U. S. Department of the Interior

U. S. Geological Survey

Geologic Map of Kious Spring and Garrison 7.5' Quadrangles, White Pine County, Nevada and Millard County, Utah

By Allen J. McGrew[1] and Elizabeth L. Miller

Department of Geological and Environmental Sciences, Stanford University. Stanford, CA 94305-2115

Compiled by Janet L. Brown, U.S. Geological Survey, Denver, CO 80225-0046

Open-File Report 95-10

Prepared in cooperation with the U.S. National Park Service

This report was prepared under an interagency agreement between the U.S. Geological Survey and the U. S. National Park Service. This report is preliminary and has not been reviewed for conformity with the U.S. Geological Survey editorial standards (or with the North American Stratigraphic Code). Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

[1]Now at: Geologisches Institut ETH-Zentrum CH-8092 Zurich, Switzerland

1995

INTRODUCTION

The Snake Range is located in White Pine County, east-central Nevada, in the northern Basin and Range Province. Sacramento Pass separates the range into two main parts, the northern and the southern Snake Range (fig. 1). The Kious Spring quadrangle, Nevada, and the adjacent Garrison quadrangle, Utah-Nevada, cover part of the eastern flank of the southern Snake Range. The Kious Spring quadrangle is one of six 7.5' quadrangles covering the Great Basin National Park (fig. 1).

The Great Basin National Park was established to help preserve the unique geology, human history, and plant and animal communities that characterize this part of the Great Basin region. The park includes Wheeler Peak (in the adjacent Wheeler Peak 7.5' quadrangle to the west) which at 13,063 ft. (3981.6 m), is the highest peak in the park and the second highest peak in the state of Nevada. In 1964, the world's oldest known living trees, the Great Basin bristlecone pine (*Pinus longaeva*) estimated to be about 4,950 years old, were discoved below Wheeler Peak.

GEOLOGIC SETTING

The southern Snake Range forms a broad, north-trending anticlinorium that exposes the lower part of the late Precambrian to Paleozoic miogeoclinal shelf succession of the Great Basin. This anticlinorium is bounded by the Butte synclinorium to the west and by the Confusion Range structural trough (CRST) exposed in the Burbank Hills to the east (fig. 2). Southern Snake Valley, a narrow (8 km wide) basin, separates the southern Snake Range from the relatively simple structure and well-known stratigraphy of the Burbank Hills in the adjacent Garrison quadrangle (fig. 2; Hintze, 1960; Anderson, 1983).

The southern Snake Range was previously mapped at a scale of 1:48,000 by Whitebread (1969) who also provided a fairly detailed description of most of the stratified rocks in the quadrangle. Plutonic rocks in the area have been extensively dated and investigated (D. Lee and others, 1968, 1970, 1981, 1982, 1984, and 1986a,b; Lee and Van Loenen, 1971; Lee and Christiansen, 1983a,b; Miller and others, 1988). Much of the information presented below summarizes results presented more comprehensively in McGrew (1986, 1993) augmented by unpublished data collected by the Stanford Geological Survey (Stanford University's geology summer field program) under the direction of E.L. Miller in 1984 and in later years by Miller.

STRUCTURE

The dominant structural feature of the Kious Spring quadrangle and adjacent Garrison quadrangle is a regionally extensive detachment fault known as the southern Snake Range decollement (SSRD) which was first named and described by Misch (1960). On average, this fault dips 10 to 15 degrees eastward, but like many low-angle detachment faults in the Basin and Range Province, it is warped by gentle map-scale folds or corrugations plunging approximately parallel to the inferred movement direction along this fault (in this case, approximately east-west). The upper plate of the SSRD exposes a severely attenuated, normal-fault bounded mosaic of various non-metamorphosed to slightly metamorphosed sedimentary rocks representing parts of the Paleozoic miogeoclinal carbonate sequence and portions of an overlying Tertiary sequence of conglomerate and lesser sandstone, marl and tuffaceous marl. The lower plate of the SSRD exposes a thick sequence of deformed and metamorphosed latest Precambrian to Middle Cambrian age quartzite and schist overlain by a thin horizon of white marble mylonite, representing the Prospect Mountain Quartzite, the Pioche Shale and the base of the Pole Canyon Limestone, respectively. Three plutons of Late Jurassic, Late Cretaceous, and Early Oligocene age intrude these strata (Plate I). Metamorphic and geochronologic data for the Kious Spring quadrangle and portions of the Garrison and Wheeler Peak quadrangles were summarized by McGrew (1993, fig. 3). Selected structural data collected from the Kious Spring quadrangle were also summarized by McGrew (1986, Plate III).

The position of the Snake Range in the hinterland of the Cretaceous-age Sevier orogenic belt (fig. 2) led earlier workers to relate the low-angle "decollement faulting" in the southern Snake Range to thin-skinned thrust faulting further east (Misch, 1960; Miller, 1966; Hose and Danes, 1973; Hintze, 1978), and this interpretation was adopted by Whitebread (1969) in his more detailed mapping of the area. However, as discussed in more detail by McGrew (1986, 1993), cross-cutting relationships with the Oligocene Young Canyon-Kious Basin pluton (Miller and others, 1988) and with strata as young as Miocene in age now document a Tertiary age for the southern Snake Range decollement. Reconstruction of the southern Snake Range extensional deformational system and the SSRD is illustrated by McGrew (1993) in a sequence of retrodeformed regional cross-sections.

Deformational and intrusive history of the SSRD lower plate rocks

Through most of the Kious Spring quadrangle, Tertiary extensional deformation largely obscures evidence for earlier deformation within the lower plate rocks of the SSRD, but in the Wheeler Peak quadrangle to the west and in the Windy Peak quadrangle to the northwest, pre-extensional metamorphic fabrics are well preserved (Miller and others, 1988,1994). Here, the oldest deformational fabric is a penetrative cleavage (S_1) that is gently inclined eastward with respect to bedding and forms north-trending intersection lineations (L_{0x1}) with bedding. Miller and others (1988) suggest that this deformation broadly coincided with Jurassic pluton emplacement, because the fabrics are selectively developed, with the largest strains occurring adjacent to large Jurassic plutons. In the Kious Spring quadrangle and adjacent Wheeler Peak quadrangle, andalusite and altered pseudomorphs of staurolite occur in the contact aureole of one such pluton, the Jurassic (160 Ma) Snake Creek -Williams Canyon pluton. Thin section studies indicate that contact metamorphic porphyroblasts grew synchronously with and overprint this cleavage, but adjacent to the pluton, hornfels textures locally obliterate it.

In contrast to the Jurassic relationships, the emplacement of the Cretaceous Pole Canyon-Can Young Canyon pluton in the northwestern Kious Spring quadrangle produced minimal contact metamorphic effects, except for the retrogression of Jurassic andalusite porphyroblasts to sericitic mats and growth of new chlorite in the immediate contact aureole of the pluton. Overprinting the penetrative S_1 cleavage is a weak, sporadically developed S_2 crenulation fabric. The L_{1x2} intersection lineation trends consistently northwestward throughout the map area, but bedding to cleavage angles and dip directions of S_2 vary. At thin section scale, the S_2 cleavage cuts and rotates chlorite porphyroblasts that grew during the 160 Ma metamorphic event, thus placing an upper bound on the age of deformation. In contrast, andalusite porphyroblasts that grew in the contact aureole of the 36 Ma Young Canyon- Kious Basin pluton statically overprint and therefore post-date the S_2 cleavage. Consequently, the timing of S_2 deformation is broadly bracketed between 160 Ma and 36 Ma in the southern Snake Range, although Miller and others (1988) argue on the basis of regional relationships that S_2 fabric development probably broadly coincided with Cretaceous plutonism in this region.

In the Kious Spring quadrangle the lower plate Prospect Mountain Quartzite, Pioche Shale and Pole Canyon Limestone were penetratively deformed and visibly foliated and lineated during the Tertiary. In many respects, the orientation and character of deformational fabrics developed in lower plate quartzite units resemble mylonitic fabrics widely developed in the northern Snake Range (Miller and others, 1983; Gans and Miller, 1983; Lee and others, 1987), but the extent and intensity of mylonitic deformation are much lower in the southern Snake Range than farther north. The tectonic foliation in these rocks (defined by the preferred orientation of deformed quartz grains and micas) is oriented perceptibly parallel to bedding and to the SSRD, and on this foliation a mineral elongation lineation is developed, oriented a little south of east. Like the SSRD itself, lower plate bedding and foliation are gently folded about an axis essentially parallel to this lineation.

