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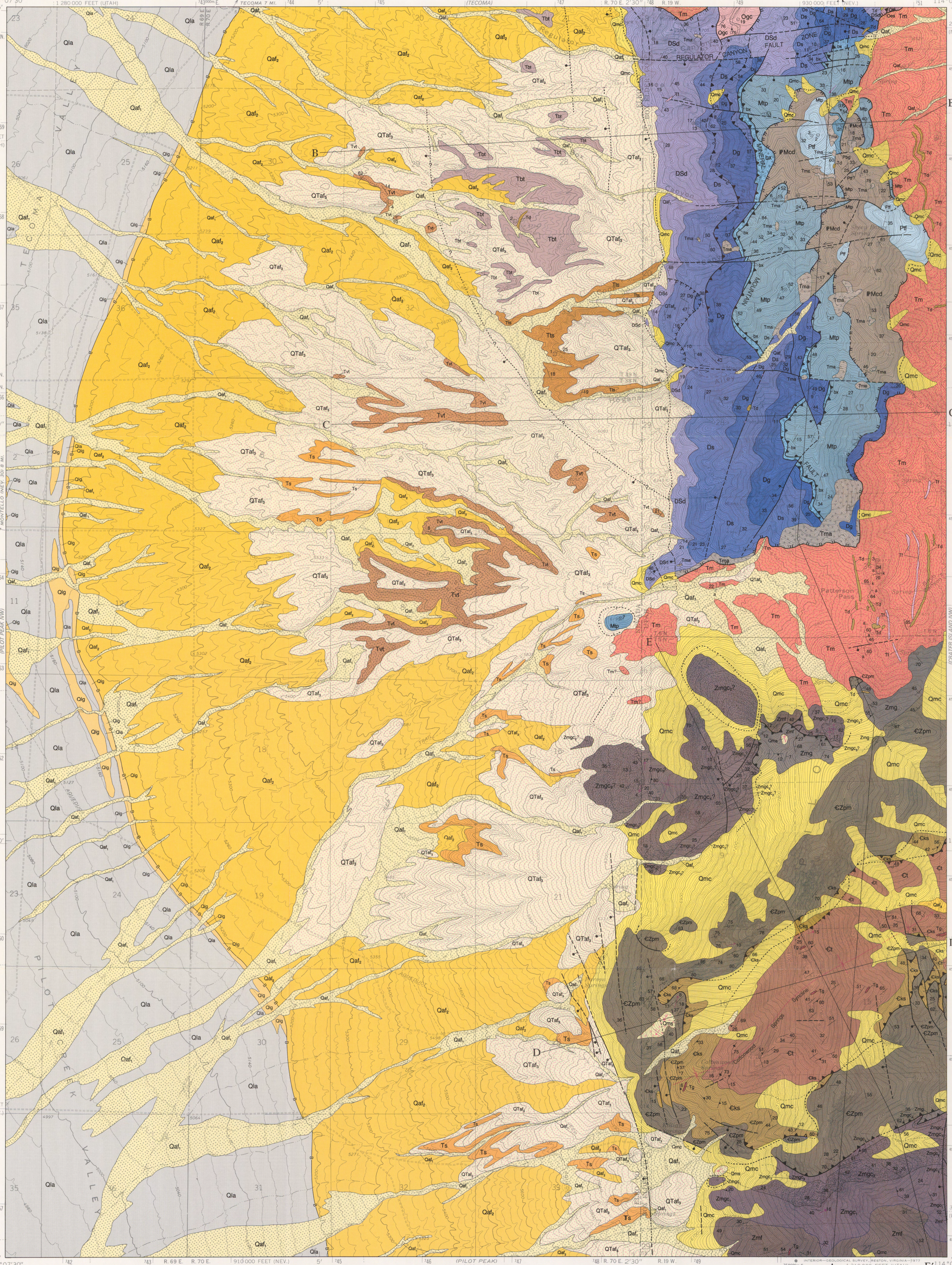


Base Map from U. S. Geological Survey
Patterson Pass 7.5′ Quadrangle, 1967

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Geology mapped by authors
1979 - 81, 1988; assisted
by M. A. Pernokas, 1980
Lori J. Douglas, Cartographer

UTM GRID AND 1992 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

QUADRANGLE LOCATION

GEOLOGIC MAP OF THE PATTERSON PASS QUADRANGLE, BOX ELDER COUNTY, UTAH, AND ELKO COUNTY, NEVADA

by

David M. Miller, Andrew P. Lush, and Joel D. Schneyer

1993

DESCRIPTION OF MAP UNITS

Qms Landslide deposits (Holocene and Pleistocene)—*Displaced deposits of disaggregated rock and alluvium that form hummocky terranes. Huge detached masses of bedrock are mapped as gravity-slide blocks, identified by bedrock unit symbols.*

Qmc Colluvium and talus (Holocene and Pleistocene)—*Unconsolidated, blocky deposits on talus slopes and conglomerate, gravel, and sand slope-wash deposits.*

Qaf$_1$ Alluvial-fan deposits (Holocene and Pleistocene)—*Unconsolidated stream and fan deposits of poorly sorted gravel, sand, and silt. Deposited as alluvial cones at mouths of canyons and gullies, as alluvial floodplains bordering streams, and as sediments in stream channels. Slopewash included locally.*

Qla Lacustrine and alluvial deposits, undivided (Holocene and Pleistocene)—*Varied, complexly interlayered deposits of lacustrine and alluvial origins. In most places, unit consists of thin sheets of alluvium on erratically exposed lacustrine deposits.*

Qlg Lacustrine gravel (Pleistocene)—*Moderately to well-sorted pebble, cobble, and sand deposits, with sand and silt matrix.*

Qaf$_2$ Older alluvial-fan deposits (Pleistocene)—*Unconsolidated, poorly sorted gravel and sand forming piedmont flanking Pilot Range. Mostly stream and fan deposits; slopewash included locally. Overlain by deposits of Lake Bonneville.*

QTaf$_3$ Oldest alluvial-fan deposits (Pleistocene and Pliocene?)—*Unconsolidated to partly consolidated, poorly sorted boulder, cobble, pebble, gravel, sand, and silt alluvial deposits forming terraces. Locally contains extensive pedogenic calcite.*

Td Diabase (Pliocene?)—*Undivided reddish-brown, resistant diabase dikes and large nonresistant bodies that weather to soft, loose brown soils. Generally fine-grained, hornblende-plagioclase diabase and pyroxene-plagioclase mafic rock. Diabase intrudes faults cutting Miocene strata.*

Ts Sedimentary rocks (Miocene)—*Lithified, but generally nonresistant, green and brown fanglomerate; siliceous lake deposits such as conglomerate, sandstone, and siltstone; limestone. Thin interbeds of white, altered, water-laid vitric tuff included. Lake deposits generally thin bedded and fine grained.*

Tvt Vitric tuff (Miocene)—*White to light-gray, thin- to thick-bedded, vitric tuff containing no phenocrysts. Grading, cross-stratification, and interbedding of silt and sand suggest subaqueous deposition.*

Tf Felsite (Oligocene?)—*Light-gray felsite containing sparse phenocrysts of subhedral quartz, plagioclase, and alkali feldspar in an aphanitic, pale-gray groundmass. Most outcrops are of north-striking, steeply dipping dikes.*

Tts Tuff and sedimentary rocks (Oligocene? and Eocene)—*Poorly exposed, interbedded rhyolite and dacite tuff and varied sedimentary rocks, including conglomerate, sandstone, siltstone, lacustrine marl, and alluvium.*

Tbt Biotite rhyolite tuff (Oligocene? and Eocene)—*Poorly exposed, deeply weathered, biotite-alkali feldspar-plagioclase-quartz unwelded ash-flow(?) tuff, tuff breccia, and conglomerate. Minor welded tuff and air-fall tuff containing pumice clasts also present. Grades upward and laterally into tuff and sedimentary rocks unit (Tts).*

Tm McGinty Monzogranite (Eocene)—*Coarse-grained, white to gray, porphyritic monzogranite to granodiorite. Phenocrysts of alkali feldspar, as large as 5 cm (2 in) maximum diameter, set in coarse-grained matrix of plagioclase, alkali feldspar, quartz, and biotite. Biotite, generally 6-9% modally, is partially altered to chlorite. Age is latest Eocene. Locally, includes:*

Tma *Altered part— Fine-grained, yellow, tan, green, and brown siliceous rock containing quartz, feldspar, and calc-silicate minerals. Forms irregularly shaped bodies at intrusive contacts of main part of the McGinty Monzogranite and as pods within carbonate strata.*

Tg Granodiorite dikes (Eocene)—*Light-gray, medium-grained, hornblende-biotite-granodiorite with aphanitic to fine-grained matrix. Dikes vary in composition but are generally granodiorite.*

Pbg Badger Gulch Formation (Permian)—*Laminated to thin-bedded, platy, dark-gray to black, silty limestone; less common laminae and thin beds of siltstone are browner than limestone. Some beds bioclastic, typically containing crinoid fragments, spirifer brachiopods, and fusulinids.*

Ptf Third Fork(?) Formation (Permian)—*Gray and brown, slope-forming, calcareous, platy sandstone and arkose, and silty limestone.*

IPMcd Chainman Shale and Diamond Peak Formation, undivided (Pennsylvanian and Mississippian)—*Dark-gray shale, and dark-gray, dark-brown, and black sandstone and conglomerate with quartz, chert, and feldspar clasts. Moderately well bedded in medium to thick beds; conglomerate beds are 0.5 to 2 m (1.5 to 6 ft) thick and form cliffs.*

Mtp Tripon Pass Limestone (Mississippian)—*Platy, dark-gray to black, regularly bedded, silty limestone with subordinate interbeds of calcareous siltstone. Weathers light-gray with a pinkish hue.*

bx Silicified breccia—*Dense, resistant, dark-brown, brecciated jasperoid, silicified sandstone, altered carbonate rock, and siliceous vein and vug fillings. Lies on limestone of the Guilmette Formation (Dg) and probably represents replacement of the upper sandstone part of the Guilmette.*

Dg Guilmette Formation (Devonian)—*Light-gray-weathering, dark-gray, blue-gray, and black, cliff-forming limestone. Well-bedded or laminated throughout and fossiliferous. Sedimentary breccia and soft-sediment slump features common. Lower part contains common stringers and beds of dolomite. As mapped, locally includes (within uppermost part of unit) strata referred to as the Joanna Limestone.*

Ds Simonson Dolomite (Devonian)-*Interlayered dark- to medium-gray and light-gray calcareous dolomite forming steep slopes with distinctive light-dark banding. Medium to thick beds in lower part alternate in color; beds are uniformly dark or light in middle and upper parts. Characterized by fine laminations in all but a few beds.*

DSd Thick-bedded dolomite (Devonian and Silurian)—*Off-white, light- and medium-gray, faintly bedded to structureless dolomite and calcareous dolomite. Upper part is light-colored throughout, and locally contains quartz sand beds. Middle part is medium-gray and crinoid-bearing, with some layers of light- and dark-gray. Lower part is light gray and contains sparse chert nodules.*

Oes Ely Springs Dolomite (Ordovician)—*Medium-gray to black, poorly bedded, fractured calcareous dolomite.*

Oe Eureka Quartzite (Ordovician)—*Fractured, white and light-gray orthoquartzite. Well-size-sorted and well-rounded, medium quartz sand grains are indented by pressure solution, and in places are partly recrystallized.*

Ogc Garden City Formation (Ordovician)—*Thinly interbedded blue-gray limestone, gray and brown silty limestone, and brown calcareous siltstone. Quartzite unit indicated by dotted pattern.*

Ꞓt Toano Limestone (Cambrian)—*Gray to tan, platy, laminated and thin-bedded limestone and phyllitic limestone with dolomite and siltstone partings. Lower part is dark gray, silt-rich, and gradational into the underlying Killian Springs Formation (Ꞓks).*

Ꞓks Killian Springs Formation (Cambrian)—*Dark-colored, graphitic phyllite forming a gentle to moderate slope. Lower part is bench-forming homogeneous dark-gray, black, and dark-blue-gray, graphitic phyllite and siltstone, and upper part is dark-gray calcareous phyllite. Calcite content increases upward in upper part.*

ꞒZpm Prospect Mountain Quartzite (Cambrian and Late Proterozoic)— *Light-colored, prominently bedded, and cross-laminated quartzite forming massive cliffs.*

McCoy Creek Group of Misch and Hazzard (1962) (Late Proterozoic)—*Alternating phyllite and quartzite units. In this area, consists of Unit G—Divided into:*

Zmg Upper subunit —*Dark phyllite and metasiltstone with interbedded marble and quartzite.*

Conglomerate subunit—Divided into:

Zmgc$_4$ Interval 4 — *Dark-gray to black conglomerate and coarse-grained quartzite.*

Zmgc$_3$ Interval 3 — *Dark brown, rhythmically bedded phyllite and metasiltstone forming gentle slopes.*

Zmgc$_2$ Interval 2 —*Light-gray, coarse-grained to conglomeratic quartzite forming steep cliffs. Generally medium- to thick-bedded and cross-laminated, brown weathering, and micaceous.*

Zmgc$_1$ Interval 1 —*Dark-brown, quartzose phyllite with interbeds of coarse quartzite and conglomerate. Quartzite is dark-gray, brown, and light- gray, impure and poorly size-sorted. Conglomerate is polymict and contains phyllite rip-up wedges. Forms slopes with small cliffs.*

Zmf Unit F —*Gray, well-bedded and cross-laminated, cliff-forming quartzite. Lenticular conglomerate at top contains rip-up clasts of phyllite, boulders and cobbles of quartzite, and rare jasperoid clasts.*

UNITS PRESENT ONLY IN CROSS SECTION

McCoy Creek Group (Late Proterozoic)—*Divided into:*

Zme Unit E—*Brown quartzose schist and metasiltstone.*

Zmd Unit D —*Massive pebbly to granular quartzite.*

Zmc Unit C —*Tan metasiltstone.*

Zmb Unit B (?)—*Light-colored massive to laminated marble.*

Zma Unit A (?)—*Flaggy quartzite and mica schist capped by green amphibole schist.*

CONTACT - Dotted where covered

HIGH ANGLE FAULT - Dashed where location inferred, dotted where concealed; dip indicated; bar and ball on down thrown side

STRIKE SLIP FAULT - Dashed where location inferred; arrows show sense of separation and, on cross section, **A** is away from viewer, **T** is toward viewer

BEDDING PLANE FAULT - Dashed where inferred; barbs on hanging wall, dip indicated

LOW ANGLE NORMAL FAULT- Dashed where inferred; barbs on hanging wall

GRAVITY SLIDE BLOCK - dotted where concealed

ORIENTATION OF BEDDING

Inclined

Vertical

Overturned

ORIENTATION OF FOLIATION

Inclined

Vertical

ORIENTATION OF FOLIATION AND BEDDING AT SAME OUTCROP

LINEATION - Showing trend and plunge

MINOR FOLD - Showing trend and plunge of axis

TRACE OF AXIAL SURFACE OF ANTICLINE - Showing plunge

TRACE OF AXIAL SURFACE OF SYNCLINE - Showing plunge

STRIKE AND DIP OF IGNEOUS FEATURES - a, aplite; k, layer of alkali feldspar phenocrysts

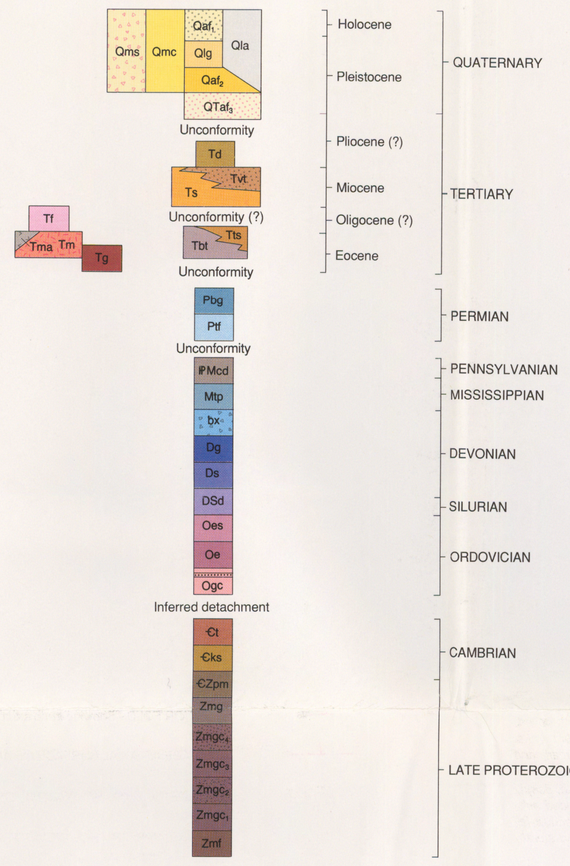
DRILL HOLE - Approximate location reported by Doelling (1980, p.89)

