-and-Thrust Belt (Tschanz and Pampeyan, 1970), which deforms Upper Devonian and Mississippian rocks, most likely continues to the north into the Chert Ridge area, where imbricate thrusting of the Upper Mississippian strata is evident on air photos, and into the Jumbled Hills area, where Devonian strata are thrust over the Mississippian strata. Continuation into the East Pahranagat Syncline, as suggested by Tschanz and Pampeyan (1970), is less likely.

Middle Oligocene to upper Miocene strata in the Pahranagat Fault Zone were not disrupted significantly until after 7.7 Ma (Jayko, Sarna-Wojcicki, and Meyers, unpub. data, 1989), which is the youngest age of the interbedded tuffs and alluvial deposits above the volcanic section. Fault scarps in alluvial deposits, as well as active seismicity at the north end of the Sheep Range, indicate Quaternary activity for at least the Maynard Lake Fault. Fault scarps also cut alluvial deposits north of the Arrowhead Mine Fault.

Summary

Proterozoic to Permian sedimentary rocks form a thick miogeoclinal sequence that was deformed by thrust faulting and folding during the Mesozoic and early Cenozoic(?) (Armstrong, 1968). Ash-flow tuffs were deposited and andesitic and basaltic flows were erupted during much of the middle and late Tertiary. This volcanic activity was contemporaneous with extensional deformation. From the late Tertiary through the present, extensional deformation has been active and has been accompanied by basin filling and alluvial sedimentation.

Extensional deformation began before the middle Oligocene and was active in the middle Miocene in the western part of the quadrangle. The lack of significant middle Miocene deformation in the eastern part of the quadrangle suggests that the extension was localized, so that fairly large blocks remained undeformed. The latest deformation is characterized chiefly by normal faults that dip 50º or more, whereas some of the older normal faults that are, in part, covered by Tertiary rocks are flatter lying (for example, in the Halfpint Range); this suggests that the shallower fault dips are, in part, related to rotation caused by younger faulting and tilting to expose deeper structural levels. Strike-slip faulting within the Pahranagat Fault Zone was accompanied by folding of Tertiary strata. These folds are generally broad, open structures.

Cenozoic activity on the Pahranagat Fault Zone apparently did not begin until latest Miocene or early Pliocene time (7.7 Ma or younger), as suggested by deformation of the youngest deposits near the top of the conformable Tertiary section. The fault zone is interpreted as a transfer fault that accommodates extension by connecting detachment faults between the Delamar and Dry Lake Valleys and the Desert Valley, as suggested by previous workers (Liggett and Ehrenspeck, 1974; Wernicke and others, 1984). This fault zone is also part of the Death Valley Fault Zone described by Wernicke and others (1988).

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DESCRIPTION OF MAP UNITS

[Description of units in Halfpint Range modified from Colton and Noble (1967), Barnes and others (1965), and Byers and Barnes (1967). Phenocryst compositions for volcanic units in Pahranagat and Groom Ranges are from Ekren and others (1977)]

SEDIMENTARY DEPOSITS AND ROCKS

Q **Quaternary surficial deposits, undivided (Quaternary)**—Shown on cross sections only. May include units Qs, Qsc, Qog, QTog, and QTs

Qs **Surficial deposits (Quaternary)**—Generally unconsolidated, boulder- to sand-sized deposits in alluvial fans, talus, and washes. Poorly sorted and poorly rounded clasts. Generally little cementation and poorly developed desert pavement. Commonly gradational into unit Qsc

Qe **Eolian deposits (Quaternary)**—Unconsolidated sand and silt in stable and active dunes

Ql **Lacustrine and playa deposits (Quaternary)**—Generally unconsolidated clay, silt, sand, and lenses of gravel. Thin bedded and well stratified

Qsc **Stream-channel and wash deposits (Quaternary)**—Generally unconsolidated boulder- to sand-sized deposits. Commonly gradational into unit Qs