The rarity of strain markers hinders rigorous assessment of finite strains in these rocks but thinning of bedding in the Prospect Mountain Quartzite and a decrease in the thickness of the Pioche Shale eastwards across the map area has been noted (McGrew, 1986, 1993). The fact that this youngest deformation overprints fabrics of possible Late Cretaceous age and appears to affect the Tertiary Young Canyon - Kious Basin pluton suggests a Cenozoic age.

The final stage of plutonism in the southern Snake Range involved emplacement of the Young Canyon - Kious Basin pluton in the northeastern part of the map area. A 36 $\pm$ 1 Ma U-Pb zircon age (Miller and others, 1988) and a 37.4 $\pm$ 1.5 Ma Rb-Sr whole rock isochron (Lee and others, 1986b) constrain the age of this intrusion. Garnet, poikiloblastic andalusite, and biotite aggregates forming pseudomorphs after earlier chlorite porphyroblasts characterize peak metamorphism in the immediate contact aureole of this pluton, and these assemblages statically overprint earlier deformational fabrics.

Faulting in the SSRD Upper Plate

Overprinting and locally obscuring the earlier deformational history outlined above is the major extensional deformational event that is largely responsible for the present-day structural configuration of the Kious Spring quadrangle, including the most prominent structure of the range, the southern Snake Range dÇcollement (SSRD). Several lines of evidence indicate an Oligocene to Miocene age for the SSRD and the normal faults in the upper plate. Most significantly, the SSRD either cuts or merges with upper plate normal faults that themselves cut and offset probable Miocene age strata.

Upper plate rocks are little metamorphosed and have deformed primarily by brittle rather than ductile processes. Within the map area, the upper plate consists of a thick sequence of Paleozoic miogeoclinal carbonate rocks and coarse-grained Tertiary clastic deposits. A complex fault mosaic of these lithologies is exposed in a shallow structural trough in the SSRD south of the Young Canyon Pluton (Plates I and II). Here, the upper plate section has been severely attenuated by a closely spaced system of mostly NNW trending low to moderate angle normal faults. Cross-section A-A' shows that these faults resolve into at least two oppositely dipping sets of faults. The older group of faults now dips 15 to 30 degrees west or southwest and is spaced at intervals averaging less than about 0.5 km. The second set of faults trend north-south, are more widely spaced, and dip eastward at apparently moderate angles. Palinspastic reconstruction of the upper plate is possible, but should not be considered precise because cutoffs are generally lacking and many fault geometries are poorly constrained in this very complicated area. Nevertheless, it seems likely that at least a few hundred per cent extension has occurred across the map area, as suggested by the restorations presented in McGrew (1986).

The dips of upper plate rocks are frequently erratic and are difficult to correlate directly to fault block rotations. Several factors may have contributed to this, including pre-extensional variability in bedding dips, complex boundary conditions along the SSRD, and opposite-sense rotations imposed by fault sets that dip in opposite directions and are slightly askew to each other. Nonetheless, careful inspection of the map and cross-sections suggests that fault blocks containing parts of the Ordovician-Silurian dolomite section (OS) most accurately record the fault block rotations experienced during the first episode of faulting, i.e. about 30 degrees to the east.

The fault block rotations characterizing the second episode of normal faulting may be best approximated by the rotation of the basal Tertiary unconformity. A small inlier of Tertiary rocks that is poorly exposed overlying the Devonian Guilmette Formation (Dg) in the central part of the map area crudely suggests that the Tertiary unconformity was rotated moderately to the west. The best exposures of Tertiary rocks occur along the east flank of the range where they dip on the average 20 to 40 degrees west (Plate I).

The range-front fault that juxtaposes these deposits against the older rocks in the range is poorly exposed, and it is not clear from field or map relations whether it cuts the SSRD or soles into it. McGrew (1986, 1993) has argued that the range-front fault represents one of the second generation east-dipping normal faults discussed above and that it, like these other parallel faults, might sole into the SSRD at depth. However, the clast composition of these conglomerates and the apatite fission track ages from clasts indicate that the fault bounding these deposits must postdate motion along the portion of the SSRD exposed in the range as clasts in the conglomerates are derived from both upper and lower plate lithologies. Thus it seems likely that this bounding fault cuts the SSRD in the subsurface,but the possibility remains that this younger fault may actually merge with it at depth. In any event, the relatively intact Tertiary section presents a stark contrast to the complexly faulted mosaic of Paleozoic rocks exposed to the west, suggesting that these sediments are indeed younger than most, if not all of the upper plate faulting seen in the range.

STRATIGRAPHY

Late Precambrian to Paleozoic strata form part of a regionally extensive sequence of miogeoclinal strata deposited on the subsiding western continental shelf of North America. 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. In the Kious Spring quadrangle, Paleozoic rocks in the upper plate of the SSRD are cut by two or more sets of normal faults. Most stratigraphic sections in the map area are incomplete because of this faulting, but the stratigraphy of these fault-bounded, partial sections is correlative to equivalent parts of the more intact successions in the Burbank Hills and Confusion Range to the east (see fig. 2). Similarly, Late Precambrian and Early Cambrian rocks in the lower plate of the SSRD are quite deformed and metamorphosed in the Kious Spring quadrangle, thus their present thicknesses are not representative of their original stratigraphic thicknesses. However, these same units can be mapped westward and northwestward into the Wheeler Peak and Windy Peak quadrangles (see fig. 1) where they form a less deformed, intact stratigraphic succession that ranges in age from the late Precambrian to the Middle Cambrian (Miller and others, 1994).

Faulted and tilted Tertiary alluvial fan deposits are exposed in the Kious Spring and Garrison quadrangles (Plates I and II) and are inferred to be present in the near subsurface across a large portion of the Garrison quadrangle. Most of these deposits occur along the eastern flank of the range where they are in low to moderate angle fault contact with bedrock lithologies of the southern Snake Range. However, patches of similar conglomerate occur in several upper plate fault blocks, where they are bounded by the youngest (east-dipping) set of upper plate faults (Plates I and II). Where contacts can be argued to be stratigraphic rather than faults, Tertiary strata appear to consistently overlie the Devonian Guilmette Formation. Based on the attitude of overlying Tertiary strata compared to the attitude of beds in the underlying Guilmette Formation, this contact can be further argued to be an angular unconformity (Plate I). Several indirect constraints exist on the age of the Tertiary conglomerates in the map area. Rare clasts of volcanic rocks derived from the erosion of the 30.6 Ma and 29.5 Ma Cottonwood Wash and Wah Wah Springs members of the Needles Range Formation (Best and others, 1989) are present in the conglomerate exposures along Big Wash. Fission track analyses of apatite separated from granitic boulders in conglomerate exposed east of the mouth of Snake Creek yield ages of 16 ± 3 Ma (2 sigma error) providing a maximum age limit of mid-Miocene for these conglomerates (Miller, Gans and Brown, unpublished data). The conglomerates themselves attest to important structural relief developed during Miocene and younger Basin and Range faulting. Conglomerates at the mouth of Snake Creek contain abundant clasts of both upper and lower plate rocks, suggesting that the faults that controlled the development of the Miocene basin must have been younger than the SSRD, in order for erosion to have incised into lower plate rocks.

ACKNOWLEDGEMENTS

This Open-File map results from the 1992 collaboration of the U.S. Geological Survey, the U.S. National Park Service, Stanford University, and University of California at Santa Barbara. We gratefully acknowledge research funding from the U.S. National Park Service through an Interagency Agreement with the U.S. Geological Survey to support geologic mapping for Great Basin National Park, Nevada. Janet L. Brown of the U.S. Geological Survey formulated the collaborative Interagency Agreement and the effort to complete and publish these geologic maps. We owe thanks to Albert J. Hendricks, Superintendent, Great Basin National Park, Vidal Davila, Acting Chief Ranger, and Kurt S. Pfaff, Ranger and Geologist for their expertise and support.

Geologic mapping of the northern and southern Snake Ranges at a scale of 1:24,000 began in 1981 by the "Stanford Geological Survey", Stanford University's Geology Summer Field program, which was taught in this general region by Elizabeth L. Miller and Phillip B. Gans until 1987. We are grateful to Stanford University's School of Earth Sciences and to the Sohio Petroleum Company for financial support of this program. We also thank all of the undergraduate students and graduate student teaching assistants who energetically and enthusiastically contributed to the making of the preliminary geologic maps of the region over these six years.