LOCATION OF PALEONTOLOGY SAMPLE

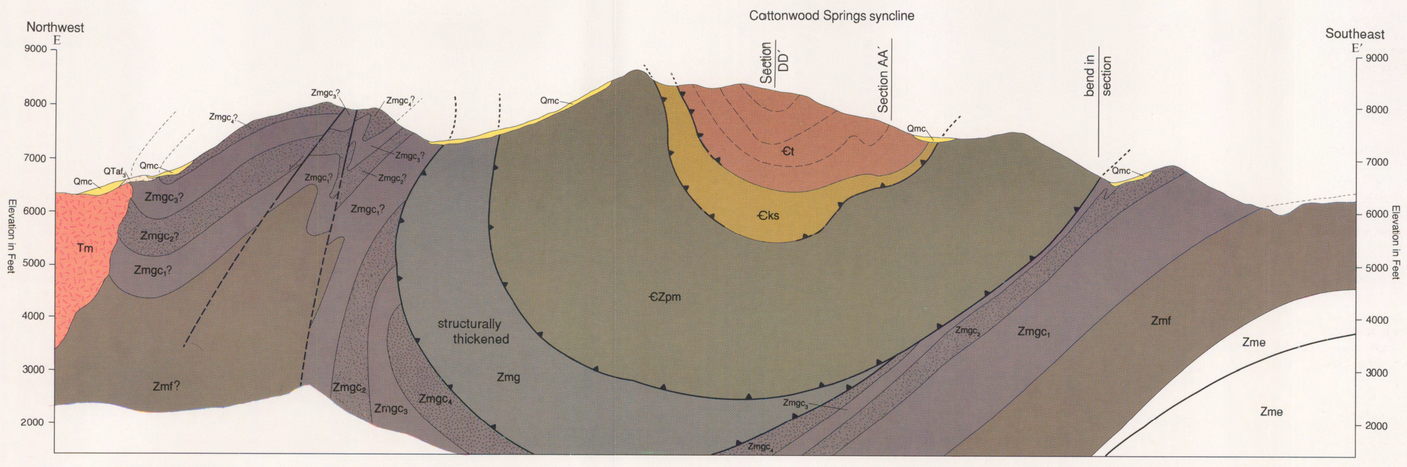
LOCATION OF GEOCHRONOLOGY SAMPLE

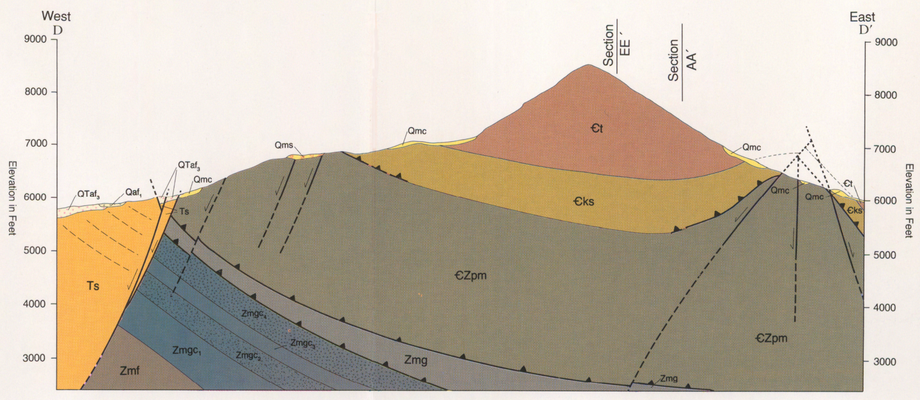
BONNEVILLE SHORELINE

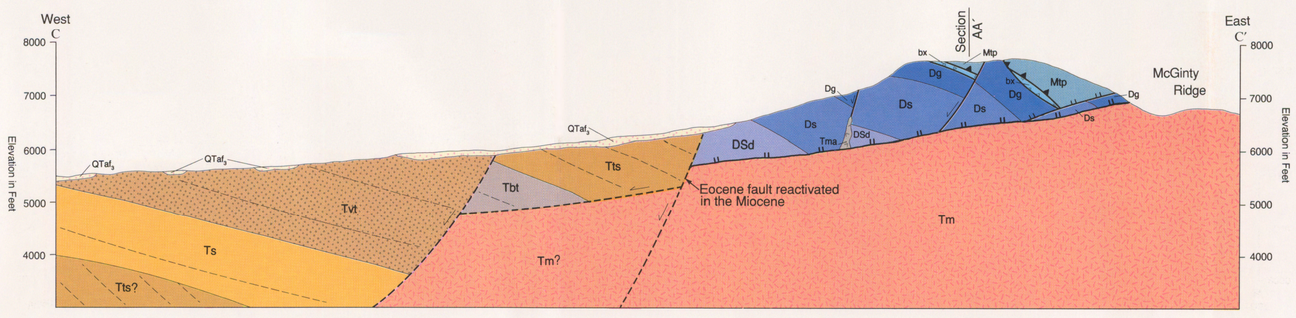
CORRELATION OF MAP UNITS

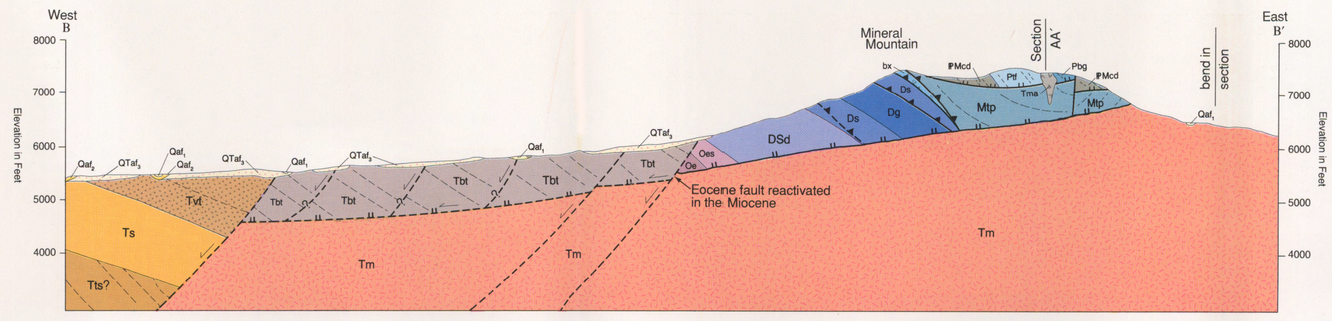


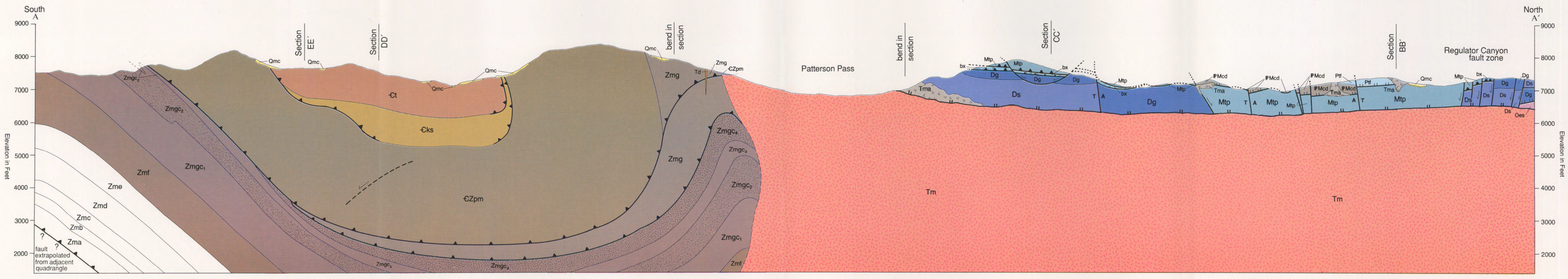
Formation	Symbol	Thickness feet (meters)	Lithology
Vitric tuff	Tvt	2,300 (700)	
Sedimentary rocks	Ts	1,300 (400)	
Tuff and sedimentary rocks	Tts	2,300 (700)	
Biotite rhyolite tuff	Tbt	1,650 (500)	
Badger Gulch Formation	Pbg	260 (80)	
Third Fork (?) Formation	Ptf	720 (220)	
Chainman Shale and Diamond Peak	IPMcd	600 (185)	
Tripon Pass Limestone	Mtp	1,400 (425)	
Silicified breccia	bx	130 (40)	
Guilmette Formation	Dg	1,280 (390)	
Simonson Dolomite	Ds	1,200 (365)	
Thick-bedded dolomite	DSd	1,640 (500)	
Ely Springs Dolomite	Oes	390 (110)	
Eureka Quartzite	Oe	260 (80)	
Garden City Formation	Ogc	885 (270)	
Toano Limestone	Ꞓt	1,970 (600)	
Killian Springs Formation	Ꞓks	990 (300)	
Prospect Mountain Quartzite	ꞒZpm	2,840 (865)	
McCoy Creek Group — Unit G — upper subunit	Zmg	1,725 (525)	
McCoy Creek Group — Unit G — Conglomerate subunit — interval 4	Zmgc$_4$	65 (20)	
McCoy Creek Group — Unit G — Conglomerate subunit — interval 3	Zmgc$_3$	165 (50)	
McCoy Creek Group — Unit G — Conglomerate subunit — interval 2	Zmgc$_2$	475 (145)	
McCoy Creek Group — Unit G — Conglomerate subunit — interval 1	Zmgc$_1$	1,310 (400)	
McCoy Creek Group — Unit F	Zmf	1,400 (425)	











Miller, Lush, Schneyer

GEOLOGIC MAP OF THE PATTERSON PASS QUADRANGLE

UGS Map 144

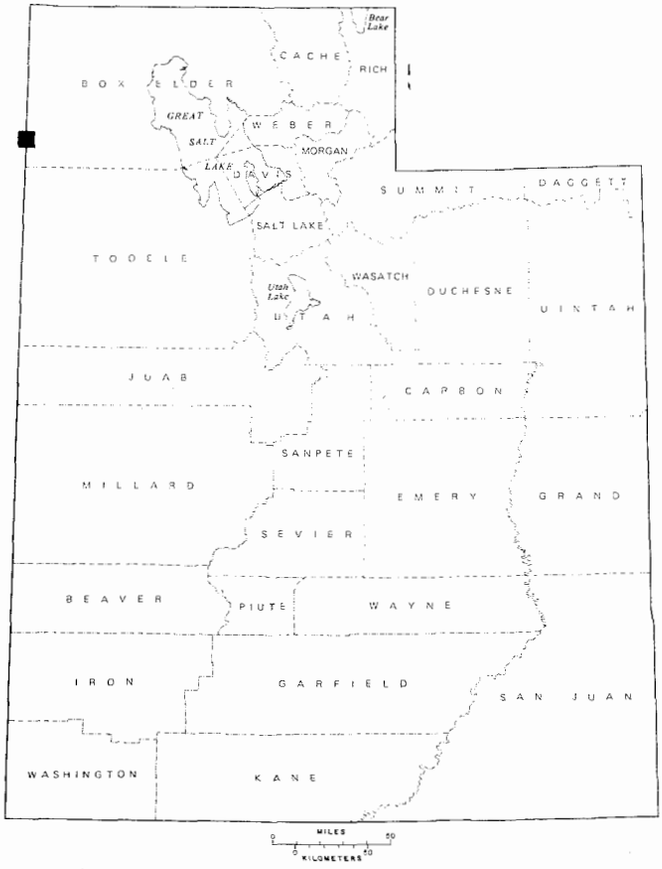
GEOLOGIC MAP OF THE PATTERSON PASS QUADRANGLE, BOX ELDER COUNTY, UTAH, AND ELKO COUNTY, NEVADA

by

David M. Miller, U. S. Geological Survey

Andrew P. Lush, Applied Geosystems

Joel D. Schneyer



MAP 144 **1993**

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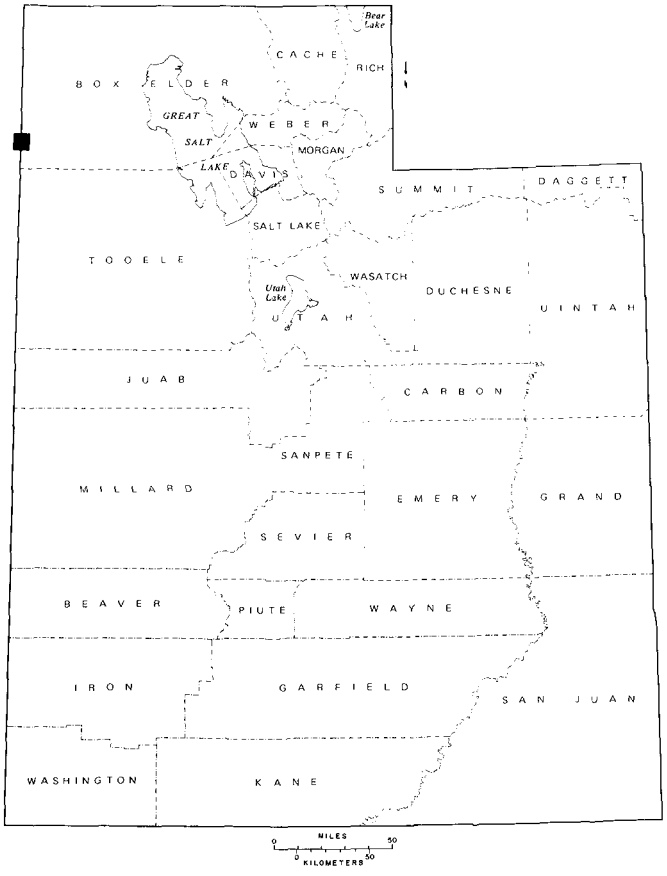

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by

David M. Miller[1], Andrew P. Lush[2], and Joel D. Schneyer[3]

ABSTRACT

The Patterson Pass quadrangle straddles the Utah-Nevada border in northwestern Utah and includes much of the central Pilot Range and a broad, west-sloping piedmont west of the Pilot Range. The north-trending fault block forming the Pilot Range is typical of the northern Basin and Range Province. The fault block is composed of two lithotectonic domains that are separated by a latest Eocene granitoid pluton, and a third domain flanks the range. South of the pluton, Mesozoic ductile deformation and metamorphism affected Late Proterozoic and Cambrian rocks. North of the pluton lie generally unmetamorphosed Ordovician to Permian carbonate strata. These northern rocks are broken by numerous high- and low-angle faults that mainly record Cenozoic extension of the upper crust. Flanking much of the Pilot Range are Eocene to Miocene volcanic and sedimentary rocks, which record development of structural basins during tectonic extension. Miocene to Quaternary basin and range normal faulting has produced the current physiography of the area.

INTRODUCTION

The Patterson Pass quadrangle straddles the Utah-Nevada border in northwestern Utah and includes much of the central Pilot Range (figure 1). The crest of the Pilot Range trends northward along the east side of the quadrangle. This crest is divided by a broad pass, Patterson Pass, in the east-central part of the quadrangle. The mountain crest is as high as 2,654 m (8,712 ft) south of Patterson Pass and 2,399 m (7,875 ft) north

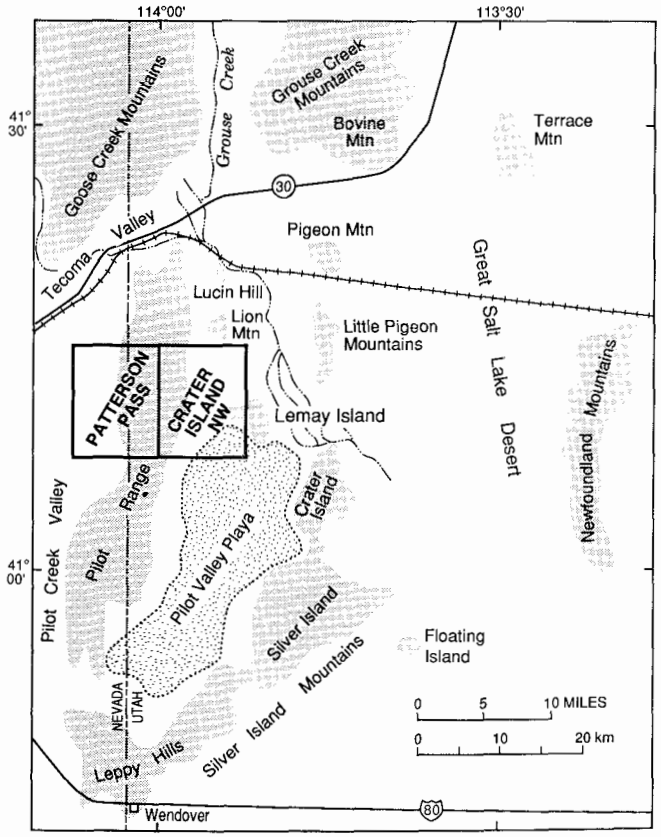

Figure 1. Location of physiographic features in the vicinity of the Patterson Pass and Crater Island NW (a companion report) quadrangles, northwestern Utah and northeastern Nevada.

