Text and references to accompany NBMG Field Studies Map 21

GEOLOGY OF THE OLD MANS CANYON QUADRANGLE, NEVADA

by

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INTRODUCTION

The Snake Range, in eastern White Pine County, Nevada, is a 150-km-long, north-trending mountain range in the northern Basin and Range province (fig. 1). Sacramento Pass divides the range into two main parts, the northern and southern Snake Range. The Old Mans Canyon Quadrangle is one of twelve 7.5' quadrangles that cover the northern Snake Range and is situated along the southern flank of the range, bordering Sacramento Pass (fig. 2). Main access into the part of the range covered by this quadrangle is via gravel roads from U.S. Highway 50 and from the north Snake Valley road into the mouth of Silver Creek Canyon and Old Mans Canyon. Access to the upper part of Hendry's Creek drainage is by foot or horseback along a well-maintained trail that begins at the mouth of the canyon. A maintained gravel road leads from north Snake Valley road to the trailhead.

The northern Snake Range includes the Mount Moriah Wilderness Area, which was established in 1989. The steep-walled canyons and rugged ridge crests of the northern Snake Range provide access to The Table at about 11,000 feet (3,300 m) and Mount Moriah at 12,067 feet (3,678 m), forming some of the most scenic hiking country in the Basin and Range province. The broad, arch-like physiography of the northern Snake Range is shaped by its geology, which is unique compared to other mountain ranges in the region. The northern Snake Range is now considered a classic example of a Cenozoic "metamorphic core complex" (for example, Coney, 1979). The most prominent structural feature of the range is the northern Snake Range décollement (NSRD), a low-angle fault that juxtaposes an upper plate of complexly normal-faulted Paleozoic and Tertiary strata against a lower plate of ductilely attenuated metasedimentary and igneous rocks (figs. 2 and 3). The NSRD defines a north-trending asymmetric dome with about 5000 feet (1.5 km) of structural relief (fig. 4). The age, origin, and tectonic significance of the NSRD have been topics of continuing debate since the fault was first described by Hazzard and others (1953) and Misch (1960). Although the origin of the NSRD and core complex detachment faults in general remain controversial, there is common agreement that these complexes provide excellent exposure of both brittle and ductile structures formed as a result of large-magnitude crustal extension.

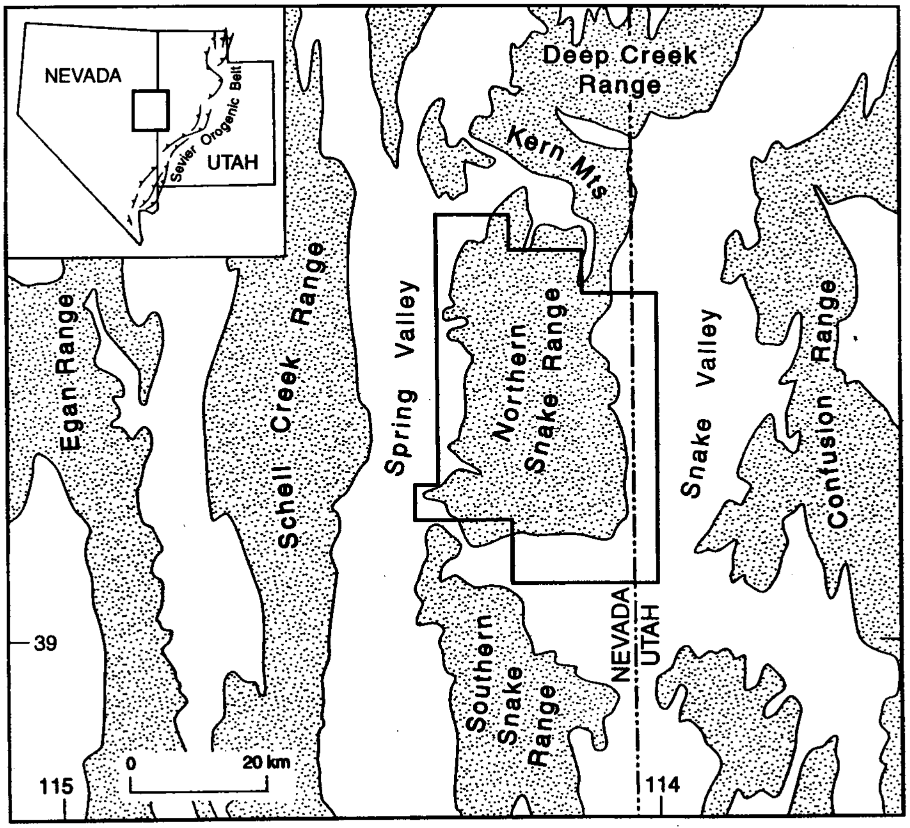

Figure 1. Index map of east-central Nevada and west-central Utah showing location of the Snake Range with respect to surrounding mountain ranges in the northern Basin and Range province, western United States.

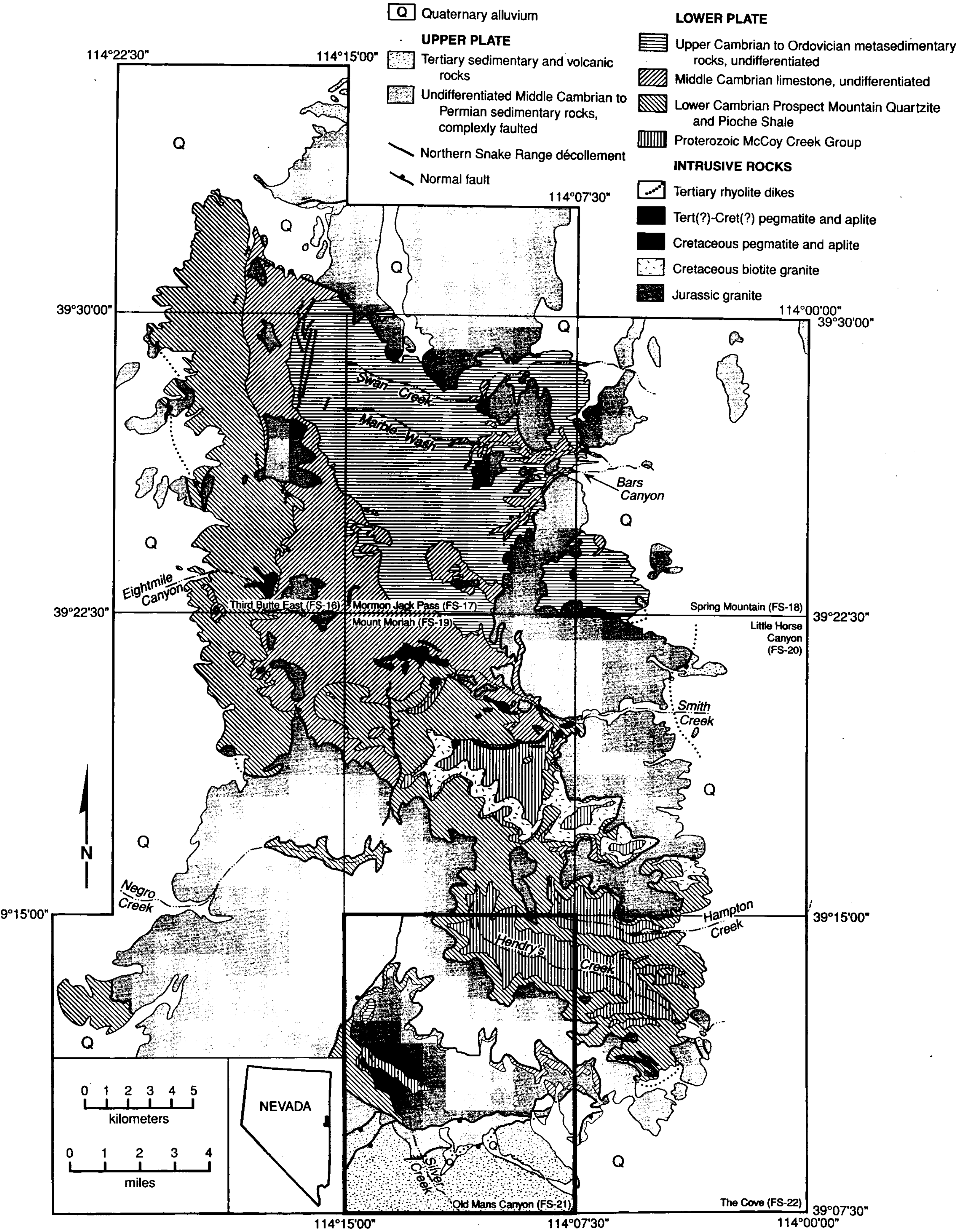

Figure 2. Index map of the northern Snake Range showing simplified geology and location of mapped 7.5-minute quadrangles.