Additional geologic mapping and studies in the Kious Spring and Garrison quadrangles were carried out in 1985 by Allen McGrew as part of MS thesis work at Stanford University. These investigations were supported by ARCO, SOHIO and NSF EAR 8418678 awarded to Miller. Additional work in these two quadrangles was carried out by Miller supported by NSF Grant EAR-T2-06399, EAR8418678 and EAR8804814 awarded to Miller at Stanford University. Final compilation and field checking were carried out in 1992 under the project described below.

REFERENCES CITED

Anderson, R.E., 1983, Cenozoic structural history of selected areas in the eastern Great Basin, Nevada-Utah: U.S. Geological Survey Open-File Report, 83-504, 47 p.

Best, M.G., Christiansen, E.H., and Blank, H.R., 1989, Oligocene calc-alkaline rocks of Indian Peak volcanic field, Nevada and Utah: Geological Society of America Bulletin, v. 101, p. 1076-1090.

Drewes, H. and Palmer, A.R., 1957, Cambrian rocks of the southern Snake Range, Nevada: American Association of Petroleum Geologists Bulletin, v. 41, p. 104-120.

Gans, P.B., and Miller, E.L., 1983, Style of mid-Tertiary extension in east-central Nevada, in Geologic Excursions in the Overthrust Belt and Metamorphic Core Complexes of the Intermountain Region, Nevada, *in* Geological Society of America Guidebook Part 1: Utah Geological and Mineral Survey Special Studies 59, p. 107-160.

Hintze, L.F., 1960, Geology of the Burbank, Tunnel Spring and northern Needle Ranges, Millard and Beaver Counties, Utah: Brigham Young University Geology Department, Salt Lake City, Utah, scale 1:48,000.

Hintze, L.F., 1978, Sevier orogenic attenuation faulting in the Fish Springs and House Ranges, western Utah: Brigham Young University Geological Studies, v. 25, pt. 1, p. 11-24.

Hose, R.K., and Blake, M.C., Jr., 1976, Geology and mineral resources of White Pine County, Nevada--Part 1, Geology: Nevada Bureau of Mines and Geology Bulletin 85, p. 1-35.

Hose, R.K., and Danes, Z.E., 1973, Development of late Mesozoic to early Cenozoic structures of the eastern Great Basin, *in* Gravity and Tectonics, K.A. De Jong and R. Scholten, eds., John Wiley, New York, p. 429-441.

Lee, D.E., and Christiansen, E.H., 1983a, The mineralogy of the Snake Creek - Williams Canyon pluton, southern Snake Range, Nevada: U.S. Geological Survey Open-File Report 83-337, 21 p.

Lee, D.E., and Christiansen, E.H., 1983b, The granite problem in the southern Snake Range, Nevada: Contributions to Mineralogy and Petrology, v. 83, p. 99-116.

Lee, D.E., Friedman, I., and Gleason, J.D., 1982, The oxygen isotope composition of granitoid and sedimentary rocks of the southern Snake Range, Nevada: Contributions to Mineralogy and Petrology, v. 79, p. 150-158.

Lee, D.E., Friedman, I, and Gleason, J.D., 1984, Modification of delta D values in eastern Nevada granitoid rocks spatially related to thrust faults: Contributions to Mineralogy and Petrology, v. 88, p. 288-298.

Lee, D.E., Kistler, R.W., and Robinson, A.C., 1986b, The strontium isotope composition of granitoid rocks from the southern Snake Range, Nevada, *in* Shorter Contributions to Isotope Research, Z.E. Peterman and D.C. Schnabel, eds.: U.S. Geological Survey Bulletin B1622, p. 171-179.

Lee, D.E., and Van Loenen, R.E., 1971, Hybrid granitoid rocks of the southern Snake Range, Nevada: U.S. Geological Survey Professional Paper 68, p. 1-46.

Lee, D.E., Marvin, R.F., Stern, T.W., and Peterman, Z.E., 1970, Modification of K-Ar ages by Tertiary thrusting in the Snake Range, White Pine County, Nevada: U.S. Geological Survey Professional Paper 700-D, p. D92-D102.

Lee, D.E., Stacey, J.S., and Fischer, L., 1986a, Muscovite phenocrystic two mica granites of northeastern Nevada are Late Cretaceous in age, *in* Shorter Contributions to Isotope Research, Z.E. Peterman and D.C. Schnabel, eds.: U.S. Geological Survey Bulletin B1622, p. 31-39.

Lee, D.E., Stern, T.W., Mays, R.W., and Van Loenen, R.E., 1968, Accessory zircon from granitoid rocks of the Mt. Wheeler Mine area, Nevada: U.S. Geological Survey Professional Paper 600-D, p. D197-D203.

Lee, D.E., Stern, T.W., and Marvin, R.F., 1981, U-Th-Pb isotopic ages of zircon from the southern Snake Range, Nevada: Isochron West, v. 31, p. 25.

Lee, J., Miller, E.L., and Sutter, J.F., 1987, Ductile strain and metamorphism in an extensional tectonic setting--A case study from the northern Snake Range, Nevada, U.S.A., *in* Continental Extensional Tectonics, M.P. Coward et al., eds., Geological Society of London Special Publication 28, p. 267-298.

Lee, J., and Sutter, J.F., 1991, Incremental $^{40}Ar/^{39}Ar$ thermochronology of mylonitic rocks from the northern Snake Range, Nevada: Tectonics, v. 10, p. 77-100.

McGrew, A.J., 1986, Deformational history of the southern Snake Range, Nevada, and the origin of the southern Snake Range dÇcollement: M.S. thesis, Stanford Univ., Stanford, Calif., 46 p.

McGrew, A.J., 1993, The origin and evolution of the southern Snake Range decollement, east-central Nevada: Tectonics, v. 12, p. 21-34.

Miller, C.F. and Bradfish, L.J., 1980, An inner Cordilleran belt of muscovite-bearing plutons: Geology, v. 8, p. 412-416.

Miller, E.L. and Gans, P.B., 1989, Cretaceous crustal structure and metamorphism in the hinterland of the Sevier thrust belt, western U.S. Cordillera: Geology, v. 17, p. 59-62.

Miller, E.L., Gans, P.B., and Garing, J., 1983, The Snake Range dÇcollement--An exhumed mid-Tertiary ductile-brittle transition: Tectonics, v. 2, p. 239-263.

Miller, E.L., Gans, P.B., and Grier, S.P., 1994, Geologic Map of Windy Peak quadrangle, White Pine County, Nevada: U.S. Geological Survey Open-File Report 94-687, scale 1:24,000.

Miller, E.L., Gans, P.B., Wright, J.E., and Sutter, J.F., 1988, Metamorphic history of the east-central Basin and Range province--Tectonic setting and relationship to magmatism, *in* W.G. Ernst, ed., Metamorphism and Crustal Evolution of the Western United States: Rubey Volume VII, p. 649-682.

Miller, G.M., 1966, Structure and stratigraphy of the southern part of the Wah Wah Mountains southwest Utah: American Association of Petroleum Geologists Bulletin, v. 50, p. 858-900.

Misch, P., 1960, Regional structural reconnaissance in central-northeast Nevada and some adjacent areas: observations and interpretations, *in* Guidebook to the Geology of East-central Nevada: Intermountain Association of Petroleum Geologists and Eastern Nevada Geological Society, 11th Annual Field Conference, Salt Lake City, Utah, p. 17-42.

Stewart, J. H., 1980, Geology of Nevada--A discussion to accompany the Geologic Map of Nevada: Nevada Bureau of Mines and Geology Special Publication 4, 136 p.

Whitebread, D.H., 1969, Geologic Map of the Wheeler Peak and Garrison Quadrangles, Nevada and Utah: U.S. Geological Survey Miscellaneous Field Studies Map I-578, scale 1:48,000.

Wright, J.E., and Wooden, J.L., 1991, New Sr, Nd, and Pb isotopic data from plutons in the northern Great Basin--Implications for crustal structure and granite petrogenesis in the hinterland of the Sevier thrust belt: Geology, v. 19, p. 457-460.

Figure 1. Index map showing simplified geology of part of the Snake Range, outline of Great Basin National Park, and names and locations of 7.5' topographic quadrangles in the Southern Snake Range. The simplified geologic map emphasizes the distribution of variably metamorphosed upper Precambrian-Cambrian miogeoclinal strata and the various age plutons that intrude these rocks. Geologic base map modified after Miller and others (1988).

Figure 2. Regional geologic setting of the Snake Range showing its location with respect to surrounding geology and structural features.

Plate I. Geologic map of the Kious Spring quadrangle, Nevada.

Plate II. Geologic map of the Garrison quadrangle, Utah.

Plate III. Geologic cross-section across the Kious Spring and Garrison quadrangles.