[1]U.S. Geological Survey, Menlo Park, CA 94025
[2]Applied Geosystems, Sacramento, CA 95826, formerly U.S.G.S.
[3]50 Hillpark Ave., Apt 1 R, Great Neck, NY 11021, formerly U.S.G.S.

of the pass. A broad, west-sloping piedmont lies west of the Pilot Range, in the western part of the quadrangle; it ranges from about 1,889 m (6,200 ft) to 1,307 m (4,290 ft) in altitude. This piedmont lies along the east side of valleys west of the Pilot Range (figure 1). The topographic divide between the southward-draining Pilot Creek Valley and the northward-draining Tecoma Valley is formed by a broad alluvial fan and piedmont in the western part of the quadrangle (plate 1).

The Pilot Range and nearby mountains (figure 1) are north-trending fault blocks, typical of the northern Basin and Range Province. This part of the eastern Great Basin was part of the subsiding continental margin during Late Proterozoic and Paleozoic time, when great thicknesses of sedimentary rock accumulated (Miller, 1984; Hintze, 1988). During the Jurassic and possibly continuing into the Cretaceous, the Pilot Range region was the site of igneous intrusion, metamorphism, folding, and low-angle faulting (Miller and others, 1987) and later probably was passively thrust eastward as part of the hinterland of the Cordilleran fold and thrust belt. During the Cenozoic, the region was tectonically extended. High- and low-angle normal faulting, plutonic and volcanic activity, and subsidence of deep sedimentary basins are characteristic of the Cenozoic. During Pleistocene time, Lake Bonneville inundated the northwestern Utah area; shorelines cut into older alluvial aprons and lacustrine deposits about 1,579 m (5,185 ft) along this west flank of the Pilot Range reflect the maximum height of the lake surface after isostatic rebound.

Within the Patterson Pass quadrangle, two lithotectonic domains (regions characterized by similar rocks and deformational structures) in the Pilot Range are separated by a latest Eocene granitoid pluton, which occupies Patterson Pass, and a third domain flanks the range. South of the pluton, Mesozoic ductile deformation and metamorphism affected Late Proterozoic and Cambrian rocks that are continuous with those described in the Pilot Peak quadrangle to the south (Miller and Lush, 1981). North of the pluton lie generally unmetamorphosed Paleozoic carbonate strata ranging in age from Ordovician to Permian. These northern rocks are broken by numerous high- and low-angle faults and are continuous with rocks of the Tecoma quadrangle (Miller and Schneyer, 1985) to the north. Eocene to Miocene volcanic and sedimentary rocks flank much of the Pilot Range, forming a third, structurally highest, lithotectonic domain.

The Pilot Range was mapped as part of a project to understand the Mesozoic and Cenozoic tectonics of northwestern Utah, a project that has yielded many geologic maps in the area (figure 2). This mapping of the Pilot Range uncovered structural, stratigraphic, and metamorphic relations that were not apparent in earlier studies by Blue (1960) and O'Neill (1968). Complicated Mesozoic and Tertiary faults control the present distribution of sedimentary, metamorphic, and igneous rocks. This report and a companion report on the Crater Island NW quadrangle (Miller, 1993) provide new information and interpretations that supercede a preliminary map of the Patterson Pass and Crater Island NW quadrangles (Miller and others, 1982).

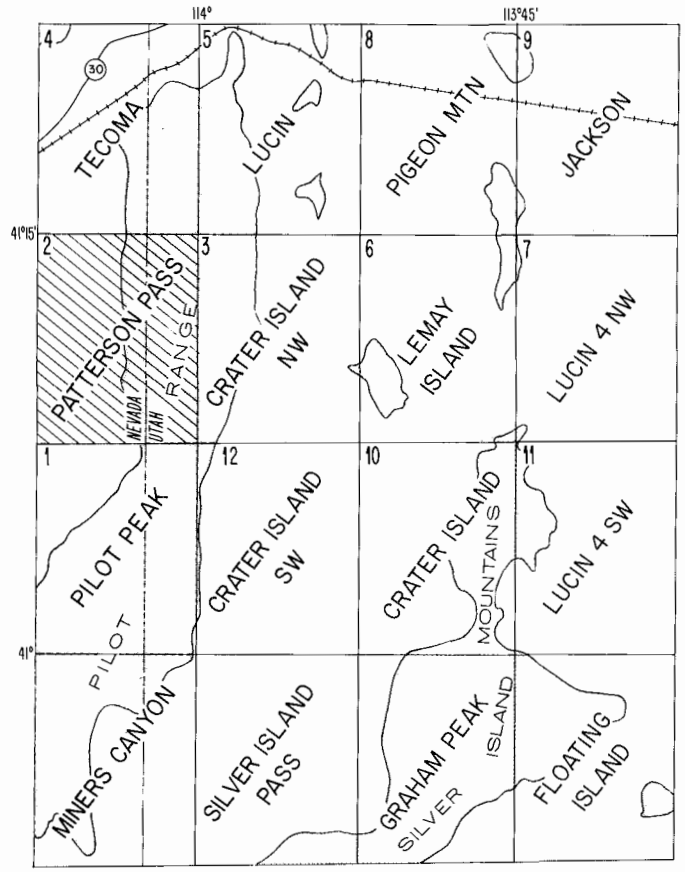

Figure 2. Quadrangle map index for Patterson Pass and nearby quadrangles. Numbers indicate published 1:24,000-scale geologic maps (1)Miller and Lush,1981; (2) this report; (3) Miller, 1993; (4) Miller and Schneyer, 1985; (5) Miller, 1985; (6) Miller and Glick, 1986; (7) Glick and Miller, 1986; (8) Glick and Miller, 1987; (9) Miller and Glick, 1987; (10) Miller, Jordan, and Allmendinger, 1990; (11) Miller, 1990a; (12) Miller, 1990b.

DESCRIPTION OF ROCK UNITS

The rock units within the Patterson Pass quadrangle consist of Late Proterozoic and Paleozoic strata of the Cordilleran miogeocline, Cenozoic intrusive igneous rocks, Cenozoic sedimentary and volcanic deposits, and Quaternary deposits. Detailed descriptions of these rock units, interpretive discussions, and interrelations between units are included in this section. Most Paleozoic rock units in the quadrangle were geographically extended to the Pilot Range by Miller and Schneyer (1985), some igneous rocks were named and described by Miller and others (1987), and Late Proterozoic and Cambrian strata were extended to the Pilot Range (and in some cases named) by Woodward (1967), Miller (1983), and McCollum and Miller (1991). Late Proterozoic and Cambrian strata everywhere are metamorphosed to greenschist and lower amphibolite facies, whereas Ordovician and younger strata show no evidence of dynamothermal metamorphism. We describe most metamorphic rocks by their protolith compositions. The chief exceptions are fine-grained, micaceous rocks, which we term phyllite; these rocks generally lack sedimentary structures and textures and probably represent shale and siltstone protoliths.

LATE PROTEROZOIC

McCoy Creek Group

The McCoy Creek Group of Misch and Hazzard (1962) was defined for a thick sequence of alternating phyllite and quartzite units underlying the Late Proterozoic and Cambrian (restricted) Prospect Mountain Quartzite in the Schell Creek Range, east-central Nevada. This nomenclature was extended to the Pilot Range by Woodward (1967), O'Neill (1968), Miller and Lush (1981), and Miller (1983). Miller (1983) followed Stewart (1974) by including the uppermost unit of Misch and Hazzard's (1962) McCoy Creek Group, unit H, within the lower part of the Prospect Mountain Quartzite because the two units are indistinguishable in most locations. This modified sequence of the McCoy Creek Group extends from unit G at the top to unit A at the base.

In the Patterson Pass quadrangle, units G and F of the McCoy Creek Group crop out south of Patterson Pass; both are metamorphosed. Unit G in this central part of the Pilot Range differs from the unit in the southern Pilot Range and in the Schell Creek Range by the addition of thick conglomerate and phyllite intervals within its lower part (Miller, 1983). Detailed descriptions of units G and F are given by Miller (1983).

McCoy Creek Group, Unit F

Unit F is composed of gray, well-bedded, cross-laminated quartzite that forms steep slopes and cliffs. The thick beds of quartzite typically display tabular, wedge, and trough cross-laminations. Bed surfaces bounding the cross sets locally carry scattered white vein quartz pebbles. The basal 40 m (130 ft) or so of the unit (exposed in the adjacent Pilot Peak quadrangle) is composed of faintly bedded gray quartzite containing feldspar fragments and rare beds of conglomerate. The uppermost part of the unit, as much as 20 m (65 ft) thick, contains lenticular channels and beds of massive conglomerate separated by quartzite and rare mica schist beds. Rip-up wedges of phyllite (originally shale), boulders and cobbles of quartzite, feldspar grains, and rare jasperoid clasts are common throughout this conglomeratic upper part of the unit. Although unit F is about 425 m (1,400 ft) thick in the central Pilot Range (Miller, 1983), only the upper part of the unit is exposed in the Patterson Pass quadrangle.

McCoy Creek Group, Unit G

Miller (1983) divided unit G of the McCoy Creek Group into two subunits, the upper subunit and the (lower) conglomerate subunit. The upper subunit consists mainly of phyllite and metasiltstone, whereas the conglomerate subunit consists of alternating coarse conglomerate and phyllite intervals.

Conglomerate subunit - The (lower) conglomerate subunit consists of four alternating intervals of phyllite and conglomerate, designated intervals 1 through 4 in ascending order. Phyllite in this subunit was metamorphosed to biotite-muscovite-staurolite-plagioclase-quartz assemblages in the northern limb of the Cottonwood Springs syncline. Retrograde minerals near the McGinty Monzogranite include muscovite, chlorite, and epidote.

Interval 1 - This interval is composed of dark-brown, quartzose phyllite and silvery schist, and interbedded coarse-grained quartzite and conglomerate. Phyllite and quartzite are interbedded on a scale of 10 to 25 m (30 to 80 ft). Phyllite zones weather dark brown and consist of micaceous quartzite, slate, green phyllite, and schist. Quartzite beds are dark-gray, brown, and light-gray, and are impure and poorly size sorted. Conglomerate is polymict; in addition to several types of quartz, it contains feldspar fragments and phyllite rip-up wedges. Interval 1 is about 400 m (1,310 ft) thick.

Interval 2 - This interval is composed of light-gray, coarse-grained to conglomeratic quartzite forming steep cliffs. It is generally micaceous and medium to thick bedded with tabular cross-laminations, and brown weathering. Quartzite beds are coarse grained, impure, and poorly size-sorted. Locally, beds contain as much as 20 percent detrital feldspar. The upper 105 m (345 ft) of the interval is polymict conglomerate. Interval 2 is about 145 m (475 ft) thick.

Interval 3 - This interval is composed of dark-brown, rhythmically bedded phyllite and metasiltstone forming gentle slopes. It is about 50 m (165 ft) thick and, at the top and bottom, is interbedded with adjacent units.

Interval 4 - This interval is composed of cliff-forming, impure, black to gray quartzite that is generally poorly size-sorted; it contains feldspar and mica. Conglomerate interbedded with the quartzite is polymict and is similar to, but darker in color than, the conglomerate in interval 2. Clasts in the conglomerate consist of slate, jasper, and quartzite of various colors, and the clasts range considerably in size, shape, and roundness. Interval 4 is greater than 20 m (65 ft) thick, but its top is truncated by faults.

Upper subunit - The upper subunit can be roughly divided into four parts with gradational boundaries. The lowermost part consists of flaggy quartzite containing rare lenses of coarse quartzite that grade upward to a thick, dark phyllite part. Above the phyllite part is a distinctive interval of interbedded light-colored marble, metasiltstone, and dark, fine-grained quartzite. The marble is commonly epidotized near the McGinty Monzogranite. The uppermost part is dark-colored, thin- to medium-bedded and cross-laminated, fine-grained quartzite. The upper subunit is about 525 m (1,725 ft) thick 1 km (0.6 mi) south of Patterson Pass, where it has a faulted base; it is structurally thinned even more in other places. Near Patterson Pass, rocks from this unit have been extensively metasomatized by surrounding granite; they contain alkali feldspar, plagioclase, muscovite, and andalusite porphyroblasts.

Unit G of the McCoy Creek Group apparently represents deposits in fluvial and shallow marine environments. Thinly interbedded limestone and shale with flaser bedding and ripples indicates marine deposition. Similar deposits are widespread in the Great Basin, suggesting fairly uniform conditions of deposition. Much of the unit could represent fluvial deposits.

LATE PROTEROZOIC AND CAMBRIAN

Prospect Mountain Quartzite

The Prospect Mountain Quartzite is a prominent, thick, cliff-forming unit that primarily is composed of thick-bedded, distinctly cross-laminated quartzite. Three subdivisions of the Prospect Mountain can be discerned in locations where it is well exposed (Miller, 1983): a lower white, vitreous, pure quartzite; a middle blue-gray quartzite containing as much as 30 percent feldspar fragments; and an upper gray, thick-bedded, distinctly

cross-laminated quartzite. The upper interval makes up most of the Prospect Mountain. The upper interval ranges in grain size from medium sand size to pebble, but for the most part is coarse. The quartzite of the upper interval generally consists of quartz with small amounts of metamorphic mica and detrital feldspar. Cross sets are commonly tabular or wedge shaped although festoons were noted in several localities. Beds typically have gravel layers at their base, perhaps representing lag deposits. Distinctive color and grain size mark the uppermost 70 m (230 ft) of the Prospect Mountain Quartzite. Many quartzite beds in this part are dark gray due to the presence of iron oxide minerals, and conglomerate beds as much as 4 m (13 ft) thick locally are present. Thick conglomerate sections contain phyllite beds and rip-up wedges of phyllite (originally shale). The Prospect Mountain is a minimum of 700 m (2,300 ft) thick in an incomplete section in the north limb of the Cottonwood Spring syncline, and about 865 m (2,840 ft) thick in the south limb, where a low-angle fault cuts out part of the base. The lower part of the Prospect Mountain is about 100 m (330 ft) thick, and the middle part is about 15 m (50 ft) thick.

The Prospect Mountain Quartzite is herein used as defined by Misch and Hazzard (1962) and further modified by Woodward (1967), Stewart (1974), and Miller (1983). Following Stewart (1974), we consider the Prospect Mountain Quartzite to be mainly Late Proterozoic in age but also to contain Early Cambrian beds in its upper part.

The Prospect Mountain Quartzite was deposited in braided-stream and shallow-marine environments, on the basis of lithologies and structures (McCollum and Miller, 1991). Marine deposits are concentrated near the top of the unit.

CAMBRIAN

Killian Springs Formation

The Killian Springs Formation is a dark-colored phyllite forming topographic benches, in striking contrast to the white cliffs of the underlying Prospect Mountain Quartzite. The lower part of the Killian Springs is mostly homogeneous, dark phyllite and metasiltstone; rare fine-grained metasandstone layers outline bedding. The upper part consists of slightly calcareous phyllite and siltstone that is interbedded with laminated and cross-laminated dark limestone and calcareous quartzite in the uppermost 10 to 15 m (33 to 45 ft). The limestone beds typically are 2 to 10 cm (1 to 4 in) thick and the interbedded phyllite is 10 to 30 cm (4 to 12 in) thick. The entire Killian Springs contains disseminated cubes of pyrite. Metamorphic minerals include fine grains of biotite, muscovite, and chlorite. The base of the Killian Springs is in sharp contact with thick-bedded quartzite of the Prospect Mountain Quartzite, and the top grades into clastic limestone of the lower part of the Toano Limestone. The basal contact in many places is a bedding-plane fault of probable small separation; quartzite beds are truncated at low angles at many locations, but the Prospect Mountain and Killian Springs are noticeably thinned only along steep limbs of the Cottonwood Springs syncline. The Killian Springs is about 300 m (990 ft) thick; the lower part is about 125 m (410 ft) thick, and the upper part is about 175 m (580 ft) thick.

