Text and references for Nevada Bureau of Mines and Geology Map 138

GEOLOGY OF THE BOBS FLAT QUADRANGLE

EUREKA COUNTY, NEVADA

by

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INTRODUCTION

The Bobs Flat Quadrangle is about 40 km west of the town of Carlin. Interstate 80 cuts generally northwest to southeast through the south part of the quadrangle, with the turnoff exit to Beowawe and Crescent Valley near the south-central part of the quadrangle. Geologic mapping was conducted in the area to help define the nature of structural and stratigraphic controls along a regionally prominent structural zone that is associated with large gold mines in the Carlin trend approximately 25 km to the northeast (figs. 1 and 2).

The oldest rocks in the Bobs Flat Quadrangle are moderately to intensely deformed rocks of the upper plate of the Roberts Mountains allochthon (fig. 2). Rock types include laminated pelitic chert, massive chert, silty and calcareous sandstone, massive dolomitic, fine-grained sandstone, quartzite, and geochemically intermediate volcanic rocks. Bedding along a northeast-striking corridor has been dismembered and transposed, such that 1- to 100-cm-thick competent layers have been broken or deformed into phacoids in a matrix of irregularly cleaved shale or clast-in-matrix rock. The upper-plate rocks previously were assigned by Roberts and others (1967) and by Stewart and Carlson (1976) to the Ordovician Vinini Formation named by Merriam and Anderson (1942). Devonian calcareous sedimentary rocks interbedded with these rocks also were noted by Roberts and others (1967) on the east side of Bobs Flat Quadrangle and to the northeast in the Welches Canyon Quadrangle by Evans (1980), and some previously were assigned to the Roberts Mountains Formation (figs. 1 and 2).

Mapping at 1:24,000 scale, however, suggests that rocks originally assigned to the Vinini Formation consist of two packages of Silurian(?) to Devonian or younger rocks that are separated by the newly defined Dunphy thrust. Rocks assigned to the Roberts Mountains Formation by Stewart and Carlson (1976), consist of Early Pennsylvanian rocks of the overlap assemblage. Mesozoic intrusive and Tertiary intrusive and volcanic rocks also are present on the east side of the Bobs Flat Quadrangle. The igneous rocks lie along a prominent aeromagnetic anomaly (Hildenbrand and Kucks, 1988). Structurally, the area is dominated by the Crescent Valley-Independence lineament (CVIL), which is expressed geomorphically by northeast-elongated ridges of intensely tectonized rock of the upper plate of the Roberts Mountains allochthon, and by adjacent northeast-trending valleys and local Mesozoic and Tertiary dikes (Peters, 1998).

GEOLOGIC HISTORY

Reconstructions of the tectonic history of north-central Nevada indicate that early and middle Paleozoic, “western assemblage” deep-water sedimentary and igneous rocks were thrust eastward approximately 75 to 200 km during the Late Devonian to Early Mississippian Antler orogeny (Roberts and others, 1958). These rocks comprise the Roberts Mountains allochthon, which lies upon “eastern assemblage” coeval shallow-water rocks of the continental platform (fig. 2). The two packages of rocks, the upper and lower plates, are separated by the Roberts Mountains thrust (Merriam and Anderson, 1942; Roberts and others, 1958; not shown in fig. 2).

Emplacement of the allochthon produced a topographic high. Sediments were shed from the highland to the east and west in the late Paleozoic to form the overlap assemblage of rocks (Roberts, 1960, 1966; Madrid and others, 1992). Local volcanism and magmatism took place in the Mesozoic (fig. 2). Other reconstructions of the tectonic history of the region suggest that some geologic relations in the region