DESCRIPTION OF MAP UNITS

Qa Alluvium (Quaternary)--Generally unconsolidated sands and gravels deposited within modern drainage systems

Qao Alluvium (older Quaternary)--Flat-lying consolidated to unconsolidated alluvial-fan sand and gravel deposits which form pediment surfaces along the eastern flank of the Snake Range. Also includes talus and slope wash in higher and steeper areas. Rest in sharp angular discordance above older rocks and are incised by present-day drainage systems. Clast types and morphology of these deposits indicate they are derived or sourced from the major present-day drainage systems developed in flanking mountain ranges. Good exposures of Qao and the basal unconformity beneath these deposits are to be found along the cliffs in Big Wash

Tc Conglomerate (Tertiary)--Alluvial-fan conglomerates, gravels, sands, and lesser marls and tuffaceous marls. Tilted alluvial-fan deposits are well-exposed in Big Wash drainage and east of the mouth of Snake Creek; elsewhere poorly exposed, forming gray hills, often overlapped or mantled by older alluvium (Qao). In Big Wash an apparently unfaulted, uniformly SW-dipping section of conglomerate in fault contact with older rocks is at least 1360 m thick. Blocks of internally brecciated Paleozoic strata that range from tens of meters up to 0.7 km in dimension occur within the conglomerate. Some blocks are monolithologic while others consist of several identifiable Paleozoic units. As they are encased within the Tertiary section, they are interpreted by us, and previously by Whitebread (1969), to be displaced masses or gravity slide blocks. Tertiary conglomerate overlies Devonian Guilmette Formation along an angular unconformity and contains occasional clasts derived from the erosion of the 30.6 Ma and 29.5 Ma Cottonwood Wash and Wah Wah Springs members of the Needles Range Formation (Best and others, 1989). Fission track analyses of apatite separated from granitic boulders in tilted conglomerate exposed east of the mouth of Snake Creek yield ages of approximately 16$\pm$3 Ma (2 sigma error) Ma (Miller, Gans and Brown, unpublished data), providing an even younger age limit for the conglomerates

Trdi Rhyolite dikes (Tertiary)--Rare altered dikes occur in the Kious Spring quadrangle; one of these cuts upper plate normal faults north of Snake Creek. Fine-grained, composed of phenocrysts of quartz and altered feldspar up to 4 mm diameter in an aphanitic groundmass

Tmp Muscovite porphyry (Tertiary)--A mucovite quartz-porphyry sill containing distinctive euhedral muscovite phenocrysts up to 3mm across, is exposed on either side of the North Fork of Big Wash where it intrudes the Lincoln Peak Formation. Phenocrysts of quartz, alkali feldspar, plagioclase, muscovite and trace biotite compose 5-10% of the rock. Groundmass is light colored and aphanitic. The sill dips moderately southward parallel to layering in the Lincoln Peak Formation and Pole Canyon Limestone. It has not been directly dated. Although Lee and others (1986b) argue that granites with phenocrystic muscovite in east-central Nevada are probably all Late Cretaceous in age, virtually identical muscovite phenocrystic dikes and sills in the Windy Peak quadrangle have been dated as Oligocene (Miller and others, 1994)

TMzg Granite (Tertiary or Mesozoic)--Coarse-grained, leucocratic, muscovite- and biotite-bearing granite. May originate from the Tertiary (36 Ma) Young Canyon pluton exposed to the south (Miller and others,1988). Designated Mesozoic in undated granite bodies. In the Windy Peak quadrangle, the granite forms a sill-like body just west of Lehman Caves

Tg Granite (Tertiary)--The Young Canyon-Kious Basin pluton crops out in the northeastern portion of the Kious Spring quadrangle and is the youngest of the three major intrusions. U-Pb analysis of two zircon size fractions from this pluton defines a chord whose lower intercept with concordia yields an age of 36 $\pm$ 1 Ma (Miller and others, 1988). In addition, a 37 Ma Rb-Sr whole rock isochron (Lee and others, 1986b) and K-Ar muscovite ages as old as 31 Ma (recalculated from Lee and others, 1970) have been obtained on this pluton. Although a substantial amount of isotope work has been conducted (Lee and others, 1970,1984; Wright and Wooden, 1991), previous work does not satisfactorily establish the extent and cross-cutting relationships of the plutonic rocks in this area. The map unit designated **Tg** is applied to undifferentiated Tertiary granite. In the Young Canyon-Kious Basin area on the north side of the pluton, the main phase of the pluton, designated **Tg_m**, is a medium-grained equigranular granite containing 5-8% biotite, no primary muscovite, and sphene as a locally abundant accessory mineral. This granite grades through a thin transition zone designated **Tg_t**, to an aplite granite designated **Tg_a**. In the transition-zone granite, biotite and muscovite coexist, and garnet may or may not be present. The aplitic granite is characterized by abundant (3-12%) primary muscovite , variable amounts of garnet, and little or no biotite. In Horse Heaven, on the south side of the pluton, the aplitic phase again appears but without the transitional phase separating it from the main phase. The contact is not exposed but may well be auto-intrusive at this locality. Much of the rock has been cataclastically deformed and hydrothermally altered along a complex system of shear zones immediately subjacent to the southern Snake Range decollement. Lee and Van Loenen (1971) mapped a fault contact between these cataclastic rocks and a much less deformed "aplitic" phase on the northwestern side of Kious Basin, but our mapping indicates that both the magnitude of deformation and the mineralogy of the pluton change gradationally across a relatively narrow transition zone.

Kg Granite (**Cretaceous**)--The Pole Canyon-Young Canyon pluton intruding the north-central portion of the map area belongs to a family of Cretaceous two-mica granites that occur in a north-trending band through eastern Nevada (Miller and Bradfish, 1980; Lee and others, 1981; Lee and others, 1986a; Miller and Gans, 1989). The main phase of this granite is characterized by large, euhedral muscovite phenocrysts up to 2 cm in diameter that contain tiny euhedral biotite inclusions. Biotite and muscovite are also intimately intergrown in the equigranular matrix. A Rb-Sr whole-rock isochron of 79.1 $\pm$ 0.5 Ma (Lee, and others, 1986a) agrees well with a minimum age of 79.7 Ma from K-Ar analysis of muscovite (Lee and others, 1970). A dense swarm of approximately E-W trending aplite and pegmatite dikes forms a second major intrusive phase within the outcrop area of this pluton, but these dikes may well be derived from the Tertiary Young Canyon-Kious Basin pluton adjacent to the east

Jg Granite (Jurassic)--The Snake Creek-Williams Canyon pluton, intruding the western portion of the map area, has been carefully studied and dated by D.E. Lee and his co-workers (Lee and Van Loenen, 1971; Lee and others, 1981; Lee and Christiansen, 1983a,b). Extensive dating of this body by U-Pb zircon, K-Ar hornblende, K-Ar muscovite, and Rb-Sr methods narrowly constrains the age at about 160 Ma (Lee and others, 1968; Lee and others, 1970; Lee and others, 1981; Lee and others, 1986b). The pluton is strongly zoned both chemically and mineralogically from tonalitic compositions near its eastern edge to granitic compositions to the west (Lee and Van Loenen, 1971; Lee and Christiansen, 1983a,b)

The Late Precambrian and Paleozoic units described below form part of a regionally extensive and concordant sequence of Late Precambrian to early Mesozoic shelf and miogeoclinal strata deposited across this region and described in detail by Drewes and Palmer (1957), Hose and Blake (1976), Whitebread (1969), and Stewart (1980) among others. Because of the complex faulting in the Kious Spring quadrangle and the degree of ductile deformation of rocks beneath the SSRD, Paleozoic rock units are generally incomplete unless otherwise indicated. Our brief descriptions of Paleozoic units follow those of the above authors. The youngest formation present in either the Kious Spring or Garrison quadrangles is the Mississippian Joana Limestone.