The Killian Springs Formation was formally named by McCollum and Miller (1991), revising the informal term "phyllite of Killian Springs" of Miller (1983) and Miller and others (1982). The new name was proposed to emphasize the contrast between the graphitic, black phyllite in the Pilot Range and the green siltstone, quartzite, and limestone of the broadly correlative Pioche Formation (Hintze and Robison, 1975), which overlies the Prospect Mountain Quartzite in much of eastern Nevada and western Utah. The Killian Springs also is exposed in the neighboring Silver Island Mountains, Utah, and Toano Range, Nevada (McCollum and Miller, 1991). Siliceous sponge spicules, abundant in the upper part of the unit, are suggestive of Middle Cambrian forms (McCollum and Miller, 1991). McCollum and Miller (1991) provisionally regarded the Killian Springs to be Early and Middle Cambrian in age.

The Killian Springs Formation represents deposition on a subsiding platform margin, probably in an anoxic environment below wave base (McCollum and Miller, 1991). Lack of fossils and bioturbation in the black shales point to a deep-water setting.

Toano Limestone

The Toano Limestone is composed mainly of slightly metamorphosed, thin-bedded to laminated, gray, silty limestone. It occupies the core of the Cottonwood Springs syncline (plate 1) and is tightly folded and cleaved in places. The base of the unit is drawn at the top of the uppermost dark calcareous phyllite bed of the underlying Killian Springs Formation. The lower part of the section is mainly medium-gray, laminated limestone with tan dolomitic laminations and interbeds. Sparse calcareous quartzite beds also are present. The lower part grades upward into very thinly bedded, tan, silty limestone and fissile, gray, calcareous and graphitic phyllite. The unit contains cubes of pyrite throughout. Primary soft-sediment structures such as folds caused by slumping, trough cross-stratification, and chaotic bedding are common. Metamorphic minerals in the unit are muscovite and chlorite. The maximum thickness of the unit is estimated to be about 600 m (1,970 ft), but the stratigraphic top is not exposed. The unit is 850 m (2,790 ft) thick in the type section at the Toano Range (McCollum and Miller, 1991).

Middle Cambrian trilobites were recovered from the Toano Limestone in the adjacent Crater Island NW quadrangle to the east (Miller, 1993) and at the type section in the Toano Range 15 km (9 mi) to the southwest (McCollum and Miller, 1991), where the youngest fossils are late Middle Cambrian in age. The type Toano Limestone is considered to be Middle Cambrian in age (McCollum and Miller, 1991).

The Toano Limestone probably was deposited on a distally steepened carbonate ramp (McCollum and Miller, 1991). Sedimentary structures and graded bedding suggest that some sediment was emplaced as debris flows, and the cosmopolitan trilobite fauna indicates unrestricted open-marine conditions.

ORDOVICIAN

Garden City Formation

The Garden City Formation is exposed in a fault-bounded block north of Regulator Canyon. It consists mainly of strongly cleaved, thinly bedded, gray limestone with interbedded zones of silty limestone. Rare beds of calcareous quartz sand and beds

containing abundant brown chert nodules also are present. A white orthoquartzite unit, about 20 m (65 ft) thick, that we correlate with a similar orthoquartzite unit in the upper part of the Garden City Formation in the Toano Range to the west (Glick, 1987) and farther south in the Pilot Range (D.M. Miller, unpublished mapping, 1982), lies within the exposed silty limestone. This orthoquartzite unit was not recognized as a part of the Garden City on earlier maps of the northern Pilot Range (Miller and others, 1982; Miller and Schneyer, 1985), and instead was assigned to the Eureka Quartzite, requiring complicated fault relations. The Garden City is about 270 m (885 ft) thick, but both the top and bottom of the section are faulted. The unit represents deposition on a shallow marine carbonate platform.

The Garden City Formation is Early Ordovician in age. Recrystallized brachiopods are abundant, and gastropods and worm burrows are common. A gastropod collected above the orthoquartzite unit was identified as probably late Early Ordovician in age (table 1, no. 19). The unit is lithologically similar to thick sections of the Lower Ordovician Garden City Formation in the southern Pilot Range and Toano Range, with which it is correlated.

Eureka Quartzite

The Eureka Quartzite is a prominent, white, cliff-forming unit that crops out in the extreme northeastern corner of the quadrangle. It consists of white, vitreous orthoquartzite; it typically is highly fractured. More extensive outcrops of the unit lie to the north in adjacent quadrangles (Miller, 1985; Miller and Schneyer, 1985), where the unit is 80 m (260 ft) thick.

Ely Springs Dolomite

Black to dark-gray, calcareous dolomite lying on the Eureka Quartzite in the northeastern corner of the quadrangle is assigned to the Ely Springs Dolomite. This unit is poorly exposed, and the rocks are poorly bedded and highly fractured. In more extensive exposures in the contiguous Tecoma quadrangle, the unit is 110 m (390 ft) thick.

SILURIAN AND DEVONIAN

Thick-bedded Dolomite

A thick section of generally light-colored, thick-bedded to structureless dolomite (DSd) underlies the Simonson Dolomite of latest Early and Middle Devonian age. The lower part of the thick-bedded dolomite is light gray and chert bearing, the middle part is medium gray with some darker beds, and the upper part is light gray and buff. Locally within the upper part are quartz-sand beds composed of well-rounded, medium sand grains and sparse calcite grains supported by a dolomite matrix. This sand interval is about 15 m (50 ft) thick and lies about 30 m (100 ft) below the top of the unit. The dolomite unit is non-fossiliferous in most places, although crinoid fragments are present locally in the middle part. The unit is greater than 500 m (1,640 ft) thick; its base is faulted or unexposed.

We do not assign the thick-bedded dolomite unit to formations recognized elsewhere in the eastern Great Basin because it appears to represent a transitional facies. To the east, the Silurian Laketown and Devonian Sevy Dolomites are widespread, and to the west, the Roberts Mountains Formation and Lone Mountain Dolomite are widespread. Neither the distinctive tripartite division of the Laketown Dolomite nor the laminations characteristic of the Sevy Dolomite are present in the thick-bedded dolomite unit. In addition, platy limestone of the Roberts Mountains Formation is not present. Rocks in the upper part of the thick-bedded dolomite unit are similar to those in the Lone Mountain Dolomite and conodonts indicate deeper water environments than typical for the Laketown and Sevy, suggesting that the northern Pilot Range rocks have a closer affinity to the western-facies rocks than to the eastern-facies rocks.

The thick-bedded dolomite unit is Silurian and Early Devonian in age in the northern Pilot Range. Beds 4 m (13 ft) below the top of the unit west of Mineral Mountain yielded latest Silurian to earliest Devonian conodonts (table 1, no. 17); beds in the middle of the unit yielded Middle to Late Silurian conodonts (table 1, no. 16); and beds in the middle to lower parts of the unit yielded Late Silurian or Early Devonian conodonts (table 1, nos. 15, 18). Because beds near the top of the unit are earliest Devonian or older and beds in the middle of the unit are Middle to Late Silurian, much of the thick unit must be Silurian. We consider the unit to be mainly Silurian in age, with the uppermost part presumably earliest Devonian in age.

DEVONIAN

Simonson Dolomite

The Simonson Dolomite (Ds) is generally dark-colored, finely laminated, recrystallized dolomite that forms steep slopes. Alternating light- and dark-colored intervals are a hallmark of the Simonson. The lower contact is generally sharp: black, laminated dolomite of the Simonson overlies faintly bedded to structureless, pale-gray to white dolomite of the thick-bedded dolomite unit (DSd). Most beds of the Simonson are strikingly laminated and cross-laminated, but rare beds are nearly homogeneous because the laminations were destroyed by extensive bioturbation. The uppermost 20 m (65 ft) of the unit contains bioclastic beds containing abundant brachiopods, typically in an alternating limestone/dolomite sequence or in shaly limestone. The maximum thickness of the Simonson is 365 m (1,200 ft), but the unit varies in thickness, due in part to uncertainty in assigning the upper and lower boundaries because of secondary dolomitization.

Blue (1960) considered the Simonson to be Middle Devonian in age on the basis of stromatoporoids and brachiopod fragments. Conodonts and brachiopods are the most age-definitive fossils we found in the Simonson Dolomite. Brachiopods from shaly limestone near the top of the Simonson are Middle Devonian in age (table 1, no. 12), and conodonts from the basal part of the unit are latest Early Devonian to earliest Middle Devonian in age (table 1, no. 14). Other fossil data (table 1, nos. 10, 11, 13) are compatible with these conodont results. Basal beds of the overlying Guilmette Formation are late Middle Devonian in age, indicating that the upper part of the Simonson is Middle Devonian, in accordance with ages of the unit in nearby ranges (Poole and others, 1977). The age of the Simonson in the Pilot

Table 1. *Paleontologic data for the Patterson Pass quadrangle.*

Map no.	Field (USGS) no.	Rock unit	Fossil age	Date of report	Paleontologist	Faunal description	Latitude	Longitude
1	M81PR-27 (f14482)	Badger Gulch Formation	Early Permian	8/3/82	R.C. Douglass	This sample contains *Parafusilina* sp. and should be Early Permian in age.	41°14'20"	114°0'48"
2	M82PR-59	Third Fork(?) Formation	Early Permian (late Leonardian?)	7/28/82	M. Gordon, Jr.	This collection contains one undescribed species of *Crurithyris* brachiopods. It is rather large for the genus, about twice the size of *C. Planiconvexa* (Shumard), the common Pennsylvanian species. This species is common in Lower Permian rocks in eastern Nevada. At some localities it is regarded as late Leonardian in age. However, it also occurs in the Wolfcampian to Leonardian Riepetown Sandstone.	41°14'14"	114°01'01"
3	M81PR-116	Third Fork(?) Formation	Early Permian (late Leonardian?)	7/29/82	M. Gordon, Jr.	This collection contains the same species, *Crurithyris*, as was in sample M82PR-59, and is Early Permian in age.	41°14'18"	114°01'04"
4	M84PR-124 (29557-PC)	Joana Limestone (mapped as part of Guilmette Formation)	Early Mississippian (Kinderhookian)	2/19/85	K.S. Schindler and A.G. Harris	This sample contains: 4 incomplete Pa element fragments of *Siphonodella* of post-Lower *Duplicata* Zone morphotype 1 indet. bar or blade fragment Age is Kinderhookian. CAI=5	41°13'39"	114°01'41"
5	M81PR-12 (28589-PC)	Tripon Pass Limestone	Early Mississippian (Kinderhookian)	6/17/82	A.G. Harris, K. Denkler, and J.E. Repetski	This sample contains: 5 P elements of *Polygnathus* cf. *P. Symmetricus* Branson 61 *Siphonodella* sp. indet. fragments 7 *Siphonodella Isosticha* (Cooper) elements 52 indet. bar, blade, and platform fragments Age is late Kinderhookian. CAI=4 to 4.5.	41°13'18"	114°01'17"
6	M81PR-08 (28590-PC)	Tripon Pass Limestone	Early Mississippian (Kinderhookian)	6/17/82	A.G. Harris, K. Denkler, and J.E. Repetski	This sample contains: 2 *Siphonodella* aff. *S. Isosticha* (Cooper) elements 1 posterior platform fragment of *Siphonodella* sp. indet. 1 indet. fragment Age is late Kinderhookian. CAI=4.	41°13'51"	114°01'22"
7	M80PR-29 (27690-PC)	Tripon Pass Limestone	Early Mississippian (Kinderhookian)	8/11/80 (revised 1/5/90)	E.F. Mac Donald, L. Savoy, A.G. Harris	This collection contains: 3 Pa element fragments of *Gnathodus punctatus* (Cooper). 106 Pa and 26 Pb elements of *Siphonodella obsoleta* Hass 8 Pa elements of *Polygnathus longiposticus* Branson 7 Pa elements of *Polygnathus communis communis* Branson & Mehl 3 P element fragments of *Polygnathus* sp. indet. 13 Pa elements of *Spathognathodus crassidentatus* (Branson & Mehl) Unassigned elements 10 M, 27 Sc & 2 Sa The overlapping ranges of *Siphonodella obsoleta* and *Gnathodus punctatus* restricts the age of the collection to the lower part of the *Isosticha*-Upper *Crenulata*-Zone. This species association indicates deposition on outer shelf to slope environments. The age is late Kinderhookian. CAI=3.5.	41°11'19"	114°02'37"
8	M80PR-63 (10219-SD)	Guilmette Formation	Late Middle Devonian	8/11/80	E.F. MacDonald, L.Savoy, A.G. Harris	This collection contains: 11 I elements of *Icriodus brevis* Stauffer 7 P elements of *Ozarkodina semialternans* (Wirth) 84 indet. bar, blade, and platform elements 1 ostracode The species association indicates that this sample is late Givetian (late Middle Devonian). *Icriodus brevis* indicates a shallow, warm water depositional environment. CAI=4.	41°14'19"	114°01'49"
9	M81PR-15	Guilmette Formation (possibly, its included Joana Limestone)	Middle Devonian to Early Mississippian	6/17/82	A.G. Harris, K. Denkler, and J.E. Repetski	This sample contains: 8 *Polygnathus* sp. indet. element fragments of Middle Devonian through Early Mississippian morphotype 1 incomplete spathognathodiform element 6 indet. bar, blade, and platform fragments Age is Middle Devonian through Early Mississippian. CAI=4	41°12'41"	114°01'03"
10	CON-11	Simonson Dolomite	Ordovician to Permian	7/10/83	A.G. Harris	This sample contains: 2 indet. bar fragments Age is Ordovician to Permian. CAI=5.	41°14'47"	114°01'01"
11	CON-10	Simonson Dolomite	Silurian or Devonian	7/10/83	A.G. Harris	This sample contains: 2 Pa elements of *Ozarkadina*? sp. indet. (both fragmentary) Age is Silurian or Devonian.	41°14'46"	114°01'05"

Table 1. *(cont'd)*

Map no.	Field (USGS) no.	Rock unit	Fossil age	Date of report	Paleontologist	Faunal description	Latitude	Longitude
12	M79PR-89 (10170-SD)	Simonson Dolomite	Middle Devonian	2/27/80	J.T. Dutro and A.G. Harris	This sample contains: 3 I elements of *Icriodus* sp. (short morphotype characteristic of Middle and Upper Devonian rocks) 23 indet. bar, blade, and platform elements echinoderm debris corroded atrypid brachiopods The *Icriodus* elements indicate a Middle through Late Devonian age. CAI=4.5. The brachiopods suggest a Middle Devonian age.	41°14'05"	114°01'50"
13	M81PR-03	Simonson Dolomite	Silurian through Mississippian	6/17/82	A.G. Harris, K. Denkler, and J.E. Repetski	This sample contains: 1 P element fragment of *Ozarkadina* sp. indet. Age is Silurian through Mississippian. CAI=3.5 to 4.	41°14'18"	114°01'56"
14	M82PR-83 (10722-SD)	Simonson Dolomite	Latest Early Devonian through earliest Middle Devonian	4/25/83	A.G. Harris	This sample contains: 2 Pa elements of *Pandorinellina expansa* Uyeno & Mason 7 indet. bar and blade fragments *Pandorinellina expansa* ranges from the *Polygnathus serotinus* Zone of the late Emsian (latest Early Devonian) through the *Polygnathus costatus costatus* Zone of the earliest Middle Devonian. CAI=5.5.	41°11'48"	114°02'03"
15	M80PR-58	Thick-bedded dolomite	Possibly Middle Silurian or Early Devonian	8/11/80	E.F. MacDonald, L.Savoy, A.G. Harris	This collection contains: 2 indet. bar or platform fragments The fragments recovered look similar to fragments of *Ozarkadina excavata excavata* (Branson & Mehl); indicating a possible Middle Silurian-Early Devonian age. A (post-Ordovician) Paleozoic age is definite. CAI=4.5 to 5.	41°14'32"	114°02'16"
16	M80PR-57 (10217-SD)	Thick-bedded dolomite	Middle to Late Silurian	8/11/80 (revised 1/07/91)	E.F. MacDonald, L.Savoy, A.G. Harris	This collection contains: *Ozarkadina excavata excavata* (Branson & Mehl) 3 P elements, 1 A1 element, 1 A3 element 12 *Panderodus* sp. elements 1 N element 2 A3 elements of *Kockelella*? sp. indet. 25 indet. bar, blade, and simple cone fragments The conodont fauna and lithology indicate deposition in the inner shelf, but not in the shallowest part of the inner shelf. Age is Wenlockian-Ludlovian. CAI=4.	41°14'32"	114°02'19"
17	M80PR-60 (10216-SD)	Thick-bedded dolomite	Latest Silurian to earliest Devonian	8/11/80	E.F. MacDonald, L.Savoy, A.G. Harris	This sample contains: 1 P element of *Ozarkadina* cf. *o. Remscheidensis remscheidensis* (Ziegler) 4 indet. bar, blade, and platform fragments Age is latest Silurian to earliest Devonian. CAI=4 to 4.5.	41°12'18"	114°02'01"
18	M82PR-02	Thick-bedded dolomite	Middle Ordovician to Middle Devonian	11/10/82	Kate Schindler	This sample contains: 10 *Panderodus* sp. elements 1 indet. bar fragment Age is Middle Ordovician to Middle Devonian. CAI=5.5.	41°14'48"	114°02'21"
19	M81PR-31	Garden City Formation	Probably late Early Ordovician	11/14/81	E.L. Yochelson	This sample contains a gastropod, *Teiichispira*, which is almost certainly of late Early Ordovician age.	41°14'55"	114°01'35"

Range is therefore Middle Devonian and presumably latest Early Devonian. Our conodont ages show that the base of the Simonson in the Pilot Range is older (Emsian or Eifelian) than is shown on the paleogeographic maps of Johnson and others (1989). Since the uppermost part of the underlying dolomite unit is no younger than earliest Early Devonian in age, nearly the entire Early Devonian is missing in the northern Pilot Range. This unconformity covers much of northwestern Utah (Johnson and others, 1989). The Simonson represents prograding shallow carbonate platform rocks.

