U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

PRELIMINARY GEOLOGIC MAP OF THE BRISTOL WELL QUADRANGLE, LINCOLN COUNTY, NEVADA

By

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DESCRIPTION OF MAP UNITS

Descriptive colors for map units are from the Rock-Color Chart Committee (1951). Alluvial deposits of Quaternary and Tertiary ages are delineated on the basis of level above modern streams and of dissection. The oldest fan remnants stand at the highest levels and in general are the most dissected; the fans tend to grade into each other toward Dry Lake Valley and in places become arbitrary and approximate.

Qa	**Alluvium (Holocene)**--Unconsolidated silt, sand, gravel, and boulders in active washes and in Dry Lake Valley. Thickness 10 m and greater
Qc	**Colluvium (Holocene)**--Talus, slopewash, and landslipped debris, mapped where they obscure bedrock. Generally less than 20 m thick
Qac	**Alluvium and colluvium undivided (Holocene)**--Silt, sand, and gravel in small washes and low interfluvial areas. Thickness 10 m and greater
Qoa	**Older alluvium (Holocene and Pleistocene)**--Mostly weakly cemented conglomeratic sandstone and conglomerate. Conglomerate contains subrounded and subangular cobbles and boulders composed of mostly Paleozoic carbonate rocks. Beds locally contain zones that are strongly cemented with secondary carbonate, and thin sandstone interbeds of probable eolian origin are ubiquitous. Thickness 10 m and greater
Qfa	**Fanglomerate (Holocene and Pleistocene)**--Moderately-dissected and moderately cemented (with secondary carbonate) conglomeratic sandstone in well-graded fans on the west flank of the West Range. Cobbles and boulders are subangular to subrounded and composed chiefly of Paleozoic carbonate rocks and quartzite. Thickness 20 m and greater
QTa	**Older fanglomerate (Pleistocene and Pliocene)**--Mostly well-dissected, well-cemented (with secondary carbonate) conglomerate and conglomeratic sandstone. Cobbles and boulders are entirely of Paleozoic origin except for small areas in the extreme northeast and southeast parts of the mapped area, thereby suggesting that any volcanic rocks in the Bristol Range were either stripped very early during the initial uplift of the range or were never deposited there. Thickness 20 m and greater
QTu	**Alluvial deposits undivided (Quaternary and Tertiary)**--May include any of the alluvial units listed above; shown in subsurface only where beds as old as Tertiary are present. Thickness 300 m or greater

Tfg **Oldest fanglomerate (Pliocene?)**--Composed chiefly of poorly sorted, subangular to subrounded boulders and cobbles derived from the Eureka Quartzite (Oe) and Ely Springs Dolomite (Oes). Fan surfaces consist of abundant carbonate soil fragments and are vegetated with pinyon and juniper trees. Unit forms fan remnants that stand above surfaces of the older fanglomerate (QTa) in the northeast quarter of the mapped area on the flanks of the northern Bristol Range. Maximum thickness 40 m

Tts **Tuffaceous sedimentary rocks (Pliocene and Miocene)**--Mostly white, flaggy-weathering and thin-bedded, poorly exposed, east-tilted, valley-fill sequence. Includes fine-grained sandstone, reworked ash, thin papery shale, and locally light- brown, medium- to coarse-grained volcanic sandstone and pebble conglomerate. Probably time equivalent to older parts of the Panaca Formation, a basin-fill deposit exposed east of the Bristol Range. The exposed strata dip as steeply as 35° adjacent to the ranges in the map area, and are probably mostly lacustrine in origin. In the vicinity of the "mine" in the north-central part of the quadrangle, the rocks include impure, white to very pale brown diatomite and fresh-water limestone. At least 30 m of the unit is exposed; the entire sequence could be as thick as several hundred meters

Intrusive Rocks

Tg **Granitic to dioritic rocks (Oligocene)**--Composite intrusive masses of the Blind Mountain stock (southeast corner of Bristol Well quadrangle) that range in composition from diorite to true granite. The rocks of dioritic composition are porphyries that occur as isolated dikes and apophyses (principally in the adjacent Bristol Range SE quadrangle) and as dikelets in the vent tuff (Tvt) within a possible small caldera in this and the adjoining Bristol Range SE quadrangle, and as mafic margins to the more silicic rocks. The porphyries are gray, and contain 15-25 percent phenocrysts that consist of plagioclase, 85-90 percent (1 to 4 mm), and altered mafic minerals, 10-15 percent, that mostly or entirely replace pyroxene. One thin section of porphyry had a dense groundmass showing only incipient plagioclase microlites; another had a subautomorphic-granular groundmass too fine to count but containing randomly oriented equant crystals of plagioclase (0.2-0.4 mm), sparse biotite (0.4 mm), and interstitial quartz and probable sanidine. This rock is quartz diorite or possibly granodiorite in composition. The granites are gray, reddish gray, and pale red, equigranular, fine to medium grained, generally fairly rich in biotite, and with minor hornblende. Two thin sections showed quartz, 19-28 percent, cloudy orthoclase, 24-34 percent, plagioclase, 40-29 percent, biotite, 7-15 percent, and altered hornblende, 2 percent. The Blind Mountain stock has been dated at 27.7 Ma (Armstrong, 1970) and 34.9 Ma (Johnston, 1972)

Tvt **Vent tuff (Oligocene)**--Gray, weathering to brownish-gray, densely welded, flow layered ash-flow tuff that underlies the Blind Mountain area in the southeast part of the mapped area. Tuff intrudes rocks of the Guilmette Formation that may have been downdropped as part of a small caldera (G.J. Axen, written commun., 1994). Contains conspicuous black pumice fragments as long as 1 m, and numerous quartzite and carbonate lithic fragments as long as 20 cm. Phenocrysts, 10-18 percent, consist of plagioclase, 85-90 percent (0.3 to 2.5 mm) and an altered mafic mineral that is mostly replacing pyroxene, 10-15 percent (0.3 to 2 mm). A fresh phenocryst of hornblende was observed in one thin section. The lithology of this vent tuff is indistinguishable from some tuffs mapped herein as Isom, and indicates that the Blind Mountain area may have been a local source for some Isom-like rocks