Mj Joana Limestone (Mississippian)--Exposed in the Burbank Hills, eastern side of Garrison quadrangle. Regional thicknesses reported for the Joana Limstone are about 120 m. The Joana Limestone is a resistant unit above the slope-forming Pilot Shale. It is a light-gray, medium- to massive-bedded fossiliferous, bioclastic marine limestone

MDp Pilot Shale (Mississippian and Upper Devonian)--Exposed in the Burbank Hills, eastern side of the Garrison quadrangle where a complete section is present. Regional thicknesses reported are 120-245m. The Pilot Shale is a slope-forming olive-gray to dark gray calcareous shale and siltstone. Limestone interbeds occur at the base of the section

Dg Guilmette Formation (Upper and Middle Devonian)--Incomplete sections of the Devonian Guilmette Formation occur in both Garrison and Kious Spring quadrangles. Regional thicknesses reported for the Guilmette are 760 m. In Kious Spring quadrangle, directly overlain by Tertiary conglomerate at several locations. Dark gray, thin-bedded to massive, very fine-grained sublithographic limestone and brown to dark brown dolomite. Generally more massive at base, better bedded up-section. Fossils include corals, gastropods, brachiopods, crinoids and stomatoporoids

Dsi Simonson Dolomite (Devonian)--Several faulted and/or severely brecciated sections of Simonson Dolomite occur in the Kious Spring quadrangle. Regional thicknesses reported are 175 m. Consists of light- to dark-brown, thin- to medium-bedded, laminated, microscrystalline to coarsely crystalline dolomite. Basal part is thicker bedded and uniformly light brown. Fossils include gastropods, crinoids, and brachiopods

Dse Sevy Dolomite (Devonian)--Several faulted and/or brecciated sections of Sevy Dolomite occur the Kious Spring quadrangle. Regional thicknesses reported are 245 m. The Sevy consists of distinctive white-weathering, light gray, thin- to medium-bedded, very fine-grained, non-fossiliferous, laminated dolomite. Diagnostic dark brown-weathering stringers of well-rounded coarse to medium-grained quartz sand occur in the Sevy, and it is notable for its lack of fossils

OS Fish Haven Dolomite and Laketown Dolomite undifferentiated (Upper and Middle Silurian and Upper Ordovician)--Includes the Fish Haven Dolomite and Laketown Dolomite. Most intact section of OS is exposed south of the mouth of Snake Creek in the southeastern part of the Kious Spring quadrangle. Regionally, reported thicknesses for the combined Fish Haven and Laketown dolomites are about 460 m. Lower part is medium- to dark-brown dolomite with some stromatolitic fossiliferous and cherty intervals; upper part is light brown, coarse-grained dolomite. Fossils include colonial corals, rugose and tabulate corals, and stromatolites

Oe Eureka Quartzite (Ordovician)--Several apparently complete sections exposed in Kious Spring quadrangle. Best exposures include those on either side of mouth of Snake Creek, where locally both top and bottom contacts of the formation are exposed. Regional thickness reported for the Eureka Quartzite is about 135 m. The Eureka Quartzite is a white, cliff-forming, well-sorted, well-rounded, fine- to medium-grained, thick-bedded quartzite. It is a distinctive stratigraphic marker, occuring as it does between dark dolomites above and the yellow-weathering, gray, slope-forming limestone of the Pogonip Group below

Pogonip Group (Ordovician)--Most complete section of the Pogonip Group occurs on the north side of Snake Creek immediately above the SSRD, where all of its included formations are present, and where it is depositionally overlain by the Eureka Quartzite. Regional thicknesses for the Pogonip are about 460-500 m. The

Pogonip Group is a yellow-weathering, blue-gray, generally quite fossiliferous, thin-to medium-bedded, slope to ledge-forming silty limestone.

Op **Pogonip Group undifferentiated**

Oph **House Limestone--**Cherty limestone with flat-pebble conglomerate

Opf **Fillmore Limestone**--Yellow-weathering, blue-gray platey limestone

Opk **Kanosh Shale**--Yellowish-brown to olive-gray fissile shale containing beds and lenses of fossiliferous shaley limestone

Opl **Lehman Formation--**Blue-gray fossiliferous limestone

€np **Notch Peak Formation (Upper Cambrian)--**Several partial sections of the Notch Peak Formation are present in the Kious Spring quadrangle. Regional reported thicknesses are about 485-550 m. The Notch Peak Formation is a medium-gray, thin-bedded, cliff-forming limestone containing abundant chert stringers and thin nodules parallel to bedding. Locally it contains massive dolomite intervals. In general, upper part is more silty and fossiliferous. Fossils include stromatolites, brachiopods and gastropods

€d **Dunderberg Shale (Upper Cambrian)--**A good section of the Dunderberg Shale is exposed in the upper reaches of Big Wash, where it incises Paleozoic strata (Plate I). Here, unit is in contact with the overlying Notch Peak Formation and underlying Johns Wash Limestone. Regional reported thicknesses for the Dunderberg are about 20 m. The Dunderberg is a distinctive olive-gray to dark-brown fissile calcareous shale and siltstone. Coarsely clastic limestone with abundant trilobite hash near base

€jw **Johns Wash Limestone (Upper Cambrian)--**A good exposure of the Johns Wash Limestone occurs at the same locality described above, where it is overlain by the Dunderberg Shale and underlain by the Lincoln Peak Formation. Thickness is about 75 m. The Johns Wash Limestone is a white- to light blue-gray, massive, cliff-forming limestone including oolitic and cross-bedded layers

€lp **Lincoln Peak Limestone (Upper Cambrian)--**Best exposures of the Lincoln Peak Formation occur on the south slopes of Big Wash, in the southern part of the Kious Spring quadrangle. Here, Whitebread (1969) reports thicknesses up to more than 1,400 m but internal deformation may compromise these estimates. Regionally, the Lincoln Peak Limestone is about 1220-1370 m thick. The Lincoln Peak Limestone is a medium- to dark-gray, thinly bedded, platy, slope-forming silty limestone. Silty intervals and chert stringers weather distinctly brown. Contains sparse trilobite hash and oncolites

€pc **Pole Canyon Limestone (Middle Cambrian)--**No complete section of the Pole Canyon Limestone exists in the Kious Spring and Garrison quadrangles, but it has been described in detail by Whitebread (1969) in the adjacent Wheeler Peak quadrangle, where it is reported to be about 500-550 m thick. It is a light- to bluish-gray, cliff-forming limestone with *Girvanella*, fenestral fabrics and oolitic layers. Members A and C as described by Whitebread are dark gray and contain discontinuous silty partings. Members B and D are light gray massive cliff-formers and E is light-gray with argillaceous partings and varicolored shale near its top

€pi **Pioche Shale (Lower Cambrian)--**The Pioche Shale forms an important lithologic transition between dominantly clastic Lower Cambrian and older strata and the overlying carbonate-rich Middle Cambrian limestone section. In the map area, the Pioche is in general metamorphosed to biotite- and muscovite- bearing psammite, schist and calc-silicate bearing rocks. Original bedding and sedimentary structures are obscured by metamorphism and deformation. Regionally, the Pioche Shale consists of dark siltstone, sandy siltstone and calcareous quartzite that is greenish gray to olive gray and is mostly thin bedded. True shale is less common in the section in the southern Snake Range. An intact section 90 m thick is exposed just to the west of the Kious Spring quadrangle, in the cirque wall at the headwaters of Snake Creek in the Wheeler Peak quadrangle. Here, the Pioche is transitional with the underlying Prospect Mountain Quartzite, containing in its lower part thin dark-colored quartzite beds which are interbedded with muscovite, biotite, chlorite-bearing schist and siltstone. Calcareous layers occur intermittently throughout the unit. Several thick (meters to tens of meters thick) layers of micaceous quartzite occur near the top of the unit, and the amount of limestone with respect to shale increases upward toward the base of the massive overlying limestone of the Pole Canyon Formation

€Zpm Prospect Mountain Quartzite (Lower Cambrian and Late Proterozoic)--A complete section of the Prospect Mountain Quartzite is not present in the map area. Regional thickness of the Prospect Mountain Quartzite is reported to be on the order of 1525 m. A complete section of the Prospect Mountain Quartzite is present on the northeastern flanks of the southern Snake Range between Strawberry Creek and Lehman Creek in the Lehman Caves and Windy Peak quadrangles. The base of the formation and its contact with the underlying Osceola Argillite is exposed on the northern extreme of Blue Ridge in the Windy Peak quadrangle. Its upper contact with the Pioche Shale is exposed in the adjacent Lehman Caves quadrangle to the east. Strata are little metamorphosed beneath Wheeler Peak but become more metamorphosed both northward towards Jurassic plutons in the Windy Peak quadrangle and eastward towards Cretaceous intrusives exposed in the Kious Spring quadrangle. Section at Wheeler Peak is approximately 1,500 m thick. In general, the Prospect Mountain Quartzite forms cliffs and talus slopes that weather rust-brown, tan, or purple. Bedding thicknesses are quite consistent, and the .3-1m thick beds are ubiquitously cross-bedded, with cross-bedding defined by dark laminations. In hand specimen, the quartzite is white to gray, well-sorted, fine- to medium-grained, and consists of 90-95% quartz, 5% feldspar, and lesser muscovite, chlorite, and opaque oxides. The abundance of crossbeds and the more regular bedding thicknesses help to distinguish the Prospect Mountain Quartzite from similar quartzite units in the underlying McCoy Creek Group outside these quadrangles. In addition, pelitic intervals and pebble conglomerates are both much rarer in the Prospect Mountain Quartzite than in the McCoy Creek Group. Both the basal and the upper sections of the Prospect Mountain Quartzite contain intervals of siltstone and shale and thus are clearly in conformable and gradational contact with the underlying Osceola Argillite of the McCoy Group of Late Proterzoic age and the overlying Pioche Shale of Early Cambrian age. In the Kious Spring quadrangle, the Prospect Mountain Quartzite was deformed during Cenozoic time; bedding has been thinned during development of a variably developed bedding-parallel foliation and a lineation parallel to the stretching or extension direction is well developed

