GEOLOGIC MAP OF THE SOUTHERN SAND SPRINGS RANGE, CHURCHILL AND MINERAL COUNTIES, NEVADA

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Depositional or intrusive contact Dashed where approximately located.

High-angle fault Dashed where approximately located; queried where concealed by Quaternary sediments; bar and ball on downthrown side; Cenozoic in age.

Low-angle fault Separating Cenozoic units from pre-Cenozoic units, scallops on upper plate; dashed where approximately located.

Low-angle fault Dashed where aproximately located; Mesozoic, syn-D_1 in age; teeth on upper plate; interpreted to be a thrust fault.

High-angle fault Dashed where approximately located; Mesozoic, syn-D_1 in age; offset sense unknown.

Surface trace of axial plane of D_1 fold.

Surface trace of axial plane of D_2 fold.

Surface trace of axial plane of D_3 fold Shown on map only in n7d.

Strike and dip of bedding (S_b).

Strike and dip of bedding (S_b), stratigraphic facing known to be upright.

Strike and dip of bedding (S_b), stratigraphic facing known to be overturned.

Strike and dip of conspicuous foliation in tuff within Tr.

Strike and dip of magmatic layering in Kg; only found near the Red Ant Mine in the northwestern portion of the map.

Strike and dip of metamorphic foliation and/or cleavage (S_1). Mesozoic, syn-D_1 in age.

Strike and dip of S_1 and bedding where S_1 and bedding are parallel.

Strike and dip of fault surface containing slickenlines and arrow indicating trend and plunge of slickenlines.

Strike and dip of joint surface in Kg.

Trend and plunge of stretching lineation defined by elongate clasts. Mesozoic, syn-D_1 in age.

Trend and plunge of mineral lineation. Mesozoic, syn-D_1 in age.

Location of age-diagnostic and significant fossils; descriptions of fossils summarized in table 3.

Location of sample providing isotopic date; descriptions and dates summarized in table 1.

Location of outcrops in southwestern Sand Springs Range containing outcrop-scale, superposed D_1, D_2, and D_3 folds.

Original bedding (S_b); symbol only used on cross-sections.

Stratigraphic up direction interpreted from sedimentary structures; symbol only used on cross-sections.

Figure 2. Locations of Mesozoic fault blocks n1 through n9. Symbols used: CC, Chukar Canyon Quadrangle; BKM, Big Kasock Mountain Quadrangle; FC, Fourmile Canyon Quadrangle; R, Rawhide Quadrangle.

These dates are: 85.47±0.33 Ma (isotopic date sample 1; $^{40}Ar/^{39}Ar$ on hornblende; Satterfield, 1995) and 77 Ma (isotopic date sample 3; $^{40}Ar/^{39}Ar$ on actinolite; Satterfield, 1995). The Nevada Scheelite pluton has been dated at 85.9±3.5 Ma and 89.9±1.0 Ma (K-Ar on biotite; Schilling, 1964; fig. 1) and at ~98 Ma (Rb-Sr, John, 1992). Kg aplite plutons are distinguished from Gd_{Mc} aplite plutons by being within 1 km of large granite-granodiorite pluton contacts.

Dark-green feldspar porphyry plutons (Jurassic and/or Triassic) Dark-green feldspar porphyry exposed as nine plutons that crosscut contacts and bedding in the southern portion of the map area. Exposed in n6d, n7c, n7d, and n8, including extensive exposures in the southwestern portion of the map in n7d. Contains 0.5-1 mm plagioclase feldspar phenocrysts and rare, mostly altered olivine(?) phenocrysts in an aphanitic matrix. $J\mathcal{R}tp$ locally is phaneritic, consisting of 0.5-1 mm feldspar and mafic minerals. Rarely contains 2- to 20-mm-thick contorted parallel laminae interpreted to be a flow foliation. Intrusive igneous origin suggested by: a) sleep, non-planar, and discontinuous contacts, such as on the southwest flank of Big Kasock Mountain; b) unit crosscuts $Tc(?)pt$-$Tr(?)pt$ contacts in n6d; and c) unit crosscuts bedding (S_b) and $Tc(?)c$-$Tr(?)ct$ contacts in n7c.

A spaced cleavage (S_1) has been recorded at several locations. Metamorphic minerals include biotite and chlorite.