Qog **Older alluvial gravels (Quaternary)**—Generally unconsolidated, boulder- to sand-sized deposits in alluvial fans. Deposits are usually dissected by washes, forming irregular surface. Commonly cemented by caliche; desert varnish developed on clasts

QTog **Older gravel deposits (Quaternary and (or) Tertiary)**—Poorly sorted deposits consisting of angular and subrounded clasts. Deposits are deeply incised and channeled. Commonly have well-developed caliche horizon a meter or more thick

QTol **Older landslide deposits (Quaternary and (or) Tertiary)**—Poorly sorted, weathered, and incised deposits of disrupted Tertiary strata that include very large boulder- and block-sized clasts

QTos **Older stream-channel deposits (Quaternary and (or) Tertiary)**—Generally unconsolidated silt, sand, and gravel. Deposits are found in meandering stream channel known as the "ancestral White River" (Reso, 1959), which ran along axis of Pahranagat Valley

QTs **Sedimentary deposits (Quaternary and (or) Tertiary)**—Generally unconsolidated and partly consolidated, stratified silt, sand, and gravel in alluvial fan. Rare white volcanic ash beds preserved locally. Upper surface commonly cemented by caliche. Poorly developed desert pavement

VOLCANIC AND SEDIMENTARY ROCKS

HALFPINT RANGE

QTb **Basalt (Pleistocene and (or) Pliocene)**—Flows and dikes of dark-gray, olivine-bearing basalt. Also includes intrusive basaltic rocks and microgabbro that consists of labradorite, augite, and iddingsite after olivine. Present as basalt dikes and microgabbro pluglike intrusions in southwest corner of map area

Timber Mountain Tuff (Miocene)—Crystal-rich, quartz-bearing, rhyolitic to quartz-latitic ash-flow tuff. Was erupted from Timber Mountain caldera, located about 15 km west of quadrangle, about 10.7 to 12.7 Ma (Byers and others, 1976). In this area, consists of following members:

Tta **Ammonia Tanks Member**—Rhyolitic to quartz-latitic ash-flow tuff. Compound-cooling unit of yellowish-brown, partially welded to nonwelded ash-flow tuff. Contains devitrified pumice fragments as large as 2 cm across; abundant phenocrysts of feldspar and bipyramidal quartz as much as 3 mm in length; rare biotite. Degree of welding and thickness increase to southwest. Forms craggy outcrops; erupted about 11.5 Ma (Kistler, 1968)

Ttr **Rainier Mesa Member**—High-silica rhyolite; multiple-flow compound-cooling unit. Consists of, in decreasing order: brown, densely welded vitrophyre; biotite ash-flow tuff; pinkish-gray, pumiceous, partly welded ash-flow tuff; locally includes ash-fall tuff found between this unit and the underlying Topapah Spring Member (of the Paintbrush Tuff). Was erupted about 11.4 Ma (Marvin and others, 1970)

Paintbrush Tuff (Miocene)—In this area, consists of following member:

Tpt **Topapah Spring Member**—Crystal-poor, quartz-poor, densely welded, zoned rhyolite to quartz-latite tuff. Was erupted from Claim Canyon caldera segment of Timber Mountain caldera, located about 10 km west of quadrangle, about 12.6 to 13.4 Ma (Kistler, 1968; Marvin and others, 1970; Byers and others, 1976)

Tv_1 **Tuff, undivided (Miocene)**—Mainly nonwelded ash-flow tuff and ash-fall tuff, locally reworked by wind and water. Locally welded near base. Sandy tuff and tuffaceous sandstone in upper part; bedded tuff in lower part. Generally white, light-gray, pale-yellow, and pink shades. Locally zeolitized

Belted Range Tuff (Miocene)—In this area, consists of following members:

Tbg **Grouse Canyon Member**—Chemically distinctive peralkaline assemblage. Was erupted from Silent Canyon caldera, located 15 km east of quadrangle (Warren, 1983; Warren and others, 1985). Compound-cooling unit of densely welded, generally crystal-poor, devitrified comendite ash-flow tuff. Was erupted about 14.2 Ma (Marvin and others, 1970)