Tsp **Shingle Pass Formation (Oligocene)**--Two cooling units, upper and lower, are included in this formation on the basis of macro- and microscopic characteristics, but only the upper correlates directly with cooling units at the type locality at Shingle Spring in the Egan Range, 50 km to the northwest, where it rests directly on the Wah Wah Springs Formation of the Needles Range Group (Tn). The lower unit is not present at Shingle Spring, but nevertheless is so similar to the upper unit as exposed in the Bristol Well quadrangle that a common magma source is indicated. The upper cooling unit is moderately resistant, densely welded ash-flow tuff. Unit has a brown, nonwelded base with conspicuous shards, that grades upward to pale red, and finally to pale purple, densely welded tuff that weathers to moderate red and contains conspicuous well-flattened pink and tan-white pumice. Phenocrysts range from 10 to 15 percent, and consist of quartz, 12-17 percent (as large as 2 mm); alkali feldspar, 49-56 percent (1 to 3 mm); plagioclase, 24-27 percent (2 mm); and altered mafic minerals, probably pyroxene, 4-6 percent (1.5 mm). The alkali feldspar shows broad zoning and 2V's of 10^{o} or larger, which is unusual for Nevada sanidines that typically show 2V's of 0^{o}. These peculiar sanidines also characterize the Shingle Pass Tuff at the type locality (Shingle Spring) in the Egan Range. Thickness about 20-30 m. The lower cooling unit is resistant, cliff-forming, and forms the mesa cap about 1.6 km west of Scotty Wash. It has a poorly exposed, light-brown ash base that grades upward to partially welded, pale-red "clinkstone", and farther upward to pale-red-purple and pale-pink densely welded tuff that weathers moderate reddish brown or, where a weathered rind is developed, dark brownish gray or black. The top is lithophysal and vapor-phase crystallized; mostly grayish pink, and it too weathers to a brownish-black rind. Phenocrysts range from 10 to 15 percent and consist of quartz, 6-15 percent (1 to 2 mm); alkali feldspar, 32-43 percent (2.5 mm); plagioclase, 44-59 percent (0.1 to 1.5 mm); and altered pyroxene(?), 1-5 percent (0.5 mm). Some alkali feldspar crystals are as long as 7 mm. Thickness of lower cooling unit at least 30 m. Best and others (1989) give an isotopic age of 26.7 to 26.0 Ma for the Shingle Pass. For additional information concerning the Shingle Pass, see Swadley and Rowley (1994) and Ekren and others (1977)

Ttu **Tuffaceous bedded rocks, upper (Oligocene)**--Poorly exposed, slope-forming, light-gray and white tuffaceous sandstone and ash-fall tuff(?) with interbeds of weakly cemented conglomerate containing cobbles and boulders of the Wah Wah Springs and Cottonwood Wash Formations of the Needles Range Group (Tn), rhyolite (Tr), and andesite lava flows (Ta). Thickness 5-30 m

Ti **Isom Formation (Oligocene)**--Simple cooling units of rib-and cliff-forming, high-temperature, densely welded ash-flow tuff. Two separate cooling units are suggested by phenocryst amounts. West of Bristol Well, a 10-m thick unit occurs that contains 10 percent phenocrysts at the base and 15 percent at the top, consisting of 80 percent plagioclase (to 3.5 mm), 12 percent clinopyroxene (to 2 mm), and 6 percent opaque minerals. This tuff has a dark-gray vitrophyre at the base (1.0 m-thick) that grades upward to devitrified rock that is moderately reddish brown to moderate brown, and that contains conspicuous, but not abundant, lithophysae and well-flattened pale-brown, gray-brown, and black pumice. "Case hardening" along joints caused by rising hot volatiles during cooling has given rise to very resistant outcrop surfaces. Trace-element chemical analyses, using a Kevex analyzer, obtained by P.D. Rowley (written commun., 1994) indicate that this unit correlates with the Bald Hills Member of the Isom Formation. Another cooling unit, also about 10-m thick, of Bald Hills lithology crops out in the lower plate of the West Range fault (see "Structural Geology" section) at the south end of the West Range. This tuff is red in color and extremely lithophysal from base to top. It contains 23 percent phenocrysts, consisting of plagioclase, 84 percent (to 2 mm); altered pyroxene, 11 percent (to 2 mm); and opaque minerals, 5 percent (1 mm). The Isom Formation has an isotopic age of 27 Ma (Best and others, 1989). For other pertinent information for the Isom, see Swadley and Rowley (1994), Scott and others 1994, 1995, in press; Mackin (1960), and Anderson and Rowley (1975)

Ttl **Tuffaceous bedded rocks, lower (Oligocene)**--Slope-forming, gray and white, tuffaceous sandstone and ash-fall tuff(?) and interbeds of conglomerate that contain the same clasts as in the upper tuffaceous bedded rocks (Ttu). This lower unit also contains thin beds (less than 2 m) of ash-flow tuff. One of these beds occurs throughout the northwest part of the quadrangle; it is a dark-yellowish-orange to moderate-yellow rhyolitic tuff that contains 10 percent phenocrysts of quartz, sanidine, plagioclase, and biotite, all less than 2 mm long, in a matrix of non welded shards and dust. Thickness of entire unit probably as much as 30 m

Tr **Rhyolite (Oligocene)**--An eroded grayish-red, weathering to light-brown volcanic dome in northwest part of the mapped area; and a pale-pink to pale-red-purple dike-like mass in northeast part. At both localities, the rhyolite contains fewer than 1 percent phenocrysts (sanidine > biotite > quartz) 2 mm long or less. Thickness of the dome is about 40-60 m

Needles Range Group and intercalated tuffs and sedimentary rocks (Oligocene)

Tnl **Lund Formation**--Moderately resistant, pale-yellowish-brown densely welded ash-flow tuff in lower part, grading upward to medium-light-gray, then light-brownish-gray tuff in middle part, and from there to weakly welded, very-light-gray tuff in upper part. Contains 20-28 percent phenocrysts that consist of quartz, 20-36 percent (to 3 mm); sanidine, 20 percent (1 to 2 mm) at the base, grading upward to only 3 percent at the top; plagioclase, 50-59 percent (1 to 2 mm); biotite, 5 percent at the base, 12 percent at the top; hornblende, trace at the base, 3 percent at the top; and accessory sphene, 1 or 2 grains at the base, 30 grains at the top. The tuff is only a few tens of meters thick in Scotty Wash; it is several hundred meters thick in the northwest corner of the quadrangle, where it is in fault contact with the Wah Wah Springs Formation of the Needles Range Group (see below). The basal part of the formation, containing 20 percent sanidine, is probably quartz latite in composition, but the bulk of the formation is dacite according to Best and Grant (1987). At Scotty Wash, the tuff at the top is vapor-phase crystallized. P.D. Rowley (oral commun., 1993) suggested that the thick sequence in the northwest corner may have been deposited in an easterly-trending trough that subsided concurrently with the Lund eruptions. The Lund Formation has an isotopic age of 27.9 Ma (Best, Christiansen, and Blank, 1989)