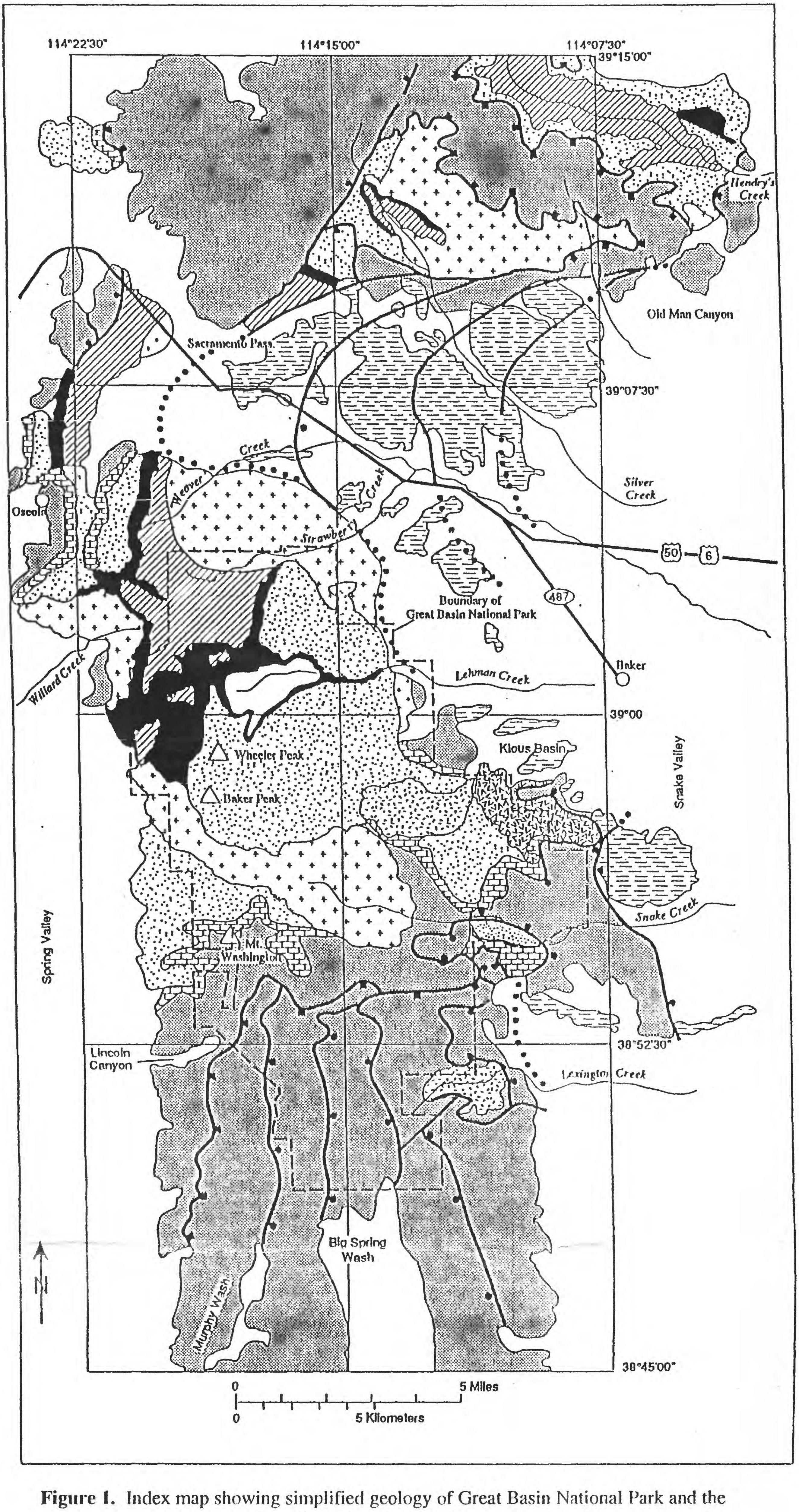
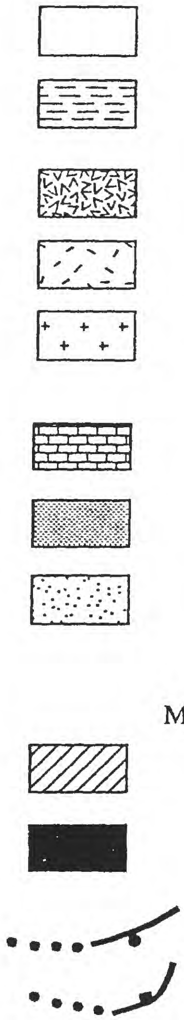


Figure 1. Index map showing simplified geology of Great Basin National Park and the Snake Range, Nevada.

EXPLANATION



Alluvial deposits (quaternary)

Continental deposits, undivided (Tertiary)

Granitic deposits (Tertiary)

Granitic deposits (Cretaceous)

Granitic deposits (Jurassic)

Miogeoclinal strata (Paleozoic)

Pioche Shale (Middle and Lower Cambrian)

Prospect Mountain Quartzite (Lower Cambrian and Late Paleozoic)

McCoy Creek Group of Misch and Hazzard, 1962, late Precambrian

McCoy Creek Group, undivided

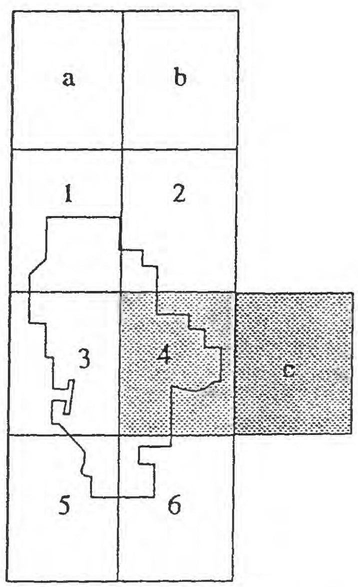
Osceola Argillite

Major Cenozoic faults--Ball on downthrown side

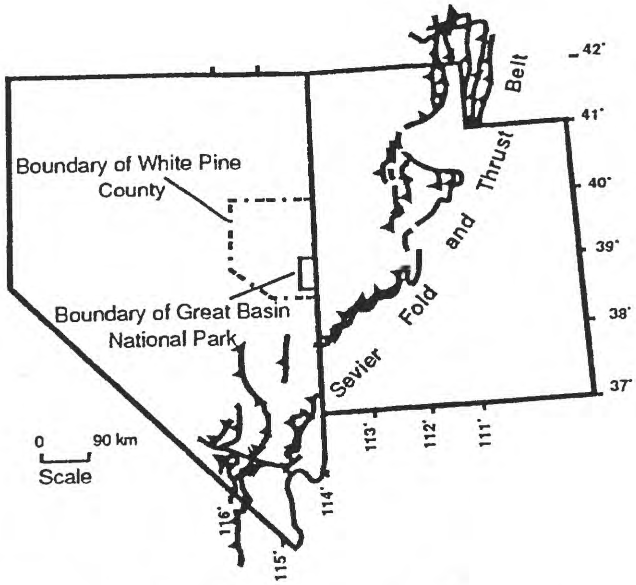
Snake Range decollement--Squares on upper plate

1. Windy Peak
2. Lehman Caves
3. Wheeler Peak
4. Kious Spring
5. Minerva Canyon
6. Arch Canyon

a Sacramento Pass
b Old Man's Canyon
c Garrison



Index map showing numbered 7.5' topographic quadrangles that include Great Basin National Park and location of Garrison 7.5' Quadrangle


Boundary of White Pine County
Boundary of Great Basin National Park
Sevier Fold and Thrust Belt
0 90 km
Scale
42°
41°
40°
39°
38°
37°
113°
112°
111°
114°
115°
116°