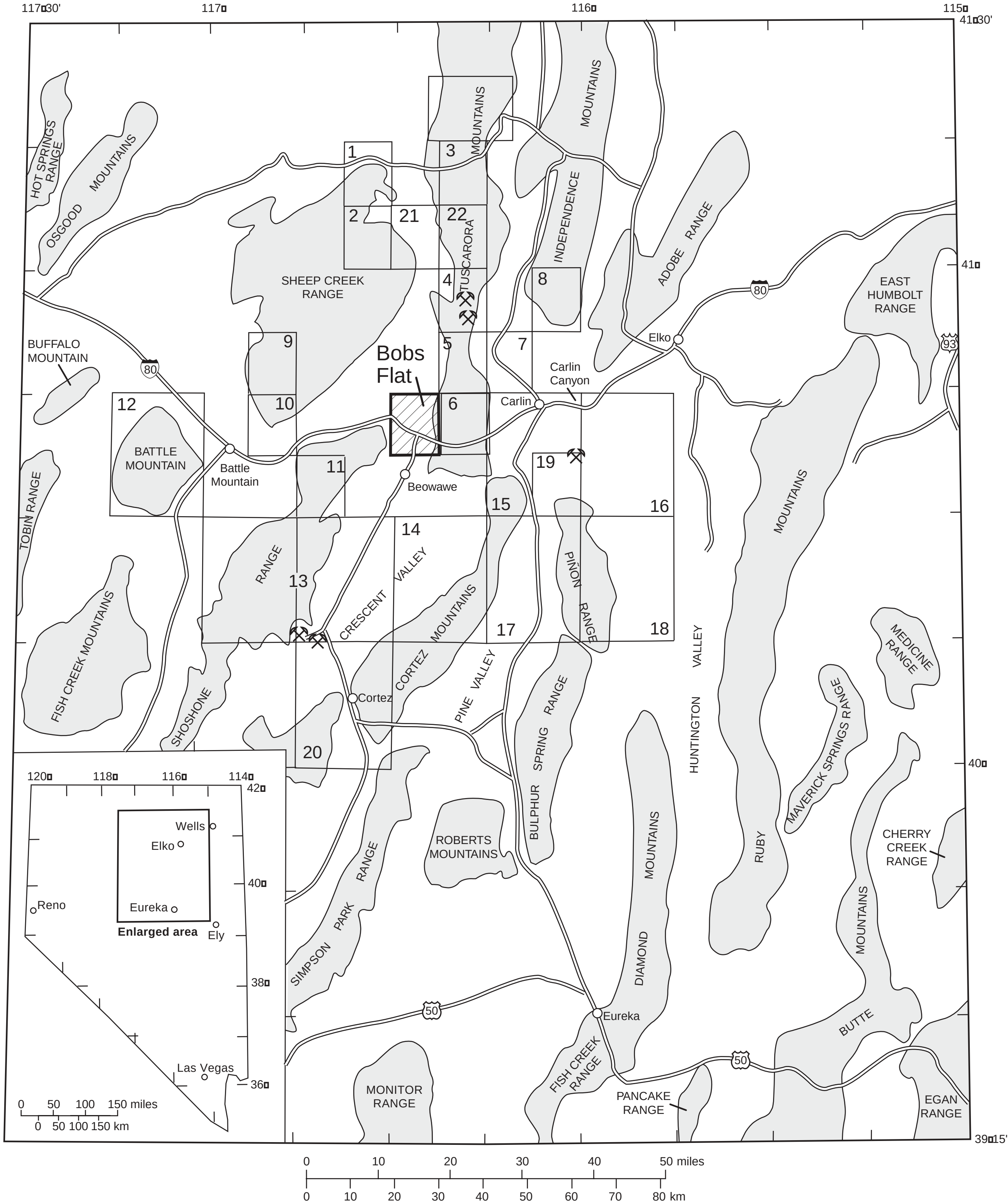

Figure 1. Index map of northeastern Nevada showing location of major mountain ranges and Bobs Flat Quadrangle and locations of some quadrangles. 1, Willow Creek Reservoir (Wallace, 2003a); 2, Willow Creek Reservoir SE (Wallace, 2003b); 3, Sugarloaf Butte; 4, 5, Rodeo Creek NE and Welches Canyon (Evans, 1980); 6, Emigrant Pass (Henry and Faulds, 1999); 7, Schroeder Mountain (Evans and Cress, 1972); 8, Swales Mountain (Evans and Ketner, 1971); 9, Izzenhood Spring (Wallace and John, 1998; John and Wrucke, 2000); 10, Stony Point (Ramelli and others, 2001); 11, Mule Canyon (John and others, 2000; John and Wrucke, in press); 12, Antler Peak (Roberts, 1964; Doebrich, 1995); 13, Mount Lewis and Crescent Valley (Gilluly and Gates, 1965); 14, Frenchie Creek (Muffler, 1964); 15–18, Carlin, Dixie Flats, Pine Valley, and Robinson Mountain (Smith and Ketner, 1978); 19, Ravens Nest (R.M. Tosdal, unpub. data, 1998); 20, Cortez (Gilluly and Masursky, 1965); 21, Santa Renia Fields (Theodore, unpub. data, 2000); 22, Beaver Peak (Theodore, in press). Crossed picks represent sedimentary rock-hosted gold mines along the Carlin trend and in Crescent Valley.