Tdm	**Tuff of Deadman Spring**--Moderately welded, grayish-orange-pink, weathering to light-brown, rhyolite ash-flow tuff. Limited exposures in Scotty and Fairview Washes suggest a simple cooling unit a few tens of meters thick containing 20-25 percent phenocrysts that consist of smoky quartz, 44 percent (to 3 mm); sanidine, 32 percent (2 mm); plagioclase, 22 percent (2 mm); and biotite, 1 to 3 percent (2 mm). Just north, northwest, and west of this quadrangle, the tuff of Deadman Spring is densely welded and at least several hundred meters thick. A thin section from the lower part of the tuff just north of the quadrangle is modally identical to the unit in Scotty Wash. Like the Lund Formation, the possibility exists that the Deadman, with its thick east-trending exposures, was also deposited in an easterly oriented trough that subsided concurrently with tuff eruptions
Tns	**Sedimentary rocks above the Wah Wah Springs Formation**--Slope-forming, biotite-rich ash-fall tuff, tuffaceous sandstone, and interbeds of conglomerate; the conglomerate contains mostly pebble- to cobble-sized, and very sparse boulder-sized Paleozoic rocks, and minor variegated volcanic rocks. Thickness is from 30 to 60 m

Tn **Needles Range Group, undivided**--Discontinuous, poorly exposed outcrops of biotite-rich ash-flow tuff in the lower plate of the West Range fault. Outcrops include both the Wah Wah Springs and Cottonwood Wash formations. The Wah Wah is densely welded, pale-reddish-brown tuff that contains conspicuous, silver-dollar-sized, off-white to tan pumice lapilli. It contains 26 percent phenocrysts in the basal vitrophyre, and as much as 50 percent phenocrysts in overlying devitrified tuff. The phenocryst percentages from three thin sections are: quartz, 3 percent (vitrophyre), 8 to 12 percent (devitrified tuff); sanidine, trace amounts; plagioclase, 58 to 60 percent; biotite, 3 to 9 percent; hornblende, 22 to 24 percent; and clinopyroxene, trace to 1 percent. Quartz is mostly less than 2 mm; plagioclase mostly less than 3 mm; biotite less than 2 mm in the vitrophyre, but as large as 4 mm in devitrified rock; hornblende generally less than 2 mm but locally 5 mm. The Cottonwood Wash is densely welded, grayish-red weathering to light-brown ash-flow tuff. Phenocrysts total 49 percent in the basal vitrophyre and consist of the following: quartz, 12 percent (to 3.5 mm); sanidine, 1 percent (2 mm); plagioclase, 64 percent (3 mm); biotite, 11 percent (3 mm); hornblende, 11 percent (4 mm); and clinopyroxene, < 1 percent. Biotite is larger overall than in the Wah Wah Springs Formation and commonly occurs in books, in contrast to mostly small flakes in the Wah Wah Springs. The Wah Wah Springs Formation has an isotopic age of 29.5 Ma, and the Cottonwood Wash Formation is 30.6 Ma (Best, Christiansen, and Blank, 1989). Maximum thickness of combined Wah Wah Springs and Cottonwood Wash formations is about 130 m

Ta **Andesite lava flows (Oligocene)**--Medium- to dark-gray, obscurely flow-layered lava flows. Contains 28 percent phenocrysts that consist of plagioclase, 60 percent (as long as 4 mm); clinopyroxene, 18 percent (3 mm); orthopyroxene, 18 percent, (3 mm); and magnetite, 3 percent, (1 mm). Some glomerophenocrysts of plagioclase include pyroxene. Maximum thickness a few tens of meters

Mj **Joana Limestone (Lower Mississippian)**--In the southern Fairview Range (northeast corner of the quadrangle), consists of massive cliff-forming, medium-crystalline, dark-gray limestone that weathers medium gray to light olive gray; beds contains scattered chert lenses and nodules, crinoid columnals, and solitary rugose corals. In the West Range, mapped to include at the base about 10 m of slope-forming, dusky yellow-weathering, silty limestone that correlates with the Pilot Shale in the adjacent Coyote Spring quadrangle (Ekren and Page, 1995). The Pilot Shale here is conspicuously bedded (beds average about 25 cm thick) and is gradationally overlain by about 40 m of smooth-weathering, massive Joana Limestone that is quite cavernous in its lower part. The cavernous zones, and smaller continuous cavities that also are interpreted to represent avenues of ground-water flow, are heavily stained with yellow-brown iron oxides. The limestone is mostly medium crystalline, obscurely bedded in the lower 20 m and well bedded in the upper 10 m; it locally contains scattered chert lenses and nodules. The upper, well-bedded cliff rock grades upward to alternating bench and ledge- forming medium- to coarsely crystalline limestone that is mostly brownish gray and weathers light gray. Many of these ledges, and much of the underlying massive cliff as well, weather to a light-gray, pitted rind whose surfaces are marked by abundant small run-off channels, or rivulets, that reflect the extreme solubility of the limestone. The bench and ledge-forming zone contains fossiliferous beds that are mostly 7 to 25 cm thick; most contain brachiopods, coral fragments, and abundant crinoid columnals of small diameter (<4 mm). Some beds contain chert layers and some thicker beds are cross laminated, with coarse laminae alternating with finer laminae. Some yellow-weathering clay or silt partings are conspicuous between the limestone beds. According to Langenheim and others (1969) the Joana contains the "Madison" fauna of presumed Kinderhookian-Osagean age. Langenheim and others (1969) reported a thickness of 30 m for the unit. In and near the hill shown with elevation 6027, just north of the T.3 N. /T.2 N. line, however, we estimate a thickness of well over 250 m

MDp **Pilot Shale (Lower Mississippian and Upper Devonian)**--Slope-forming, well-bedded, silty-gray and pale-brown limestone that weathers dusky yellow; beds are mostly 5 to 8 cm thick. Most beds are aphanic to finely crystalline and some near the top are dolomitic; bedding, like that in the underlying West Range Limestone, is mostly stylolitic and nodular-weathering throughout. Limestone in the uppermost 1 m or so is extremely fossiliferous containing brachiopods and abundant crinoid columnals. In the West Range, only about 10 m of the unit is exposed; therefore, it was included in the overlying Joana Limestone. In the southernmost Fairview Range (northeast part of quadrangle) the unit is poorly exposed but was estimated to be 40 to 50 m thick; at this location, the upper contact was drawn at the base of the massive lower cliff of the Joana Limestone, and the lower contact with the West Range Limestone is gradational and arbitrary

Dw **West Range Limestone (Upper Devonian)**--Medium-gray to brownish-gray limestone in even beds mostly 2.5 to 7.5 cm thick, but locally as thick as 30 cm, that weather to distinct ledges 0.6 to 1.0 m thick. Bedding is almost entirely stylolitic; where extremely thin bedded, the stylolitic habit causes the beds to weather to nodular zones. Most beds contain fossils; some beds are extremely fossiliferous. The upper beds (20 m or so), like the Pilot Shale, are silty and weather dusky yellow. The basal contact is everywhere tectonically disturbed and its exact nature cannot be deciphered. However, in the adjacent Coyote Spring quadrangle (Ekren and Page, 1995), about 13 km west of the West Range, the basal contact is undisturbed, well exposed and knife sharp, and it appears to be an unconformity. Here gray and brownish-gray, stylolitic-bedded, unfractured (almost unjointed) West Range Limestone overlies highly fractured dolomite and quartzite of the Guilmette Formation. Many fractures and joints in the Guilmette terminate at this contact, but no local angular discordance could be determined. In places, coarse sand is present in the basal limestone of the West Range Limestone, but in most places, the basal beds are pure limestone. Westgate and Knopf (1932) measured 187 m of West Range Limestone in the West Range, the type locality