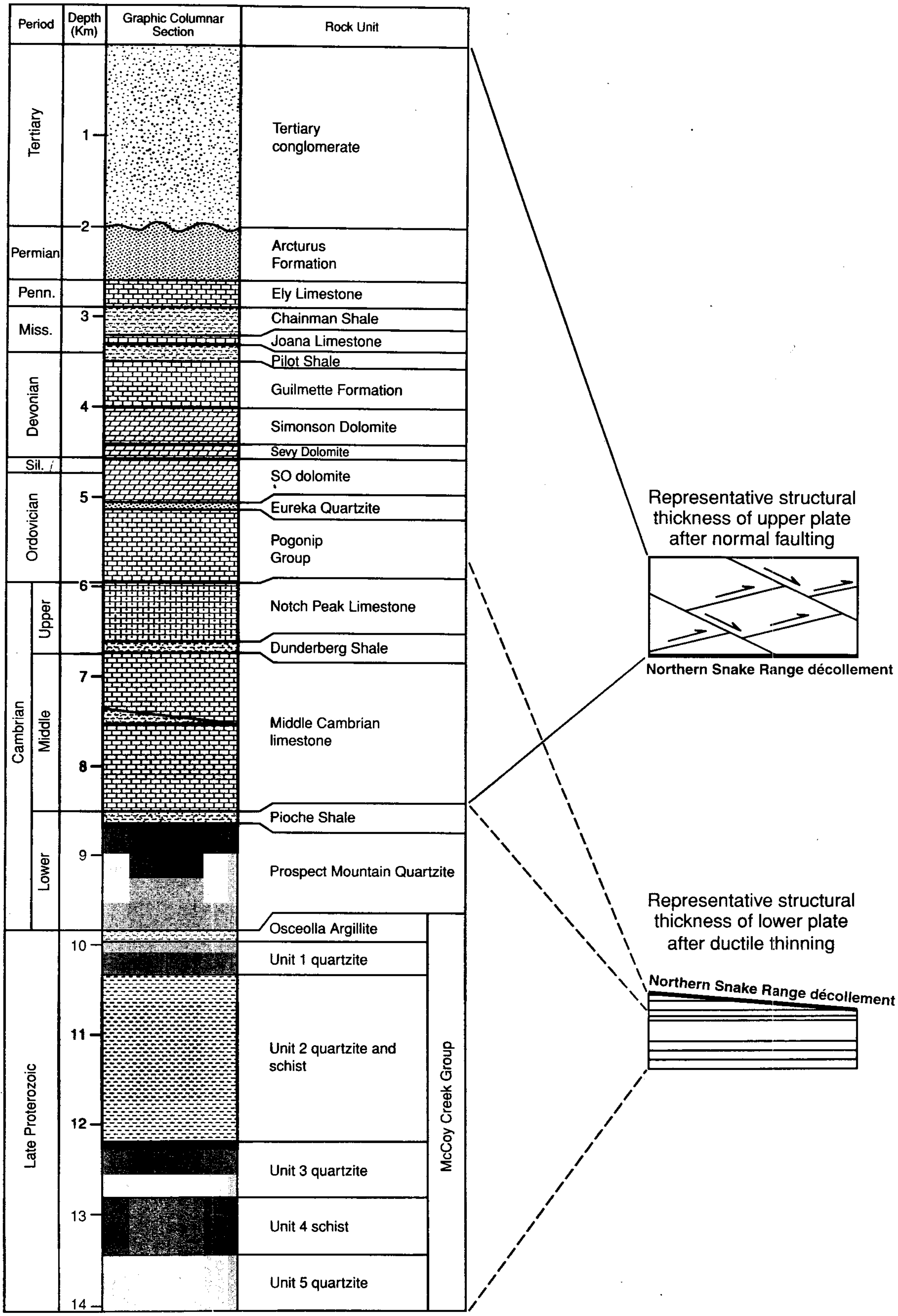

Figure 3. Representative stratigraphic column for the Snake Range and environs. Representative structural thicknesses for upper plate and lower plate rocks after normal faulting and ductile thinning.

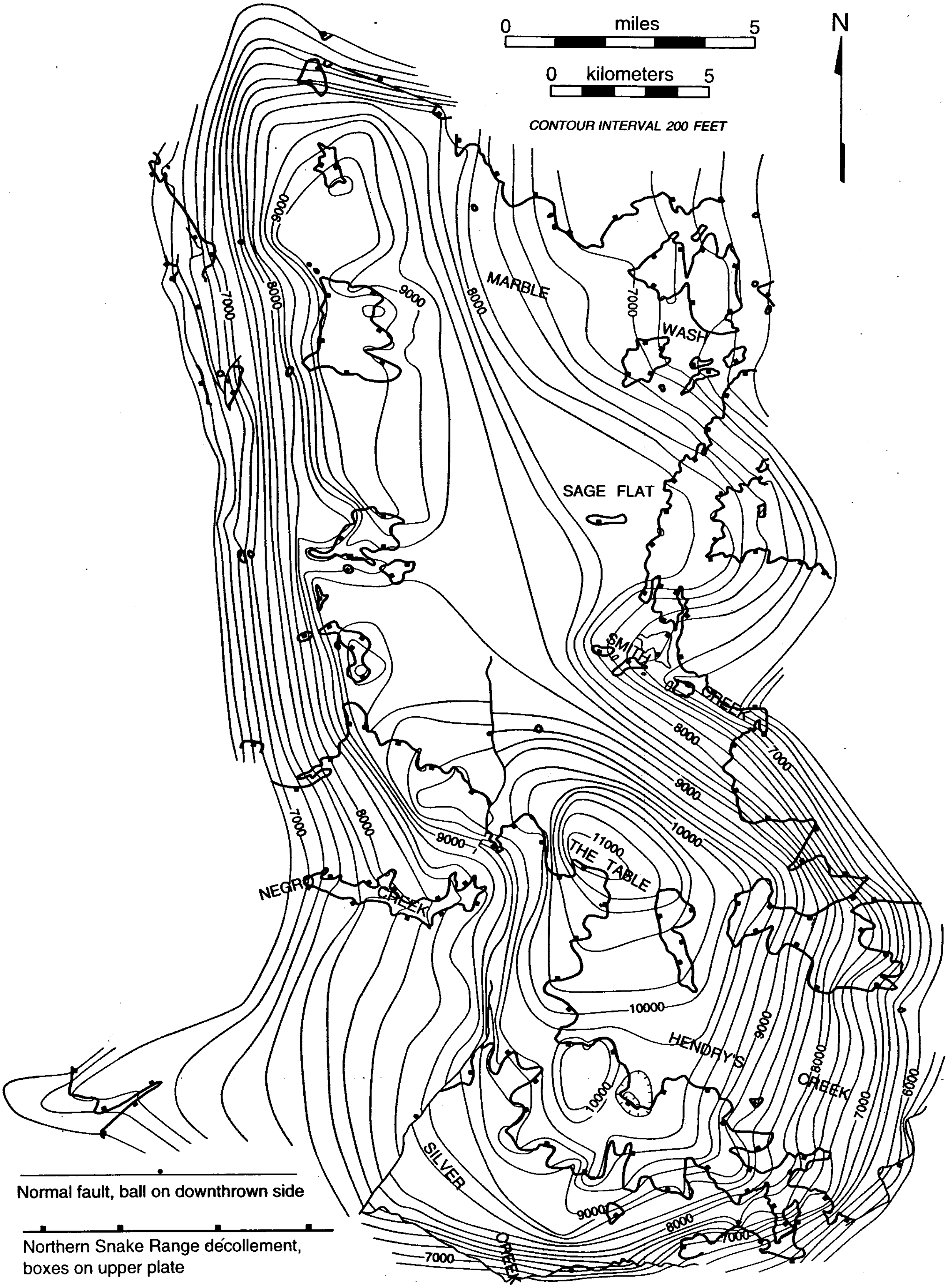

Figure 4. Structure contour map of the northern Snake Range décollement (from Lee, 1990).

GEOLOGIC SETTING AND PREVIOUS WORK

Both the northern and southern Snake Range are underlain primarily by Late Proterozoic to Permian miogeoclinal shelf strata deposited along the subsiding continental margin of western North America (fig. 3). Miogeoclinal strata in the footwall of the NSRD range in age from Late Proterozoic to Ordovician and generally define a broad, north-trending antiform. These rock units are relatively unfaulted but record a polyphase history of ductile deformation, metamorphism, and intrusion. The hanging wall or upper plate of the NSRD includes Middle Cambrian to Permian miogeoclinal rocks, as well as Tertiary sedimentary and volcanic rocks. In striking contrast to the lower plate, these rocks are little metamorphosed but highly faulted and tilted by multiple generations of normal faults (fig. 3).

In many ways, the evolution of ideas concerning the origin of the NSRD charts the progress of our understanding of the extensional history of the Cenozoic Basin and Range province as a whole. Until the early 1970s, most low-angle faults like the NSRD in the western United States were mapped as thrust faults. The Snake Range décollement was first described by Hazzard and others (1953). A more detailed study of the geology of the northern Snake Range by Misch (1960) and Misch and Hazzard (1962) followed as part of a regional survey of the geology of eastern Nevada. They noted that the major structure in the northern Snake Range was a low-angle "décollement" that separated an autochthon of strongly metamorphosed rocks from an allochthon of faulted and folded, but largely unmetamorphosed, carbonate rocks. Nelson (1966, 1969) mapped the northern end of the range as part of a regional mapping project that included the Kern Mountains and southern Deep Creek Range. He mapped the décollement of Misch (1960) and identified lower-plate schists and marbles as metamorphosed equivalents of Proterozoic and Cambrian-Ordovician miogeoclinal units and upper plate rocks as Cambrian to Permian carbonate rocks and younger Tertiary rocks. Nelson proposed that rocks in the lower plate (his "autochthon") recorded three deformational events, the youngest of which involved the generation of mylonites and formation of folds that he assigned to the Mesozoic. He believed that these structures were associated with east-directed thrusting along the décollement horizon. The position of the Snake Range in the hinterland of the Cretaceous Sevier orogenic belt (fig. 1) led these and later workers to relate the low-angle "décollement faulting" in the northern Snake Range to Mesozoic thin-skinned thrust faulting further east, where the NSRD represented the basal shearing-off plane for these thrusts (Misch, 1960; Miller, 1966). However, Hose and Danes (1973) and Hintze (1978) recognized that the deformation in the upper plate was dominated by normal faulting and attenuation of the stratigraphic section rather than by shortening and thickening of the rock column. This led them to propose a model wherein the Snake Range and environs represented an uplifted hinterland, where extension was linked to coeval shortening in the foreland via a basal detachment fault now exposed as the NSRD. Armstrong (1972) was the first to suggest that many of these faults might be Tertiary rather than Mesozoic in age, and therefore unrelated to Mesozoic thrust faulting. Armstrong specifically cited geochronologic and stratigraphic relations from the southern Snake Range as some of his principal evidence for a Cenozoic age for the Snake Range décollement. Coney (1974) suggested that at least some of the lower plate deformation in the northern Snake Range might be related to the Snake Range décollement. He studied folds in marble mylonite beneath the NSRD and proposed "quaquaversal" or radial sliding of upper plate rocks off the northern Snake Range.