Map unit descriptions include: a) where map unit is exposed; b) descriptions of sedimentary or igneous rocks comprising the map unit, including protolith descriptions of pre-Cretaceous metamorphic tectonites; c) structural fabric and metamorphic mineral descriptions of metamorphic tectonite map units; d) age and age constraints; and e) how the unit can be distinguished from similar map units, if any. Locations of pre-Cretaceous map units are given in terms of Mesozoic fault blocks, labeled n1 through n9, that they are found within. The accompanying paper describes how fault blocks are delineated. Figure 2 (on this plate) shows the location of each fault block. A stratigraphic chart below figure 2 identifies map units in each fault block. Sedimentary or igneous rock descriptions cover minerals present, their crystal sizes, clast types and sizes, primary sedimentary or igneous structures, bed thicknesses, and overall map unit thicknesses. Map unit thicknesses are measured from cross sections and could differ greatly from pre-metamorphic thicknesses. Stratigraphic facings of pre-Cretaceous successions are generally not known. Sedimentary structures allow facings of successions in n7b and n7c to be determined. Igneous rocks comprising the map unit are described as to their igneous origin. Metamorphic minerals listed, unless noted otherwise, define a metamorphic foliation, S_1, that developed during the first deformation (D_1). The structural history of the range includes three phases of Mesozoic deformation, D_1 - D_3, described in the accompanying text.

Qa **Recent alluvium (Quaternary)** Unconsolidated gravel, sand, and mud in active stream channels which crosscut all other map units. Unit identified by examining aerial photographs.

Qt **Talus (Quaternary)** Unconsolidated gravel and sand in talus deposits on steep slopes.

Qf **Recent alluvial fan deposits (Quaternary)** Unconsolidated sand, gravel, and mud in continuous fan or apron shapes. Upper surfaces typically have a smooth, undissected appearance on aerial photographs, although Qf includes several continuous fan shapes that are deeply dissected. Unit identified by examining aerial photogrpaps.

Qof **Older alluvial fan deposits (Quaternary?)** Unconsolidated sand, gravel, and mud in discontinuous exposures dissected by many small streams. Qf crosscuts this unit. Identified from aerial photographs.

QTg **Terrace gravel (Quaternary and/or Tertiary)** Unconsolidated to slightly lithified tan sand and unsorted gravel only exposed in significant thickness in Fourmile Canyon and adjacent hills in northwest portion of map area. Angular and rounded gravel clasts up to boulder size include fragments of $M\mathcal{P}$axs, $\mathcal{T}$ccp, Kg, and Tbs. Sandstone grains are dominantly 0.1-0.5 mm rounded quartz. Bedding is locally defined by contacts between lithified sandstone and conglomerate and by 1-2 mm laminations in sandstone. Maximum thickness is ~460 m.

QTg is not metamorphosed or internally deformed. Cenozoic age of QTg is inferred from inclusions of Tertiary and Cretaceous units within, partly unconsolidated nature, and high stratigraphic and topographic position (overlies Tbs). Similar in description to the Tertiary gravel map unit in Bell Canyon Quadrangle, adjacent to the northeast, which is late Miocene to Pliocene (Henry, 1996).

Tcg **Cobble conglomerate (Tertiary?)** Well-cemented gray-green conglomerate containing clasts of diverse composition exposed only in small exposures in Fourmile Canyon and near the Red Ant Mine in the northwest portion of the map. Mostly rounded clasts comprising 60% of rock range from 0.5 cm to 1.5 m long; averaging ~25 cm long. Clast types include granite, stretched pebble conglomerate, and feldspar porphyries differing in feldspar percent and matrix color. Matrix consists of 40-70% 1-3 mm feldspar grains or crystals and 1% quartz grains in a dark green matrix. No stratification recognized within.

Tcg is not metamorphosed or internally deformed. Probably Tertiary in age because unit contains probable Cretaceous granite inclusions, is not metamorphosed or internally deformed, and is more lithified than Quaternary units.

Ta **Porphyritic andesite (Miocene?)** Medium-brown-weathering dark gray feldspar-hornblende porphyry exposed atop one ridge in the west-central Sand Springs Range (SSR). Porphyry consists of 1 mm feldspar and 3-10 mm hornblende crystals in an aphanitic matrix. No layering identified within. Ta is ~34 m thick.

Unit is not metamorphosed. Ta is Tertiary or possibly Quaternary in age because horizontal lower contact overlies Tr. Correlative unit dated at 12.2 Ma and 17.6 Ma elsewhere in Churchill County (Willden and Speed, 1974).