Dg **Guilmette Formation (Upper and Middle Devonian)**--An extremely diverse sequence composed mostly of dolomite but containing abundant quartzite and clean orthoquartzitic sandstone in the upper one third, and with thin zones of limestone that occur from near the base to the top. In the West Range, the upper one third (at least 100 m) consists of 30 to 50 percent quartz sand that occurs as sandy carbonate layers, hard quartzite beds, and almost friable but nevertheless resistant sandstone beds. Most sandy beds weather brown and yellowish brown; however, a conspicuous white quartzite 5 to 10 m thick is commonly present at the top, directly below the West Range Limestone. Carbonate beds between the sandstone beds are 80 percent grayish-red or brownish-gray dolomite and 20 percent dark-gray limestone. There are numerous *Amphipora* beds in the dolomite and several "zebra" beds of alternating white and medium-gray dolomite, and brownish-gray dolomite. The middle 100 to 150 m of the formation is mostly cliff-forming, medium- and thick-bedded, brownish-gray dolomite interbedded with ledgy, but not cliff-forming, alternating grayish-brown and medium-gray dolomite; sparse dark-gray limestone beds are more prevalent near the top. The lower 100 to 150 m is cliffy dolomite with distinct ledges, and with bedding outlined by alternating light-gray and brownish-gray beds that grade downward to a middle zone characterized by a massive cliff about 30 m thick. This massive cliff consists of indistinct ledges containing abundant stromatoporoids, and of interbeds of medium- to thick-bedded, dark-gray dolomitic limestone. This zone gives way to mostly pale-brown, grading to grayish-red ledgy dolomite containing beds with chert layers and nodules as long as 6 cm, and beds rich in stromatoporids. The lowest zone of the formation (about 20 to 30 m) is the slope-forming "yellow bed" of Tschanz and Pampeyan (1970), which consists mostly of aphanic dolomite beds averaging about 25 cm thick and containing sparse amounts of fine-grained, well-rounded quartz and silt grains; these grains always coincide with the moderate yellowish brown color that weathers to dusky yellow. The yellowest weathering beds are in the lower 4 m of this lowest zone. The thickness of the entire formation in the West Range is believed to be between 300 and 450 m. The Guilmette Formation is also exposed in the northeast corner of the quadrangle at the southern end of the Fairview Range (north of Bristol Pass), and on the west flank of the northern Bristol Range where it is in fault contact with the Silurian Laketown Dolomite. Exposures at these localities contain quartzite and sandstone beds and therefore represent the upper one third of the Guilmette Formation; these rocks appear to be lithologically similar to those in the West Range. At Blind Mountain and vicinity, in the extreme southeast corner of the quadrangle and in the southwest part of the adjacent Bristol Range SE quadrangle, rocks of the Guilmette consist mostly of white dolomite marble with indistinct bedding. The metamorphism is caused by the Blind Mountain stock and related apophyses. Where not altered to white marble, some dolomite, including some limy dolomite, is medium gray to light gray, and laminated with dark-brownish-gray partings; other beds are massive and black alternating with medium gray. Some of these black rocks, when broken, emit a fetid odor, and several beds contain abundant light-gray *Amphipora*, and others contain *Syringapora* coral mounds. The sequence also includes beds of orthoquartzite, with sand grains so well rounded and perfectly sorted that the beds can easily be confused with the Ordovician Eureka Quartzite. Total thickness of the Guilmette in the Blind Mountain area is uncertain, however, a cross section through a series of beds that dip 60° west there indicates a thickness of at least 600 m

Dsi **Simonson Dolomite (Middle Devonian)**--In the northern Bristol Range, only the basal tan coarse crystalline informal member of Osmond (1954) is exposed in the upper plate of the Bristol Range fault (see "Structural Geology" discussion). The basal member is medium-light-gray dolomite that weathers light olive gray. The dolomite is coarsely crystalline, and contains bedding-parallel laminations and interbedded silicified, 5 to 10 cm thick sandy beds that weather orangish brown; the sandy beds increase in number and thickness toward the basal contact with the underlying Sevy Dolomite. At the base of the member is a 3 m thick yellowish-gray, calcareous quartzite that weathers moderate yellowish brown (weathered); quartz grains are fine grained, subrounded, and well sorted. In the West Range, the formation is almost conspicuously laminated throughout. The upper part contains the *Stringocephalus* zone of Osmond (1954) and Langenheim and others (1969). In places it consists of finely to medium crystalline black- and dark-gray dolomite in beds about 1 to 2 m thick. In other places, just below the basal "yellow bed" of the Guilmette Formation, the beds consist of distinctly laminated, ledgy-weathering, non-fossiliferous dolomite that is grayish red and olive brown; these beds are much grayer weathering overall than the ledges above the "yellow bed". At the southern end of the West Range, where a dip of 13^o is shown, Langenheim and others (1969) identified *Thamnopora limitaris* (Rominger), *Fodjia cordillera* (Frost and Langenheim), *Stringocephalus sp.*, and *Icriodus sp.* On the basis of this collection, they assigned the Simonson to Middle Devonian. The middle part of the formation was consisdered by Langenheim and others (1969) to be more or less equivalent to both the upper and lower alternating informal members of Osmond (1954). Beds of the middle part are conspicuously laminated and consist of ledgy-weathering fine, medium, and coarsely crystalline, light-gray and dark-brownish-gray dolomite. The dolomite ledges are thicker in the upper part than in the lower. The oldest beds include the tan coarse crystalline informal member of Osmond (1954) described above from the Bristol Range. The dolomite in the basal member is very similar to, but coarser grained than typical Sevy dolomite. The thickness of the Simonson is about 230 m

Dse **Sevy Dolomite (Lower Devonian)**--Medium-dark-gray, aphanic dolomite that weathers light gray to light olive gray; beds are thin to thick bedded and algal laminated throughout. A 2- to 3-m-thick, resistant ledge consisting of thin beds of moderate-brown dolomitic quartzite is near the middle of the unit; these dolomitic quartzite beds occur sparsely throughout the upper half of the formation. Unit forms ledgy cliffs and thickness is indeterminable, but Hurtibise (1989) reported a thickness of 377 m for the Sevy in the Schell Creek Range, approximately 25 km to the northwest