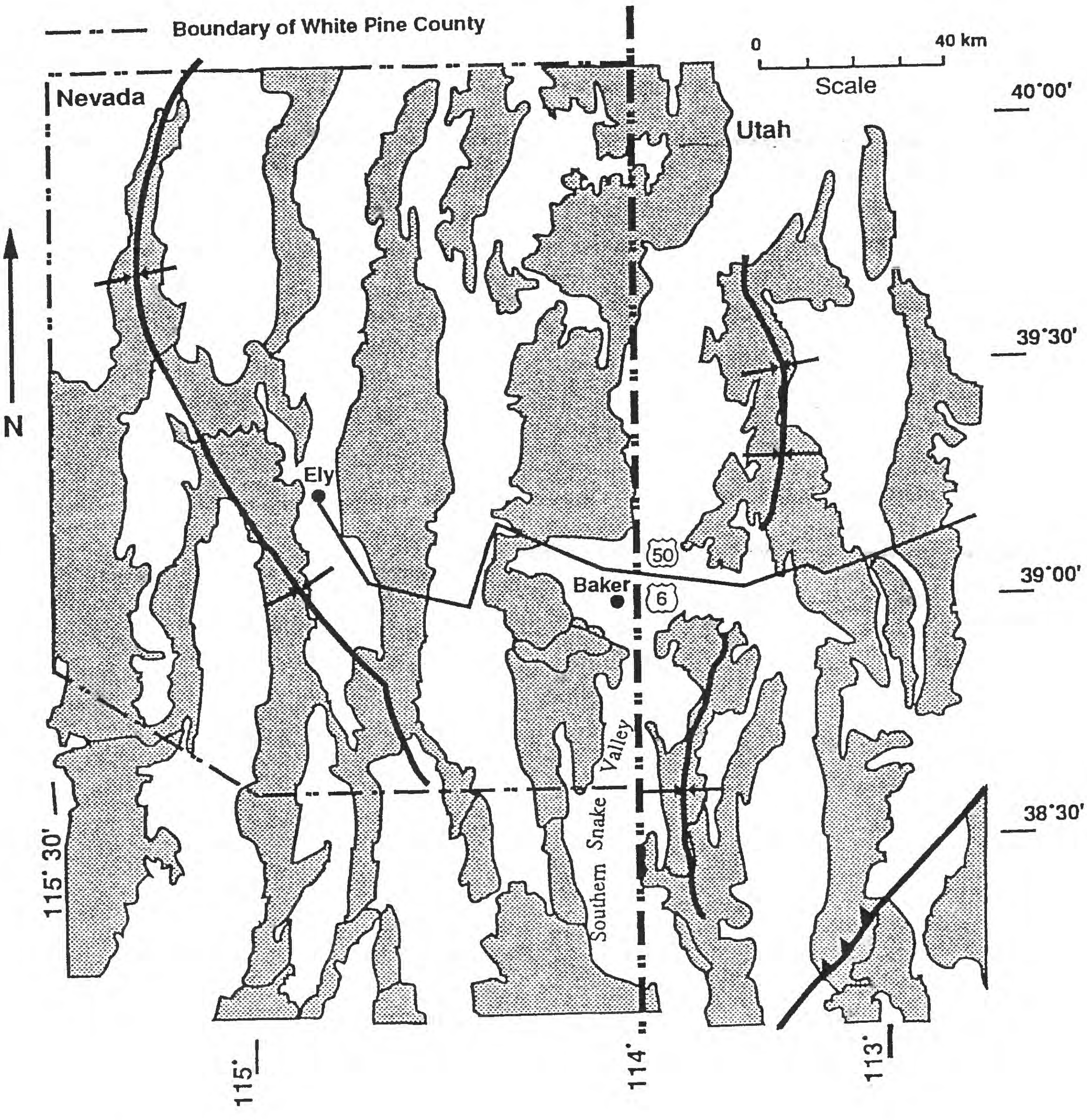
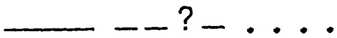

Boundary of White Pine County
0 40 km
Scale
Nevada
Utah
N
Ely
Baker
50
6
Southern Snake Valley
40°00'
39°30'
39°00'
38°30'
115° 30'
115°
114°
113°

Figure 2.

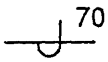
EXPLANATION OF MAP SYMBOLS

Kious Spring and Garrison 7.5 Quadrangles



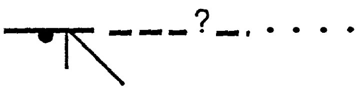
CONTACT --Solid line continuous, dashed where inferred, queried where uncertain, dotted where concealed

STRIKE AND DIP OF BEDDING



STRIKE AND DIP OF OVERTURNED BEDS

STRIKE AND DIP OF FOLIATION AND DIRECTION AND PLUNGE OF LINEATION



FAULT -- Solid line continuous, dashed where inferred, queried where uncertain; dotted where concealed; ball on downthrown side; short arrow shows dip of surface; long arrow shows plunge of striae on fault surface

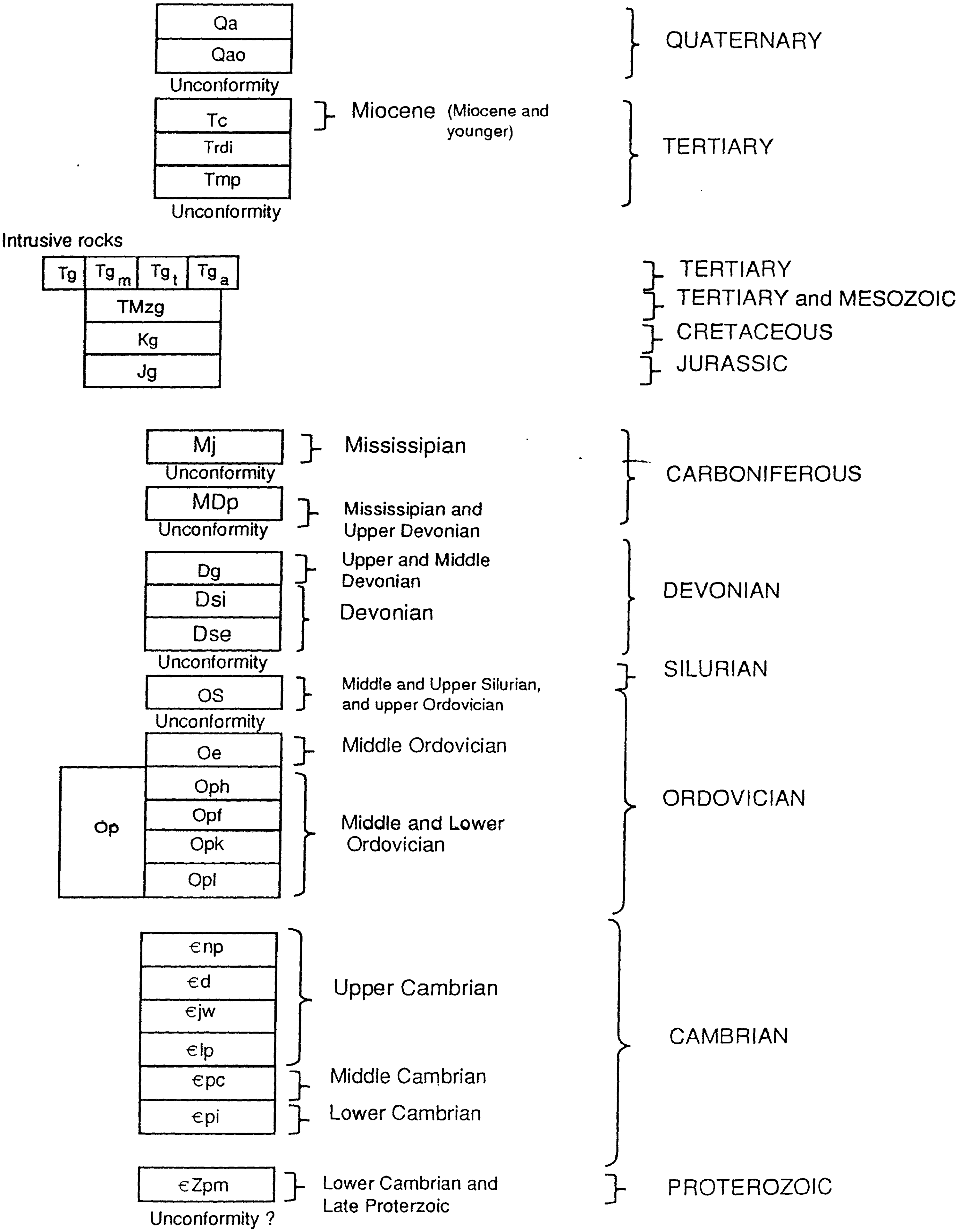
BASAL CONTACT OF TERTIARY SLIDE BLOCKS -- Solid line continuous, dashed where inferred, open crescents on upper side. Symbols of Paleozoic units forming slide blocks in parentheses