Tvb **Flow breccia (Tertiary)** Brown- and yellow-brown-weathering igneous breccia only exposed in western flank of Fourmile Canyon in the northwest portion of the map. Slightly rounded clasts 1-25 cm in diameter consist of 30-40% 1-2 mm feldspar laths in a medium gray aphanitic matrix. The matrix of breccia contains 50% phenocrysts in an aphanitic matrix. Phenocrysts in the matrix include 0.5-1 mm feldspar laths, 2-6 mm amphibole crystals, and sparse 0.5-1 mm quartz crystals. Clasts are sporadically distributed, comprising from 0-60% of the rock. No stratification identified. Tvb is not metamorphosed or internally deformed and appears to overlie Tr. Relative age relations between Tvb and Tri are unclear.

Tri **Rhyolite intrusive rocks and crystal-lithic tuff (Oligocene and Miocene)** White-, yellow-brown-, and reddish-brown-weathering quartz-feldspar-biotite porphyry and white to light-gray to maroon to glassy dark-brown crystal-lithic tuff extensively exposed on the western, southern, and eastern flanks of the range. Outcrop belts composed exclusively of intrusive quartz-feldspar-biotite porphyry are mapped as **Tri**. Outcrop belts composed of all crystal-lithic tuff are designated **Trt**. In one fault block in the southwestern SSR a white unlithified zone at the base of one cooling unit in Tri is designated **Trw**. The unit is labeled **Tr** where the distinction between Tri and Trt is not mappable or has not been made.

White porphyry contains 1-10% 0.2-1 mm quartz, feldspar, and sparse biotite phenocrysts in aphanitic white to light gray matrix. Convoluted parallel layering 3-10 cm thick, interpreted to be a flow foliation, is abundant in Tri at several locations. White to glassy dark brown tuff contains feldspar, quartz, sparse biotite crystals, and variable percentages of clasts in an aphanitic matrix. Clasts include 0.2- to 30-cm long flattened glassy black to dull white pumice clasts displaying wispy ends and 1- to 10-cm diameter, equant, angular feldspar porphyry and aphanitic clasts light in color. Pumice clasts define a pervasive compaction foliation. Tuff exposures include 850-m-thick fault-bounded section. Other portions of Tr show intrusive relations: contacts with Mesozoic rocks are locally steep and irregular, and a Tr sill several meters wide intrudes $\mathcal{T}(?)pt$ in northwestern n6d. Some steep, irregular contacts and compaction foliation orientations may result from deposition of Tr tuff atop a steep, irregular topography. Similar discontinuous Oligocene tuff units in the Yerington district 75 km to the east onlap pre-earlthow hills (Proffett and Proffett, 1976).

Tr is not metamorphosed or internally deformed, except for the compaction of pumice clasts. Isotopic date sample 4 from Tr near the eastern edge of the map yielded an age of 31.03±0.15 Ma ($^{40}Ar/^{39}Ar$ on sanidine; C. Henry, written commun., 1999). Separate tuffs from the southwestern SSR yielded dates of 24.95±0.06 Ma and 28.74±0.07 Ma (isotopic date samples 11 and 12; $^{40}Ar/^{39}Ar$ on sanidine; C. Henry, written commun., 2001). A rhyolite dike, apparently Tri, from the Black Eagle Mine in the Rawhide area 4 km west of the southwest corner of the map was dated at 14.7 Ma (K-Ar, Silberman and others, 1975).

Ekren and Byers (1986) mapped Tri in the quadrangle adjacent to the south as the Miocene rhyolite of Rawhide. Tri southwest of the Nevada Scheelite Camp as the Miocene tuff of Copper Mountain, and Trt south of the Nevada Scheelite Camp as the Oligocene or Miocene tuff of Gabbs Valley. Black and others (1991) tentatively correlated other portions of Tr exposed in this map area as the early Miocene tuff of Arc Dome. C. Henry (written commun., 2001) correlates the tuff at isotopic date sample 11 to one of the tuffs in the tuff of Gabbs Valley of Ekren and Byers (1986).

Tbs **Red feldspar porphyry (Tertiary)** Brick-red-weathering feldspar porphyry found in several small exposures primarily near the northwestern rangefront and in the northeast, east of State Highway 839. The porphyry contains distinctive 1 x 4-8 mm to 4 x 4 mm feldspar phenocrysts in an unaltered aphanitic matrix. Vesicles and amygdules 2 cm long are locally common. No internal stratification or definitive intrusive relations were observed.

Tbs is not metamorphosed or internally deformed. Tbs is a pre-31-Ma basaltic andesite map unit mapped in the State Mountain Quadrangle to the east by C. Henry (written commun., 1999).