Tbt **Tub Spring Member—**Compound-cooling unit of densely welded, comenditic ash-flow tuff. Contains 15–30% phenocrysts; mainly sodic sanidine and quartz; less abundant iron-rich clinopyroxene, fayalite, and opaque oxides; and traces of biotite in some ash-flow tuffs

Tcl **Conglomerate (Miocene)**—Conglomerate and breccia or fanglomerate, consisting mainly of quartzite clasts in red arkosic matrix

Tot **Older tuff (Miocene)**—Includes the biotite-rich welded tuff of Barnes and others (1965), which consists of simple-cooling unit that contains welded devitrified ash-flow tuff; brownish red to reddish gray; phenocrysts of abundant biotite and plagioclase, sparse hornblende, rare quartz; dark-gray vitrophyre locally in upper part. Also contains red, welded, devitrified ash-flow tuff; abundant quartz and feldspar phenocrysts. Locally includes dark-gray vitrophyre and yellowish-gray devitrified tuff. Locally underlain by basal conglomerate or breccia

PAHRANAGAT AND GROOM RANGES

Ts_2 **Sedimentary deposits (Pliocene? and Miocene)**—Alluvial deposits. Poorly consolidated, poorly stratified silt, sand, pebble conglomerate, and gravel. Also, minor amounts of interbedded volcanic ash, in beds that range in thickness from about 7–10 cm to 3 m. Conglomerate clasts derived primarily from the Kane Wash Tuff

Tb_3 **Basalt flows (Miocene)**—Flows of olivine-bearing basalt. Restricted to easternmost part of map area. Whole-rock K/Ar analyses yield ages of 11.4 to 12.7±0.3 Ma (Novak, 1984). Overlies the Kane Wash Tuff

Kane Wash Tuff (Miocene)—Predominantly peralkaline rhyolite ash and welded ash-flow tuff. Multiple cooling units. K/Ar determinations on sanidine of 13.4 to 14.0 Ma. Common aqua-blue chatoyant sanidine, clinopyroxene, and fayalite+quartz (Noble, 1968; Armstrong, 1970; Marvin and others, 1970; Novak, 1984). In this area, overlies either the Hiko Tuff or unit Tb_2. Consists of following subunits:

Tku **Undivided part**—White, pale-pinkish- and orangeish-weathering, moderately welded ash-flow tuff. On cross sections, may include units Tk_1, Tk_2, and Tk_3

Tk_3 **Upper compound-cooling unit**—One to five densely welded flows. Dark weathering. Forms thin ledges

Tk_2 **Middle compound-cooling unit—**Thick, poorly welded, whitish and pinkish, cavernous-weathering ash-flow tuff. Abundant dark and reddish lithic fragments. Slope forming

Tk_1 **Lower compound-cooling unit**—One to five densely to moderately welded ash-flow tuffs that increase in number and degree of welding to east

Tb_2 **Upper basaltic andesite flows (Miocene)**—Flows of olivine-bearing basalt or basaltic andesite 3 to 20 m thick; as much as 65 m thick. Dark brown or reddish brown weathering; black or grayish black on fresh surface. Typically vesicular. One whole-rock K/Ar analysis gives age of 15.6±0.4 Ma (Novak, 1984). Overlies the Hiko Tuff

Th **Hiko Tuff (Miocene)**—Poorly welded, crystal-rich, pinkish to purplish-gray rhyodacite (Dolgoff, 1963). Contains 30–40% phenocrysts: hornblende, 2–5%; quartz, 15–23%; biotite, 10–15%; alkali feldspar, 10–25%; plagioclase feldspar, 40–57%; ubiquitous accessory sphene; accessory zircon and apatite. K/Ar determinations on biotite and sanidine give ages of 17.8±0.5 Ma (Armstrong, 1970), 19.6 Ma (Noble and McKee, 1972), and 18.8 Ma (*in* Bartley and others, 1988)

Tsa **Sedimentary rocks and ash (Miocene)**—White- and pale-cream-weathering unit that consists of fine and coarse sand, reworked tuff that is locally crossbedded, and thin beds of minor gravel and conglomerate. Underlies the Hiko Tuff in northeast corner of quadrangle