Hose and Blake (1976) compiled a 1:250,000-scale geologic map of White Pine County which included the first compiled geologic map of the northern Snake Range based largely on reconnaissance mapping by Hose. They mapped the low-angle NSRD in its entirety, which they described as separating a lower plate of undifferentiated Lower Cambrian quartzites and pelites and Middle Cambrian marbles from an upper plate of complexly faulted Middle Cambrian to Permian carbonate rocks. Hose and Blake (1976) proposed that two metamorphic and deformational events were recorded in lower plate rocks, a post-mid-Jurassic to pre-early Eocene intrusive and high-grade metamorphic event followed closely by a low-grade metamorphic event associated with the development of a strong penetrative foliation and west-northwest-trending mineral elongation lineation. This was followed by post-early Eocene movement along the NSRD and associated faulting in the upper plate. As part of the Wilderness RARE II study, additional mapping of the southern part of the northern Snake Range was carried out at a scale of 1:62,500 (Hose, 1981). This publication pointed out the magnitude of structural thinning of upper plate units by normal faulting. In an influential paper by Wernicke (1981) on the geometry and kinematic significance of extensional detachment faults, the Snake Range décollement was cited as a key example of a large-displacement, eastward-rooting low-angle normal fault.

Studies in the northern Snake Range by geologists based at Stanford University began in 1981 and are still ongoing. Miller and others (1983) and Gans and Miller (1983) suggested that the basic structural relationships in the northern Snake Range were best explained as extensional in origin and Cenozoic in age. For the first time, the Late Proterozoic lower plate units in the central and southern part of the range were identified and correlated, bringing to light the incredible tectonic stretching or attenuation of these rock units by ductile deformational processes. The upper plate units were shown to have been affected by multiple generations of predominantly east-dipping normal faults, and it was pointed out that over much of the range there appeared to be near stratigraphic continuity between the oldest units present above and youngest units present below the décollement. These and other relations led Miller and others (1983) to question the need for significant displacement on the décollement and to propose instead that the NSRD originated as a subhorizontal ductile-brittle transition zone between a brittlely extending upper plate and a ductilely stretching lower plate. This interpretation was challenged by Bartley and Wernicke (1984), who specifically proposed that the NSRD represented a low-angle normal fault or shear zone with 60 km or more displacement that brought lower plate rocks up and out from under a thrust plate in the Sevier belt to the east. In their model, the near continuity or lack of stratal omission between upper and lower plate rock units cited by Miller and others (1983) was strictly fortuitous. Gans and Miller (1985) responded to this alternative interpretation by citing additional regional stratigraphic and structural relations that created difficulties with Bartley and Wernicke's proposed model.

Further studies in the northern Snake Range expanded our geologic mapping and utilized structural and kinematic analyses, seismic reflection profiling, metamorphic petrology, and extensive geochronology and thermochronology in order to help resolve issues as to the amount of displacement and initial angle of the NSRD, as well as the age of lower plate deformation and its geometric and kinematic relationship to the evolving NSRD (Rowles, 1982; Gans and Miller, 1983; Grier, 1983, 1984; Miller and others, 1983, 1987, 1988, 1989; Gans and others, 1985, 1989; Geving, 1987; Lee and others, 1987; Gans and others, 1989; Huggins, 1990; Lee, 1990, 1995; Lee and Sutter, 1991). Our geologic mapping at scales of 1:12,000 and 1:24,000 over a 12-year period (1981-92) was the first detailed mapping to be completed in the range. During the first half of this project, mapping was carried out on 1:16,000 black-and-white and 1:24,000 color aerial photographs and compiled upon orthophotoquadrangles because topographic maps were not yet available for the region.

Our studies have shown that lower plate rocks consist of metamorphosed Late Proterozoic to Lower Cambrian quartzites and pelites and Middle Cambrian to Ordovician marbles that correlate in a straightforward fashion to less deformed and metamorphosed sections in the adjacent Schell Creek, Deep Creek, and southern Snake Ranges. Jurassic and Cretaceous granitic plutons and Tertiary dike swarms intrude lower plate units. Lower plate rocks record at least three metamorphic and deformational events. The first metamorphic event, of Jurassic age, is best preserved along the southern flank of the northern Snake Range. Here, Late Proterozoic and Lower Cambrian quartzites and metapelites have been intruded and contact metamorphosed by a mid-Jurassic plutonic complex (fig. 2). Structural fabrics associated with this event are strongly overprinted by superimposed Cretaceous and Cenozoic fabrics.

The second metamorphic event, of Late Cretaceous age, affected a much broader region of the lower plate. A series of mineral-in isograds mapped along the eastern side of the range indicates that the grade of metamorphism increases from greenschist to amphibolite facies from south to north and with structural depth in the succession (Geving, 1987; Huggins, 1990). A Late Cretaceous pegmatite and aplite dike swarm was intruded during this metamorphic event, which has been dated at about 82 to 78 Ma (Huggins and Wright, 1989; Huggins, 1990). Structural fabrics associated with this metamorphic event have also been strongly overprinted by Cenozoic fabrics, making their analysis and interpretation difficult. However, on the northwestern flank of the range, Tertiary strain decreases and eventually dies out. Here, west-dipping foliations, minor thrust faults, and a map-scale fold now inferred to be of Cretaceous age are preserved (Lee, 1990; P. B. Gans, 1992, unpub. data). Lower to upper greenschist-facies metamorphism of Eocene to Miocene age (Lee and Sutter, 1991; Lee, 1995) strongly affected much of the lower plate, causing retrogression of older mid-Jurassic and Late Cretaceous metamorphic assemblages. The Tertiary metamorphic event was accompanied by vertical thinning and horizontal stretching, resulting in a subhorizontal, bedding-parallel mylonitic foliation and west-northwest-trending stretching lineation. This foliation is axial planar to isoclinal, recumbent folds in the northern half of the range. A strong gradient in the amount of deformation or strain of lower plate rock units developed during this youngest event. Strain increases dramatically from west to east across the range. Mesoscopic, microstructural, and petrofabric studies on lower plate rocks were utilized by Lee and others (1987) to modify the in-situ pure shear model proposed by Miller and others (1983). Lee and others (1987) proposed a strain path whereby pure and simple shear (top to the east) acted in unison and in sequence in the lower plate and that this strain was intimately tied to the evolution of the NSRD, ultimately leading to slip along this surface in the brittle regime. Structural studies by Gaudemier and Tapponnier (1987) were used to promote a model whereby lower plate deformation occurred entirely by simple shear. As pointed out by Lee and others (1987), the question of simple versus pure shear remains controversial, as most structural and petrographic observations used to resolve these questions do not yield unique interpretations. In sum, important questions still remain regarding the exact age of development of lower plate fabrics, whether they are developed as a consequence of pure and/or simple shear, and what the exact kinematic relation is between these fabrics and the evolving NSRD.

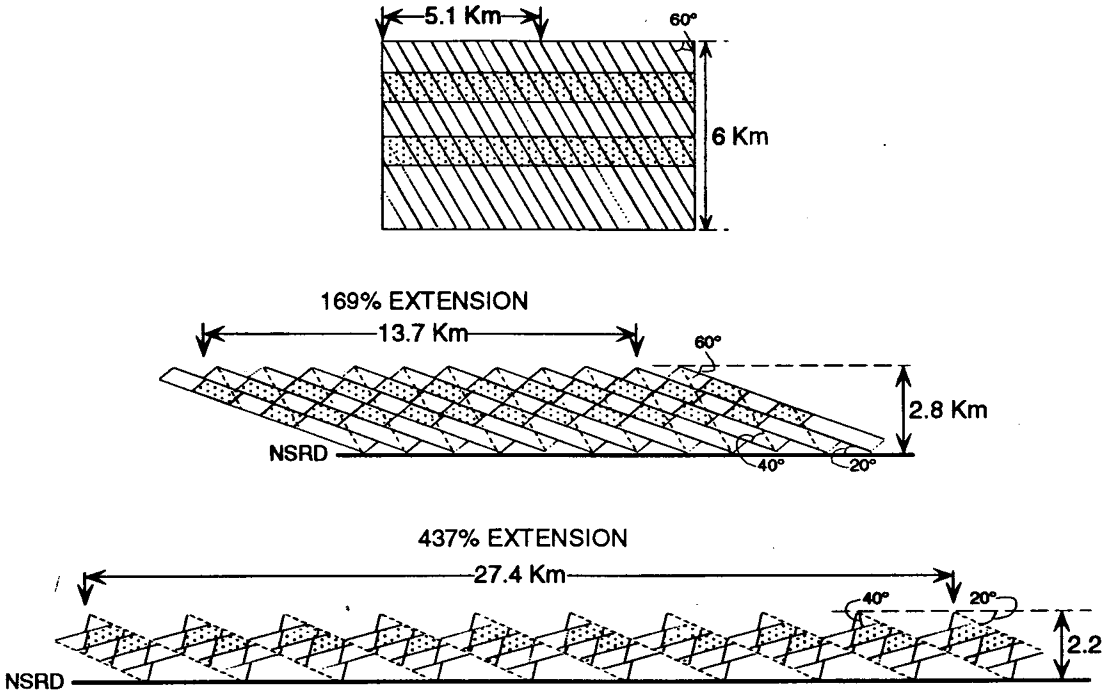

Figure 5. Schematic diagram illustrating two generations of normal faults and attendant rotation that may be responsible for the observed attenuation of the stratigraphic section shown in figure 3 (modified from Miller and others, 1983).