Gd_{Mc} **Felsic plutons (Cenozoic and/or Mesozoic)** Six pale tan felsic dikes and small plutons mapped northwest, north, and northeast of Big Kasock Mountain and one light to medium-brown dike 2 km southeast of the Red Ant Mine. Most intrusions consist primarily of 1 mm feldspar crystals, plus quartz and white mica. Dike southwest of Red Ant Mine contains 50% phenocrysts of 2-6 mm hornblende and 1-2 mm feldspar in a medium brown aphanitic matrix. Gd_{Mc} plutons are not folded, metamorphosed, or penetratively deformed. Gd_{Mc} is Cenozoic and/or Mesozoic in age because unit postdates pre-Late Cretaceous penetrative deformation (D_1) and post-metamorphic deformation (D_2 and D_3). Gd_{Mc} plutons are not near Cretaceous granite contacts and thus are not necessarily related to them. One pluton intruded along the Cenozoic fault forming the n6b-n7a boundary apparently postdates the fault, implying that this pluton is Cenozoic.

Kg **Granitoid (Late Cretaceous)** Pale pink and white, yellow-brown-weathering granitoid, including aplite and pegmatite, primarily exposed as five large plutons, 0.5 km in length. The Sand Springs and Nevada Scheelite plutons are labeled on map. Seven smaller granitoid dikes and plutons are also mapped. Kg crosscuts n1, n2a, n6b, n6c, n7b, n7c, and n7d. Granitoid consists of quartz, orthoclase, unaltered feldspar, biotite, and locally hornblende in 0.1-3 mm crystals. The granite is locally porphyritic; orthoclase phenocrysts range up to 20 mm long. Bass and others (1964) and Schilling (1964) described three composition types within Kg. A porphyritic granite phase, comprising most of the Sand Springs pluton, contains 40-70% potassium feldspar phenocrysts in a groundmass of 40-60% plagioclase feldspar (percentage of groundmass), 25-40% quartz, 5-10% potassium feldspar, 5-10% biotite, 0-1% hornblende, and <1% sphene, apatite, and magnetite. A granodiorite phase exposed in the northwestern portion of the Sand Springs pluton contains 60-70% plagioclase, <10% potassium feldspar, 5-10% quartz, 5-10% hornblende, 1-5% biotite, and <1% sphene, apatite, zircon, and magnetite. A biotite-rich granodiorite phase exposed in the Nevada Scheelite pluton contains 55-65% plagioclase feldspar, 10% potassium feldspar, 15% quartz, 5-15% biotite, and 0-5% hornblende. Kg shows no stratification except 1 km east of the Red Ant Mine where segregations of felsic and mafic minerals are parallel to the pluton contact and at a high angle to S_1. Kg is not metamorphosed or deformed in D_1 or D_2 (see accompanying text for documentation).

Different dating techniques provide a wide range of Late Cretaceous dates from samples located on the map and on figure 1 (table 1). A small granitoid pluton 0.2 km from the northern margin of Sand Springs pluton (fig. 1; 39° 16' N. latitude, 118° 21' W. longitude) is tentatively dated at no younger than ~80 Ma (U-Pb on zircon; table 4; Satterfield and Oldow, 1996). The Sand Springs pluton in the southern Sand Springs Range has been dated at 67±4 Ma, 78±2.0 Ma and 81.7±2.0 Ma (K-Ar on biotite; Schilling, 1964; fig. 1). The Sand Springs pluton has been dated at 81-82 Ma by Rb-Sr (John, 1992). $^{40}Ar/^{39}Ar$ dates of metamorphic rocks flanking the Sand Springs pluton in the map area are also interpreted to be ages of Sand Springs pluton emplacement (see text for documentation).

$J\mathcal{R}tp$ **Dark-green feldspar porphyry pluton (Jurassic and/or Triassic)** Dark-green feldspar porphyry exposed as single pluton within n6c. $M\mathcal{P}$vfp contains 0.1-mm feldspar phenocrysts within an aphanitic matrix. The matrix displays a primary, non-tectonic alignment of microscopic feldspar crystals (pilotaxitic texture). The irregularity and steepness of the the $M\mathcal{P}$vfp-$M\mathcal{P}$rc contact and the observation that the $M\mathcal{P}$vfp body is completely surrounded by $M\mathcal{P}$rc suggest that $M\mathcal{P}$vfp is an intrusive rock.