Tvg **Volcanic rocks of Groom Range area (Miocene)**—Undivided tuff. Contacts were mapped on air photos and (or) modified from Ekren and others (1977) because area is presently inaccessible owing to military activities. Includes lava flows and tuffs that vary in composition from basaltic andesite to quartz-latite. Includes the tuff of Bald Mountain of Ekren and others (1977)

Tb **Lower basaltic andesite flows (Miocene)**—Massive flows of olivine-bearing basaltic andesite; vesicular; reddish weathering. Overlies the Harmony Hills Tuff in southwestern part of Pahranagat Range

Thp **Harmony Hills Tuff and Pahranagat Lakes Tuff of Williams (1967), undivided (Miocene)—** The Harmony Hills Tuff is crystal-rich andesitic ash-flow tuff that has about 30–55%

phenocrysts, dominated by plagioclase (70%); also, biotite, 15%; quartz, 2–10%; clinopyroxene, 1–8%; olivine, 2%; trace amounts of alkali feldspar and hornblende. Biotite is present in course-grained books about 4 mm wide by 3 mm thick (Ekren and others, 1977). Grayish green on fresh surfaces; weathers to reddish color. Generally forms massive, resistant ledges. Was erupted about 20 to 21 Ma (Armstrong, 1970; Noble and McKee, 1972). The Pahranagat Lakes Tuff of Williams (1967), which underlies the Harmony Hills Tuff in most areas, is rhyolitic ash-flow tuff having moderate amount of crystals that include distinctive chatoyant feldspars. Combination of chatoyant feldspars and quartz distinguishes it from the overlying Kane Wash Tuff. Generally poorly welded and shows nodular and irregular weathering resulting from differential erosion of easily weathered pumice fragments. In general, slope forming

Tv **Volcanic rocks of Groom Range, Jumbled Hills, and Fallout Hills areas, undivided (Miocene and Oligocene?)**—May locally include tuff as old as the Oligocene Shingle Pass Tuff, as well as tuffs of middle Miocene age (Ekren and others, 1977). Inaccessible owing to restricted access on military property

Tcc **Condor Canyon Formation (Miocene)**—Consists of the Swett Member and the Bauers Tuff Member, undivided. The Bauers Tuff Member, which is more widespread, consists of generally crystal-poor, densely welded, brick-red-weathering ash-flow tuffs. The Bauers Tuff Member contains about 10–20% phenocrysts: no quartz; alkali feldspar, 30–40%; plagioclase feldspar, 50–70%; biotite, 3–7%; olivine, 1%. The Swett contains about 5% phenocrysts: no quartz or alkali feldspar; plagioclase feldspar, 85–95%; biotite, 15%; altered mafic minerals, 1–3%; olivine, 2%. The Bauers Tuff Member was erupted about 23 Ma (Armstrong, 1970; Fleck and others, 1975)

Ta **Andesitic flows (Miocene and (or) Oligocene)**—Dark-purple, red, green, and black, clinopyroxene- and plagioclase-bearing andesite flows, breccias, cinder, and tuff beds. Present in northeasternmost corner of quadrangle. Locally as much as 65 m thick (Moring, 1987)

Tlc **Leach Canyon Formation (Miocene and (or) Oligocene)**—In this area, consists of white, pinkish, and reddish, slightly to moderately welded rhyolitic ash-flow tuff. Crystal poor, having subequal amounts of plagioclase, sanidine, and quartz. Considered to be Oligocene and (or) Miocene, on the basis of K-Ar ages that range from about 22 to 24 Ma obtained on rocks of this unit located outside map area (Armstrong, 1970)

Tspl **Shingle Pass Tuff, Leach Canyon Formation, and associated rocks (Miocene and Oligocene)**—Consists of undivided Shingle Pass Tuff (Oligocene), Leach Canyon and Condor Canyon Formations (Miocene), and unnamed ash beds. The Shingle Pass Tuff and the Leach Canyon Formation are present wherever this unit is mapped, but the Condor Canyon Formation generally is present only in more eastern exposure areas of this (undivided) unit