Guilmette Formation

The Guilmette Formation in the northern Pilot Range is a thick, cliff-forming limestone unit. It is well bedded and highly fossiliferous throughout. In places, sedimentary breccias and slump masses containing algal heads and other fossils suggest deposition near bioherms or reefs. In the section west of Mineral Mountain, the base of the unit is placed above the thin, shaly, highly fossiliferous limestone beds in the uppermost part of the

Simonson and at the base of the first thick, cliff-forming bed of limestone of the Guilmette. However, in most places the contact between the Guilmette and the Simonson is difficult to define because of variable dolomitization and because the lithologically distinctive shaly limestone at the top of the Simonson is missing. Near Patterson Pass, the shaly limestone is not present, but a highly fossiliferous zone of interbedded limestone and dolomite appears to represent the same interval because the same brachiopod-rich assemblage is present. The contact there is drawn at the top of the last slope-forming dolomite beds at the base of limestone cliffs. Irregular zones of calcareous and quartzose sand at the top of the Guilmette may represent sandy infilling of karst features; these fillings are locally as much as 50 m (165 ft) thick. Calcareous quartz sandstone, similar to the sandstone karst(?) fillings, is interbedded with the upper part of the Guilmette farther north in the Pilot Range (Miller and Schneyer, 1985). The Guilmette is about 390 m (1,280 ft) thick north of Cook Canyon but the top is faulted. It represents deposits on a shallow carbonate shelf.

Blue (1960) described late Middle to Late Devonian fossils from the Guilmette (his massive limestone member). We have recovered late Middle Devonian (late Givetian) conodonts about 12 m (39 ft) above the base of the unit (table 1, no. 8), and fossils collected in adjacent quadrangles are consistent with a Middle and Late Devonian age for the unit (Miller and Schneyer, 1985). Miller (1985) recovered Late Devonian fossils from the Guilmette northeast of the Pilot Range.

In several places near the top of the cliffs of the Guilmette, the rock type changes abruptly to black, coarse-grained limestone that contains black, irregular-shaped chert nodules as long as 30 cm (12 in). The upper part of this coarse limestone is locally encrinitic. These rock types are characteristic of the Joana Limestone in the southern Pilot Range (Miller, 1984) and the Silver Island Mountains (Schaeffer, 1960; Schneyer, 1984); in these locations, the Joana is Early Mississippian in age and rests on the Guilmette Formation or the intervening Pilot Shale. South of Hogans Alley in the Patterson Pass quadrangle, this upper black limestone is 10 to 15 m (33 to 50 ft) thick and contains Middle Devonian to Early Mississippian conodonts (table 1, no. 9). North of Cook Canyon, the same rock type is about 15 m (50 ft) thick and contains Early Mississippian conodonts in the encrinitic upper part (table 1, no. 4). Although the black limestone is not distinguished on the map (plate 1) because its outcrop is thin and sporadic, we believe it to be the Joana Limestone on the basis of lithology and age. In all locations where the Joana Limestone is well exposed, it is bounded by breccia zones marked by wispy, brown, silicified sandstone, and is capped by the silicified breccia unit. The breccia beneath it probably represents a fault-modified unconformity of Mississippian on Devonian rocks, similar to that noted in the northern Silver Island Mountains (Miller and others, 1990).

Silicified breccia

This rock unit (bx), always capping cliffs of the Devonian Guilmette Formation, is partly of hydrothermal and tectonic origin. The rock was cemented by silica following brecciation of jasperoid, indicating a long-lived silicification and brecciation event, or two silicification events, prior to and following brecciation. Locally, the rock is a cataclasite with flow structures in an extremely fine-grained, siliceous matrix with jasperoid "augen." Recognizable rock types in the breccia are fragments of calcite-cemented sandstone of the upper part of the Guilmette and carbonate rock probably also derived from the Guilmette. Rarely, voids between fragments contain silica-solution infillings. Disaggregated quartz sand grains morphologically identical to those comprising the sandstone in the upper part of the Guilmette are present locally in the matrix of the breccia fragments. We consider the fragments of sandstone from the upper part of the Guilmette to indicate that the upper part of the Guilmette Formation was the protolith of most or all of the silicified breccia unit. The sandstone was reconstituted during silicification and brecciation at an unknown time; therefore we do not designate an age for the silicified breccia unit.

The silicified breccia unit rests discordantly on limestone of the Guilmette Formation (and the Joana Limestone) and several different rock units ranging from Mississippian to Permian in age lie above the breccia (Miller and Schneyer, 1985). A sedimentary breccia origin (at a presumed unconformity) for the unit is ruled out because, a) silicified fragments are brecciated and re-silicified, b) the unconformity necessary above the breccia is required to have two orders of magnitude more relief than documented unconformities in this part of the stratigraphic section in nearby ranges (Schaeffer, 1960), and c) where the presumed unconformity removes section, such as between Regulator Canyon and Box Canyon, where the Tripon Pass Limestone is missing on the presumed paleo-high, the breccia thickens, rather than thins.

The silicified breccia seems to be the result of karst infilling of the upper (sandstone) part of the Guilmette, hydrothermal silicification, tectonic and/or hydrothermal brecciation, and renewed silicification. The tectonic breccia probably was formed during Mesozoic to Paleogene faulting because the breccia is cut by the altered part of the McGinty Monzogranite. Hydrothermal silicification is of unknown age.

MISSISSIPPIAN

Tripon Pass Limestone

The Tripon Pass Limestone typically forms rounded, grassy slopes covered with light-gray, fissile to platy, cleaved limestone fragments. Less common are small cliff exposures of medium- to thin-bedded limestone. Fresh surfaces in the limestone are invariably black; the limestone typically is fetid. Worm burrows, crinoid fragments, and rare bryozoan fragments are present locally, but the unit generally contains remarkably few megafossils. However, microscopic fragments of fossils make up nearly the entire rock, with only a minor amount of micrite and silt matrix. Laminae are defined by size sorting of the fossil fragments and by preferred orientation of elongate fragments. Rust-colored, quartz-sand-bearing laminae are present locally, and brown chert nodules are present locally near the top. The unit was termed the shaly limestone member of the Devonian Guilmette Formation by Blue (1960) in the absence of paleontologic data. The Tripon Pass tectonically rests on the silicified breccia unit in most places. The maximum thickness of the Tripon Pass Limestone is 425 m (1,400 ft), but it is faulted at both top and bottom.

Conodonts collected from the Tripon Pass Limestone in a gravity slide block west of Patterson Pass are Early Mississippian (Kinderhookian) in age (table 1, no. 7), as are conodonts from the Tripon Pass north of Hogans Alley (table 1, nos. 5, 6).

Reworked Ordovician conodonts in the sample west of Patterson Pass indicate that the Mississippian conodonts may also be redeposited, but we consider the replication of Kinderhookian ages for this unit to be a strong indication that the Kinderhookian conodont ages accurately date the unit. The Tripon Pass is the same age as black, cliff-forming limestone that we refer to the Joana Limestone.

The Tripon Pass Limestone in the Pilot Range is similar to the unit exposed 40 km (25 mi) to the west in the Pequop Mountains, but differs from the temporally equivalent Joana Limestone. The Joana is interpreted as a shallow-water shelf deposit, whereas the Tripon Pass represents turbidite deposits on a steeper slope west of the shelf (Poole and Sandberg, 1977).

MISSISSIPPIAN AND PENNSYLVANIAN

Chainman Shale and Diamond Peak Formation, undivided

This unit is mainly composed of quartzite, gray shale and siltstone, and polymict conglomerate. Clasts in the quartzite, seen in thin section, are primarily five types: (1) well-rounded undeformed quartz, (2) subrounded to subangular dark chert or siliceous siltstone, (3) subangular to angular quartz with undulatory extinction, (4) subrounded quartzite with angular, very fine detrital grains of quartz ± calcite ± muscovite, and (5) fragments of intermediate to mafic volcanic rocks. Rare plagioclase also is present. Volcanic rock fragments constitute approximately 50 percent of the clasts in a 3-m (10-ft) thick interval of quartzite near the base of the section. The matrix of quartzite is composed of fine sand- to silt-sized quartz, calcite, and /or clay. Conglomerate is silicified and resistant, containing clasts of chert, sandstone, calcareous sandstone, and jasperoid. Maximum clast diameter is 20 cm (8 in), but most clasts range from 3 to 6 cm (1 to 2 in). Rare interbeds of medium-gray, calcareous shale contain bryozoan and brachiopod fragments. The rocks were deposited as a clastic wedge shed eastward from the Antler orogen in central Nevada. Although possibly representing flysch (Poole and Sandberg, 1977), they are shallow-marine in the nearby Silver Island Mountains (Schneyer, 1984).

The undivided Chainman Shale and Diamond Peak Formation is cut by a low-angle fault at its base, where it is juxtaposed with the Mississippian Tripon Pass Limestone or the silicified breccia unit. We interpret this contact as a fault, rather than an unconformity, because, a) beds of the Tripon Pass Limestone adjacent to the contact are tightly folded and discordant to the contact, and b) the entire Chainman-Diamond Peak unit is truncated against the Tripon Pass south of Copper Mountain and yet no indications of an unconformity with 150 to 200 m (500 to 650 ft) of relief, such as clasts of the Tripon Pass, are present in the Chainman-Diamond Peak unit. The structural thickness of the unit is about 185 m (600 ft) thick where it concordantly underlies the Third Fork(?) Formation south of Copper Mountain. In the Silver Island Mountains, the unit is Pennsylvanian and Mississippian in age (Schaeffer, 1960; Schneyer, 1984).

PERMIAN

Third Fork(?) Formation

This unit, lying between the Badger Gulch Formation and the undivided Chainman Shale and Diamond Peak Formation, is of uncertain correlation. The contact with the Chainman-Diamond Peak unit is a poorly exposed gradational change of lithology and color. Beds in the two units are parallel and distinctive rock types are laterally persistent along the contact, suggesting that the contact is depositional. The lower part of the Third Fork(?) consists of dark- to medium-gray, well-sorted, medium-grained, quartz sandstone with a calcite matrix. Less common beds are granular to coarse grained. In thin section, quartz is angular with undulatory extinction, similar to that in underlying beds of the Chainman-Diamond Peak unit. The upper part of the Third Fork(?) is medium-bedded, medium- to dark-gray, sandy and silty limestone containing angular to subangular detrital clasts of quartz and rare plagioclase, microcline, and muscovite. A zone in the upper part contains reworked nodules of phosphorite. The top of the Third Fork(?) is poorly exposed and may be faulted; much of the contact is intruded by altered granite. The maximum thickness of the unit is about 220 m (720 ft).

Brachiopods recovered from the upper part of the Third Fork(?) Formation are an undescribed species of *Crurithyris*, which is found in Lower Permian rocks ranging from late Wolfcampian to late Leonardian age elsewhere in northeastern Nevada (table 1, nos. 2, 3). We therefore regard the Third Fork(?) Formation to be Permian in age. We tentatively correlate the unit with the Third Fork Formation exposed elsewhere in this region (Miller and others, 1984) on the basis of its stratigraphic position beneath the Badger Gulch Formation and its Permian age.

Although the Third Fork(?) Formation appears to rest concordantly on the Chainman- Diamond Peak unit, it is lithologically unlike the Pennsylvanian Ely Formation which conformably overlies the Chainman-Diamond Peak unit in the southern Pilot Range (Miller, 1984). Elsewhere in the northern Pilot Range (Miller and Schneyer, 1985), Leach Mountains (Miller and others, 1984), and Little Pigeon Mountains (Miller and Glick, 1986), Permian strata rest unconformably on the Chainman-Diamond Peak unit. However, the rock types in the Third Fork(?) do not closely match any Permian units of the area. Particularly unusual is the presence of subarkosic sandstone and phosphorite nodules.

Badger Gulch Formation

The Badger Gulch Formation is a thick unit composed of dark, platy, silty limestone and a few bioclastic limestone beds. The lower part of the Badger Gulch Formation is exposed in this quadrangle, but elsewhere in the northern Pilot Range and to the east (Miller and Glick, 1986) the entire unit is present. The Badger Gulch Formation is about 80 m (260 ft) thick in this quadrangle. Bioclastic limestone beds yielded early Leonardian fusulinids (table 1, no. 1), in accordance with the age of the unit elsewhere (Miller and others, 1984; Miller, 1993). Although Blue (1960) reported early Wolfcampian fusulinids from similarly described rocks in approximately the same location, we

consider our Leonardian age to better fit regional data and to be more compatible with the fact that the Badger Gulch Formation overlies late Wolfcampian to Leonardian Third Fork(?) Formation. The Badger Gulch Formation correlates with the middle part of the Pequop(?) Formation of Miller (1985) farther north in the Pilot Range (Miller and Schneyer, 1985) and represents the lower part of a thick regressive sequence (Miller and others, 1984).

TERTIARY

Granodiorite dikes

Dikes of granodioritic composition (Tg) crop out sparsely south of Patterson Pass. The dikes typically are fine to medium grained, subequigranular, and contain quartz, alkali feldspar, plagioclase, and biotite. Some also contain hornblende. Many are slightly to highly sericitized. Granophyric textures are common. The dikes strike from north-northeast to east-northeast, and in several cases intrude small faults. Lithologic similarity with a pluton (Bettridge Canyon Granodiorite) in the Pilot Peak quadrangle (figure 2; Miller and Lush, 1981) and an increase in the number of dikes toward that pluton suggest that the granodioritic dikes are about the same age as that pluton, 38.9 ± 0.9 Ma (Miller and others, 1987). The presence of hornblende in some dikes indicates that the McGinty Monzogranite is probably not the source for the dikes.

McGinty Monzogranite

The McGinty Monzogranite (Miller and others, 1987) is a porphyritic, coarse-grained pluton occupying Patterson Pass, where it separates metamorphosed Late Proterozoic and Cambrian strata to the south from unmetamorphosed Ordovician to Permian strata to the north. Previous workers termed the pluton "granite" (Hague, 1877, p. 495), "monzonite" (Blue, 1960; Doelling, 1980), "granodiorite" (Hoggatt and Miller, 1981), and "monzogranite of Patterson Pass" (Miller and others, 1982). Modal analyses of stained slabs indicate that the McGinty ranges from monzogranite to granodiorite (Miller, 1993). Euhedral phenocrysts of alkali feldspar, as large as 5 cm (2 in) in maximum diameter, are set in a coarse-grained matrix of subhedral plagioclase and alkali feldspar (5-12 mm [0.2 - 0.5 in]), subhedral quartz (typically 8-12 mm [0.3-0.5 in], rarely as large as 20 mm [0.8 in]), and biotite (5 mm[0.2 in]). Accessory minerals are hornblende, zircon, sphene, apatite, and xenotime(?). Biotite, generally 6-9 percent modally, typically is partially altered to chlorite or, rarely, to sericite. At one location west of Patterson Pass, an unusually mafic phase of the pluton contains abundant hornblende and biotite.