Locally $M\mathcal{P}$vfp contains spaced cleavage (S_1). Metamorphic biotite clots have replaced possible mafic phenocryst mineral relicts. Biotite is not necessarily syn-D_1. Age of $M\mathcal{P}$vfp is constrained to be Mesozoic and/or Paleozoic because pluton intruded $M\mathcal{P}$rc and was deformed in pre-Late Cretaceous D_1. $M\mathcal{P}$vfp is distinguished from $J\mathcal{R}tp$ by the smaller size of feldspar phenocrysts and pilotaxitic texture of $M\mathcal{P}$vfp.

$M\mathcal{P}$vf **Felsite intrusive rocks (Mesozoic and/or Paleozoic)** Yellow to white intrusive igneous rock exposed over large areas in n6c, n7c, and n7d. Contains 1- to 2-mm feldspar phenocrysts that are difficult to recognize in hand sample within an aphanitic matrix. Large carbonate inclusions 0.2 km long and possibly as long as 0.5 km are present in n7c and n7d. Inclusion boundaries are difficult to recognize and typically not mappable; one is mapped on the south flank of Big Kasock Mountain in n7d. Also indicating an intrusive nature are contacts that cross-cut the $M\mathcal{P}$rc-$M\mathcal{P}$rc contact south of Big Kasock Mountain in n7d and irregular $M\mathcal{P}$vf-$M\mathcal{P}$rc contacts in n7d and n7e. $M\mathcal{P}$vf lacks internal stratification.

$M\mathcal{P}$vf typically shows a fracture cleavage (S_1). Matrix contains the metamorphic minerals chlorite and white mica. Age constrained to be Mesozoic and/or Paleozoic because $M\mathcal{P}$vf is deformed in pre-Late Cretaceous D_1 and intruded $M\mathcal{P}$rc and $M\mathcal{P}$ss.

$M\mathcal{P}$rc **Schist and carbonate rocks (Mesozoic and/or Paleozoic)** White, yellow, green, and brown actinolite-biotite schist interstratified with gray, yellow, and dark-green carbonate and gray, yellow, and dark-brown-weathering structureless carbonate exposed in several small areas in the northwestern portion of n6c. Schist layers contain 1- to 3-mm actinolite porphyroblasts. Schist protolith is not known. Carbonate layers contain 3 cm to 1 m-long tectonically flattened and stretched light-colored carbonate clasts in a carbonate matrix. Bedding is not preserved. Individual schist and carbonate layers are typically 3 cm to 9 m thick. $M\mathcal{P}$rc is 100 m thick.

Carbonate and schist display a penetrative metamorphic foliation and fissility (S_1). Actinolite porphyroblasts are foliated and locally lineated. Flattened carbonate clasts also define S_1. Schist at isotopic date sample 3 contains metamorphic minerals actinolite, biotite, chlorite, quartz, and calcite. Other schist samples also contain white mica and feldspar. $M\mathcal{P}$rc is constrained to be older than 77 Ma, the $^{40}Ar/^{39}Ar$ date on actinolite at sample location 3. The 77-Ma date is interpreted to be the age of intrusion of Cretaceous plutons (Kg); not the age of the metamorphism of the schist or the crystallization age of the schist protolith. Field relations show syn-D_1 metamorphism predated Cretaceous plutons (see accompanying text).

$M\mathcal{P}$rc **Carbonate rocks (Mesozoic and/or Paleozoic)** White, light-gray, and dark-gray foliated and locally banded carbonate extensively exposed in n1, n2b, and n7d. $M\mathcal{P}$rc also exposed in n2b and n6a. Typically completely metamorphosed to foliated marble consisting of elongate calcite crystals 0.2- to 0.3-mm-long. In n7d west of the Nevada Scheelite pluton (fossil locality 4), in n7d east of Big Kasock Mountain and State Highway 839, and in the northern portion of n6c, $M\mathcal{P}$rc contains abundant bivalve, gastropod, and echinoderm fragments 1- to 30-mm-long. In the same part of the range, $M\mathcal{P}$rc contains crinoid and bryozoan fragments of indeterminate age (C. Stevens, written commun. to H.J. Brown, Pluess-Staufer Inc., 1994). $M\mathcal{P}$rc includes rare carbonate conglomerate consisting of 4-cm-long tectonically stretched clasts in a light gray carbonate matrix. Original bedding is locally preserved as 0.5- to 1.5-m-thick resistant benches continuous locally up to 50 m and visible on aerial photographs. $M\mathcal{P}$rc also locally contains several-mm-thick white calcite stringers in dark gray carbonate. Mapped $M\mathcal{P}$rc units range in thickness from 20 to several hundred meters.