Taf **Ash-flow tuff (Miocene and (or) Oligocene)**—Nonwelded, white-weathering, crystal-poor, biotite-bearing ash. Preserved only locally

Twb **Tuff of White Blotch Springs (Miocene and (or) Oligocene)**—Light-gray, pale-brown-weathering, crystal-rich tuff. Phenocrysts, 20–30%: quartz, 35%; alkali feldspar, 25–50%; plagioclase feldspar, 15–50%; biotite, 3–5%; hornblende, trace; olivine, trace. Was erupted about 24 to 25 Ma (Ekren and others, 1977)

Tsp **Shingle Pass Tuff (Oligocene)**—Multiple cooling units of crystal-poor, felsic-rich, mafic-poor, quartz-poor, densely welded ash-flow tuff. Contains 8–20% phenocrysts: alkali and plagioclase feldspars, in ratios that range from 1:6 to about 1:4; biotite, 2–5%; hornblende, 0–2%; clinopyroxene, 0–2%; olivine, trace. A more quartz- and crystal-rich, red, densely welded tuff is interbedded in unit in northern part of Pahranagat Range and in Groom Range

Tm **Monotony Tuff and related rocks (Oligocene)**—Crystal rich. Poorly to partly welded. Contains abundant large biotite and common hornblende and sphene. Consists of water-worked ash-fall tuff. Locally includes grayish, gravelly, impure lacustrine limestone; alluvial gravel; and crystal-poor, pyroxene-rich, densely welded tuff or vitrophyre at base. Age is approximately 27 Ma (Armstrong, 1970; Marvin and others, 1970)

Ts_1 **Sedimentary rocks, undivided (Oligocene)**—Preserved alluvial deposits of poorly sorted conglomerate and local grayish- and cream-colored limestone. Basal conglomerate contains both clasts of Paleozoic rocks and clasts derived from the Monotony Tuff

SEDIMENTARY ROCKS

TKs **Sedimentary rocks, undivided (Oligocene to Upper Cretaceous?)**—Generally unconsolidated deposits of boulder- to sand-sized clasts. Typically weathers to deep orange-red or yellow-orange color. Clasts, which are poorly sorted and rounded to subrounded, are of Cambrian(?) through Mississippian age. Conglomerate is overlain locally by a cream-and-pinkish limestone that ranges from a meter to tens of meters in thickness and is presumably of early Tertiary age. Lithologically similar to limestone north of map area which has yielded Eocene fossils (D. Taylor, oral commun., 1988). Conglomerate is not dated but is generally thought to be Tertiary in age

PIPbs **Bird Spring Formation (Permian and Pennsylvanian)**—Bioclastic, silty to shaly calcarenite and calcisiltite; minor chert lenses and nodules. Light- to dark-brownish-gray on fresh surfaces; typically weathers to pale pastel shades of pinkish orange, yellowish orange, and grayish orange. Medium- to thin-bedded; tends to form ledges and benches. Very fossiliferous; contains abundant bryozoans and brachiopods. Correlative with part of the Tippipah Limestone (Johnson and Hibbard, 1957) and lower part of the Ely Limestone (Kellogg, 1960). At least 350 m thick; top not exposed

Msc **Scotty Wash Quartzite and Chainman Shale, undivided (Mississippian)**—Predominantly dark-gray, fissile shale. Weathers to reddish color. Lesser amounts of reddish-brown silty arenite and calcarenite present in upper part. Slope forming. Probably correlative with part of the Eleana Formation (Poole and others, 1961). About 300 m thick

Mj **Joana Limestone (Mississippian)**—Light- to dark-gray calcilutite, calcisiltite, and calcarenite; locally abundant cherty layers and nodules. Basal part is mainly massive, cliff-forming beds; upper part, medium to thin bedded and bench forming. Commonly yields strong hydrocarbon odor from fresh surfaces. Weathers to medium- to light-gray color. As mapped, includes the Peers Spring Formation (Westgate and Knopf, 1932). Probably correlative with parts of the Monte Cristo Group and the White Pine Shale of Langenheim and others (1962) and part of the Eleana Formation (Poole and others, 1961). About 350–400 m thick