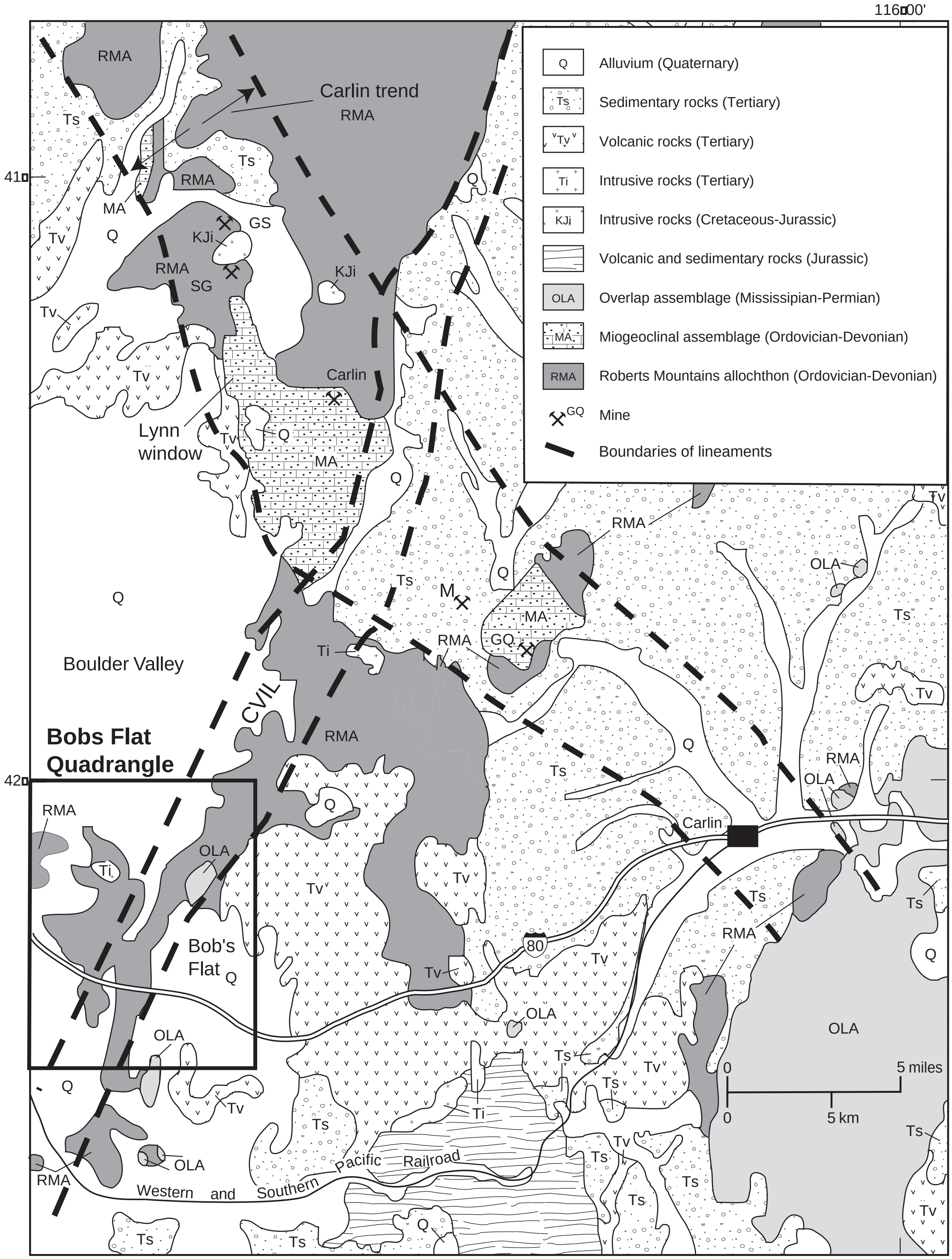

Figure 2. Generalized geology of the Carlin trend (modified from Stewart and Carlson, 1976) showing location of Bobs Flat Quadrangle. Most gold mines are located along a NW-trending zone, the Carlin trend associated with tectonic windows of lower-plate Devonian-Ordovician miogeoclinal assemblage rocks (MA), which underlie the Devonian-Ordovician Roberts Mountains allochthon (RMA). Mississippian-Permian overlap assemblage rocks (OLA) are present in the SE part of the map area. Major mines are noted as follows: GQ = Gold Quarry, SG = Genesis-Blue Star, GS = Goldstrike, M = Mike deposit. The Crescent Valley-Independence lineament (CVIL) strikes through the Bobs Flat Quadrangle and through the Carlin trend.