Sl **Laketown Dolomite (Silurian)**--Consists of a characteristic three-part subdivision including upper dark gray, middle light gray, and lower dark gray dolomite informal members, exposed in much of eastern Nevada and parts of Utah (Tschanz and Pampeyan, 1970); parts of all three informal members are exposed in the quadrangle, but individual members were not separately mapped. The upper dark gray member consists of finely-crystalline to slightly-aphanic, dark-gray dolomite that weathers olive black; it is thin to thick bedded and contains bedding-parallel laminations and discontinuous beds and nodules of light-brown to dusky-yellowish-brown chert. Fossils include crinoid columnals and silicified corals. This member is exposed in the Bristol Range (east-central part of the quadrangle) where it is about 55 m thick. The middle light gray member is light-gray dolomite that is similar in appearance to the Sevy Dolomite; however, textures of the rock range from finely to coarsely crystalline whereas the Sevy is mostly aphanic. The middle member is generally less fossiliferous than the upper and lower dark gray members. The lower dark gray member is finely-crystalline, dark-gray dolomite that weathers medium gray, olive gray, and light olive gray; the member is thin to thick bedded and contains bedding-parallel laminations and moderate-yellowish-brown to dark-brown chert lenses and nodules. Fossils in the lower member include silicified rugose corals, *Halysites*, *Favosites*, pentamerid brachiopods, and crinoid columnals. Overall, the Laketown Dolomite forms cliffs; its overall thickness cannot be determined, although Kellogg (1963) reported it to be 315 m thick in the southern Egan Range, 40 km to the northwest

Oes **Ely Springs Dolomite (Upper Ordovician)**--Medium-dark-gray, finely-crystalline dolomite that weathers olive gray to light olive gray. The formation is thin to thick bedded and contains bedding-parallel laminations and common discontinuous beds and nodules of dark-brown weathering chert. Fossils include crinoid columnals, brachiopods, and silicified corals. The Ely Springs forms cliffs, and its dark gray color contrasts sharply with the white color of the underlying Eureka Quartzite. Unit is not completely exposed in this quadrangle, but is estimated to be about 160 m thick in the Ely Springs Range, 5 km to the south (Axen and others, unpub. mapping)

Oe **Eureka Quartzite (Middle Ordovician)**--White quartzite that weathers dusky yellowish brown, moderate brown, light brown, and dark reddish brown. Quartz grains are fine grained and rounded to subrounded. Unit is thin to thick bedded, and shows tabular planar and trough crossbeds. Forms rounded cliff and is about 80 m thick

Op **Pogonip Group (Lower and Middle Ordovician)**--Medium-dark-gray finely-crystalline limestone that weathers olive gray, dark yellowish orange, grayish orange, and pale red. Also includes some coarsely crystalline wackestone and packstone, and intraclastic limestone. Locally contains abundant grayish-orange burrow mottles. Uppermost 50 to 60 m is characteristically thin bedded; lower part is generally thick bedded and contains pale-red and grayish-orange, thin silty laminae and oncoids, and sparse tan shale interbeds. Fossils include crinoid columnals, gastropods, trilobites, and brachiopods; the *Receptaculites* zone is about 40 below the top of the Pogonip in the adjacent Coyote Spring quadrangle (Ekren and Page, 1995). Uppermost part of unit forms ledgy slopes, and remainder of unit forms massive cliffs. A complete section of unit is not exposed in the map area but a maximum of 260 m of the unit is exposed in the northern Bristol Range. Kellogg (1963) reported a maximum thickness of 1,080 m for the Pogonip Group in the southern Egan Range, 40 km to the northwest

Ꞓm **Mendha Formation (Lower Ordovician and Upper Cambrian)**--Medium-gray to medium-dark-gray, fine- to medium-crystalline dolomite and subordinate limestone that weather olive gray, light olive gray and dark yellowish orange. The dolomite is thin to thick bedded, generally burrow mottled to medium gray, and contains crinoid columnals and trilobite fragments. The limestone is packstone to wackestone, and contains peloids, intraclasts, and abundant trilobite fragments. The overall unit is equivalent to the Mendha Formation of Merriam (1964) in the Pioche district, and occurs in isolated fault blocks on the east flank of the West Range. The thickness of the unit cannot be determined, but Merriam (1964) and Westgate and Knopf (1932) estimated about 600 m in the Highland Range, about 10 km south

Ꞓhp **Highland Peak Formation (Middle and Upper Cambrian)**--Grayish-black to medium-dark-gray, finely-crystalline, mostly thick-bedded limestone that contains conspicuous light-brownish-gray and light-olive-gray dolomitic-burrow mottles, and oncoids and poorly preserved trilobite and brachiopod shell fragments. The formation is exposed in the Bristol Range where it forms the lower plate rocks of the Bristol Range fault (see "Structural Geology" discussion). At many places in the northern Bristol Range, limestone of the Highland Peak Formation is recrystallized to white and grayish-pink calcite marble; wollastonite crystals were identified in thin sections of some samples. These features are attributed to contact metamorphism associated with a proposed pluton underlying the northern Bristol Range (see "Structural Geology" discussion). Based on lithologies and sedimentary structures, and on an east-west cross section along the west flank of the Bristol Range (Tschanz and Pampeyan, 1970), rocks of the Highland Peak Formation exposed in the northern Bristol Range are probably equivalent to the part of the formation ranging between unit 9 and the Meadow Valley member of Merriam (1964). Tschanz and Pampeyan (1970) reported that approximatley 70 percent of the ore in the Bristol Mining District came from the Meadow Valley member of the Highland Peak. Formation forms massive cliffs and is reported to be about 1,370 m thick 10 km to the south in the Highland Range (Merriam, 1964)

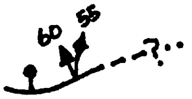
Ꞓc **Chisholm Shale (Middle Cambrian)**--Subsurface only. Consists of pinkish-brown, moderate-brown, and tan shale, and interbedded light-olive-gray to medium-gray, finely crystalline limestone; shale and limestone are locally fossiliferous (Merriam, 1964). Unit forms topographic saddles, and is about 40 m thick 10 km to the south in the Highland Range (Merriam, 1964)

€l **Lyndon Limestone (Middle Cambrian)**--Subsurface only, although part of the unit is exposed in the southwestern part of the adjacent Bristol Range SE quadrangle. Consists of light-gray to white, thick bedded limestone, and dark-gray, thin-bedded and finely-crystalline oolitic limestone (Merriam, 1964). Unit forms massive cliffs, and is about 100 m thick in the Highland Range, 10 km to the south (Merriam, 1964)