Inclusions are sparse throughout most of the pluton, but zones with abundant inclusions are present in several places. The two common inclusions are porphyritic biotite-hornblende-pyroxene quartz monzonite to quartz monzodiorite and hornblende quartz diorite(?); the inclusions typically are 10 to 20 cm (4 to 8 in) in diameter. The quartz diorite(?) is also included within the biotite-hornblende-pyroxene quartz monzonite inclusions. Non-systematically oriented mafic schlieren and irregularly shaped zones of phenocryst-rich rock are common. Dikes of aplite and pegmatite, distinguished on the accompanying geologic map (plate 1), generally strike north-northwest. They are considered to be closely related to the main phase of the McGinty Monzogranite. The dikes consist of quartz, plagioclase, and alkali feldspar with accessory biotite and an iron oxide mineral, and commonly grade to quartz-feldspar pegmatite at their borders or centers.

Isotopic dating indicates that the McGinty Monzogranite is latest Eocene in age, a revision of the "Eocene or Oligocene" age of Miller and others (1987). Coats and others (1965) obtained a biotite K-Ar cooling age of 31 ± 6 Ma, and Hoggatt and Miller (1981) obtained a biotite K-Ar cooling age of 36.6 ± 0.5 Ma (table 2, no. 3). The McGinty Monzogranite is one of several granitoids forming generally small plutons and dikes throughout most of the Pilot Range. Many dikes have yielded K-Ar biotite ages similar to those for the McGinty, and the crystallization age of one pluton, the Bettridge Canyon Granodiorite (5 km [3 mi] to the south), is firmly fixed by a U-Pb zircon age of 38.9 ± 0.9 Ma (Miller and others, 1987). The K-Ar age on biotite from the McGinty probably records the cessation of Ar diffusion after at least a few million years of cooling following crystallization of the pluton. The pluton therefore is older than 36.6 million years, and probably about 38 or 39 million years, approximately the same age as the Bettridge Canyon body.

The pluton has a nearly flat roof, judging from a) its exposure northward along the east side of the Pilot Range at nearly constant altitude for 11 km (6.6 mi), b) lithologically similar rock that crops out at the northern extreme of the map on the west side of the range, and c) drill-hole data reported by Doelling (1980, p. 89) indicating that the pluton underlies Paleozoic strata near the crest of the range at a depth of about 300 m (1,000 ft) (drill hole locations plotted on plate 1). The south margin of the pluton probably dips steeply, judging from the approximately straight contact across the Pilot Range and extending into the adjacent Crater Island NW quadrangle (figure 2). However, the vertical dimension of the pluton is not well known; the pluton may be a thin tabular body that projects upward to the south or it may be a thick body with steep walls and flat roof.

Small bodies of altered intrusive rocks (Tma) are composed of yellowish (less commonly greenish) siliceous materials. Phenocrysts of quartz and altered feldspars are generally present, and in some cases round calcite and quartz grains indicate that sedimentary rocks were absorbed by the intrusions. Mineralization in the altered rocks includes silica, widely dispersed iron oxide grains, rare sericite , and rare chlorite. The altered intrusive rocks commonly lie along fault zones, suggesting that magmas and fluids preferentially intruded along these zones of weakness. Contacts between the altered intrusive rocks and the McGinty are not exposed, but we consider the altered intrusive rock to be the McGinty Monzogranite where it has undergone extensive reaction with wall rocks.

Felsite

Dikes of light-gray felsite (Tf) crop out in the eastern part of the quadrangle. The felsite contains common rounded, embayed quartz phenocrysts of two types, dark-colored and clear (5-10 mm [0.2-0.4 in]), and less common anhedral plagioclase (5 mm [0.2 in]) and alkali feldspar phenocrysts (5 mm [0.2 in]). Feldspars in most dikes are altered to clays. Felsite dikes locally grade into brown, siliceous, flow-banded breccia; in these sites,

Table 2. *Geochronologic data for the Patterson Pass quadrangle.*

Map no.	Sample no.	Sample site Lat.	Sample site Long.	Rock unit	Mineral dated	Mean K_2O (wt pct)	$^{40}Ar_{rad}$ (pct)	$^{40}Ar_{rad}$ (10^{-10}mol/ g)	Age (Ma)
1	M80PR-48	41°12'55"	114°03'08"	Tuff and sedimentary rocks	Biotite	6.76	73.04	3.6459	37.1±1.1
2	M81PR-97	41°13'43"	114°03'27"	Biotite tuff	Biotite	4.86	66.44 75.41	2.3153 2.2710 mean age =	32.8 32.2 32.5±1.0
3	M79PR-116*	41°11'44"	114°00'32"	McGinty Monzogranite	Biotite	8.58	84.2	4.565	36.6±0.5

Analyses by W.C. Hillhouse. Decay constants given by Steiger and Jäger (1977).

* Reported by Hoggatt and Miller (1981) and Miller and others (1987).

the gray felsite also contains inclusions of brown, brecciated felsite. Felsite dikes cut the latest Eocene McGinty Monzogranite, and are in turn cut by Pliocene(?) diabase dikes. The felsite may be a late magmatic phase of the McGinty intrusion or distinctly younger. Although felsite dikes are common in and near the McGinty Monzogranite, the dikes crop out much farther south than the McGinty (Miller and Lush, 1981), suggesting that the dikes are not related to the pluton. We regard the felsite to be of Oligocene(?) age.

Biotite rhyolite tuff

Biotite rhyolite tuff (Tbt) is widely exposed in the northeastern part of the piedmont west of the Pilot Range. The white tuff is generally unwelded or slightly welded, although highly welded zones with anastomosing foliation crop out in a few places. The tuff contains brown, euhedral biotite (5 mm [0.2 in]), zoned alkali feldspar (10 mm [0.4 in]), plagioclase (7 mm [0.3 in)], and anhedral quartz (5 mm[0.2 in]) phenocrysts in a light-colored, glassy matrix that in most places is devitrified. Pumice clasts are found in air-fall tuff and tuff breccia beds. The pumice contains abundant biotite phenocrysts. Air-fall ash contains biotite and feldspar phenocrysts. Siltstone and fine sandstone lie at the base of one outcrop of the biotite tuff, and also overlie the tuff in some outcrops. The thick deposits probably represent multiple ash flows and local reworking by fluvial processes. Although bedding is rare in the tuff, steeply dipping bedding in one location suggests that a considerable thickness of tuff is present. The thickness is approximately 500 m (1,650 ft) if the structure sections (plate 2, sections BB', CC'), constructed using a moderate average dip and several hypothetical faults, are accurate. Southward, the tuff unit shows increasing signs of being reworked. It typically is a clast-rich breccia or conglomerate with ash and sandstone matrix. Clasts consist of highly welded tuff, slightly welded tuff, and various highly altered igneous rocks of brown and green color. Silicification and calcification are common. Interbedded yellowish siltstone and sandstone suggest intertonguing with the tuff and sedimentary rocks unit (Tts) to the southeast.

Slightly oxidized biotite from the biotite rhyolite tuff yielded a K-Ar age of 32.5 ± 1.0 Ma (Oligocene) (table 2, no. 2). However, two lines of evidence suggest that the biotite rhyolite tuff is primarily or entirely Eocene in age. First, the tuff appears to grade upward or laterally into the tuff and sedimentary rocks unit (Tts), which includes uppermost Eocene tuff. As discussed below, the tuff and sedimentary rocks unit is structurally above and adjacent to the biotite rhyolite tuff and contains tuff beds of similar composition. Second, other rhyolite tuffs in the vicinity are latest Eocene in age, including the older tuff from the northeastern Pilot Range (Miller, 1985) and tuff from the west side of the Grouse Creek Mountains reported by Compton (1983). All three tuffs are similar in composition and may represent the same source. Compositional similarity of the biotite rhyolite tuff with Eocene tuffs along with the Eocene age on correlative or overlying rocks in the Patterson Pass quadrangle strongly suggests that the 32.5-Ma K-Ar age for oxidized biotite does not indicate the age of the unit. We regard the biotite rhyolite tuff as Eocene and Oligocene(?) in age.

Tuff and sedimentary rocks

A heterogeneous sequence of thin volcanic beds and coarse- to fine-grained sedimentary rocks is assigned to the tuff and sedimentary rocks unit (Tts). Volcanic rocks include felsic and intermediate composition tuffs, including biotite rhyolite tuff similar to that in the biotite rhyolite tuff unit (Tbt). Sedimentary rocks include conglomerate, arkosic sandstone, siltstone, and marl. Conglomerate clasts commonly consist of chert, siltstone, and dolomite. Deposition appears to have taken place near the margin of lakes because beach deposits and alluvial-fan sequences interfinger with lacustrine marl. The clast provenance is much like that observed from the present Pilot Range: Tertiary sedimentary rocks and Devonian to Permian carbonate and siliciclastic rocks. Most beds in the unit dip moderately to gently eastward, indicating that the unit lies structurally above and partly adjacent to the biotite rhyolite tuff. The thickness of the unit is poorly constrained by structural data but is estimated to be about 700 m (2,300 ft).

Rhyolite tuff containing quartz, altered plagioclase, and biotite lies near the base of the tuff and sedimentary rocks unit; it yielded a biotite K-Ar age of 37.1 ± 1.1 Ma (table 2, no. 1), indicating that at least the lower part of the unit is latest Eocene in age. However, the unit appears to structurally overlie and /or interfinger with the biotite rhyolite tuff, which yielded an early

Oligocene K-Ar age. Although the biotite in the K-Ar sample of the tuff and sedimentary rocks unit was in better condition than that for the biotite tuff unit and we therefore regard the age of both units to be Eocene, we assign the tuff and sedimentary rocks unit to an Eocene and Oligocene(?) age because of the uncertainty in interpreting the K-Ar ages.

We consider the tuff and sedimentary rocks unit to be either the lateral equivalent of, or to overlie, the biotite rhyolite tuff. Because there is no direct evidence for faults between the units and because tuff in the two units is similar, the generally eastward dip of the tuff and sedimentary rocks unit requires that it overlies or is laterally continuous with the biotite rhyolite tuff. A gradational relationship between the units is suggested by common lithologies. Two paleogeographic interpretations for these units seem likely to us. First, if the units are temporal equivalents, three depositional environments (lacustrine, alluvial fan, and piedmont covered by extensive tuffs) coexisted. A paleogeographic scenario is one of a fault-bounded, low mountain range from which alluvial fans extended into lakes. A nearby eruptive center shed numerous ash flows onto the alluvial piedmont. On the other hand, if the tuff and sedimentary rocks unit is the younger unit, it records the establishment of alluvial and lacustrine sedimentation following extensive eruptions. The latter interpretation is preferable on the basis of simplicity, but field relations allow either interpretation or a combination of the two.

Sedimentary rocks

We assign heterogeneous, non-marine sedimentary rocks that are poorly exposed in the piedmont west of the Pilot Range to the sedimentary rocks unit (Ts). The main rock types are tuffaceous sandstone and siltstone that are thin bedded, finely cross-laminated, and well sorted. Volcanic glass is the primary constituent of many rocks, but igneous minerals are rare and silt- and sand-size quartz is common, suggesting that the rocks represent thoroughly reworked felsic tuff and mature sediments derived from Paleozoic rocks. The sedimentary structures indicate primarily lacustrine deposition. Less common rock types are conglomerate, arkosic sandstone, and claystone. Conglomerate contains chert and fine-grained quartzite clasts as large as 1.5 cm (0.6 in) in an arkosic matrix. The sedimentary rocks unit is greater than 400 m (1,300 ft) thick on the basis of simple interpretations of the structure (cross-sections BB' and CC'), but exposures are poor and many unrecognized faults could be present in the piedmont.

The sedimentary rocks unit is lithologically similar to, and probably structurally continuous with, the sedimentary rocks unit to the north in the Tecoma quadrangle (figure 2; Miller and Schneyer, 1985). We consider the unit to be Miocene in age because it is disconformably capped by an approximately 8.7-million year old rhyolite (Miller and Schneyer, 1985) and an ignimbrite within it is approximately 12 million years old (Miller, 1985).

Vitric tuff

Light-colored, laminated, thin- and medium-bedded ash deposits that are moderately lithified comprise the vitric tuff unit (Tvt). Many beds are composed almost entirely of volcanic glass with sparse biotite and plagioclase fragments; these beds form blocky outcrops. Rare constituents of the tuff are obsidian, pumice, and hornblende. Whereas the low-density, poorly compacted, pure ash beds may represent air-fall deposits, other beds are dense, well-compacted, and contain laminae and interbeds of silt and sand, indicating subaqueous or fluvial deposition. The unit is well exposed at outcrops along the south border of section 5, T. 38 N., R. 70 E. Channel conglomerate at the base, containing clasts of shaly limestone and siltstone, grades upward to laminated, coarse tuffaceous sandstone that in turn grades upward to well-sorted, coarse, vitric tuff. Above the vitric tuff are calcareous, thin-bedded claystone and sandstone with soft-sediment flame structures. The fine grain size and good size sorting suggest deposition near the shore of a lake. North-trending bimodal ripples suggest that wave energy at beaches was east- or west-directed.

Simple structural interpretations suggest that the thickness of the vitric tuff unit is as much as 700 m (2,300 ft) but exposures are poor and many unrecognized faults may be present. In the Tecoma quadrangle, the vitric tuff unit is interbedded with Miocene sedimentary rocks (Miller and Schneyer, 1985), on which basis we consider the vitric tuff unit to be Miocene in age.

Diabase

The diabase unit (Td) includes narrow dikes of fine- to coarse-grained, hornblende-pyroxene-plagioclase rock and pyroxene-plagioclase diabase with ophitic texture. An iron oxide mineral (probably ilmenite) is abundant. Many dikes contain alteration products such as talc, sericite, and carbonate minerals. The dikes generally strike approximately northward. Diabase dikes intruded Eocene igneous rocks in the Patterson Pass quadrangle, and intruded Miocene sedimentary rocks in the Crater Island NW quadrangle (Miller, 1993). The dikes are unconformably overlain by Pliocene(?) and Pleistocene alluvium. The diabase is therefore regarded as Pliocene(?).

TERTIARY(?) AND QUATERNARY

Oldest alluvial-fan deposits

Consolidated to unconsolidated coarse gravel underlying extensive dissected terraces along much of the western part of the quadrangle is assigned to the oldest alluvial-fan deposits unit ($QTaf_3$). Clasts in the gravel are derived from the Pilot Range and the alluvial-fan morphology of the deposits indicates that the clasts were derived from the range in approximately its current physiographic configuration. The gravel is in many places underlain by as much as 2 m (6 ft) of brown silt, fine sand, and clay that is probably loess. Thickly laminated pedogenic calcrete is common in the gravels, and the unit is overlapped by an alluvial fan unit (Qaf_2) that is older than upper Pleistocene deposits of Lake Bonneville. The geomorphic relations are characteristic of "old alluvial-fan deposits" of Christenson and Purcell (1985), which they consider to be generally older than 500 thousand years. Thick laminae in pedogenic calcrete suggests a middle Pleistocene or older age (Machette, 1985). We consider the oldest alluvial-fan deposits to be Pliocene(?) to middle Pleistocene in age.

The most extensive exposures of the oldest alluvial-fan deposits form arcs west and southwest of Patterson Pass that represent two major fan complexes. Both complexes contain

gravel derived from the McGinty Monzogranite, but the granite gravel is most abundant in the fan complex lying southwest of the pass. This latter complex contains gravel deposits greater than 40 m (130 ft) thick that evidently were shed from a major canyon in the Pilot Range located at the apex of the fan just north of Parson Spring. This canyon, now floored primarily by talus and colluvium (Qmc), was apparently beheaded as the current Patterson Pass drainage developed, because subsequent deposits are thin. The fan complex west of Patterson Pass is thinner (about 10 to 15 m [30 to 45 ft]) than its neighbor to the south and contains less granite gravel but is overlain by thick younger deposits, suggesting that during its deposition the drainage basin in the Pilot Range that fed it must have been much smaller than at present. The fan complex west of Patterson Pass overlies Tertiary sedimentary and volcanic rocks with angular unconformity.

