GEOLOGY OF THE WINDERMERE HILLS, NORTHEASTERN NEVADA

(text to accompany NBMG Field Studies Map FS-4)

by Karl J. Mueller

The Windermere Hills lie astride the northern margin of the Ruby-East Humboldt-Wood Hills metamorphic complex, a tract of mid-crustal rocks exhumed during late Mesozoic(?) to Tertiary extension (Dallmeyer and others, 1986; Dokka and others, 1986; Hodges and others, in press). Structures exposed in the map area are related predominantly to overprinted periods of Tertiary extension as well as an earlier, less well understood history of crustal shortening. Strata exposed in the Windermere Hills and northern Pequop Mountains range in age from Ordovician to Miocene and consist of a variety of lithofacies (Mueller, 1992). Paleozoic-Mesozoic strata were deposited on the long-lived continental shelf (eastern facies) of the Cordilleran miogeocline and include both clastic and carbonate rocks. Tertiary strata were deposited in half-grabens formed by upper crustal normal faulting during overprinted periods of extension and volcanism.

PALEOZOIC-MESOZOIC STRATIGRAPHY

Paleozoic and Mesozoic strata exposed in the map area range in age from Ordovician through Triassic and consist of clastic and carbonate units or their metamorphosed equivalents. Excision, or stratal omission, of some portions of this stratigraphic section occurred due to movement along Tertiary low-angle normal faults. Repetition or stacking of Paleozoic units has also occurred along Mesozoic thrust faults. The northern portion of the map area, north of Wells Peak, exposes an incomplete sequence of Ordovician through Triassic strata. Based on the lack of repetition of pre-Tertiary strata and absence of tightly appressed folds in this portion of the map area, Paleozoic-Mesozoic strata probably comprised a single structural plate, prior to stratal omission along a Tertiary low-angle normal fault. This sequence or sheet does not appear to have been tectonically buried by overlying thrust sheets, based on depth of burial estimates defined by Conodont Alteration Indices (Harris and others, 1980). Paleozoic strata exposed south and east of Wells Peak suggest the existence of stacked thrust plates (Coats and Riva, 1983), which were later thinned along a system of low-angle normal faults which lie structurally beneath the fault system to the north.

The oldest strata in the study area are Ordovician units exposed northwest of Wells Peak and in a thrust klippe in the northwestern Pequop Mountains. The oldest of these units is the Lower Ordovician Pogonip Group, which comprises 2,100 feet of limestone and shale as measured from its faulted lower contact to the base of the overlying Eureka Quartzite. These strata are light- to dark-gray limestone, poorly exposed shaly limestone, and sandy dolomite.

The Middle Ordovician Eureka Quartzite comprises 117 feet of light-gray to white quartz-rich sandstone. Incipient grain boundary migration of individual quartz grains at this locality suggests that this unit has undergone minor heating without appreciable strain.

The Late Ordovician Fish Haven Dolomite comprises 263 feet of medium-bedded dark-gray dolomite with minor amounts of black chert. This unit is in turn overlain by 920 feet of platy, gray argillaceous limestone of the lower portion of the Silurian-Devonian Roberts Mountains Formation. The total thickness of Roberts Mountains Formation in the map area is unknown.

Devonian strata north of Wells Peak include the Sevy and Simonson Dolomites and the Guilmette Limestone. The Sevy and Simonson Dolomites consist of light- to dark-gray, thick-bedded dolomite. These combined units, originally mapped as Nevada Formation, have been measured as 1,700 feet thick by Oversby (1969). The overlying Late Devonian Guilmette consists of at least 300 feet of light-gray, thick-bedded, cliff-forming limestone (Oversby, 1969).

The Guilmette is overlain by the 1,550-foot-thick Mississippian Tripon Pass Limestone (Oversby, 1973), described as gray, thin-bedded limestone and thick-bedded, clast-supported limestone conglomerate of turbidite origin. These limestones are interbedded with and grade into coarse sandstones and chert pebble grit and conglomerate of the overlying Melandco sandstone, a Mississippian clastic unit named by Thorman and Brooks (1988) for nearby exposures in the Snake Mountains. An intact section of Melandco sandstone is unknown in the Windermere Hills and adjacent ranges; as recognized it is composed mainly of chert-pebble grit and coarse-grained sandstone, contains minor limestone and black fissile shale, and exceeds 4,500 feet in thickness.