Elongate calcite crystals define a metamorphic foliation (S_1). This foliation and parallel fissility (S_1) is not pervasive throughout the map area. In a broad zone 1 km wide west of the Nevada Scheelite pluton foliated marble is replaced by white unfoliated marble consisting of coarse, 1 mm, unoriented calcite crystals. Age of $M\mathcal{P}$rc is constrained to be Mesozoic and/or Paleozoic because unit predates pre-Late Cretaceous D_1. $M\mathcal{P}$rc could be at least partly equivalent to similar-appearing $\mathcal{T}(?)c$ and/or $\mathcal{T}$cc. Carbonate rocks are mapped as $M\mathcal{P}$rc where compelling rock type, fossil, or stratigraphic succession correlations to $\mathcal{T}(?)c$ or $\mathcal{T}$cc do not exist. Unlike $\mathcal{T}(?)c$, $M\mathcal{P}$rc units are not interstratified with or in depositional contact with quartz-bearing tuff. Unlike $\mathcal{T}$cc, $M\mathcal{P}$rc units are not in contact with quartz-bearing volcanogenic conglomerate. Different $M\mathcal{P}$rc map units in different fault blocks are not necessarily correlative.

$M\mathcal{P}$ss **Black slate (Mesozoic and/or Paleozoic)** Dark-gray to black non-calcareous slate containing sparse interbeds of feldspathic sandstone, lithic-crystal tuff, and carbonate mapped only in two areas in n6c. Tuff and sandstone interbeds are similar in appearance: both contain varying amounts of 1- to 10-mm-long aphanitic black clasts, some flattened with wispy ends and others equant and rounded. Tuff and sandstone typically contain abundant 0.1- to 1-mm feldspar grains or crystals and trace amounts of quartz and chert within varying amounts of aphanitic, dark gray matrix. Chert grains may be silicified volcanic rock fragments. Beds containing lithic and euhedral feldspar crystals, abundant matrix, and wispy, flattened clasts are interpreted to be tuff. Beds containing little matrix and rounded grains are interpreted to be sandstone. Sandstone and tuff beds are 5- to 10-cm-thick. Silty laminations are locally present in slate. Overall thickness of $M\mathcal{P}$ss is 100 m.

Fissility in slate defines a tectonic foliation (S_1). Flattened and locally stretched clasts in tuff define a lineation (S_1) and lineation. Chlorite is the syn-D_1 metamorphic mineral in sandstone and tuff. $M\mathcal{P}$ss is Mesozoic or Paleozoic in age because it postdates pre-Late Cretaceous D_1. Mapped as a separate unit from $M\mathcal{P}$sas, which is similar in appearance, because $M\mathcal{P}$ss lacks andalusite porphyroblasts, contains tuff and sandstone interbeds different in composition from interbeds in $M\mathcal{P}$sas, and clastic interbeds in $M\mathcal{P}$ss contain only trace amounts of quartz, unlike quartz-rich interbeds in $M\mathcal{P}$sas.

$M\mathcal{P}$vs **Volcanogenic sandstone, mudstone, and conglomerate (Mesozoic and/or Paleozoic)** Tan to dark-brown feldspathic sandstone and conglomerate beds intercalated in light to dark brown mudstone comprise the only map unit in n6d. Sandstone and conglomerate beds are typically 0.5-1 meter-thick carbonate interbeds. Sandstone beds are composed of 0.1- to 2-mm plagioclase feldspar, untwinned feldspar, and small amounts of volcanic rock fragments in abundant micro-lich matrix. Tan and medium brown pebbles and cobbles consist of 1- to 20-cm-long, tectonically stretched feldspar porphyry, mudstone, and rare sandstone clasts. Bedding is commonly preserved: sandstone and conglomerate beds are 5 cm to several meters thick and locally contain parallel and convolute laminations, graded beds, cross-laminations, and load casts. Four subunits comprising a stratigraphic succession of known facing are mapped in $M\mathcal{P}$vs. $M\mathcal{P}$vs$_1$ Mudstone and subordinate amounts of sandstone, 50 m thick. $M\mathcal{P}$vs$_2$ Sandstone, 100 m thick. $M\mathcal{P}$vs$_3$ Mudstone and subordinate amounts of sandstone, 75 m thick. $M\mathcal{P}$vs$_4$ Sandstone, 75 m thick.