In the overlying upper plate, unmetamorphosed to weakly metamorphosed Middle Cambrian to Permian carbonate rocks have been in general attenuated by at least two sets of imbricate normal faults. This resulted in successive northwestward tilting about a common axis in response to WNW-ESE extension, parallel to that recorded by the ductile deformational fabrics in the lower plate (Miller and others, 1983). However, the amount of strain indicated by these faults and the amount of rotation related to faulting varies across the range, as does the direction of tilting or rotation. Despite the extremely complex map pattern of upper plate normal faults, this generally systematic structural style is evident upon close inspection. Structural sections of Middle Cambrian to Permian (and locally Tertiary) strata that "young" to the west are repeated eastward on east-dipping normal faults that merge with, but do not offset the NSRD. These faults are labeled as "second-generation" faults on the cross sections on the map sheet. Within these tilted sections, older, gently west-dipping faults omit units as well, and are interpreted as originating as steep, down-to-the-east normal faults that once shallowed into the NSRD. These older faults (labeled as "first-generation" faults on the cross sections on the map plate) rotated to low angles as they moved until cut by younger faults, which rotated them past horizontal and into their present westward dips. Macroscopically ductile deformation such as warping, normal drag, folding and complex arrays of smaller faults and their splays helped alleviate space problems at the toes of normal faults as they merged with the NSRD. Figure 5 schematically illustrates how this faulting history operated. Regardless of the details and the exact geometry of the faults themselves, it is clear that the process of faulting led to tremendous attenuation of the stratigraphic sequence which once formed the hanging wall or upper plate of the NSRD (figs. 3 and 5). Normal-sense movement along the NSRD during the time span of upper plate faulting is indicated, as only a few mapped faults actually cut and offset the NSRD. Motion along the NSRD is believed to have been down-to the east and resulted in the juxtaposition of the less metamorphosed and mostly younger upper plate rocks down upon the more highly metamorphosed and generally older lower plate rocks. An important exception to this occurs in the northern part of the range where Middle Cambrian and younger rocks of the upper plate routinely overlie Late Cambrian and locally Ordovician strata in a lower plate position.

We previously postulated that most of the movement on the NSRD was Oligocene to early Miocene in age (for example, Gans and Miller, 1983; Miller and others, 1983; Gans and others, 1985; Lee and Sutter, 1991). However, new thermochronologic and geologic data suggest that movement along the NSRD was likely episodic and occurred during the Eocene to middle Miocene. Multiple diffusion domain analyses of potassium feldspar Arrhenius data and ^{40}Ar/^{39}Ar age spectra together with apatite fission-track studies show three rapid cooling events: 1) middle Eocene (48-41 Ma), 2) late Oligocene (30-26 Ma) and

3) early to middle Miocene (20-15 Ma) (Miller and others, 1989, 1990; Lee, 1995). These cooling events may indicate diachronous exhumation of footwall rocks from beneath the NSRD. The spatial and temporal distribution of these cooling events suggest that the NSRD is a composite structure; the NSRD along the west flank of the range moved during the Eocene and Oligocene (Lee, 1995), and the NSRD along the east flank of the range moved during the Early to Middle Miocene (Miller and others, 1989, 1990; Lee, 1995). Field relations indicate that Miocene or younger sedimentary sequences along the northern, eastern and southern flanks of the range are cut and tilted by a set of normal faults that we infer either to cut or to sole into the NSRD in the subsurface supporting the inferred Early to Middle Miocene episode of movement along the NSRD (Gans and others, 1989; Miller and others, 1989, 1990).

In summary, we now think that the combined data on the deformational history of upper and lower plate rocks indicate that the NSRD is a composite structure rather than a single fault; thus it was never simultaneously active over its entire mapped extent. East-dipping normal faults along the eastern flank of the range and specifically the faults along the southern part of the range in the Old Mans Quadrangle were likely active in mid-Miocene and later times and perhaps originated as steep faults that have since been rotated to present low dips. If the high-strain rocks and mylonites of the lower plate represent more than one Tertiary event, our studies to date have not unequivocally resolved these with confidence. Limiting factors include the resolution of available geochronologic techniques, given the complex thermal and deformational histories of the minerals available for dating, and the inability of structural studies to distinguish more than one superimposed event if these are developed at low angles to one another. Clearly, the NSRD represents the end result of an involved history of extensional strain at both ductile and brittle levels of the crust and that more than one episode of faulting is responsible for the relative uplift and exposure of ductile extensional fabrics in the range. However, more sophisticated studies and modeling of existing data are necessary to fully understand the kinematic history and mechanics of deformation and faulting.

GEOLOGY AND STRUCTURAL HISTORY OF THE OLD MANS CANYON QUADRANGLE

The southern, low-lying portion of the Old Mans Canyon Quadrangle is underlain by non-resistant Tertiary sedimentary rocks that underlie much of the Sacramento Pass region. Along the southern flank of the range, a series of north-striking faults that cut the Tertiary section swing into east-west strikes along the edge of the range. Here these same faults bound portions of the upper Paleozoic section that forms depositional basement for the Tertiary section. These fault-bound slivers of upper Paleozoic strata separate Tertiary strata from structurally deeper lower plate rocks of the northern Snake Range. Topography rises steeply to the main ridge crest in the Old Mans Canyon Quadrangle, with elevations over 10,000 feet (3,000 m). The steep, dark-colored slopes beneath this ridge crest are underlain by gneissic metaplutonic rocks of Jurassic age. At higher elevations, the NSRD underlies a series of fault-repeated sections of Middle Cambrian to Devonian strata that form the higher slopes and the main ridge crest of the Quadrangle. Hendry's Creek drainage in the northeastern part of the Quadrangle deeply incises shallow-dipping Late Proterozoic and Cambrian quartzite and schist units of the lower plate.

The NSRD is the major mapped structure in the Old Mans Canyon Quadrangle. In fact, exposures of this impressive fault system with its underlying marble mylonites in the Old Mans Canyon area constitute its type area as described by Misch (1960) and Misch and Hazzard (1962). It is nearly flat-lying where it is exposed at higher elevations in the northern half of the quadrangle but descends steeply southward and eastward to the southeastern flank of the range, defining the southern and eastern side of its broad domical structure (fig. 4). In the northwestern part of the quadrangle, the NSRD is cut and down-dropped to the west by a younger, steeply west-dipping fault. The complex system of east-striking faults along the southern edge of the range are likely younger than (and thus cut) the NSRD mapped at higher elevations (see map). Conglomerate units that are cut and offset by this system of faults are middle Miocene and younger, placing an older age limit on these faults.

All of the lower plate rock units in the Old Mans Canyon Quadrangle were deformed in the Cenozoic and possess a pervasive subhorizontal mylonitic or gneissic fabric and west-northwest-trending elongation lineation. Depending on location in the quadrangle, however, rocks provide evidence for two distinct older events, one Jurassic in age and the other Cretaceous in age. Jurassic metamorphism and deformation is best recorded adjacent to the Jurassic plutonic complex in the middle part of the quadrangle, and evidence for an event of Cretaceous age is best developed in Late Proterozoic strata in Hendry's Creek.

The large gneissic pluton of Jurassic age that underlies most of the Old Mans Canyon Quadrangle is a composite pluton and consists of two distinct bodies informally referred to as the Old Mans pluton and the Silver Creek granite. The Old Mans pluton is the older and easternmost of the two and grades from a hornblende-bearing diorite in its easternmost exposures to a biotite tonalite and lesser granite on the west. Abundant pegmatite and aplite dikes, which emanate from the top of the younger Silver Creek granite, intrude overlying and adjacent tonalite of the Old Mans pluton. U-Pb ages on several fractions of zircon from three localities in this composite pluton indicate a Jurassic age of intrusion, at approximately 155±5 Ma (J. E. Wright, unpub. data). A screen of Late Proterozoic to Cambrian age metasedimentary rocks separates the two main phases of the pluton and is well-exposed along the eastern side of the Silver Creek drainage (see map). These rocks record two superimposed metamorphic events that are spatially related to the two adjacent plutons (Miller and others, 1988). Muscovite, biotite, staurolite, garnet and andalusite grew during the first metamorphic event (M_1), which was associated with the intrusion of the Old Mans pluton. In most places these minerals were severely retrograded during the second metamorphic event (M_2), which was synchronous with the development of a much stronger foliation. Muscovite, biotite, staurolite, andalusite, and cordierite grew during the second metamorphic event. Andalusite and cordierite are developed in close proximity to the margin of the Silver Creek granite. Rare kyanite is present in the more distal aureole of the younger Silver Creek granite and occurs as small, euhedral crystals growing in retrograded M_1 andalusite and in M_2 cordierite. Late stage growth of neoblastic kyanite suggests cooling at constant pressures at or below the aluminum silicate triple point. Both the pluton and the inferred Jurassic-age fabrics developed in these rocks are cut by a younger, subhorizontal fabric of Cenozoic age.