QUATERNARY

Most Quaternary deposits in the Patterson Pass quadrangle are alluvial in origin, primarily representing alluvial-fan complexes built westward from the Patterson Pass area. The alluvial deposits are divided on the basis of age and geomorphology into a sequence older than the Bonneville shoreline of Lake Bonneville (~14.5 to 16 thousand years; Currey and others, 1984) and one younger than the Bonneville shoreline. Restricted Quaternary deposits of lacustrine and mass-movement origin are also present in the quadrangle.

Older alluvial-fan deposits

Unconsolidated, poorly sorted gravel and sand (Qaf_2) underlying the piedmont flanking the Pilot Range is overlain by deposits of Lake Bonneville and underlain by the Pliocene(?) and Pleistocene oldest alluvium, and so is early to late Pleistocene in age. The thickest older alluvial fan in the piedmont lies west-southwest of Patterson Pass and is mainly composed of granite gravel derived from the McGinty Monzogranite. In contrast, deposits in this unit farther south near Parson Spring are thinner and contain little granite detritus, indicating that the canyon that fed the oldest Pliocene(?) and Pleistocene fan complex ($QTaf_3$) near Parson Spring was beheaded by the time of deposition of the Pleistocene older alluvial-fan deposits.

The older alluvial-fan deposits unconformably lie on a dissected surface cut into the oldest alluvial-fan deposits and Tertiary tuff and sedimentary rocks. These relations may indicate an episode of erosion between the deposition of the two alluvial-fan sequences. Additionally, the relations may result from a change in depositional site from close to the mountains for the oldest alluvial fans to farther from the mountains for the older alluvial fans, and a consequent incision into the oldest fans closer to the range front.

Lacustrine and alluvial deposits, undivided

At altitudes below the Bonneville shoreline, complexly interlayered deposits of lacustrine and alluvial origins are mapped as undivided lacustrine and alluvial deposits (Qla). In most places, this unit consists of thin sheets of lacustrine sand and gravel lying on the older alluvial-fan deposits. In many places, thin alluvium also lies on the lacustrine deposits. The rough topography in alluvium above the Bonneville shoreline is in sharp contrast to the smoothly beveled topography below the shoreline, where the undivided lacustrine and alluvial deposits lie.

Lacustrine gravel

The unconsolidated lacustrine gravel unit (Qlg) was deposited along shorelines of Lake Bonneville along the west margin of the quadrangle. The unit mainly represents the high stand of Lake Bonneville, presently at about 1,578 m (5,180 ft) altitude (the Bonneville shoreline [-B-]), although gravel deposits at 1,575 m (5,170 ft) and 1,561 m (5,125 ft) lie below the Bonneville shoreline west of the apex of the fans extending from Patterson Pass. The lake was at its maximum depth roughly 16 to 14.5 thousand years ago (Scott and others, 1983; Currey and others, 1984). Either gravel supply from alluvial and fluvial detritus or shorezone currents (or both) must have been greatest where lacustrine gravel deposits are most voluminous at the terminus of the fans. Lower altitude shorelines typically found in Lake Bonneville deposits lie west of the Patterson Pass quadrangle.

Alluvial-fan deposits

Unconsolidated stream and fan deposits (Qaf_1) of poorly sorted gravel, sand, and silt are younger than lacustrine deposits at the Bonneville shoreline. These stream and fan deposits are found as alluvial fans at mouths of canyons and gullies, as alluvial floodplains bordering streams, and as sediments in stream channels. The thickest accumulations of upper Pleistocene to Holocene 'youngest' alluvial-fan deposits extend west-southwest from the canyon draining Patterson Pass, as does the modern drainage. Channels containing these 'youngest' alluvial deposits have been cut into the older (Qaf_2) and oldest ($QTaf_3$) alluvial-fan deposits.

Colluvium and talus

Colluvium and talus deposits (Qmc) are common along many steep slopes in the Pilot Range. Particularly abundant and blocky talus deposits lie on slopes underlain by the Prospect Mountain Quartzite. Along the lower parts of talus slopes, such as those bordering the southern side of Birch Canyon, the talus deposits are gradational with colluvium consisting of conglomerate, gravel, and sand. Colluvium generally supports vegetation, whereas talus contains little fine material between talus blocks and supports little vegetation.

Landslide deposits

Disaggregated rock and colluvium form hummocky landslides (Qms) in two places in the Killian Springs-Parson Springs area and in one place along the south side of Patterson Pass. The ages of these landslides are limited only to the Quaternary, because they formed on current topographic surfaces and are partly overlapped by Holocene colluvium.

Huge detached masses of coherent bedrock and of jumbled bedrock are mapped as gravity-slide blocks. Two gravity-slide

blocks of jumbled bedrock, one consisting of the Tripon Pass Limestone and the other of unit G of the McCoy Creek Group, are located in the canyon west of Patterson Pass. Both appear to rest on the McGinty Monzogranite. Because this canyon was excavated down to the McGinty during deposition of the Plio-Pleistocene oldest alluvial deposits ($QTaf_3$), the gravity slides must be Pliocene(?) or younger in age. The slide deposits are well vegetated and do not display landforms such as closed depressions that would indicate a recent emplacement. We infer a Pleistocene age for these gravity-slide blocks.

A coherent block of Devonian strata along the west side of the Pilot Range between Hogans Alley and Cook Canyon that we depict as a gravity-slide block is underlain by a normal fault dipping about parallel to the slope of the range front. An alternative interpretation is that the fault represents a splay of the range-front fault system.

Two small gravity-slide blocks lie south of Patterson Pass. A block of the Prospect Mountain Quartzite, located on the northern limb of the Cottonwood Springs syncline, is composed of coherent, but displaced, quartzite. A block containing jumbled masses of interval 1 of the conglomerate subunit of unit G of the McCoy Creek Group lies on the south flank of the syncline. These slide blocks are probably Pleistocene in age on the basis of overlapping Holocene colluvium.

STRUCTURE

Diverse structures including three sets of low-angle faults, three sets of high-angle faults, penetrative folds and cleavage, and a major syncline control the distribution of rock units in the Patterson Pass quadrangle. Many of these structures are known or inferred to be post-Middle Jurassic to pre-latest Eocene in age on the basis of relations with dated igneous rocks, but some low-angle and high-angle faults are Neogene or younger.

Pre-Tertiary rocks in the quadrangles can be conveniently divided into two lithotectonic domains on the basis of age, metamorphism, and structural history. Low-grade metamorphic Late Proterozoic and Cambrian strata south of Patterson Pass form the first lithotectonic domain; these rocks have undergone ductile deformation on all scales. In contrast, little-metamorphosed Paleozoic strata north of Patterson Pass form a second lithotectonic domain; the rocks range from Ordovician to Permian and are cut by high- and low-angle brittle faults. These two domains are separated by the latest Eocene McGinty Monzogranite in Patterson Pass. The metamorphic rocks of the first lithotectonic domain are continuous southward with metamorphic rocks in the adjacent Pilot Peak quadrangle (figure 2); there, the metamorphosed rocks are structurally overlain by unmetamorphosed Paleozoic strata, similar to those of the second domain, along the Pilot Peak detachment fault ("Pilot Peak decollement" of Miller and Lush, 1981; Miller, 1983). The Pilot Peak detachment is inferred to lie between the two lithotectonic domains at Patterson Pass, and may correspond to the fault at the top of the pluton. The pluton in Patterson Pass is distinctive because the roof of the body is nearly flat (Doelling, 1980); we propose that the pluton intruded and spread laterally along the Pilot Peak detachment, and that movement along the detachment outlasted the crystallization of the pluton.

Flanking the Pilot Range is a third lithotectonic domain of Tertiary and Quaternary strata that is cut by low- to high-angle normal faults. Moderately westward-dipping faults cut Eocene to Miocene strata and locally displace Pleistocene or Holocene deposits. Some of these faults apparently form the western boundary of the uplifted Pilot Range block.

Structures are described below in order of decreasing age within the lithotectonic domains: structures (1) south of Patterson Pass, (2) north of Patterson Pass, and (3) cutting Tertiary strata.

Structures south of Patterson Pass

South of Patterson Pass, metamorphosed strata form a major northeast-trending syncline, first described by Hague (1877, p. 495-496), that we term the Cottonwood Springs syncline (plate 1). The strata are cleaved, folded, and cut by ductile bedding-plane faults in a consistent sequence of deformation. Bedding-parallel cleavage is oldest, followed by northeast-striking cleavage that is related to the development of northeast-trending folds and the bedding-plane faults. Both of these cleavage sets were formed during biotite and muscovite growth, and local staurolite growth. Miller and others (1987) demonstrated that metamorphic mineral growth took place during the Late Jurassic and possibly also during the Cretaceous in similar, but higher grade, rocks in the southern Pilot Peak quadrangle (figure 2). Chlorite and epidote crosscut deformation fabrics and probably formed during the heating associated with emplacement of the McGinty Monzogranite. Later (Tertiary?) high-angle faults cut structures formed during ductile deformation.

The oldest structural feature is penetrative cleavage in phyllite oriented nearly parallel with bedding and containing rare east-trending mineral-elongation lineation. This oldest cleavage is deformed by a steeply northwest-dipping penetrative cleavage that is axial planar to small folds with shallowly northeastward-plunging axes. Metamorphic minerals aligned with both cleavages indicate greenschist to lower amphibolite facies conditions during the ductile deformation. The small folds are generally open to moderately tight, and are similar in geometry and orientation to the major Cottonwood Springs syncline.

The Cottonwood Springs syncline is a southeast-verging fold that plunges northeast about 25 degrees; it is best defined by the map pattern of the Prospect Mountain Quartzite. The syncline has subsidiary folds on both limbs that are well displayed by the Prospect Mountain-Killian Springs contact (plate 1). These map-scale subsidiary folds appear to be parasitic with respect to the Cottonwood Springs syncline (plate 2, section EE'), although vergence directions locally are inconsistent with this interpretation. Bedding in the uppermost part of the Prospect Mountain north of Cottonwood Springs is folded by a map-scale fold with northeast trend. However, folds in the same strata on the south limb are complex and do not appear to have northeast trends. The folds on the south limb are also cut by minor normal faults. In contrast with the folded upper contact of the Prospect Mountain, the base of the unit everywhere exposed is a bedding-plane fault that truncates folded units of the McCoy Creek Group of Misch and Hazzard (1962) (plate 2; section EE').

Bedding-plane faults are primarily ductile, as indicated by: (1) absence of breccia, (2) local presence of phyllonite, and (3) abundant minor ductile structures near the faults. Minor north-

east-trending folds are especially well developed near the bedding-plane fault at the top of the McCoy Creek Group (unit G) along the south limb of the Cottonwood Springs syncline. Here, at least 100 m (330 ft) of the lowermost part of the Prospect Mountain Quartzite and variable amounts of the McCoy Creek Group are omitted by the fault. The minor folds, which are generally southeast-verging, are probably related to the faulting. On the northern limb of the Cottonwood Springs syncline, poorly exposed phyllite and conglomerate intervals of unit G of the McCoy Creek Group are complexly folded into small- to medium-scale folds (plate 2, section EE'). The larger folds verge northwestward, whereas minor folds are of inconsistent vergence.

We interpret the ductile faults and folds by a model of parasitic folding and bedding-plane faulting caused by disharmonic folding on a scale of kilometers as the Cottonwood Springs syncline formed. Bedding-plane faults near the base and top of the Prospect Mountain Quartzite appear to show greatest stratigraphic truncation along the steeply dipping limbs of the Cottonwood Springs syncline, suggesting that they are related to development of the syncline. The shear senses indicated by the fold asymmetry, northwest on the north limb and southeast on the south limb, we interpret as local shear and parasitic folding in high-strain zones caused by development of the Cottonwood Springs syncline.

Folds and bedding-plane faults south of Patterson Pass are latest Eocene or older in age, because the structures were intruded by the McGinty Monzogranite. Metamorphic minerals were retrograded near the margin of the pluton, indicating that ductile deformation and regional metamorphism distinctly predated emplacement of the pluton. In the adjacent Pilot Peak quadrangle to the south (Miller and Lush, 1981), folds and bedding-plane faults, interpreted as correlative with the structures in the Patterson Pass quadrangle, formed before 83 million years and after intrustion of 155 to 165 million- year-old muscovite granite (Miller and others, 1987). Deformation in the Pilot Peak quadrangle is therefore constrained as Late Jurassic to Late Cretaceous in age; structures south of Patterson Pass are interpreted as the same age because of physical continuity with structures in the Pilot Peak quadrangle.

A group of moderately west-dipping normal faults cuts the Cottonwood Springs syncline near the southeast edge of the quadrangle. The faults show separations of a few tens of meters in most cases and are characterized by narrow breccia zones. They are oriented parallel to Neogene faults along the west margin of the range, and therefore are probably Neogene in age. A similar age is inferred for small normal(?) faults cutting the McCoy Creek Group just south of Patterson Pass (plate 2; section EE').

Pilot Peak detachment fault

The Pilot Peak detachment fault, which places unmetamorphosed Ordovician strata on metamorphosed Cambrian strata, postdates metamorphism and predates latest Eocene to Oligocene granodiorite dikes (Miller and Lush, 1981; Miller and others, 1987). The Pilot Peak detachment cuts north-trending folds and faults in the southern Pilot Peak quadrangle, structures which in turn cut northeast-trending folds correlated with the Cottonwood Springs syncline. The detachment therefore is at least in part substantially younger than folds south of Patterson Pass. Sheared and metamorphosed rocks present in cores from holes drilled along the crest of the range (plate 1) may represent rocks associated with the detachment. These highly sheared rocks include breccia, phyllonite, and mylonite derived from protoliths of argillaceous, carbonate, and igneous rocks. They are similar to sheared Cambrian strata exposed near the Pilot Peak detachment fault in the southern Pilot Range. These sheared core rocks are cut by only modestly fractured McGinty Monzogranite, indicating that most faulting predated intrusion. It is possible that the sheared rocks represent scraps of tectonites formed by the Pilot Peak detachment fault, most of which has been eliminated by intrusion of the McGinty pluton.

Excavations in 1992 at the top of the McGinty pluton, just northeast of the Patterson Pass quadrangle, convincingly show that the top of the pluton is cut by a low-angle fault zone. The fault zone contains chloritized and brecciated wallrocks and plutonic rocks, and it is 3 to 5 m (10 to 17 ft) thick in the excavation. A few exposures of breccia at the top of the pluton in the Patterson Pass quadrangle, as well as breccia recovered in drill core, suggest that the low-angle fault continues into the Patterson Pass quadrangle and accounts for the flat top of the pluton. If our assertion that the altered granite unit (Tma) is related to the McGinty Monzogranite is correct, the fault separating these altered intrusive bodies from the McGinty Monzogranite probably did not displace the altered rocks more than a few kilometers (one or two miles). We consider the most likely scenario to be that major detachment faulting mainly predated emplacement of the pluton, and only minor faulting took place after its solidification.

Structures north of Patterson Pass

Generally unmetamorphosed Paleozoic strata north of Patterson Pass form an approximately homoclinal sequence of rocks that dips moderately eastward, but the sequence is cut by high- and low-angle faults. Faults belong to four sets: (1) faults nearly parallel to bedding, (2) low-angle normal faults cutting across bedding, (3) north-striking, high-angle faults, and (4) east-striking high-angle faults. No faults demonstrably cut the latest Eocene McGinty Monzogranite or the fault at its top, although exposures are insufficient to determine if minor offset of the McGinty may have occurred along some faults. Faults flanking the range appear to have placed Tertiary strata against the McGinty, and therefore are probably latest Eocene or younger.

Faults nearly parallel to bedding (set 1) - They generally place younger rocks on older, cutting out stratigraphic section. The most areally extensive low-angle fault, the Mineral Mountain fault (plate 1), lies above the Devonian Guilmette Formation and is marked by the resistant silicified breccia unit. The Mississippian Tripon Pass Limestone in the hanging wall is fractured and folded near the fault, and the footwall Guilmette is fractured and locally is thinned by as much as 350 m (1,150 ft). The Mineral Mountain fault and associated silicified breccia continue at the top of the Guilmette to the north end of the Pilot Range (after right-lateral offset on the Regulator Canyon fault zone), where Permian rocks typically are juxtaposed with the Guilmette (Miller and Schneyer, 1985). The Mineral Mountain fault and bedding-plane faults beneath it dip about 10 degreees more steeply eastward than do the bedding and lithologic unit boundaries. Beds near the faults are folded into concordance with the fault planes, and folds consistently show eastward vergence.