Based on mapping and stratigraphic studies in adjacent ranges and nearby well data, a thick section of Paleozoic strata has been excised in the northern portion of the study area along a major, east-rooted, low-angle normal fault, named the Black Mountain fault. This fault, as exposed in the Windermere Hills, contains Permian-Miocene strata in its hanging wall and Mississippian-Ordovician strata in its footwall. Strata omitted along the Black Mountain fault in the northern Windermere Hills include Mississippian Chainman and Diamond Peak Formations and Pennsylvanian-Permian units, including the Ely Limestone and the Riepe Springs, Ferguson Mountain, and Pequop Formations. Additional strata excised along the Black Mountain fault, as defined in the Sun Southern Pacific #1 well (Garside and others, 1988), include an unknown thickness of Permian strata which comprise the footwall of the thrust fault presently exposed in the northwest Pequop Mountains.

The oldest known Permian strata in the hanging wall of the Black Mountain fault include chert and thick-bedded gray limestone of the Murdock Mountain Formation. A section measured by Wardlaw and others (1979) defined 1,393 feet of Murdock Mountain Formation near HD Summit in the northwest corner of the map area. Permian strata that overlie the Murdock Mountain Formation include the Gerster Limestone, a gray, brachiopod-rich, thick-bedded limestone. The thickness of Gerster Limestone in the study area is unknown.

A thick sequence of Triassic sedimentary rocks overlie Permian strata in the Windermere Hills and include thin-bedded limestone and shaly limestone of the Thaynes Formation. The total thickness of Thaynes Formation in the map area is unknown; however, the areal extent of this unit on the eastern flank of the Windermere Hills and its measured thickness in nearby ranges suggests that it was originally 2,000 to 3,000 feet thick (Swenson, 1991) prior to Tertiary extension.

Paleozoic units exposed south and southeast of Wells Peak that are not present elsewhere in the map area include Mississippian Chainman Formation, Ely Limestone, Permian Pequop Formation, Kaibab Limestone, and the Meade Peak Member of the Phosphoria Formation. These units comprise portions of plates juxtaposed during movement along the Wells Peak fault, a major low-angle normal fault of early to mid Tertiary age.

Mississippian Chainman Formation is exposed in a plate underlying the Wells Peak fault which also contains Devonian Guilmette Limestone, Mississippian Diamond Peak Formation, and Pennsylvanian Ely Limestone. The Chainman Formation is here comprised of poorly sorted, fine- to medium-grained sandstone, chert-pebble conglomerate, shale, and minor limestone. These rocks were metamorphosed under greenschist facies conditions into stretched pebble conglomerate, phyllite, and metasandstone. A flat-lying foliation and north-trending mineral lineation is common in metamorphosed strata of the Chainman Formation near Wells Peak. The thickness of Chainman Formation is unknown in the study area. An exploratory oil well drilled in the southeastern Windermere Hills (Sun Southern Pacific #1) penetrated the same stratigraphic and structural succession as mapped at Wells Peak and intersected 5,500 feet of Chainman-type lithology.

Devonian Guilmette Limestone in the footwall of the Wells Peak fault is comprised of greenschist facies rocks including highly deformed marble characterized by well developed, steeply dipping foliation, incipient growth of white mica, and tightly appressed isoclinal folds with a well defined axial-planar cleavage.

Mississippian Diamond Peak Formation and Pennsylvanian Ely Limestone, exposed near the southwestern portion of the map area, also have been metamorphosed and are comprised, respectively, of stretched pebble-cobble conglomerate and thinly bedded shaly limestone and limestone. The total thicknesses of these units are unknown.

Permian strata exposed southeast of Wells Peak that are not exposed elsewhere in the field area include Pequop Formation, Kaibab Limestone, and the Meade Peak Member of the Phosphoria Formation. Permian Pequop Formation consists of at least 4,500 feet of medium- to thick-bedded limestone in its lower part and interbedded pebble conglomerate and gray limestone in its upper part. The Pequop Formation is capped by the 150-foot-thick, gray, crinoid-rich Kaibab Limestone. The overlying Meade Peak Member of the Phosphoria Formation is a highly silicified cherty shale which contains phosphatic nodules and coatings along fractures.

TERTIARY STRATIGRAPHY

Tertiary strata in the Windermere Hills are exposed in a belt along the eastern flank of the range, adjacent to the Toano Basin. Tertiary strata range from late Eocene to late Miocene in age, based on $^{40}Ar/^{39}Ar$ and fission track dating of interbedded volcanic deposits (Thorman and others, in press).

The best exposures of late Eocene and early Oligocene strata in the study area are present along the northern wall of Lower Deadman Creek. The oldest unit (Tdf on map) consists of flow breccia, clast-supported conglomerate, volcaniclastic sandstone and siltstone, and rhyolitic ash-flow tuff; these have a combined thickness of 846 feet. Abrupt along-strike variations in thickness and lithology characterize this unit, suggesting local relief and rapid facies transitions in a landscape dominated by volcanic landforms.