Ductilely attenuated Late Proterozoic and Cambrian quartzite and schist units are spectacularly exposed in the middle and upper reaches of Hendry's Creek drainage in the northeastern part of the Old Mans Canyon Quadrangle. Here, peak metamorphism has been dated as Late Cretaceous (Lee and Fischer, 1985; Huggins and Wright, 1989; Huggins, 1990) and resulted in the growth of coarse-grained garnet and staurolite in schist units of the McCoy Creek Group. This metamorphic event is responsible for the series of mineral-in isograds mapped (but not shown on these maps) along the eastern side of the range; metamorphism increases northward and with depth in the stratigraphic succession (Geving, 1987; Huggins, 1990). Deformational fabrics produced during this event are strongly overprinted by Tertiary fabrics, thus cannot be measured and analyzed. Tertiary strain that resulted in the extreme attenuation of the units in Hendry's Creek occurred at lower metamorphic grade, collapsing older metamorphic isograds (Geving, 1987; Lee and others, 1987; Miller and others, 1988). The deepest exposed levels of the lower plate occur in this portion of the Hendry's Creek drainage (Late Proterozoic McCoy Creek Group unit 5), where they are involved in a series of recumbent, open to tight folds whose axes trend parallel to the WNW-ESE stretching lineation in lower plate rocks. The presence of these folds, which are best developed in the adjacent quadrangle to the east (The Cove), explains the anomalously steep contacts between some of the units and their linear map traces.

In the rugged, thickly forested higher peaks of the quadrangle, complexly faulted Cambrian to Devonian miogeoclinal sedimentary rocks rest in fault contact above lower plate units along the high, flat-lying portion of the NSRD. Although exposure is poor in this region, a systematic faulting history is evident. Structural sections of Middle Cambrian to Devonian strata dip mostly westward and are repeated eastward on east-dipping normal faults that merge with, but do not offset, the NSRD. Older, west-dipping faults within these structural sections omit units as well and are interpreted as originating as steep, down-to-the-east, normal faults that once also shallowed into the NSRD (Gans and Miller, 1983). These older normal faults rotated to low angles as they moved until cut by the younger faults, which rotated the earlier faults through horizontal and into their present westward dips. Ductile deformation, normal drag, folding, and low-angle fault splays helped alleviate space problems at the toes of the normal faults as they merged with the NSRD. The geometry of normal faults in this quadrangle indicates extension in a WNW-ESE direction, parallel to the extension direction in metamorphic tectonites of the lower plate.

The stratigraphy and sedimentology of Tertiary strata exposed in the Sacramento Pass area, informally referred to as the Sacramento Pass section, was described in detail by Grier (1983, 1984). The Tertiary section is now tilted 30 to 60° to the west and repeated by a series of east-dipping normal faults that have extended the section by a factor of two or more in a WNW-ESE direction. These tilted sections provide excellent three-dimensional control on the stratigraphy and lateral facies variation within the section. Especially good exposures occur along the northern side of Miller Wash in the southwestern most corner of the quadrangle.

The Tertiary Sacramento Pass section includes volcanic rocks, lacustrine limestone, and alluvial fan deposits. In addition, thick units of monolithologic breccia and large coherent blocks of Paleozoic strata (up to 1 km long and more than 100 m thick) occur within the section and are interpreted as landslide or rock avalanche deposits (Hose and Whitebread, 1981; Grier, 1984; Miller and others, 1995). The base of the Tertiary section rests disconformably upon upper Paleozoic strata. The best exposures of the basal unconformity and of the lower part of the Sacramento Pass section are found in the adjacent Lehman Caves Quadrangle (Miller and Grier, 1993). Here, earlier conglomerate (Tc) of unknown age and containing clasts derived exclusively from Mississippian to Permian strata rests unconformably on the Pennsylvanian Ely Limestone. The basal conglomerate is here overlain by volcanic rocks that include dacite flows and rhyolite tuff reported as Oligocene by Hose and Blake (1976). These units, in turn, are conformably overlain by lacustrine limestone that grades upward and interfingers laterally with alluvial fan deposits of

Miocene age. The alluvial fan deposits contain varied clast types, attesting to uplift of surrounding ranges (Grier, 1983, 1984). Although clast composition and paleocurrents suggest that much of this conglomerate was derived from the southern Snake Range (Grier, 1984), quartzite and granite clasts derived from the Silver Creek drainage region are present in conglomerate exposures in the southeasternmost corner of the Old Mans Canyon Quadrangle, displaced to their present position by the normal faults that repeat the section in an eastward direction. Apatite fission-track ages on granitic and metamorphic clasts from the Tertiary conglomerates are middle Miocene in age and suggest that most, if not all, of the younger Tertiary conglomerates in the Sacramento Pass section are Miocene or younger.

Correlations of Upper and Lower Plate Rocks

Prior to Cenozoic faulting, Late Proterozoic to Paleozoic strata in the Old Mans Canyon Quadrangle formed part of a regionally extensive sequence of miogeoclinal strata deposited on the subsiding western continental shelf of North America (Gans and Miller, 1983). Formational designations, thicknesses, and regional facies variations have been described by Drewes and Palmer (1957), Whitebread (1969), Hose and Blake (1976), and Stewart (1980), among others (fig. 3), (not referenced below). In the Old Mans Canyon Quadrangle, Paleozoic rocks in the upper plate of the NSRD are complexly faulted, and most sections are incomplete. Exceptions include the intact section of Ordovician to Devonian strata in the southeastern most klippe of upper plate rocks in the quadrangle and a fairly intact section of Dunderberg Shale and conformably overlying Notch Peak Formation just to the northwest of this klippe. Similarly, Late Proterozoic and Lower Cambrian rocks in the lower plate of the NSRD are quite deformed and metamorphosed, and their present thicknesses are not representative of their original stratigraphic thicknesses. Description of the less metamorphosed and deformed counterparts of these units in the adjacent southern Snake Range can be found in Misch and Hazzard (1962) and in Miller and others (1993), where the rationale for a somewhat different nomenclature than that used by Misch and Hazzard (1962) is discussed.

At the scale of the northern Snake Range, unit designations and formational names occasionally vary. We have attempted to handle most of these in our legend of map units and stratigraphic column (fig. 3). Specifically, unit designations for Middle Cambrian units vary in different parts of the northern Snake Range so we have further clarified our unit designations and their equivalence in figure 6.

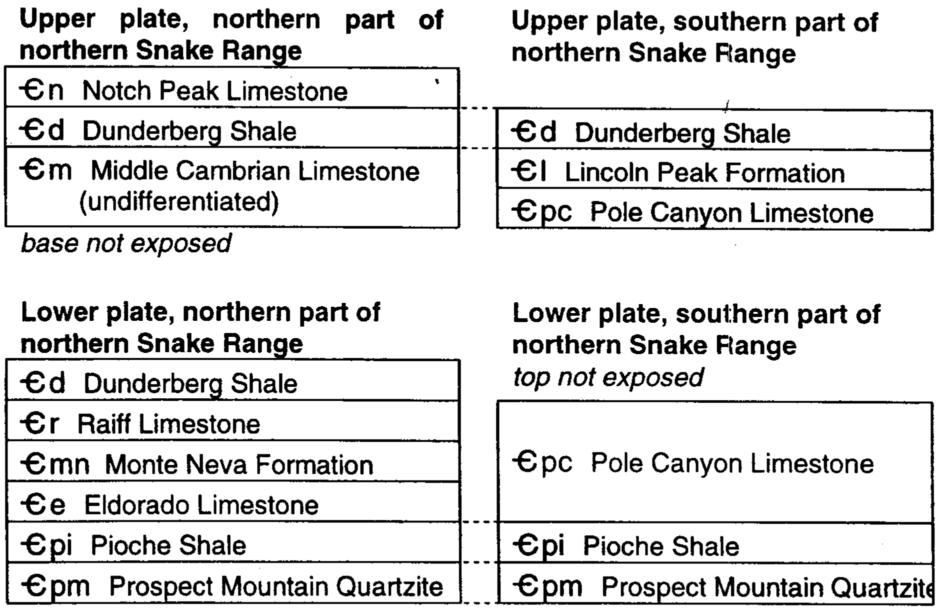

Figure 6. Stratigraphic nomenclature, unit designations, and correlations for Middle Cambrian upper and lower plate units across the northern Snake Range.