MDp **Pilot Shale (Mississippian and Devonian)**—Dominantly shale; calcareous shale, thin-bedded shaly calcisiltite, dark dense chert, and siltstone near base; limestone concretions in shale. Weathers to pale-orangeish color. Probably correlative with part of the Narrow Canyon Limestone (Johnson and Hibbard, 1957). Thickness about 80–190 m

Dg **Guilmette Formation (Devonian)**—Interbedded limestone, dolomite, and quartzite. Light- to dark-gray, and (or) brownish-gray biohermal calcarenite and calcisiltite. Quartzite weathers to yellowish to reddish color. Commonly crossbedded. Generally thick- to medium-bedded; more massive cliff-forming beds near base. Basal part of unit is silty, yellowish-weathering, thin-bedded dolomite; nonresistant, slope forming. Common stromatoporoid bioherms. In part, correlative with the Devils Gate Limestone (Nolan and others, 1956). Approximately 700–800 m thick

Dsi **Simonson Formation (Devonian)**—Interbedded, alternating light-brown, dark-brown, and gray dolomite; laminated aphanitic and phaneritic dolomite. Generally medium bedded; ledge and bench forming. Common fetid hydrocarbon odor. Basal part of section consists of sandy phaneritic dolomite; thin-bedded, pale-gray and yellowish calcareous siltstone, quartzite, and brown chert; nonresistant, slope forming. Correlative with most of the Nevada Formation of former usage (Nolan and others, 1956; Hose and others, 1982) and most of the Piute Formation of Langenheim and others (1962). Thin-bedded, nonresistant, yellowish-weathering basal part of unit mapped in this area includes rocks correlative with the Oxyoke Canyon Sandstone (formerly the Oxyoke Canyon Sandstone Member of the Nevada Formation of former usage) (Nolan and others, 1956). Approximately 375–475 m thick

Dse **Sevy Dolomite (Devonian)**—Predominately white and also very light gray, resistant dolomite. Aphanitic to fine-grained phaneritic, sugary texture. Disseminated quartzose sand. Medium bedded; ledge and bench forming. Sparsely fossiliferous to unfossilifereous. Partly correlative with the Beacon Peak Dolomite (formerly the Beacon Peak Dolomite Member of the Nevada Formation of former usage) (Nolan and others, 1956). Approximately 450–520 m thick

DSd **Dolomite (Devonian and (or) Silurian)**—Light-, medium-, and dark-gray dolomite. Bench forming

Sl **Laketown Dolomite (Silurian)**—Light- and dark-gray dolomite. Prominent light-gray, bench-forming band in middle part of unit; medium- to dark-gray, somewhat cliff-forming dolomite in upper and lower parts. Generally medium bedded; phaneritic to sandy; minor chert nodules. Correlative with lower part of the Lone Mountain Dolomite (Nolan and others, 1956) and part of the Roberts Mountains Formation (Rush, 1956). Approximately 245–310 m thick

Oes **Ely Springs Dolomite (Ordovician)**—Dark-gray, massive, cliff-forming cherty dolomite near base. Upper part is thin-bedded, yellowish-weathering, dark-gray dolomite; less resistant, slope forming; phaneritic to aphanitic. Correlative with the Fish Haven Dolomite (in part) and the Hanson Creek Formation (in part) (Nolan and others, 1956). Approximately 90–150 m thick

Oe **Eureka Quartzite (Ordovician)**—Massive, white, vitreous orthoquartzite; medium- to fine-grained; crossbedded; well sorted, well rounded clasts. Dolomitic sandstone near top. Commonly weathers to rusty, yellow-brown, or red color. Resistant, cliff-forming unit. Approximately 125–155 m thick