€p **Pioche Shale (Middle and Lower Cambrian)**--Upper part, about 60 m, exposed in southeast part of the quadrangle and southwest part of the adjacent Bristol Range SE quadrangle, where it consists of thin beds of medium-gray limestone interbedded with thin beds of light-olive to light-olive-brown shale. The limestone beds are thicker and most numerous at the top, and therefore warrant a gradational contact with the overlying Lyndon Limestone. The middle part consists of platy, pale-brown to pale-yellowish-brown mudstone that weathers to moderate brown, and interbedded flaggy, ferruginous, micaceous, fine grained sandstone. The sandstone contains abundant tubular worm burrows or casts, that are about 1 cm in diameter and 12 cm long. The lower part, which is gradational into the middle part, consists of hackly-and platy-weathering, very red weathering, very micaceous, thin-bedded siltstone, and very fine-grained sandstone. The formation is entirely marine and locally fossiliferous. The thickness of the formation is unknown in the Bristol Well quadrangle, however, according to Tschanz and Pampeyan (1970), the thickness of the Pioche is quite uniform in this region, ranging from 270 to 296 m along a broad belt which passes through the Groom, Delamar, and Pioche districts. The contact with the underlying Prospect Mountain Quartzite is gradational

€Zpm **Prospect Mountain Quartzite (Lower Cambrian and Late Proterozoic)**--Mostly pale-red, weathering reddish brown, obscurely bedded, predominantly thick-bedded, massive weathering, fine grained orthoquartzite with little or no recognizable feldspar. The rock is generally not well sorted although some thin beds certainly are. Several beds contain well-rounded quartz grains 1 mm in diameter in a matrix where the grains average less than 1/4 mm in diameter. The brown weathering is due in part to abundant iron oxide along fractures. Many of the beds have been tectonically shattered and then recemented so that they now resemble granule conglomerates. In the Chief Range, 32 km to the south, Rowley and others (1994) subdivided the Prospect Mountain Quartzite into 70 to 140 m of Zabriskie Quartzite at the top, 320 m of Wood Canyon Formation in the middle, and 600 m of Stirling Quartzite at the base. The 200 m of Prospect Mountain Quartzite exposed in this quadrangle probably is largely equivalent to the Zabriskie as mapped in the Chief Range. No Wood Canyon lithologies appear to be present

Contact



High-angle normal fault--Bar and ball on downthrown side. Showing dip (barbed arrow) and trend and plunge of slickensides (diamond-shaped arrow). Dashed where approximately located, dotted where concealed, and queried where uncertain

Low-angle normal fault--Half circles on upper plate; dotted where concealed, queried where uncertain. Showing dip (barbed arrow) and trend and plunge of slickensides (diamond-shaped arrow)

Oblique-slip fault--Ball and bar on downthrown side. Arrows show relative direction of lateral offset; in cross section, lateral offset is shown by T and A indicating motion toward and away. Dotted where concealed, and queried where uncertain

Fault location based on gravity data--dotted where concealed

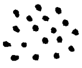
Lineament of uncertain origin

Strike and dip of beds and compaction foliation

Inclined

Vertical

Bw-308 × **Sample locality for conodont analysis**



Upper plate rocks of the West Range fault based on degree of brecciation and dip domain

STRUCTURAL GEOLOGY

Several noteworthy structural features occur in the Bristol Well quadrangle. These features include: 1) a fold of uncertain age, 2) prevolcanic(?), low- and high-angle normal faults, 3) possible Oligocene east-trending volcanic troughs, 4) Miocene or Pliocene low-angle "detachment" faults or mega-landslides in the northern Bristol Range and West Range, and 5) Late Tertiary north- to northwest-striking high-angle normal faults that affect both Tertiary and Paleozoic strata.

Fold of uncertain age

An anticlinal fold is indicated in the northernmost Bristol Range because rocks of the Highland Peak Formation dip east on the east flank of the range, and west on the west flank of the range (cross section A-A'). The axis of this anticline plunges north and the axial trace strikes southeast into the central part of the northern Bristol Range in the adjacent Bristol Range SE quadrangle. The fold is dismembered by the Bristol Range fault of Miocene or Pliocene age (discussed below); thus the folding is almost certainly pre-Miocene. Therefore, it may be related to the Late Mesozoic Sevier orogeny that affected many nearby areas (Armstrong, 1968). Axen (1986) attributed dip variations in the Paleozoic rocks across the Ely Springs Range, 5 km to the south, to folds related to the Mesozoic Sevier orogeny. Alternatively, the anticline is Oligocene in age and formed in response to the forceful injection of a pluton probably centered under the axis of the Bristol Range and exposed in the Blind Mountain area. It is necessary to point out, however, that the pluton as outlined by aeromagnetic data (Blank and others, unpub. mapping) does not coincide precisely with the axial trace of the anticline; the anticline strikes northwest and the pluton strikes north.

Prevolcanic(?) high- and low-angle faults

Westgate and Knopf (1932) first noted east-striking faults in the West Range that did not cut their "Bristol thrust" (see below), and assigned them to an early period of normal faulting. We also mapped several east-striking faults in the Paleozoic rocks of the West Range that do not appear to cut Tertiary volcanic rocks nor the West Range fault (see below) of Miocene or Pliocene age, and consider them to represent an Oligocene, possibly prevolcanic episode of high-angle normal faulting.

Reconnaissance mapping in the southwest part of the adjacent Bristol Range SE quadrangle revealed a low-angle fault that dips 25^{o}-38^{o} east and places rocks of the Highland Peak Formation over the Guilmette Formation, the upper part of the Pioche Shale, and the lower part of the Lyndon limestone. We infer that this fault is the same as the Stampede Decollement of Axen and others (1988), which is exposed farther south in the Highland Range and at other locations in the Pioche district. We interpret the Stampede Decollement to be faulted into the subsurface of the Bristol Well quadrangle as shown in cross section A-A' based on the fact that (1) where exposed at other locations in the Pioche District, the Stampede Decollement generally is a bedding-parrallel fault that occurs at stratigraphic intervals between the uppermost part of the Prospect Mountain Quartzite and lowermost part of the Highland Peak Formation (Axen and others, 1988; Rowley and others, 1994), and (2) the northernmost Bristol Range block consists mostly of rocks of the middle part of the Highland Peak Formation. In the southwest part of the Bristol Range SE quadrangle, the Blind Mountain stock, dated at 27.7 Ma (Armstrong, 1970) and questionably at 34.9 Ma (Johnston, 1972), intrudes the Stampede Decollement indicating it is pre-late Oligocene in age. Axen and others (1988) demonstrated the Stampede Decollement to be older than volcanic rocks preserved in the Highland Range area, and Taylor and others (1989) suggested that the decollement formed during an episode of early Oligocene extension.