$M\mathcal{P}$vs contains a penetrative metamorphic foliation (S_1) and fissility (S_1) that is pervasive throughout n7c and the northern part of n6c. Clasts are commonly stretched, defining a lineation. Unit contains metamorphic chlorite, biotite, and green amphibole. Tabular green amphibole porphyroblasts are 2 mm long. Only age constraint on $M\mathcal{P}$vs is that it is deformed in pre-Late Cretaceous D_1. Quartz grains are almost completely lacking in $M\mathcal{P}$vs, distinguishing sandstone and conglomerate beds in this unit from coarse clastic beds in other volcanogenic units such as $\mathcal{T}$ccg, $\mathcal{T}(?)$pt, $M\mathcal{P}$sxt, and $M\mathcal{P}$sas.

$M\mathcal{P}$sas **Andalusite schist (Mesozoic and/or Paleozoic)** Black to silver-gray slate and schist typically containing andalusite porphyroblasts. Subordinate amounts of yellow- to brown-weathering quartzose volcanogenic rocks and light brown, white to gray, foliated carbonate rocks are interstratified. $M\mathcal{P}$sas is extensively exposed in n1 and n2a and is also found in small n2b and n6. Sandstone contains 1- to 2-mm grains of abundant quartz, chert, and feldspar. Conglomerate or lithic tuff is composed of 0.5- to 5-cm-long, tectonically stretched aphanitic dark-gray, light-gray, tan, and white clasts in a quartz-feldspar sandstone matrix. Chert clasts are possible silicified volcanic rock fragments. Sandstone, conglomerate and tuff, and carbonate beds intercalated in black schist range in thickness from 8 cm to 3 m. Bedding is rarely preserved as light-brown, 1- to 20-mm-thick silty laminae and beds in sandstone and andalusite schist. $M\mathcal{P}$sas protolith is organic-rich shale. $M\mathcal{P}$sas is 60 m thick in n1, 80 m thick in n2a, and 30 m thick in n2b.

Andalusite schist and intercalated beds contain a penetrative metamorphic foliation (S_1) and fissility (S_1). Up to 5-cm-long andalusite phorphyroblasts are typically foliated (S_1) and locally lineated. Stretched clasts in conglomerate also define a lineation. Andalusite schist samples generally contain the metamorphic minerals andalusite, biotite, white mica, graphite, and quartz. Chlorite, amphibole, chloritoid, and garnet are also present in some andalusite schist samples. Intercalated volcanogenic clastic rocks commonly contain the metamorphic minerals biotite, chlorite, white mica, and quartz. Some volcanogenic clastic rocks also contain garnet or chloritoid. Only age constraint on $M\mathcal{P}$sas is that it is deformed in pre-Late Cretaceous D_1. Compelling correlations between $M\mathcal{P}$sas sections in different nappes do not exist. $M\mathcal{P}$sas differs from $M\mathcal{P}$vs, $M\mathcal{P}$sxt, and $\mathcal{T}$ka in that it contains quartz-rich clastic interbeds, and because relatively thick stratigraphic successions in n3a and n1 that include $M\mathcal{P}$sas are not correlative to thick successions in n6b, n6c, and n6a (fig. 3).

$M\mathcal{P}$sxt **Andalusite schist and carbonate rocks (Mesozoic and/or Paleozoic)** Interstratified dark gray andalusite schist and light brown to gray to white foliated carbonate beds. Also interstratified are smaller amounts of yellow-orange to light brown quartz-rich volcanogenic sandstone and conglomerate, gray to light brown felsic schist, and rare dark green feldspar porphyry. $M\mathcal{P}$sxt is mapped in the northern part of the map area within n1 and n2a. Andalusite schist, carbonate, sandstone, and conglomerate in $M\mathcal{P}$sxt are indistinguishable from those in $M\mathcal{P}$sas described above. Felsic schist in $M\mathcal{P}$sxt consists of 0.05- to 5-mm, typically 0.1- to 0.2-mm crystals. Beds or segregations of each rock type are typically one to several meters thick. Thicker carbonate layers interstratified in $M\mathcal{P}$sxt are mapped as $M\mathcal{P}$rc. $M\mathcal{P}$sxt is 370 m thick in n1.