Op **Pogonip Group (Ordovician)**—Lower part is dominated by medium- to thick-bedded, medium- and light-gray, bench-forming calcarenite; local limestone-pebble conglomerate; abundant chert nodules and lenses. Middle part consists of thin-bedded, platy, silty, orange-weathering, bioclastic limestone; abundant limestone-pebble conglomerate; wavy, knobby, calcilutite and shale. Upper part consists of massive, thick-bedded, cliff-forming, dark-gray limestone overlain by slope-forming, thin-bedded, shaly calcisiltite; minor amounts of limestone-pebble conglomerate. Approximately 850–1,010 m thick

Nopah Formation (Cambrian)—Consists of following members:

Ꞓnu **Smoky and Halfpint Members, undivided**—Massive, light- and dark-gray dolomite. Typically banded in this area; commonly characterized by thick upper and lower dark bands and thinner middle light band. Sandy in upper part; cherty in upper and lower parts; generally phaneritic and vuggy shale that has thin wavy parting in lower part. Correlative with the Windfall Formation (Nolan and others, 1956) and part of the Mendha Formation (Westgate and Knopf, 1932). Approximately 730–740 m thick

Ꞓnd **Dunderberg Shale Member**—Olive-gray shale; calcareous siltstone; thin-bedded calcisiltite, siltstone, and oolitic limestone. Weathers to yellowish-brown color; nonresistant, slope forming. Correlative with part of the Mendha Formation (Westgate and Knopf, 1932)

Bonanza King Formation (Cambrian)—In this area, consists of following members:

Ꞓbb **Banded Mountain Member**—Light- and dark-banded limestone and dolomite; minor amounts of siltstone and silty limestone. Generally thin bedded and medium bedded; cliff forming. Orange-weathering siltstone and silty limestone is present at base. Correlative with part of the Highland Peak Formation (Westgate and Knopf, 1932). Approximately 600 m thick

Ꞓbp **Papoose Lake Member**—Light- to medium-gray limestone and dolomite. Upper part is well bedded and laminated. Lower part is dark- and medium-gray limestone; massive; contains brownish-weathering siltstone laminae

Ꞓc **Carrara Formation (Cambrian)**—Interbedded limestone, siltstone, shale, and minor quartzite. Includes gray, grayish-red, and (or) yellowish-brown limestone and silty limestone; thin bedded to laminated; contains fissile shale and siltstone. Correlative with the undivided Chisholm Shale, Lyndon Limestone, and Pioche Shale (Westgate and Knopf, 1932) and lower part of the Eldorado Dolomite as mapped by Nolan and others (1956). Approximately 650 m thick

Ꞓz **Zabriskie Quartzite (Cambrian)**—Massive, resistant, ridge-forming quartzite. Weathers to pinkish-orange color. Well sorted; crossbedded. Correlative with upper part of the Prospect Mountain Quartzite (Westgate and Knopf, 1932). Approximately 75 m thick

ꞒZw **Wood Canyon Formation (Cambrian and Late Proterozoic)**—Quartzite, siltstone, and minor sandy limestone; local pebble conglomerate; micaceous, grayish-red siltstone and shale; reddish-weathering, ridge-forming quartzite. Correlative with part of the Prospect Mountain Quartzite (Westgate and Knopf, 1932). Approximately 760 m thick

ꞒZu **Sedimentary rocks, undivided (Cambrian and Late Proterozoic)**—Quartzite, siltstone, and limestone

Zs **Stirling Quartzite (Late Proterozoic)**—Quartzite; minor siltstone and micaceous quartzite; a few thin limestone beds. Reddish in lower part and grayish pink in upper part. Pebble conglomerate in lower part. Approximately 930 m thick

Zj **Johnnie Formation (Late Proterozoic)**—Brownish, greenish, and reddish, thin-bedded siltstone and calcareous siltstone; silty limestone; reddish-weathering micaceous quartzite; olive-gray to reddish siltstone and cherty dolomite in lower part. Correlative with lower part of the Prospect Mountain Quartzite (Westgate and Knopf, 1932). Base of unit not exposed in this area. At least 960 m thick

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