Possible Oligocene east-trending volcanic troughs

Anomalously thick east-trending exposures of the Tuff of Deadman Spring and the Lund Formation of the Needles Range Group (Oligocene age) occur in the northwest corner of the quadrangle and these thick outcrops extend westward nearly across the northern part of the adjacent Coyote Spring quadrangle (Ekren and Page, 1995). The unusual thicknesses coupled with an easterly trend of the tuff units that persists despite abundant north-striking faults in the region, suggests that the Deadman and Lund were deposited in a volcanic trough that may have subsided concurrently with eruption in the western part of the Indian Peak volcanic field (Best, Christiansen, and Blank, 1989). The south margin of the proposed volcanic trough is a topographically subtle east-trending boundary that separates thick volcanic tuff units to the north from highly faulted Paleozoic carbonate rocks to the south. A major east-trending ground-water flowpath in the faulted carbonate rocks south of this boundary has been identified by the Las Vegas Valley Water District (Michael Johnson, personal commun., 1994) in conjunction with work completed for this report. This flowpath transmits a substantial amount of groundwater from Lake Valley, east of the northern Bristol Range, into Dry Lake Valley, west of the Bristol and West ranges, through a highly transmissive zone in the faulted carbonate rocks beneath the northern Bristol and West ranges. The thick volcanic sequence north of the boundary dams the groundwater and diverts the water through the highly faulted and fractured Paleozoic carbonate rocks that are part of the deep carbonate aquifer of the regional White River flow system (Eakin, 1964, 1966). This system transmits a major portion of Nevada's groundwater from the eastern to the southern part of the state.

The proposed volcanic trough and ground-water flowpath may be structurally controlled by the east-striking Blue Ribbon Lineament of Rowley and others (1978) in this part of eastern Nevada. The lineament extends into the Marysvale area of western Utah, and most likely connects with the Warm Springs Lineament of Ekren and others (1976) in central Nevada (Rowley and others, 1978). East-striking lineaments, more currently referred to as transverse structures (Duebendorfer and Black, 1992; Rowley, in press), are common structural features of the Basin and Range province that apparently formed as broad, deep seated crustal accommodation zones. Many, including the Blue Ribbon and Warm Springs structures, are characterized by aligned volcanic centers and plutons, that serve as major conduits for mineralizing fluids and ground-water flow (Ekren and others, 1976; Rowley and others, 1978; Rowley, in press).

The Blue Ribbon Lineament probably plays an even greater role in the structural evolution of the region; it may control other major structural features such the Blind Mountain stock, other concealed plutons and associated ore deposits of the Bristol and Fairview mining districts, and other igneous bodies of the Indian Peak volcanic field. North of the quadrangle, the Blue Ribbon Lineament is expressed by a 30-40 km wide zone of east-trending magnetic highs that extend, from east to west, across the Wilson Creek Range, and southern Fairview and Schell Creek ranges (Blank and others, unpub. mapping).

Miocene or Pliocene low-angle "detachment" faults or mega-landslides in the northern Bristol Range and West Range

Two major low-angle "detachment" faults are exposed in the quadrangle; they include a gently west-dipping low-angle fault in the Bristol Range, referred to in this report as the Bristol Range fault, and a moderately east-dipping low-angle fault in the West Range referred to as the West Range fault. Westgate and Knopf (1932) originally correlated the two faults and referred to them collectively as the "Bristol thrust". They interpreted the fault as an east-directed Tertiary overthrust, with a synclinal form as shown by east dips in the West Range, and west dips in the Bristol Range; the synclinal geometry of the Bristol thrust was attributed to either downwarping or later downfaulting.

Tschanz and Pampeyan (1970) referred to the Bristol and West Range faults as related "Post-Oligocene thrusts" (of the Bristol thrust plate) that actually may be landslides or decollement sheets. Langenheim and others (1969, 1971) also suggested the Bristol and West Range faults were landslide or gravity-slide faults that transported Paleozoic debris in the upper plate from a source east of the Bristol Range, possibly the Sevier arch of Harris (1959).

More recently, Axen (1986), Axen and others, (1988), and Taylor and others (1989), interpreted the Bristol fault as part of a regional detachment that had its breakaway along the western Highland and Bristol Ranges, then dipped westward beneath Dry Lake Valley and the Pahroc Range--they referred to the fault as the Highland Detachment. We consider the Bristol Range fault and the West Range fault to be coextensive and to constitute a mega-landslide or slides. The sliding is youthful; it occurred after the valley between the Bristol and West ranges had partly formed because the slide mass in the West Range rests on valley-filling tuffaceous sediments (Tts) of Miocene or Pliocene age.

In the northern Bristol Range, the Bristol Range fault dips from 3^o to about 43^o westward, and average dips of the fault are about 20^o west, based on three point solution of the fault plane on the west flank of the range. The fault carries brecciated and highly faulted Middle Ordovician through Devonian rocks in the upper plate, over folded, non-brecciated, massive-bedded rocks of the Cambrian Highland Peak Formation in the lower plate. Strata in the upper plate generally dip east to northeast into the Bristol Range fault plane, and are extremely attenuated. For example, the Middle Ordovician Eureka Quartzite has a maximum thickness of 80 m in this quadrangle, and is reported to be twice as thick just 40 km to the northwest in the southern Egan Range (Kellogg, 1963). Several windows expose lower plate rocks of the Highland Peak Formation on the west flank of the Bristol Range; the largest one is as great as 0.5 km in diameter, and is shown along cross section A-A'. At many localities in the northern Bristol Range, such as in the window descibed above, lower plate rocks of the Highland Peak Formation are recrystallized to white and grayish-pink calcite marble. As mentioned in the description of map units, this alteration is attributed to contact metamorphism related to a proposed buried pluton beneath the northern Bristol Range (cross section A-A'). Evidence for a buried pluton is supported by an aeromagnetic high centered on the northern Bristol Range (Blank and others, unpublished mapping), and on the fact that the anomaly is coextensive with the exposed pluton at Blind Mountain. The fact that upper-plate rocks are unmetamorphosed indicates the Bristol Range fault postdates plutonism in the Bristol Range.

The West Range fault is a low-angle, east-dipping structure that crops out in the cental part of the West Range. Upper-plate rocks include highly brecciated Ordovician and Silurian strata. Lower-plate rocks consist mostly of the Ordovician Pogonip Group, but locally include units as old as the upper Cambrian Mendha Formation (Cm), and as young as Miocene or Pliocene tuffaceous sedimentary rocks (Tts). Because upper and lower plates of the West Range fault on the east flank of the range contain rocks of similar age, upper-plate rocks are denoted by a stipple pattern and were distinguished from lower plate rocks based on dip domain and degree of brecciation. Upper-plate rocks dip east from 12 to 27^o and are highly brecciated, attenuated, and faulted although their original stratigraphic order is preserved. In contrast, lower-plate rocks on the east flank of the range consist of large, chaotically arranged blocks that are less brecciated than upper-plate rocks and generally dip between 30 and 80^o east to northeast.