$M\mathcal{P}$sxt contains a penetrative metamorphic foliation and fissility (S_1) throughout. Andalusite long axes in andalusite schist and biotite clots in felsic schist define a mineral lineation. Stretched clasts in conglomerate also define a lineation. Conglomerate and sandstone contain pre- or syn-D_1 metamorphic minerals which include feldspar, diopside, quartz, white mica, biotite, chlorite, garnet, amphibole, and epidote. Some tremolite and diopside crystals crosscut S_1. Only age constraint on $M\mathcal{P}$sxt is that it is deformed in pre-Late Cretaceous D_1. $M\mathcal{P}$sxt is distinguished from $M\mathcal{P}$sas by a higher ratio of carbonate rocks to andalusite schist, and by the presence of additional rock types, including felsic schist, in $M\mathcal{P}$sxt.

$M\mathcal{P}$fs **Felsic schist and carbonate rocks (Mesozoic and/or Paleozoic)** Interstratified white to light-gray foliated carbonate and yellow-white, speckled light-gray schist exposed in small areas of n1. Rock types and bed thicknesses in $M\mathcal{P}$fs are similar to $M\mathcal{P}$sxt. The protolith of schist in $M\mathcal{P}$fs is unknown. $M\mathcal{P}$fs is 100 m thick.

$M\mathcal{P}$fs contains a pervasive metamorphic foliation and fissility (S_1), and locally a biotite mineral lineation and a stretched clast lineation. Schist contains metamorphic biotite, chlorite, white mica, plagioclase feldspar, calcite, and quartz. The only age constraint on $M\mathcal{P}$fs is that it is deformed in pre-Late Cretaceous D_1. The small proportion of dark-gray andalusite schist in $M\mathcal{P}$fs distinguishes this unit from $M\mathcal{P}$sxt and $M\mathcal{P}$sas.

$M\mathcal{P}$hbc **Hornblende-biotite schist (Mesozoic and/or Paleozoic)** Gray to brown to black hornblende-biotite-quartz schist containing igneous clasts interstratified with subordinate amounts of dark brown slate and sparse carbonate and calcisilicate segregations. $M\mathcal{P}$hbc is extensively exposed in n2a and also exposed in small areas in the northeastern margin of the map area. Rocks of similar protolith and metamorphic mineral assemblage are exposed on the east flanks of Slate Mountain in the Slate Mountain and Bell Canyon Quadrangles, adjacent to the east and northeast (Henry, 1996). Crystals are commonly 0.1- to 0.5-mm-long and hornblende crystals include porphyroblasts 1- to 10-mm-long. Feldspar and quartz grains or crystals are recognizable porphyroclasts. $M\mathcal{P}$hbc contains widely variable amounts of greatly tectonically stretched, 10-to 40-cm-long clasts. Clast types include: a) white speckled coarsely crystalline feldspar-amphibole and feldspar-biotite rock; b) pale yellow, light gray, and medium to dark brown feldspar porphyry, feldspar-amphibole porphyry and aphanitic rock; and c) rare brown laminated, chip-shaped mudstone. Bedding is sparsely preserved as parallel laminations within slate interbeds. Conglomerate and slate intervals are typically several meters thick. The $M\mathcal{P}$hbc protoliths may be igneous or sedimentary. $M\mathcal{P}$hbc is 160 m thick in n2a.

A penetrative metamorphic foliation and fissility define S_1. Stretched clasts and oriented hornblende and biotite crystals define lineations. Schist contains abundant metamorphic biotite and hornblende plus metamorphic actinolite, diopside, epidote, chlorite, quartz, and calcite. Only age constraint on $M\mathcal{P}$hbc is that it is deformed in pre-Late Cretaceous D_1. Unlike similar-appearing dark-colored volcanic or volcanogenic map units such as $M\mathcal{P}$vs and $M\mathcal{P}$vc, $M\mathcal{P}$hbc contains abundant quartz and larger metamorphic mineral crystals.

$M\mathcal{P}$shs **Slate and hornblende-biotite schist (Mesozoic and/or Paleozoic)** Dark-brown to olive-green slate and subordinate interstratified gray to brown to black hornblende-biotite-quartz schist extensively exposed in n2a. $M\mathcal{P}$shs contains the same rock types as $M\mathcal{P}$hbc. Recognizable beds in $M\mathcal{P}$shs include 1-cm to 2.5-m layers of parallel laminated siltstone and sandstone interstratified in slate. $M\mathcal{P}$shs is overall 360 m thick.

A penetrative metamorphic foliation and fissility define S_1. Stretched clasts and oriented hornblende and biotite crystals define lineations. Schist contains metamorphic biotite, hornblende, and quartz. Only age constraint on $M\mathcal{P}$shs is that it is deformed in pre-Late Cretaceous D_1. $M\mathcal{P}$shs is distingu