An ash-flow tuff (Tdd) overlies unit Tdf and is characterized by its light- to dark-green color and dacitic composition. This tuff was deposited during the late Eocene as a 100- to 200-foot-thick sheet spread over an area of at least 300 square miles, based on its occurrence in adjacent ranges (Thorman and Brooks, 1988). Overlying unit Tdd are strata that include a rhyolitic, lapilli ash-flow tuff (Tdr) defined by a light-green color, abundant ash and lithic fragments, and quartz phenocrysts. The thickness of this unit varies from 60 to approximately 300 feet.

The widespread ash-flow units exposed along lower Deadman Creek are overlain there by a thick succession of flow breccia, clast-supported boulder to cobble conglomerate, sandstone, and siltstone (Tdc on map). Volcanic strata present in this unit at Deadman Creek are not present along strike to the north in Medicine Creek. Strata mapped as Tdc at Medicine Creek are dominated by coarse-grained sandstone, clast-supported conglomerate, algal limestone, and laminated siltstone. Sedimentary structures in outcrops along Medicine Creek suggest that these strata were deposited in an Oligocene freshwater lake in wave reworked fan deltas, spring-fed tufa mounds, and suspension-fed laminites.

Volcanic and volcaniclastic strata at Deadman Creek are unconformably overlain by a 521-foot-thick sequence of tan sandstone and grit (Thsa). These sandstones were deposited in lacustrine fan deltas. A sharply defined unconformity separates these tan sandstones from underlying flow breccia at Deadman Creek; this contact appears to be gradational farther north at Hunter Draw where tan sandstone is interbedded with underlying conglomerate and limestone. The thickness of unit Thsa varies depending on the location and amount of slip along normal faults active during deposition. Thicker sections characteristically occur in the hanging walls of east-dipping normal faults, with thinner sections corresponding to footwall blocks. This unit also appears to vary along depositional strike depending on the point source of fan deltas feeding into the western margin of individual half-grabens.

Sandstone of unit Thsa is conformably overlain by a thick sequence of laminated siltstone, plant-rich shale, thinly bedded sandstone, and ash-fall tuff (Thsi). Well-preserved siltstone laminae, fish fossils, and the continuity of beds along strike suggest that these strata were deposited in a deep-water lacustrine environment with minimal biologic activity as suspension-fed laminites. Plant-rich shales may have also been deposited in a deep-water environment, based on abundant well-preserved laminations and a lack of root mottling. A faulted sequence of Thsi measured near Deadman Creek exceeds 960 feet in thickness; map relations south of Deadman Creek suggest that this unit may exceed 2,500 feet in thickness.

Strata included in unit Thsi are overlain by a thick sequence of volcaniclastic conglomerate and sandstone (Thc) calculated from map relations to be more than 2,800 feet thick. These coarse-grained deposits are best exposed in railroad cuts of the Southern Pacific Railroad along the northern margin of the Pequop Mountains. Paleocurrent indicators and clast imbrication tentatively suggest that unit Thc detritus was derived from the south across a north-facing fault scarp in alluvial fan, fan delta, and shoreline gravel bars.

These strata (Thc) are overlain by unit Tha along an angular unconformity or disconformity. Unit Tha includes sandstone, marl, and reworked vitric ash of late Miocene age, which was deposited in lacustrine environments, largely as debris flows in lacustrine fan deltas. Aggraded fan delta foresets and fission-track dating suggest rapid deposition in fan delta environments and fringing sand flats. An important characteristic of this unit is the presence of white to light-gray vitric ash consisting of coarse glass shards. The best exposures of unit Tha are along the Southern Pacific Railroad in the southeastern portion of the map area.

STRUCTURAL GEOLOGY

Mesozoic shortening

The earliest evidence of tectonism recorded in the map area includes Ordovician strata exposed in the hanging wall of a thrust plate in the northwest Pequop Mountains (Coats and Riva, 1983). These strata, which include Fish Haven Dolomite and Eureka Quartzite, were emplaced above Permian strata and represent the base of a thick thrust sheet. The age of this thrust fault is unknown, but it is probably Mesozoic, based on the history of crustal shortening in surrounding ranges (Riva, 1970; Thorman, 1970; Oversby, 1972; Coats and Riva, 1983; Thorman and Brooks, 1988; Ketner and Ross, 1990). This thrust fault is not exposed in the northern Windermere Hills, although it is inferred to be present at depth.