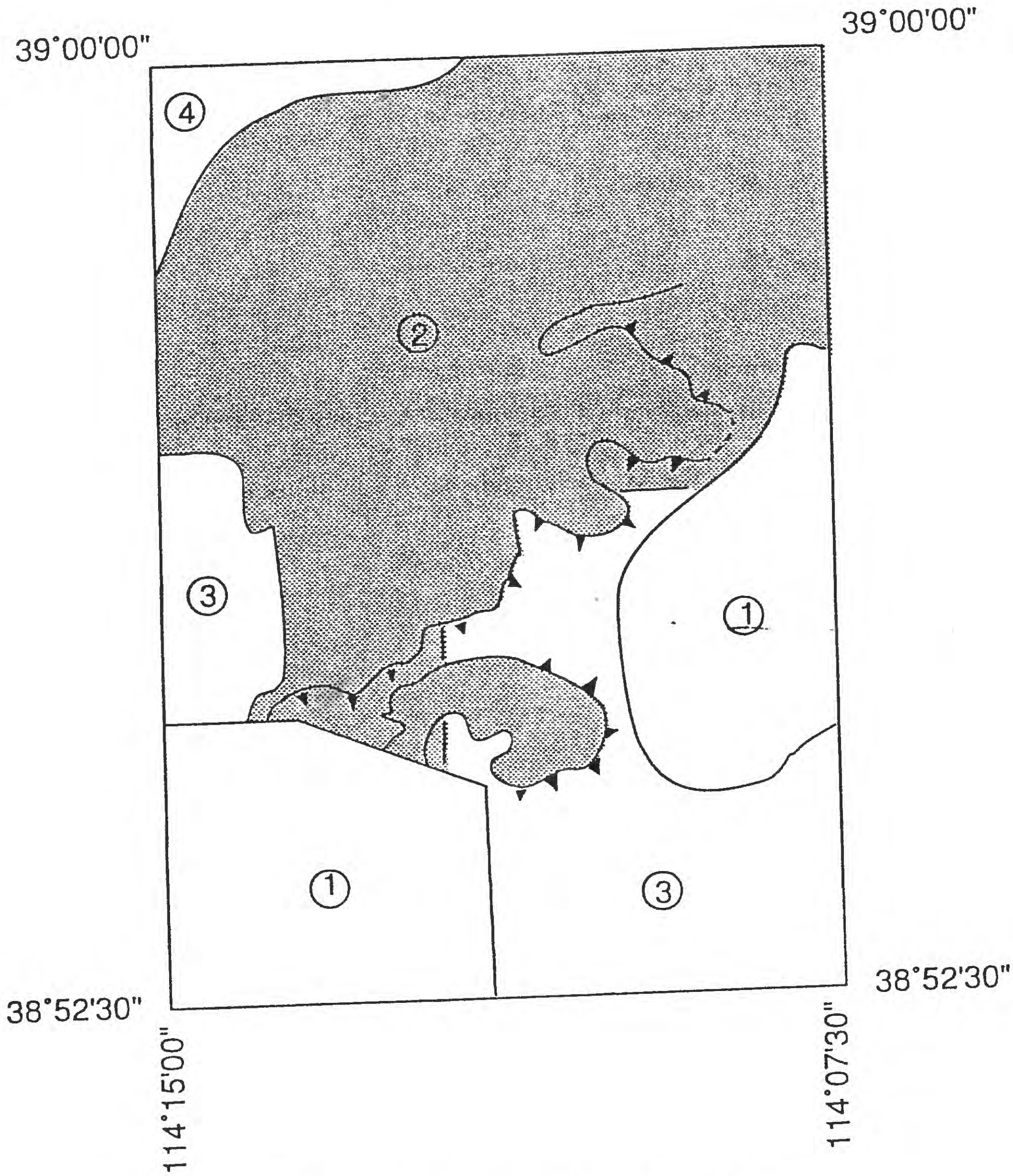
METRIC CONVERSION FACTORS

Inch-pound unit	Metric equivalent
1 inch (in)	2.54 centimeters (cm)
1 foot (ft)	0.305 meters (m)
1 mile (mi)	1.609 kilometers (km)

CORRELATION OF MAP UNITS

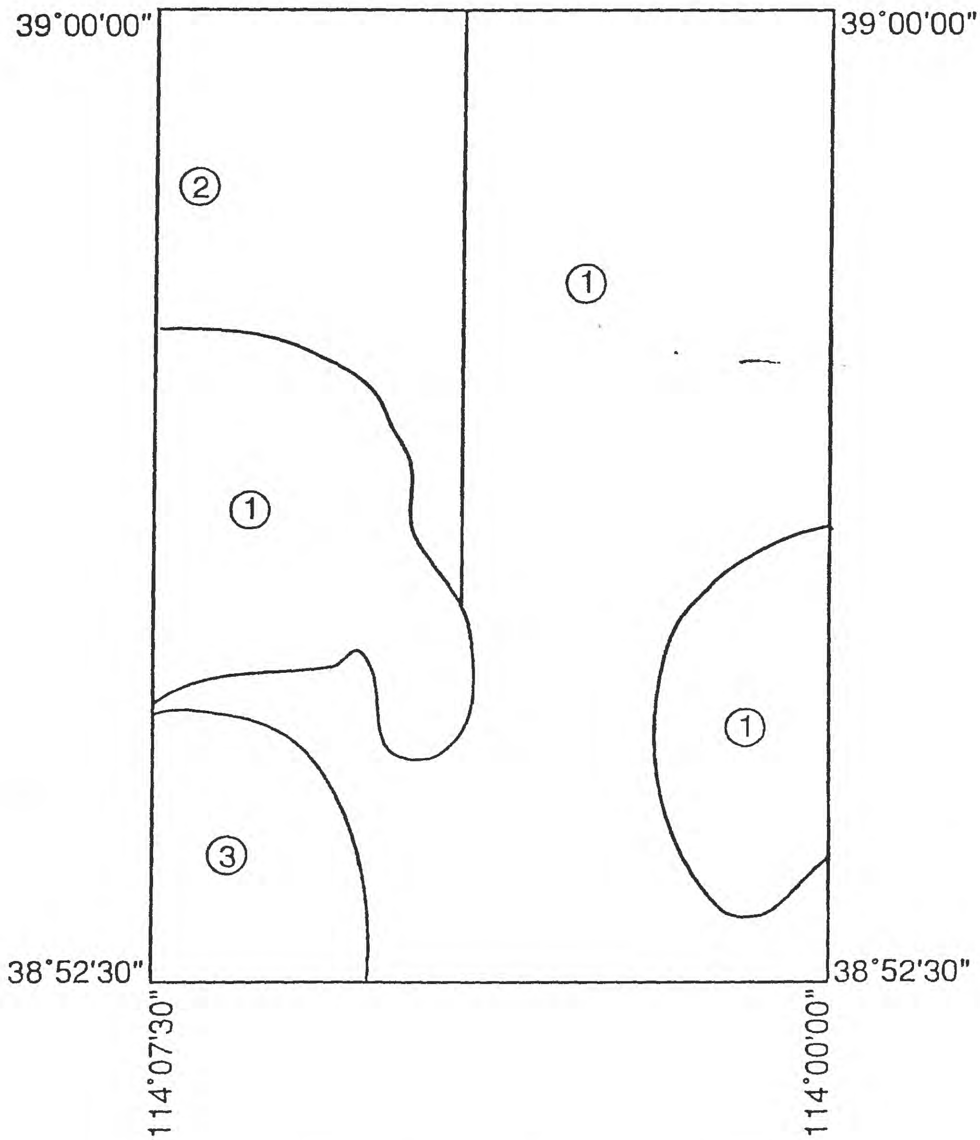
Kious Spring and Garrison 7.5 Quadrangles





Map Credits Kious Spring Quadrangle

1. Elizabeth L. Miller
2. Allen J. McGrew
3. Stanford Geological Survey, 1984
4. Donald H. Whitebread, 1969



Map Credits Garrison Quadrangle

1. Elizabeth L. Miller
2. Allen J. McGrew
3. Stanford Geological Survey, 1984