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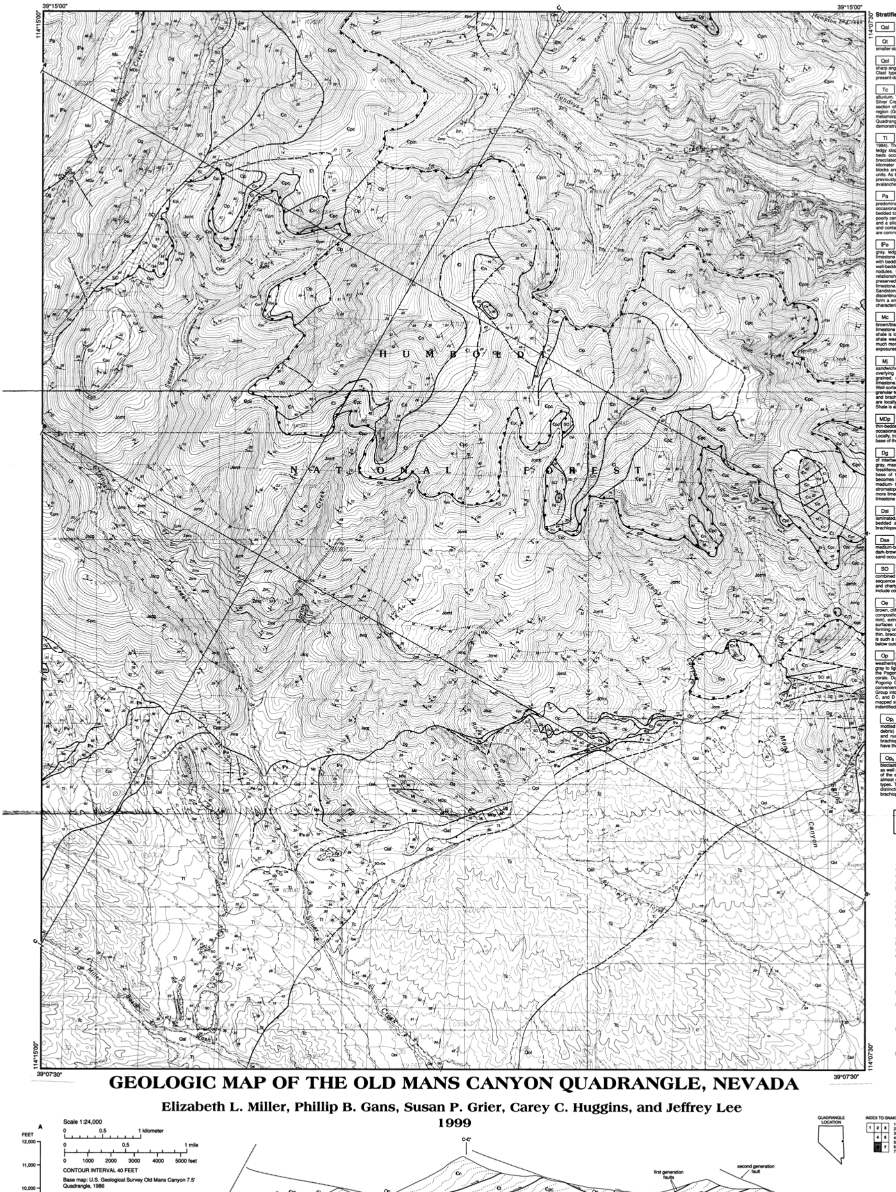

GEOLOGIC MAP OF THE OLD MANS CANYON QUADRANGLE, NEVADA

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1999

Stratified Rock Units

Qal **Quaternary alluvium** Generally unconsolidated sands and gravels deposited within modern drainage systems.

Qt **Quaternary talus** Locally derived, generally monolithologic, unconsolidated, matrix-free, angular and poorly sorted, boulder and smaller-size rock debris.

Qol **Quaternary older alluvium** Flat-lying consolidated to unconsolidated, alluvial fan, sand and gravel deposits that form pediment surfaces, rest in sharp angular discordance on older rocks, and are incised by present day drainages. Clast types and morphology of these deposits reflect derivation from the major present-day drainage systems developed in flanking mountain ranges.

Tc **Tertiary conglomerate** Tilted alluvial fan conglomerate, sandstone and lacustrine limestone and marl commonly overlapped or mantled by older alluvium. The unit is well exposed in Miller Wash drainage and on either side of the Silver Creek drainage along the southern flank of the range. A uniformly dipping section of conglomerate is at least 1,500 m thick as measured in the Miller Wash region (Grier, 1984). Fission-track analyses of apatite separated from granitic and metamorphic boulders in tilted conglomerate exposed in the Old Mans Canyon Quadrangle yield middle Miocene ages (Miller and others, 1989, 1990) demonstrating a middle Miocene or younger age for the encasing deposits.

Tl **Tertiary lacustrine limestone** Underlies and laterally interfingers with Tertiary conglomerate (Tc). The unit is described in detail by Grier (1983, 1984). The section is between 300 and 840 m thick and consists of yellow to tan ledgy slope-forming limestone interbedded with white, friable marl. Thin sandstone beds occur intermittently throughout the unit. Lensoidal masses and blocks of brecciated Paleozoic strata that range from tens of meters up to more than a kilometer in dimension occur mostly within the Tertiary lacustrine section. Some blocks are monolithologic, whereas others consist of several identifiable Paleozoic units. As they are encased within the Tertiary section, they are interpreted by us and previously by Hose and Whitebread (1981) to be displaced landslide masses or rock avalanche deposits.

Pa **Permian Arcturus Formation** Reported regional thickness for the Arcturus Formation is about 1,150 m. The Arcturus Formation is predominantly tan to white, slope-forming, fine-grained quartzose sandstone with occasional brown-gray, ledge-forming, fossiliferous, medium- to coarse-grained, thin bedded to massive limestone. The sandstone varies from moderately to well-sorted, poorly cemented quartzose sandstone, to poorly sorted, calcite-cemented sandstone and a silica-cemented orthoquartzite. The fraction of limestone increases upsection and contains diagnostic mollusks and hexagonal colonial corals. Black chert nodules are common.

ℙe **Pennsylvanian Ely Limestone** Reported regional thickness of the Ely Limestone is about 550 to 820 m. The Ely Limestone is tan-gray to brown-gray, ledge- to cliff-forming, bioclastic to fossiliferous, medium- to coarse-grained limestone that can be massive, thickly bedded (~1 m) or well bedded (1.0-4.0 cm), with bedding defined by silty partings. Some of the lower sections contain up to 50% well-bedded, generally black, but also white and reddish-brown, chert stringers and nodules. Chert also occurs in large irregular shaped patches with no apparent relationship with bedding. Fossils within the Ely Limestone include large, well-preserved brachiopods, crinoids, bryozoa, rugosan cup corals, and pelycepods. Silty limestone, silt interbeds, and sandstone lenses increase in abundance upsection. Sandstone lenses are composed of fine-grained quartzose sand and are discontinuous laterally on the order of meters to tens of meters. These lenses only form a small proportion (~15%) of the limestone and silty limestone section that is characteristic of the bulk of the Ely Limestone.

Mc **Mississippian Chainman Shale** Reported regional thickness of the Chainman Shale is about 210 to 610 m. The Chainman Shale is brown/black, slope-forming shale containing thin beds (0.5-1.5 cm thick) of tan limestone and limestone concretions around fossil shells. Outcrop is scarce, and the shale is identified by the distinctive chocolate-brown to black soil that forms as the shale weathers. An interval of reddish-weathering quartz sandstone beds that are much more resistant than the surrounding shales occurs within the Chainman Shale exposures in the Old Mans Canyon Quadrangle.

Mj **Mississippian Joana Limestone** The regional thickness reported for the Joana Limestone is about 120 m. The Joana Limestone is a resistant unit sandwiched between slope-forming shales of the underlying Pilot Shale and overlying Chainman Shale. The Joana Limestone is a medium-brown-gray, fine-grained, massive to poorly bedded, thin but prominent cliff-forming, bioclastic limestone. Bedding in the uppermost section is thick (0.5-1.5 m) to platy (2-8 cm). Well-sorted, coarse- to medium-grained fossil debris gives the limestone a distinctive granular texture. Occasional intact fossils include large corals, crinoids, pelecypods, and brachiopods. Black, reddish-brown and light-colored chert nodules and bands are locally found and usually define bedding. The contact with the underlying Pilot Shale is abrupt.

MDp **Mississippian-Devonian Pilot Shale** Regional thicknesses reported are 120 to 245 m. The Pilot Shale is dark gray-green to black, slope-forming, thin-bedded (2 mm to 2 cm thick) calcareous shale and siltstone. The shale contains occasional interbeds of platy, generally nonfossiliferous, fine-grained gray limestone. Locally, trace fossils and fossil hash can be found. Limestone interbeds occur at the base of the unit.

Dg **Devonian Guilmette Formation** The regional thickness reported for the Guilmette is about 760 m. The Guilmette Formation consists predominantly of interbedded limestones and dolomites. The base is generally light- to medium-gray, massive cliff-forming, micritic to very finely recrystallized, mottled, somewhat fossiliferous limestone. Fossils include gastropods, crinoids, and brachiopods. The base of this formation may contain solution collapse breccias. The formation becomes better bedded upwards where fine-grained gray limestone alternates with medium- to dark-brown coarser-grained dolomite. Fossils are abundant and include stromatoporoids, brachiopods, crinoids, gastropods, and corals. The top of the unit is more limestone rich, and the uppermost portion of this unit is highly burrowed, platy limestone that forms a gradational contact with the overlying Pilot Shale.

Dsi **Devonian Simonson Dolomite** Reported regional thickness is about 175 m. This unit consists of light- to dark-brown, thin- to medium-bedded, laminated, microcrystalline to coarsely crystalline dolomite. The basal part is thicker bedded and uniformly light brown. Fossils include gastropods, crinoids, and brachiopods.

Dse **Devonian Sevy Dolomite** Reported regional thickness is about 245 m. The Sevy consists of distinctive white-weathering, light-gray, thin- to medium-bedded, very fine-grained, nonfossiliferous, laminated dolomite. Diagnostic dark-brown-weathering stringers of well-rounded coarse to medium-grained quartz sand occur in the Sevy. This unit is also noted for its lack of fossils.

SO **Silurian Laketown and Ordovician Fish Haven Dolomites, undifferentiated (SO dolomite)** Regional reported thickness for the combined Fish Haven and Laketown Dolomites is about 460 m. The lower part of this sequence is medium- to dark-brown dolomite with some stromatolitic, fossiliferous and cherty intervals; the upper part is light-brown, coarse-grained dolomite. Fossils include colonial corals, rugose, tabulata, and stromatolites.

Oe **Ordovician Eureka Quartzite** Reported regional thickness for the Eureka Quartzite is about 135 m. The Eureka Quartzite is white to orange-brown, cliff- to ledge-forming, poorly but thick bedded (30-90 cm thick), texturally and compositionally mature orthoquartzite consisting of nearly 100% fine-grained (0.3-0.5 mm), extremely well-sorted and well-rounded, silica-cemented quartz grains. Fresh surfaces are white to vitreous, and weathered surfaces are irregular and pitted forming orange-brown, rounded outcrops. The Eureka Quartzite commonly occurs as thin, brecciated, fault-bounded slivers and is often smeared out along fault planes. It is such a resistant unit that large, hard boulders of quartzite are common on slopes below outcrops of the unit.