Tertiary extension — Wells Peak fault

Evidence for the earliest phase of extensional faulting is present in the southwestern portion of the map area near Wells Peak. Map relations present here indicate the presence of two low-angle normal faults (Mueller, 1992). The structurally highest fault, named the Wells Peak fault, is defined by an antiformal culmination at Wells Peak and further east by a low primary dip, based on strata penetrated by the Sun Southern Pacific No. 1 well. Strata exposed in the footwall of the Wells Peak fault include metamorphosed Guilmette Limestone, Chainman and Diamond Peak Formations, and Ely Limestone. Metamorphic fabrics present in these units are not related to the pervasive west-northwest-stretching lineation or other known Tertiary fabrics in the East Humboldt-Wood Hills metamorphic complex, suggesting that they are Mesozoic in age (Mueller and Snoke, 1993). Kinematic indicators of slip are not exposed along the Wells Peak fault; however, regional reconstruction of pre-extension stratigraphy suggest that metamorphosed footwall strata exposed near Wells Peak were excised from beneath a hanging-wall sequence present to the west in the southern Snake Mountains. The Wells Peak fault is interpreted to have exhumed high grade metamorphic rocks in the Wood Hills and East Humboldt Range in late Eocene to early Miocene time (Dallmeyer and others, 1986; Dokka and others, 1986; Thorman and Snee, 1988; McGrew and Snee, 1991; Mueller and Snoke, 1993).

East-striking normal faults

The low-angle normal faults exposed at Wells Peak are bounded on the north by a complex array of steeply dipping, east-striking faults. These east-striking faults separate highly strained and metamorphosed rocks in the footwall of the Wells Peak fault from much less plastically deformed Paleozoic strata to the north.

Evidence that suggests that the east-striking fault zone is a Tertiary, north-dipping normal fault includes: 1) the geometry of the east-striking faults, 2) the age and sense of rotation of Miocene sedimentary rocks in its hanging wall, and 3) reconstruction of the pre-extensional geometry of the Mesozoic thrust faults. The timing of movement along the north-dipping normal fault is defined by synextensional sedimentary rocks (unit Thc) of Oligocene or Miocene age that lie in its hanging wall in the northern Pequop Mountains.

Black Mountain fault

An east-rooted low-angle normal fault, named the Black Mountain fault, is exposed in the northern Windermere Hills. Strata exposed in the footwall of the Black Mountain fault, in the Windermere Hills, are Ordovician to Mississippian in age (Oversby, 1969) and unmetamorphosed, based on Conodont Alteration Indices (Harris and others, 1980). Strata exposed in the hanging wall of the Black Mountain fault vary from Permian to Tertiary in age. Stratigraphic cutoff angles, coupled with an estimated thickness of excised section, suggest 13 to 25 kilometers of top-to-the-east slip along the Black Mountain fault.

The Black Mountain fault exhibits a synformantiform geometry characteristic of low-angle normal faults throughout the North American Cordillera (Spencer, 1984; Buck, 1988). This geometry has evolved during flexure and isostatic uplift of the footwall during tectonic removal (Buck, 1988; Wernicke and Axen, 1988) or thinning of the hanging wall along rotating arrays of high-angle normal faults (Spencer, 1984).

Rotated, east-dipping normal faults, which lie above and sole into the underlying low-angle Black Mountain fault, are preserved along the eastern flank of the Windermere Hills where they offset Tertiary strata. Interaction between these rotated normal faults and the Tertiary strata they offset define extension within the hanging wall of the Black Mountain fault, and by inference, slip along it.

An early phase of extension is defined by late Eocene sedimentary rocks deposited as lacustrine fan deltas (unit Tdc) in the hanging wall of an east-dipping fault that strikes north through the eastern half of sections 5, 8, 17 and 20, T39N, R65E in the Wine Cup Ranch SW Quadrangle. The early Oligocene sedimentary rocks exposed in the hanging wall of this fault overlie a thick sequence of late Eocene volcanic deposits (units Tdr, Tdd, and Tdf), which suggests that early Tertiary extension closely followed the initiation of volcanism in this region.

Late Eocene-early Oligocene volcanic and volcaniclastic sedimentary rocks exposed in the map area (units Tdc, Tdr, Tdd, and Tdf) are depositionally overlain by Oligocene(?) strata (units Thsa and Thsi) associated with subsidence of a broad half-graben bounded by the Black Mountain fault and higher angle synthetic normal faults in its hanging wall. This half-graben was developed in response to flexure in the hanging wall of the Black Mountain fault; therefore, these middle Miocene strata effectively date movement along it.