Faults marked by breccia and silicified zones also are present beneath and parallel to the Mineral Mountain fault. Two such faults are located within the Guilmette and cut down section northward toward Mineral Mountain (plate 1). The structurally higher of these faults duplicates approximately 455 m (1,490 ft) of section, placing the Simonson on the Guilmette, whereas the lower one cuts out section. Another probable fault that lies about 10 m (33 ft) below the Mineral Mountain fault was noted but not shown on the map; it lies in the ridge north of Cook Canyon. This breccia zone separates lenses of the Joana Limestone (mapped herein as part of the Guilmette) from the underlying Guilmette Formation.

Roughly eastward movement on the Mineral Mountain fault and related faults is indicated by two observations. First, folds adjacent to the faults verge eastward. Second, the Tripon Pass Limestone in the hanging wall was deposited west of or on its roughly temporal equivalent in the footwall, the Joana Limestone (Poole and Sandberg, 1977), and, if it were thrust, likely went southeastward or eastward to lie structurally on the Joana Limestone.

Probable tear faults or lateral ramps to the Mineral Mountain fault (plate 2, section AA') are east-striking, compatible with an easterly direction for bedding-plane faults. Dramatic lateral changes in thickness of the Guilmette below the Mineral Mountain fault take place where high-angle east-striking faults cut both the Guilmette and the Mineral Mountain fault. These thickness changes presumably are caused by tear faults (later reactivated) that juxtaposed blocks showing different amounts of truncation of the Guilmette.

The Mineral Mountain and related bedding-plane faults cut down stratigraphic section to the east and generally attenuate the section, and yet they may have locally stacked unlike facies of Lower Mississippian strata. It may be that the bedding-plane faults are regional, east-directed thrust faults that attenuated section in the Pilot Range area as they cut down section to the east while crossing a broad tectonic high. Another possibility is that thrust faults were reactivated as normal faults.

The Mineral Mountain and related bedding-plane faults are older than the altered intrusions associated with the latest Eocene McGinty Monzogranite and younger than Permian strata. They may be Mesozoic and (or) early Cenozoic.

Low-angle normal faults (set 2) - These faults are parallel to the fault at the top of the McGinty pluton and lie in two main positions, above the Ordovician rocks at the north edge of the quadrangle and above the Mississippian Tripon Pass Limestone. These faults cut across stratigraphic sections (such as the Tripon Pass just south of Copper Mountain; plate 2, section BB') at moderate angles; they are normal faults dipping west with respect to bedding. The faults locally are marked by brecciated dolomite and cleaved and folded limestone. Similar low-angle normal faults cut the Mineral Mountain fault to the north (Miller and Schneyer, 1985), but relations between the fault sets in the Patterson Pass quadrangle are ambiguous.

The fault that typically lies above the Tripon Pass Limestone undulates or was broadly folded (plate 2, section BB'). Mesoscopic folds in the Tripon Pass adjacent to the low-angle normal fault plunge gently northeastward and verge to both the northwest and southeast. Pronounced axial-plane cleavage near the fault indicates localized deformation. Minor kink folds tens of meters below the fault also trend northeastward to east-northeastward but have vertical axial planes. These fold and cleavage orientations suggest southeastward or northwestward translation along the fault.

The low-angle normal fault above Ordovician rocks is continuous with a major fault in the Tecoma quadrangle to the north, which juxtaposes an eastward-dipping panel of Silurian and Devonian rocks with underlying folded Ordovician to Silurian rocks (Miller and Schneyer, 1985). Thus, the tectonic blocks of Ordovician limestone north of Regulator Canyon and Ordovician quartzite and dolomite at the northeast corner of the quadrangle represent a lower tectonic sheet beneath a low-angle normal fault (plate 2, section AA'). A high-angle fault bounds the west side of this window north of Regulator Canyon. At this window, no truncation or folding of bedding is evident at the low-angle fault, but the disruption of the stratigraphic sequence and the geometry of the contacts indicate faulting. The low-angle normal fault is folded to steep dips southward near the Regulator Canyon fault zone. The Ordovician limestone in places displays two cleavages. The first cleavage is nearly parallel to bedding and is tightly folded by northeast-trending folds, and the second cleavage is axial planar to the folds. Both cleavages are cut by abundant calcite veins.

Another low-angle normal fault crops out above the Guilmette Formation adjacent to the McGinty Monzogranite in the east-central part of the quadrangle (plate 2, section CC'). We interpret this fault as lying at a lower structural position than the fault on the Tripon Pass Limestone, but its small outcrop extent precludes confident correlation with other faults. The low-angle normal faults are older than the altered phase of the latest Eocene McGinty Monzogranite and younger than the Mesozoic or early Cenozoic bedding-plane faults. They most likely belong to a regional extensional event, which in the northeastern Great Basin is Eocene to Recent (Snoke and Miller, 1988).

The low-angle normal faults are most simply interpreted as rotated normal faults, in analogy with interpretations of low-angle normal faults in the Egan Range, Nevada (Gans and Miller, 1983). By this model, the normal faults formed at approximately 60 degrees to bedding while the strata were approximately horizontal. As faulting took place, the faults and blocks of rock bounded by the faults rotated above an underlying low-angle fault. Post-Eocene faults in the Pilot Range probably also aided in rotating the earlier faults to nearly horizontal positions.

North- and north-northeast-striking normal faults (set 3)- All dip steeply to moderately westward and have as much as 245 m (800 ft) of stratigraphic throw. Two faults with long traces extend from near Patterson Pass northward for as much as 5.5 km (3.5 mi). These faults cut both the bedding-plane and low-angle normal faults. North-striking high-angle faults were noted in Copper Mountain at the north end of the quadrangle by Blue (1960) during his examinations of mine workings. Surface exposures there do not closely delimit the positions of the faults, so we have indicated a single fault in that area by dashed lines. Two short segments of north-striking faults that cut dolomite north of Regulator Canyon may be reverse faults, but separations cannot be accurately determined in the monotonous dolomite.

Altered monzogranite bodies cut the north-striking normal faults, and the faults do not significantly displace the top of the McGinty Monzogranite, indicating that they are latest Eocene or older in age. The north-striking normal faults are most simply interpreted as the continuation of down-to-the-west normal faulting of the Paleozoic section that began with the development of the low-angle normal faults.

East-striking faults (set 4) - They cut faults belonging to sets 1, 2, and 3 but may have had multiple movements. The faults typically strike east and are nearly vertical. Discrete faults south of the Regulator Canyon fault zone contrast with the complex faults in that zone.

Faults south of the Regulator Canyon zone show as much as 100 m (300 ft) of apparent sinistral strike-slip separations of high-angle faults, but the faults probably had dip-slip movement as well. The fault located in Box Canyon displaces the flat-lying fault at the base of the Tripon Pass Limestone down to the south. The fault near Hogans Alley displaces the flat fault on top of the Guilmette Formation down to the north and displaces the east-dipping Mineral Mountain fault more than west-dipping high-angle faults, suggesting oblique separation: sinistral and down to the north. Changes in the thickness of Devonian rock units across the east-striking faults were interpreted by Miller and others (1982) as indicating tear fault behavior during bedding-plane faulting. Although small thickness changes can be accounted for by dip-slip separation along the faults, the thickness changes in the Guilmette across the fault at Cook Canyon are too large to be solely caused by a normal fault. The east-striking faults therefore were probably tear faults associated with the bedding-plane faults (and probably also the low-angle normal faults) and were reactivated as the last faulting episode in the Paleozoic rocks.

Blue's (1960) Regulator Canyon fault, which cuts strata along the south wall of the canyon, and related faults to the north and east (collectively grouped as the Regulator Canyon fault zone, plate 1) form a complex zone across which major changes in stratigraphy and structural level take place. To the north, Ordovician strata are exposed in a tectonic window (plate 2, section AA'), Carboniferous strata are thin or absent, and Permian strata are thick (Miller and Schneyer, 1985). Furthermore, the Third Fork(?) Formation south of the zone is lithologically unlike its temporal and stratigraphic equivalent north of the zone, the lower part of the Pequop(?) Formation as mapped by Miller and Schneyer (1985). These dramatic changes in stratigraphy and structure across the zone suggest that, although the Regulator Canyon fault system partly acted as a southern boundary for an east-trending horst that occupies the Copper Mountain area, it originated as a tear fault system during regional thrusting. As with the east-striking faults to the south, it is probable that the Regulator Canyon fault system acted as a tear fault system during bedding-plane and low-angle faulting and later was reactivated as a dip-slip fault zone.

East-striking faults in several places are intruded by bodies of altered rocks related to the latest Eocene McGinty Monzogranite, and the McGinty is not noticeably cut by the faults, indicating a latest Eocene or older age for faulting. The east-striking faults apparently were tear faults that accommodated different displacements of tectonic blocks during normal faulting and earlier bedding-plane faulting.

Structures cutting Tertiary strata

Several faults are inferred to cut the Tertiary strata underlying the pediment west of the Pilot Range, and a few young faults are mapped by physiographic expression and spring lines along the west side of the range (shown by dotted and queried lines). The Tertiary strata generally dip gently eastward, yet Eocene and Oligocene(?) strata lie to the east of Miocene strata. These relations require at least one fault that drops Miocene strata down in a western block. We infer that this fault separating Miocene from older strata is in its northern part a major basin-bounding fault (plate 2, sections BB' and CC'). Gravity data are sparse (Erwin, 1980) and do not constrain the location of the basin margin. Holes drilled in the Eocene and Oligocene(?) strata brought up cuttings of the McGinty Monzogranite and breccia. We interpret these data as evidence for east-dipping lower Tertiary strata that are underlain structurally by the McGinty Monzogranite (plate 2, sections BB' and CC'). The main basis for this low-angle fault interpretation is analogy with similar outcrop relations where fault geometries are well-constrained in the northeastern Pilot Range (Miller, 1985). These genetic relations require that the range-bounding fault moved in the Eocene, placing Eocene strata on the west against Paleozoic strata on the east. That fault bottomed into the flat fault on the pluton. Minor reactivation took place later.

A set of faults in the southern part of the quadrangle apparently cuts Pleistocene older alluvial-fan deposits (Qaf_2) and near Parson Springs and Killian Springs cuts Holocene younger alluvial-fan deposits (Qaf_1). Along these faults are abundant springs, and graben features are present in one location (plate 2, section DD'). Scarps are rounded and barely recognizable in Pleistocene older alluvial-fan deposits. Faults are mapped in Holocene younger alluvial-fan deposits on the basis of spring lines coinciding with linear soil color changes and vegetation zones. No scarps were conclusively identified in Holocene materials. Youthful faults may localize the several springs at the west side of Patterson Pass but, if present, they do not cut Quaternary deposits. The straight range front north of the pass is probably controlled by similar faults, but none are exposed. Spring lines and topographic lineaments at the northern edge of the quadrangle and west of the range front are interpreted as evidence for a buried fault, one that possibly controls the westward edge of elevated plateaus of Tertiary and Quaternary deposits in the Cook Canyon area.

Structural summary

The structural data from the Patterson Pass quadrangle form a key part of an interpretive structural history of the Pilot Range. The earliest events were metamorphism, plutonism, folding, and cleavage-formation in rocks underneath the Pilot Peak detachment (Miller and others, 1987). Southeast-directed shear accompanied at least part of this deformation. On the basis of deformed Jurassic granite and K-Ar data for metamorphic minerals, peak metamorphism was Late Jurassic in age in the Pilot Peak quadrangle, but metamorphic rocks did not cool to lower greenschist temperatures until the Late Cretaceous (Miller and others, 1987), perhaps indicating Cretaceous metamorphism. At structural levels above the Pilot Peak detachment, east-directed thrusting along faults nearly parallel to bedding took place during or subsequent to cleavage development in shaly limestone. The thrusting may have been coeval with metamorphism beneath the detachment, but its timing is only established as older than latest Eocene.

During the late Eocene, marked extension of the upper crust was accompanied by pluton emplacement and outpourings of volcanic rocks. The Pilot Peak detachment fault formed as a boundary separating a quasi-rigid footwall from an extending, highly faulted hanging wall. Initial faults in the hanging wall

were moderately west-dipping, but they were rotated to low angles as extension above the detachment rotated the panels of strata and faults alike. After the normal faults were rotated to shallow dips, new moderately west-dipping faults formed but ceased movement after a few hundred meters or less of offset. All of these normal faults were intruded by, and also brecciated, the latest Eocene McGinty Monzogranite, and Eocene volcanic rocks were probably deposited during extension. The volcanism, plutonism, and extension were probably roughly synchronous, as was documented for the similar initial extensional tectonics of the east-central Great Basin (Gans and Miller, 1983). Sedimentary and volcanic rocks were deposited in structurally shallow basins because the deposits are thin.

During the Miocene and probably the Pliocene, deep basins and broad tilt-blocks formed, blocking out the current basins and ranges. Moderately dipping normal faults bound the basin west of the Pilot Range, and movement along these faults produced moderate to steep tilting of Eocene volcanic rocks and Miocene basin sediments. Faults and tilted strata resulting from late Eocene extension were broken by the basin-bounding faults and also were domed or warped over the ranges. A basin deeper than 2 km (6,500 ft) filled with sediments and volcanic rocks. Some of the faults bounding the west side of the range continued activity into the Quaternary.

ECONOMIC GEOLOGY

Considerable mining activity took place north of Patterson Pass during the late 1800s and early 1900s, but virtually none took place south of the pass. Blue (1960) and Doelling (1980) summarized the history of production in the Lucin mining district, which included copper, lead, silver, and iron production from mines in Regulator Canyon and on Tecoma Hill and Copper Mountain. Total production exceeded several million dollars. Prospects also are scattered between Patterson Pass and Copper Mountain. Mineralization was mainly by replacement of carbonate rock and in fracture fillings in middle Paleozoic carbonate strata; it appears to be spatially related to abundant small altered intrusions of the McGinty Monzogranite. The most prominent group of prospects and mines is within the lowermost part of the Devonian Guilmette Formation. Mineralization was chiefly exploited for copper at Copper Mountain, and for lead, silver, and zinc at mines in the Mineral Hill and Regulator Canyon area. Exploration of the Lucin district during the last decade has included considerable exploratory drilling of the mountain range and piedmont, and minor development in some mines. In addition to the mining activity north of Patterson Pass, three small pits were dug along a quartz vein cutting unit G of the McCoy Creek Group, center of section 3, T. 5 N., R. 19 W. Chrysocolla is present in the vein (Doelling, 1980, p. 90).

Several other features in the quadrangle have potential economic interest. (1) Jasperoid in the siliceous breccia on the Guilmette Formation is similar to mineralized jasperoid located 22 km (14 mi) to the north in the Tecoma mining district (Douglas and Oriel, 1984). The Tecoma deposit contains disseminated gold and silver. (2) Small outcrops of the Eureka Quartzite in the northeastern corner of the quadrangle are a potential source for pure silica. (3) Sorted gravel deposits along the shores of ancient Lake Bonneville may be suitable for construction aggregate. (4) Barite is found sporadically in the upper part of the Guilmette Formation as carbonate-replacement zones and solution fillings. One prospect in barite is located above a cave in the west-central part of section 27, T. 6 N., R.19 W., south of Hogans Alley. (5) Felsite dikes (Tf) are locally altered and brecciated and in some cases contain casts after pyrite; they may have served as conduits for mineralizing fluids. (6) Siliceous Tertiary volcanic rocks may have potential for disseminated gold or other mineralization. (7) The upper part of the Guilmette Formation may serve as a source for pure limestone.

HYDROLOGY

All streams in the Patterson Pass quadrangle are intermittent, but in many canyons the water table evidently is shallow, because dense phreatophytes are abundant. Springs are common near the topographic margin of the Pilot Range. In many cases, linear arrays of springs suggest damming of shallow groundwater flow by fault gouge. The most extensive linear arrays of springs, in the Parson and Killian Springs areas, were developed as part of the water supply for Montello, Nevada.

GEOLOGIC HAZARDS

Quaternary faulting is indicated by rounded scarps, linear terraces, and well-developed linear arrays of springs in the Killian Springs area. These youthful faults could give rise to moderate or large earthquakes. Landslides, gravity-slide blocks, and talus slopes in the Pilot Range potentially could be activated by earthquakes, excessive rainfall, or other factors.

Alluvial fans bordering the Pilot Range and alluvial deposits in canyons were emplaced primarily by potentially destructive debris flows and by sheet wash. In many sites, alluvium is currently being deposited or eroded. There is great potential for destructive floods and debris flows, particularly in areas underlain by young alluvium (Qaf_1) close to the range front and within canyons.

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