Op **Ordovician Pogonip Group (undifferentiated)** Regional thickness for the Pogonip Group is about 460 to 500 m. The Pogonip Group is yellow-weathering, ledge/slope- to slope-forming, well-bedded, fossiliferous, medium-blue-gray to light-blue-gray, silty limestone. A number of fossil types that are abundant in the Pogonip Group include brachiopods, ostracods, coiled nautiloids, and tabulate corals. Due to areal variations within the group, various authors have divided the Pogonip Group into different formations. In the northern Snake Range it is most convenient to follow the nomenclature of Fritz (1968), who divided the Pogonip Group into six units: A, B, C, D, Kanosh Shale, and Lehman Formation. Units A, B, C, and D were not distinguished in this quadrangle and the Pogonip Group was mapped simply as Op except where Kanosh Shale and Lehman Formation could be indentified.

Op$_l$ **Lehman Formation** The Lehman Formation is medium-blue-gray, ledge/slope-forming, thinly bedded (2-5 cm thick), fossiliferous, often mottled limestone with silty partings. This unit contains some fossiliferous (trilobite debris) flat-pebble conglomerates, some beds of horizontal trace fossil burrows and numerous death assemblages containing generally one type of organism; brachiopods, trilobites, bryozoa, ostracods or coiled nautiloids. This unit seems to have the highest faunal diversity of the Pogonip Group.

Op$_k$ **Kanosh Shale** The Kanosh Shale is yellowish-brown, slope-forming, thinly bedded, shaly to silty limestone with beds of dark-brown, coarsely bioclastic limestone containing phosphatic brachiopods and echinoderm spines(?), as well as the characteristic fauna of the Pogonip Group cited above. Near the top of the section are blue or brown-gray, micritic limestones that contain beds that almost entirely consist of brachiopods, ostracods, coiled nautiloids or other fossil types. The siltstone/shale beds are almost never seen in outcrop, rather form a distinctive brown, coarse primitive soil that can contain well-preserved brachiopods, a distinctive species of tabulate coral and other fossils.

See accompanying text for figures, references, and a discussion of the geologic setting, previous work, geology, and structural history of this quadrangle.

Contact Dashed where approximately located, dotted where concealed, queried where speculative; in cross section, short dashes within stratified units indicate bedding.

Normal fault Dashed where approximately located, dotted where concealed, queried where uncertain; ball on downthrown side; arrow shows trend and plunge of striations.

Northern Snake Range décollement Dashed where approximately located, dotted where concealed, queried where uncertain; squares on upper plate.

Limit of abundant pegmatite and aplite

Slide block Tics on slide block side

Surface trace of axial surface

Synform Antiform

Strike and dip of bedding

Inclined Vertical Overturned

Strike and dip of metamorphic foliation

Inclined

Showing trend and plunge of intersection/elongation lineation.

Ꞓn **Cambrian Notch Peak Limestone** Regional reported thickness is about 485 to 550 m. The Notch Peak Limestone is medium-gray, fine- to medium-grained, cliff- to ledge-forming, bedded (typically 1-6 cm, and as much as 30 cm, thick) cherty limestone. Typically the limestone contains 1 to 2 cm thick, rust- to brown-colored chert nodules in beds 2 to 4 cm apart, but variations include 2 to 3 cm thick nodular chert beds 2 to 3 cm apart, sporadic chert nodules in massive limestone, and massive to thinly bedded limestone without chert. Bedding, defined by silty interlayers, can be irregular to well developed. Brachiopods, gastropods, trilobites, crinoids, and stromatolites are common, and echinoids are scarce.

Ꞓu **Undifferentiated Cambrian carbonates**

Ꞓd **Cambrian Dunderberg Shale** Regional reported thickness for the Dunderberg is about 20 to 100 m. The Dunderberg is distinctive olive-gray to dark-brown fissile calcareous shale and siltstone. Coarsely clastic limestone with abundant trilobite hash occurs near the base.

Ꞓl **Cambrian Lincoln Peak Limestone** Regionally, the Lincoln Peak Limestone is about 1,220 to 1,370 m thick. The Lincoln Peak Limestone is medium- to dark-gray, thinly bedded, platy weathering, slope-forming silty limestone. Silty intervals and chert stringers weather distinctly brown. This unit contains sparse trilobite hash and oncolites. The Lincoln Peak is poorly exposed in the map area, forming forested slopes at the higher elevations.

Ꞓpc **Middle Cambrian Pole Canyon Limestone** Reported to be about 500 to 550 m thick regionally, the Pole Canyon Limestone is an alternating white, light-gray, to blue-gray to dark-gray, cliff-forming limestone with girvanella, fenestral, and oolitic horizons. The formation contains a number of thick (meters to tens of meters) silty intervals with discontinuous silty partings between thin dark-gray limestone beds. Some thinner intervals of shale are present as well. Where mappable, these are shown by a series of dotted lines within the formation boundaries. In the Old Mans Canyon Quadrangle, the Pole Canyon Limestone is metamorphosed to marble and calc-silicate-bearing rocks where it is intruded by Jurassic granitic rocks within the lower plate of the NSRD (northern Snake Range décollement). Spectacular mylonites with abundant isoclinal and sheath folds are developed in these marbles where they occur beneath the NSRD in the eastern part of the Old Mans Canyon Quadrangle. The Pole Canyon Limestone is also weakly deformed and variable metamorphosed where it occurs in an upper plate position. This is especially true of the lower parts of the section exposed above the NSRD in the southeastern part of the quadrangle.

Ꞓpi **Lower Cambrian Pioche Shale** The Pioche Shale forms an important lithologic transition between dominantly clastic Lower Cambrian and older strata and the overlying clastic-absent Middle Cambrian limestone section. In the map area, the Pioche occurs only in the lower plate, where it is highly deformed and metamorphosed to biotite- and muscovite-bearing psammite, schist and calc-silicate bearing rocks, obscuring original bedding and sedimentary structures. Its thickness is variable but generally less than 20 m. Contacts are gradational with the overlying Pole Canyon marbles and underlying Prospect Mountain Quartzite in many places. Regionally, the Pioche Shale consists of dark siltstone, sandy siltstone, and calcareous quartzite that is greenish-gray to khaki-colored, is mostly thin bedded, and is about 90 m thick in the southern Snake Range.

Ꞓpm **Lower Cambrian Prospect Mountain Quartzite** A complete section of the Prospect Mountain Quartzite is present in Hendry's Creek, where it lies in gradational contact below the Pioche Shale and above the Osceola Argillite, the uppermost unit of the Late Proterozoic McCoy Creek Group. The regional reported thickness of the Prospect Mountain Quartzite is about 1,525 m, but in upper Hendry's Creek the formation has been ductiley attenuated and is only about 200 m thick, about one-eighth of its original thickness. In the Silver Creek region, the Prospect Mountain Quartzite has been similarly thinned and is intruded by Jurassic granite, which is also deformed. In general, the flaggy, resistant quartzite beds of the Prospect Mountain Quartzite form impressive buff to reddish-brown cliffs. Because of the attenuation of individual beds, cross-beds, which are ubiquitous in undeformed equivalents, are difficult to see and are generally reduced to wispy black laminations parallel to the tectonic foliation in the rocks. Where visible, cross-beds are highly strained and often exhibit isoclinal and sheath folds. In hand specimen, the quartzite is white to gray to light brown, fine to medium grained, and consists of 90 to 95% quartz, 5% feldspar, and lesser muscovite, chlorite and opaque oxides. Coarse mica-rich partings occur between the flaggy quartzite layers. In thin section, the Prospect Mountain Quartzite is a quartzose mylonite; its quartz fabrics have been studied in some detail (Lee and others, 1987). The Prospect Mountain Quartzite is distinguished from similar quartzite units in the underlying McCoy Creek Group by its general lack of pebble conglomerates (but some thin horizons are present), lack of pelitic intervals, the greater abundance of cross-beds, and by its thinner and more regular flaggy bedding.

Late Proterozoic McCoy Creek Group

Zmo **Osceola Argillite** The Osceola Argillite is well exposed in the Hendry's Creek drainage, where its attenuated thickness is about 12 to 20 m. Upper and lower contacts with the Prospect Mountain Quartzite and McCoy Creek Group unit 2 are concordant and gradational. The Osceola Argillite is typically muscovite-rich, silvery-gray to gray-blue schist, which, depending on metamorphic grade, contains chlorite, biotite, cordierite, kyanite, garnet, and/or staurolite. Accessory minerals include ilmenite, hematite, tourmaline, apatite, epidote, zircon, and monazite (Huggins, 1990). It is distinguished from other schist units lower in the succession by its general absence of coarser clastic horizons and by its highly aluminous composition. In the Hendry's Creek drainage, the Osceola Argillite typically contains a greenschist-facies assemblage that includes muscovite, chlorite, and biotite. The Osceola Argillite in less metamorphosed and deformed sections in the southern Snake Range is about 200 m thick and consists of well-bedded to laminated slates and siltstone that are distinctively green to gray blue, although locally, maroon colors are common (Miller and others, 1993).