Strata that postdate movement along the Black Mountain fault include Oligocene(?) and Miocene sedimentary rocks of units Thc and Tha. Unit Thc was deposited in the hanging wall of a north-dipping, east-striking normal fault that extends across the map area. Strata included in unit Tha were deposited in two half-grabens, bounded by high-angle east-dipping normal faults that crosscut the Black Mountain fault.

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Period	Symbol	Unit
Quaternary	Ql	Landslide deposits
	Qs	Stream deposits
	Qf	Alluvial fan deposits
Tertiary	Thva	Humboldt Formation—vitric ash member
	Thc	Humboldt Formation—conglomerate member
	Thsl	Humboldt Formation—siltstone member
	Thss	Humboldt Formation—sandstone member
	Tdc	Conglomerate, flow breccia, and sandstone of Deadman Creek
	Tb	Basaltic andesite and rhyolitic tuff of southern Snake Mountains
	Tdr	Rhyolitic ash-flow tuff of Deadman Creek
	Tdd	Green dacitic ash-flow tuff and flow breccia of Deadman Creek
	Tdf	Flow breccia, conglomerate, and rhyolitic tuff of Deadman Creek
Triassic	Tkt	Thaynes Formation
Permian	Pg	Gerster Formation
	Pm	Murdock Mountain Formation
	Pmp	Meade Peak Member of the Phosphoria Formation
	Pk	Kaibab Limestone
	Pp	Pequop Formation
	Pu	Undifferentiated Permian strata of varied age
Mississippian	Mm	Melandco Sandstone
	Mtp	Tripon Pass Limestone
Devonian	Dg	Guilmette Formation
	Ds	Sevy and Simonson Dolomites
Dev.-Silurian	Srm	Roberts Mountains Formation
Ordovician	Ofh	Fish Haven Dolomite
	Oe	Eureka Quartzite
	Op	Pogonip Group strata

Metamorphosed Units

Period	Symbol	Unit
Pennsylvanian	IPem	Ely Limestone
Mississippian	Mdpm	Diamond Peak Formation
	Mcm	Chainman Formation
Devonian	Dgm	Guilmette Formation

Pg? Formations queried where uncertain or poorly exposed

Low-angle normal fault Dashed where inferred; dotted where covered; tick marks on hanging wall; arrow denotes calculated dip of fault.

High-angle normal fault Dashed where inferred; dotted where covered; ball on down-thrown side; queried where uncertain; arrow denotes measured dip of fault.

Thrust fault dashed where inferred; teeth on hanging wall.

High-angle fault interpreted to be strike-slip or oblique-slip Dashed where inferred; dotted where covered; arrows denote inferred sense of strike-slip; U/D denotes sense of dip-slip separation.

Stratigraphic contact Dashed where inferred; dotted where covered; queried where uncertain.

Strike and dip of bedding measured on outcrop

Strike and dip of bedding measured from strata visible on aerial photograph

Strike of vertical bedding

Strike and dip of overturned bedding

Horizontal bedding

Strike and dip of foliation

Strike of vertical foliation

Strike and dip of foliation Includes trend and plunge of mineral lineation if present.

Horizontal foliation with trend of mineral lineation

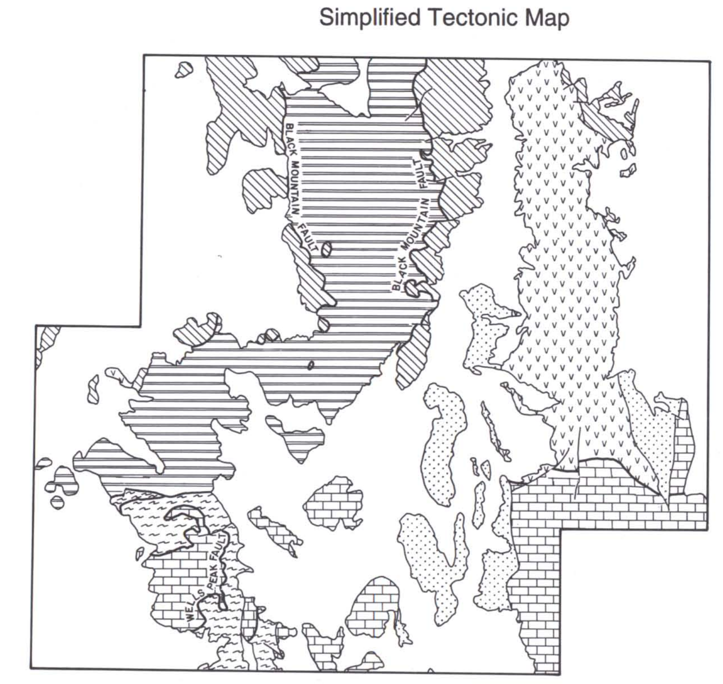
Trace of axial surface of anticline Dashed where inferred; dotted where covered; arrow denotes plunge of hinge line.