No incontrovertible evidence exists to confirm that the Bristol Range and West Range faults are correlative. The best evidence that they are parts of the same sliding episode and probably compose a contiguous mass is the similarity in the degree of brecciation and attenuation of upper-plate rocks in both ranges. Both brecciated masses reflect sliding of thin sheets under very low geostatic pressures or loads. The West Range fault, however, contrasts with the Bristol Range fault in one respect: highly brecciated Ordovician rocks in the upper plate of the West Range fault override less deformed mostly Ordovician rocks in the lower plate on the east flank of the West Range. Similar-age rocks in both upper and lower plates of the West Range fault could possibly indicate much less horizontal displacement there compared to displacements along the Bristol Range fault where Ordovician through Devonian rocks in the upper plate override rocks as old as Middle Cambrian in the lower plate. However, depending on: (1) the nature of pre-sliding structures in the presumed source area (Highland and Bristol Ranges according to Taylor and others, 1989), and (2) pre-sliding structures in the autochthonous terrane, the slide mass could rest on rocks of widely differing ages in the Bristol and West ranges.

Late Tertiary north to northwest-striking high-angle normal faults

The youngest structures in the quadrangle are high-angle normal faults that cut both Tertiary and Paleozoic rocks, and the aforementioned Bristol-West Range upper plates. A majority of these faults strike northwest, as is especially apparent in the northwest quarter of the quadrangle, but younger faults that cut the Bristol-West Range upper plates have variable orientations. The northwest-striking structural graben between the Bristol and West ranges, is more-or-less paralleled by younger faults that flank both ranges.

It is apparent from the previous discussions that a drill hole in the valley separating the West Range from the Bristol Range would penetrate upper-plate brecciated masses of the Bristol and West Range faults. The possibility exists that the same brecciated plate occurs at shallow depth in Dry Lake Valley proper west of the West Range. However, the toe of the slide mass may not have extended much farther to the west than preserved today in the West Range. If this is the case, the upper plate may be absent in the subsurface west of the West Range. This inference is reflected in the interpretation shown on cross section A-A'.

The 15° to 27° dips in the volcanic rocks of the West Range could be caused, in part or wholly, by tilting associated with basin-and-range faulting. These dips probably indicate that the configuration of the normal fault that is down to the southwest at the township line along cross section A-A' is concave upward at depth, which causes the originally flat beds to rotate as they slipped down the fault plane. In contrast, for example, the beds along the fault flanking the Bristol Range in sections 12 and 13, T.2N., R.65E. show dips of 15° to 45° west on the downthrown block, whereas beds in the upthrown block dip shallowly west and north. These attitudes suggest that the configuration of this fault, which in surface exposures, dips 60° west, is probably convex upward in a manner similar to that discussed by Anderson and Barnhard (1993). The mapped area, therefore, like other parts of the Great Basin has "basin-and-range" faults showing both concave- and convex- upward configurations. The changing attitudes of normal faults and faulted beds with time in the mapped area must indicate fluctuating stress orientations from late Oligocene time to the present.

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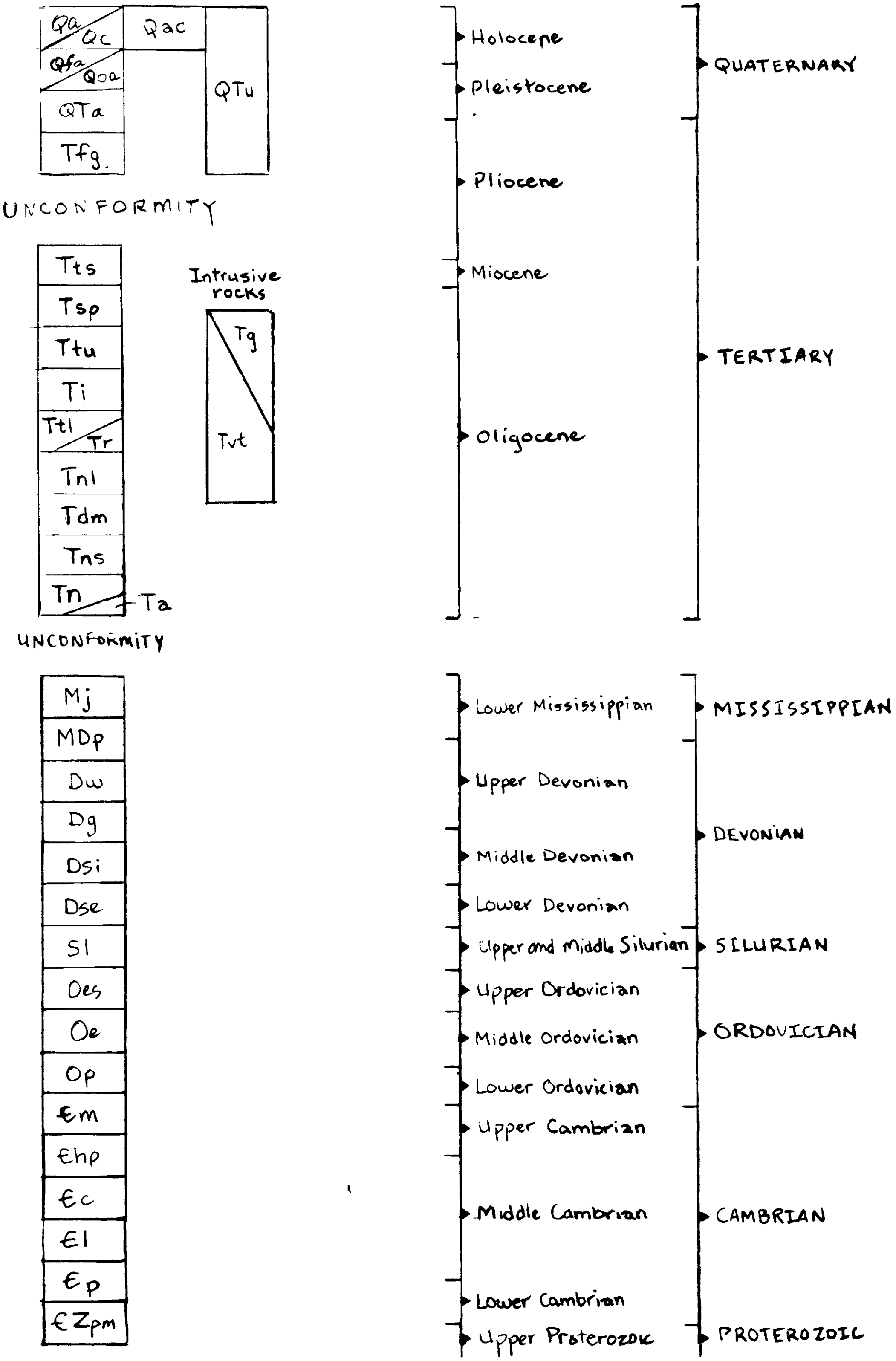
CORRELATION of Map Units, BRISTOL WELL Quadrangle



Correlation of map units