Zm$_1$ **Unit 1, quartzite** Lower plate exposures of McCoy Creek Group unit 1 in the Old Mans Canyon Quadrangle show considerable variation in composition and thickness. In the Silver Creek drainage, McCoy Creek Group unit 1 is a distinctive, thin, quartz pebble and cobble conglomerate similar in character to but more deformed than the closest correlative exposures in the southern Snake Range. To the north, in the Hendry's Creek drainage, McCoy Creek Group unit 1 is a 30- to 60-m-thick, resistant cliff former of grayish-white to buff, slightly feldspathic quartzite that weathers buff to orange. Thin conglomeratic horizons are present only at the top of the unit. In the southern Snake Range, McCoy Creek Group unit 1 varies in a similar fashion from a thin conglomeratic quartzite, no more than 30 m thick, in the north to a well-bedded quartzite 50 m or more in thickness in the southern part of the range (Miller and others, 1993).

Zm$_2$ **Unit 2, quartzite and schist** Quartzite and schist assigned to McCoy Creek Group unit 2 occur in the Silver Creek drainage and in the upper reaches of Hendry's Creek, where they consist of a thick succession (about 300 m) of alternating meter-thick intervals of light-gray to buff feldspathic quartzite and grit interbedded with coarse muscovite ± biotite ± garnet ± staurolite schist. Unit 2 rests in gradational but sharp contact above and beneath McCoy Creek Group units 3 and unit 1. Within the unit, a more quartzite-rich section is a conspicuous cliff-former, and its top and bottom within the unit are mapped by dotted lines. The position of McCoy Creek Group unit 2 within the section, its variable and more feldspathic composition, and its abundant horizons of grit make correlation with the unmetamorphosed successions in surrounding ranges straightforward. In less metamorphosed sections in the southern Snake Range, this unit is a brown-weathering, slope former with ledge to cliff-forming exposures of more feldspathic or quartz sand-rich intervals. The unit is distinguished from the Osceola Argillite by being more variable in composition and grain size and having abundant unsorted, quartzo-feldspathic grit-bearing horizons. It is a distinctive slope- or ledgy slope-former and lies in sharp and abrupt contact above the underlying massive cliff-forming quartzite of McCoy Creek Group unit 3.

Zm$_3$ **Unit 3 quartzite** In the upper reaches of Hendry's Creek, deformed and metamorphosed quartzite assigned to this unit is about 100 m thick. It is a massive white cliff former with flaggy bedding, distinguished from the younger Prospect Mountain Quartzite by its greater purity and thicker layering. In less metamorphosed sections in the southern Snake Range, this unit is massive, thick-bedded, cliff-forming quartzite with an abrupt and sharp upper contact with McCoy Creek Group unit 2. Cross-beds are less common than in the younger Prospect Mountain Quartzite and occasional quartz pebble stringers and horizons are present.

Zm$_4$ Zm$_5$ **Units 4 and 5 schist and quartzite** In Hendry's Creek, beneath the massive quartzite described above, is a schist unit about 100 m thick and a deeper quartzite unit about 100 m thick, whose base is not exposed. These two units are lithologically similar to Zm$_2$ and Zm$_3$ described above and do not have any features that clearly distinguish them from overlying parts of the succession. Because of this, they could be a repeated part of the succession. In the Hendry's Creek drainage, these are perhaps the deepest stratigraphic levels exposed and, in any case, were the most highly metamorphosed in both the Cretaceous and Tertiary metamorphic events. Schist of McCoy Creek Group unit 4 everywhere contains garnet and staurolite.

Zms Zmq **Zms (schist) and Zmq (quartzite)** Where the above units could not be identified with confidence, such as in the screen of metasedimentary rocks between two Jurassic plutons in the Silver Creek drainage of the Old Mans Canyon Quadrangle, the designations Zms and Zmq were used.

Intrusive Rocks

Trd **Tertiary rhyolite dikes and sills** Distinctive pale-colored, reddish-weathering aphanitic rhyolite dikes and sills sharply cut Tertiary mylonitic fabrics in the Jurassic granite in Silver Creek drainage. Flow banding and glassy margins are present in the dikes along their contacts with country rocks. Rare small quartz and biotite phenocrysts occur in a fine-grained groundmass of quartz and feldspar.

Jscg **Jurassic Silver Creek granite** Weakly foliated to gneissic, medium-to fine-grained grained biotite and muscovite-bearing granite with sparse equant potassium-feldspar phenocrysts 0.5 to 1.5 cm diameter. Based on crosscutting relations, inferred to be the youngest intrusive phase of the Jurassic plutonic complex exposed in the Old Mans Canyon Quadrangle. Pegmatite and aplite dikes that are muscovite- and occasionally garnet-bearing are persistently present in a 30-m-wide zone near the top of this pluton and intrude adjacent and overlying metasedimentary and granitic rocks. Their location and association with the upper contact of the Silver Creek granite indicates they are genetically associated with this pluton and are thus assigned a Jurassic age as well.

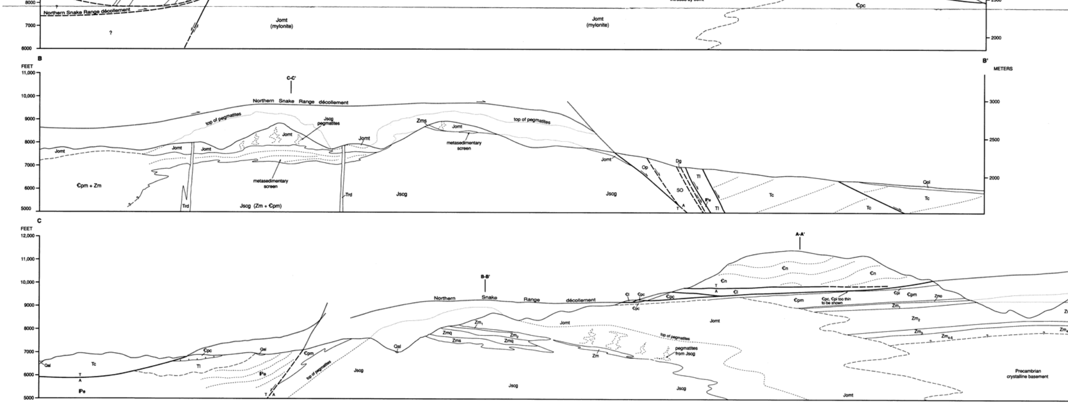
Jurassic Old Mans Pluton

Jom The Jurassic Old Mans pluton is a compositionally diverse suite of igneous rocks that range from diorite to granite. Most of the pluton is strongly gneissic, and mylonitic textures and fabrics are common. Strain is heterogeneous within the pluton; local zones of high strain are present, which include mylonite development. Deformation occurred at greenschist-facies conditions; chlorite and epidote are common retrograde minerals after biotite, hornblende, and plagioclase. Feldspars were deformed brittlely, and the degree of gneissic fabric development is compositionally controlled, with plagioclase- and hornblende-rich diorites having undergone the least penetrative strain. Based on limited crosscutting relations, it appears that hornblende-bearing phases of the pluton are the oldest and granitic sills and bodies the youngest. The composite Old Mans pluton is one of several similar bodies of Jurassic granitoid rocks in the Snake Range. The others occur in the Strawberry-Weaver Creek, Willard Creek, and Snake-Williams Creek regions of the southern Snake Range (McGrew and Miller, 1993; Miller and others, 1993). Several zircon fractions from three sites in the Old Mans pluton and from one site in the Silver Creek granite have been dated by the U-Pb method. The zircons have an older inherited component of Proterozoic age and also indicate young lead loss. All sites yield discordant ages which, together with field relations, collectively suggest intrusion of both the Silver Creek granite and the Old Mans composite pluton at about 155±5 Ma (J. E. Wright, unpub. data).

Jomg **Jurassic Old Mans granite** Lesser biotite granite occurs within the composite Old Mans pluton as dikes, sills, and smaller bodies in the eastern end of the pluton and along the contact with the Silver Creek granite in the Silver Creek drainage. Here, the biotite-bearing tonalite grades to a coarse-grained gneissic biotite granite as one approaches the western margin of the Old Mans pluton. Closer to the contact, muscovite and rare garnet are locally present. Pegmatite and aplite dikes along this contact may be in part border phases related to the Old Mans pluton or, as described above, more likely part of the border phase of the younger Silver Creek granite.

Jomt **Jurassic Old Mans tonalite** Tonalite forms the main portion of the Old Mans pluton. It is a dark brown-weathering rock that forms the dark slopes beneath the décollement along the southern flank of the range. The tonalite is coarse-grained with a strongly gneissic to mylonitic fabric, and contains approximately 20 to 30% quartz, 40 to 50% plagioclase, 20 to 30% biotite and little or no potassium-feldspar. Potassium-feldspar phenocrysts are present in patchy areas throughout the tonalite, where they are square to tabular in shape and several centimeters in size. Accessory minerals include abundant epidote, sphene, and allanite, and lesser apatite and zircon.

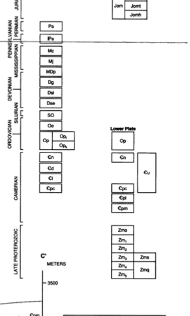
Jomh **Jurassic Old Mans hornblende-bearing diorite** Hornblende-bearing tonalite and diorite are present in the eastern part of the plutonic complex. Hornblende-bearing phases of the Old Mans tonalite are gradational with biotite-bearing tonalite; more mafic hornblende diorite is commonly present as inclusions in tonalite, suggesting that it is the earliest phase of the pluton. The hornblende diorite is often coarse grained and little deformed, contains variable amounts of plagioclase, and hornblende, and lesser biotite with accessory epidote, sphene, allanite, apatite, and zircon.



Scale 1:24,000

CONTOUR INTERVAL 40 FEET

Base map: U.S. Geological Survey Old Mans Canyon 7.5' Quadrangle, 1986



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