Trace of axial surface of syncline Dashed where inferred; arrow denotes plunge of hinge line.

Sun Oil So. Pacific 3-13 TD = 14,000' **Well drilled for oil and gas** Includes operator, well name, and total depth.

A├ ┤A′ **Ends of cross sections shown on plate 2**

Simplified Tectonic Map



- Tertiary strata unconformably overlying Black Mountain fault
- Tertiary strata offset in hanging wall of Black Mountain fault
- Pre-Tertiary strata offset in hanging wall of Black Mountain fault
- Pre-Tertiary strata offset in footwall of Black Mountain fault
- Pre-Tertiary strata offset in hanging wall of Wells Peak fault
- Pre-Tertiary strata (metamorphosed) offset in footwall of Wells Peak fault

Scale 1:48,000

1 ½ 0 1 mile

1000 0 4000 8000 feet

1 .5 0 1 2 kilometers

Mapped by Karl J. Mueller 1987–1990

Topographic base from the following U.S. Geological Survey 7½′ quadrangle maps: Melandco, Wine Cup Ranch SW, Wine Cup Ranch SE, Wells Peak, Holborn, and Pequop, 1968

Field review:
C. H. Thorman, USGS
J. G. Price, NBMG
L. J. Garside, NBMG

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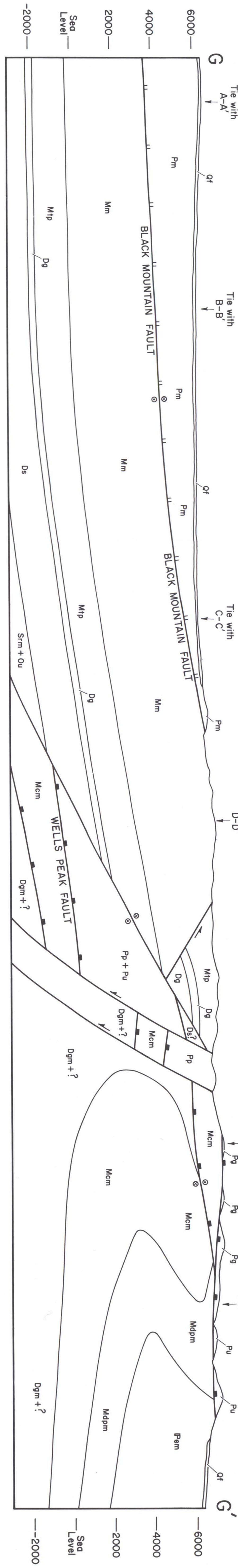
Nevada Bureau of Mines and Geology
University of Nevada, Mail Stop 178
Reno, Nevada 89557-0088

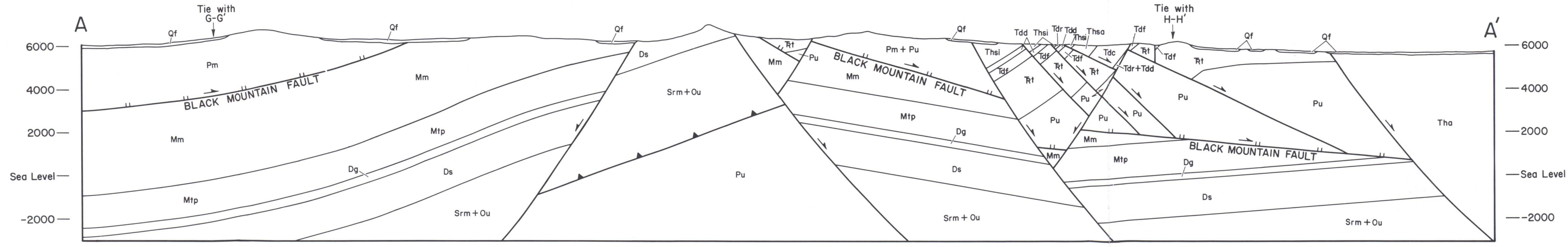
GEOLOGIC MAP OF THE WINDERMERE HILLS, NORTHEASTERN NEVADA

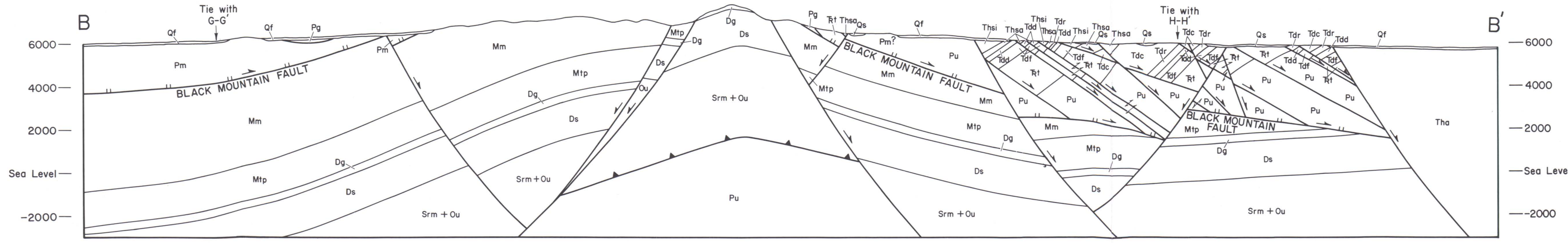
Karl J. Mueller

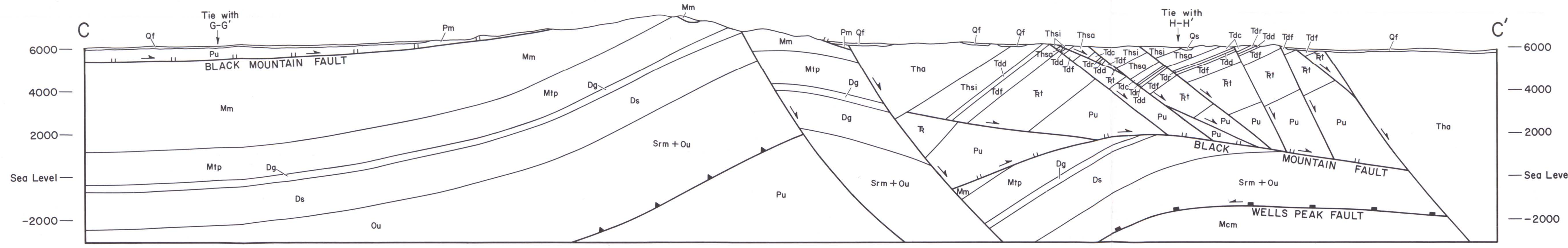
1993

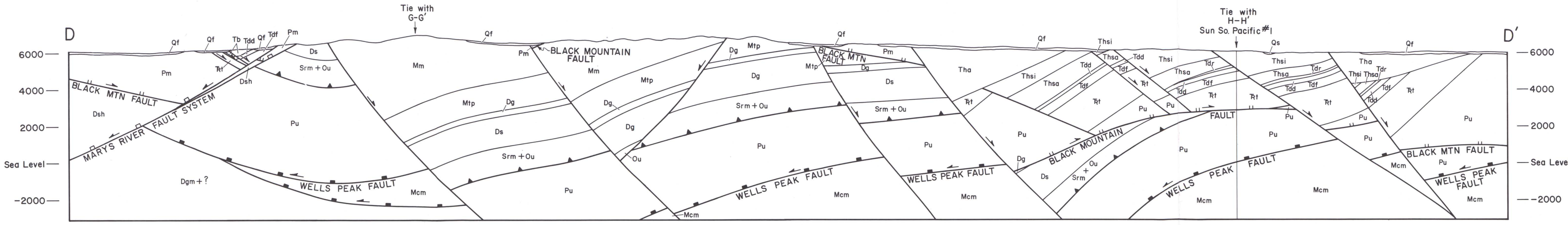
See plate 2 for cross sections. See accompanying pamphlet for discussion of stratigraphy and structural geology.

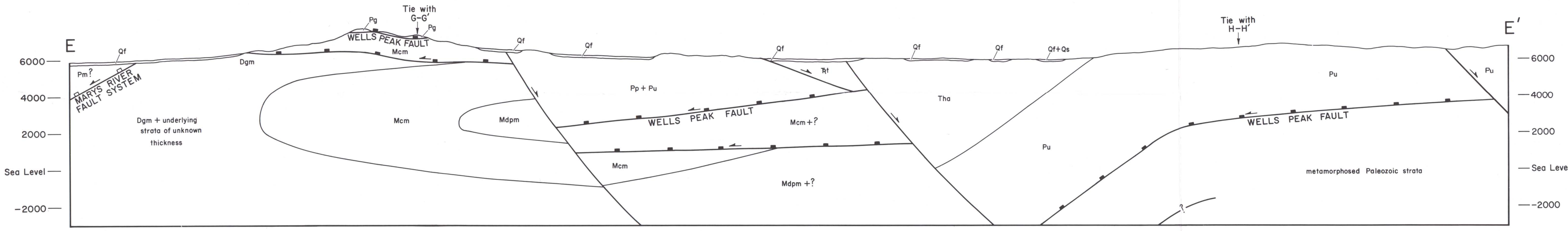


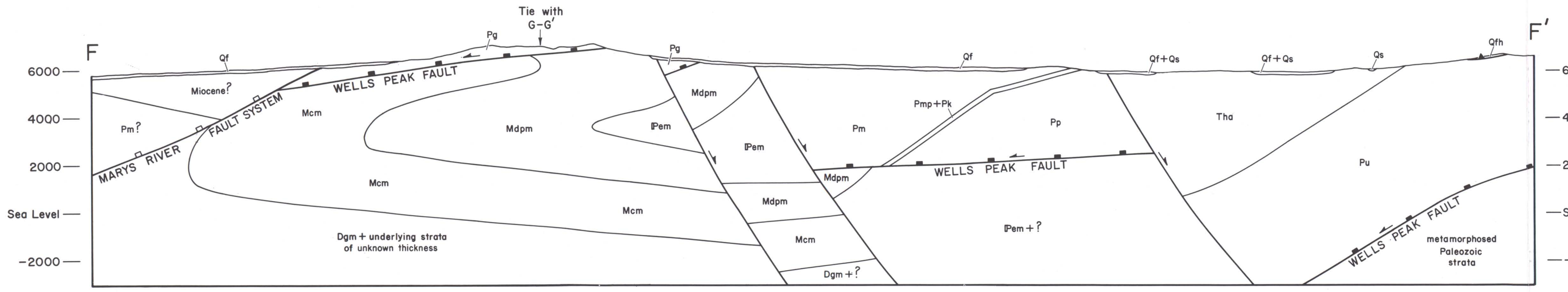


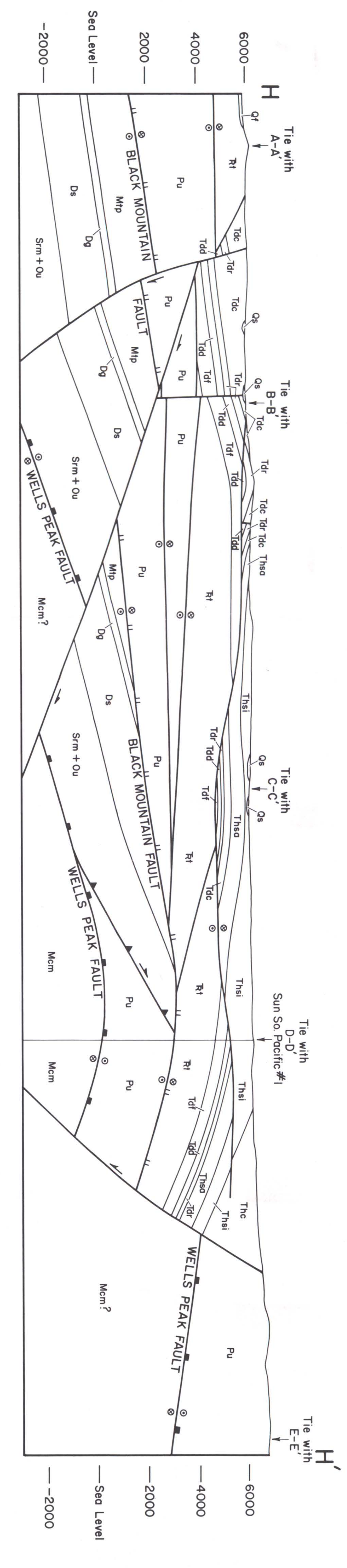


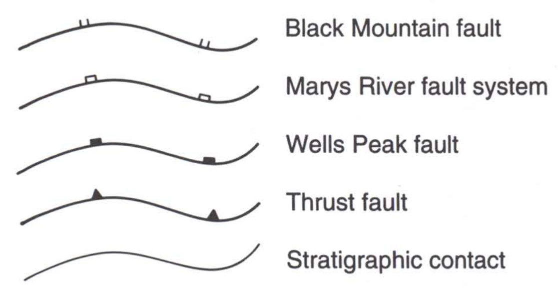












Scale 1:48,000

No vertical exaggeration

Thin surficial deposits are not shown.

Geology by Karl J. Mueller, 1992

See plate 1 legend for map unit descriptions.

CROSS SECTIONS TO ACCOMPANY

GEOLOGIC MAP OF THE WINDERMERE HILLS, NORTHEASTERN NEVADA

1993