also may be due to: (1) late Paleozoic reactivation of the Antler orogen near the end of the Sonoma orogeny (Theodore, 1999; Theodore and others, 2000) (2) local Early Triassic remobilization of the Roberts Mountains allochthon (Ketner and Alpha, 1992; Ketner and others, 1993); (3) significant tectonism in the region during the Late Jurassic Elko orogeny, locally accompanied by plutonism; (4) the Cretaceous to early Tertiary Sevier orogeny, locally accompanied by plutonism; and (5) large-scale extensional detachment faulting, accompanied by plutonism and volcanism in the late Eocene to early Oligocene (Thorman and others, 1991a, b; Seedorff, 1991; Wallace, 1991; Henry and Boden, 1998). Extensional valleys were filled with multiple alluvial fan and river deposits during Cenozoic extension and received their main current geomorphological expressions during the Miocene.

Paleozoic Sedimentary and Igneous Rocks

Paleozoic rocks in the Bobs Flat Quadrangle are represented by three principal rock packages; rocks of the Roberts Mountains allochthon above and below the Dunphy thrust, and late Paleozoic rocks of the overlap sequence (fig. 3).

Rocks above the Dunphy thrust (Silurian and younger)

Rocks above the Dunphy thrust are assigned to the Roberts Mountain allochthon on the basis of regional geologic setting and their similarity to lithologic units described by Merriam and Anderson (1942) and by Madrid (1987) and Madrid and others (1992). Rocks above the Dunphy thrust are divided into two units, Dcs in the west and DScs in the northeast parts of the Bobs Flat Quadrangle on the basis of lithology and structural style. These two units are less deformed than rocks below the Dunphy thrust. Both units may be correlative to parts of the Devonian Slaven Chert and Silurian Elder Sandstone of Gilluly and Gates (1965) on the basis of locally abundant fine-grained calcareous sandstone lithologies and radiolarians from four localities in chert in unit Dcs that suggest a Devonian or younger age (P. Noble, written commun., 1998). Radiolarians include entactinids (species and genus undetermined) and *Trilonche* of the Entactinid superzone of Noble and Aitchison (2000). Limestone (Dl) in these rocks also may correlate with Late Devonian limestone mapped in the Welches Canyon Quadrangle, 10 km to the northeast, by Evans (1974) and near Marys Mountain, 15 km to the east, in the Emigrant Pass Quadrangle by Henry and Faulds (1999). The rocks are well-bedded and fissile compared to rocks below the Dunphy thrust.

The western package of rocks designated as Dcs on the accompanying geologic map consist of chert, shale, limestone, and chert-pebble conglomerate. Chert units are tan, light gray, maroon, and light green and well-bedded with common 1- to 15-cm-wide “mammary” or compaction surfaces. Shale is soft, fissile, interbedded with chert, maroon to light gray, and locally hard and siliceous. Limestone weathers black to dark gray, commonly with knobby, pitted surfaces, and is interlayered with black and gray dolomite, chert, and siliceous shale. Chert-pebble conglomerate layers are rare but diagnostic of the unit in the area (Three specific locations are: W½ sec. 33, T33N, R49E; E½ sec. 27, T33N, R49E [Hill 4999T]; and SW¼ sec. 25, T33N, R49E).

Folding and shallow dips in unit Dcs, in the western parts of the Bobs Flat Quadrangle, preclude reliable estimates of total thickness of the unit; however, a partially intact stratigraphic section is present in sec. 33, T33N, R49E (table 1).

This truncated section is a minimum thickness of exposed rocks above the Dunphy thrust in the Bobs Flat Quadrangle.

Unit DScs lies in the northeast part of the Bobs Flat Quadrangle and is contiguous with units to the east in the Emigrant Pass Quadrangle (Henry and Faulds, 1999) and Welches Canyon Quadrangle to the northeast (Evans, 1980). The unit is steep dipping and isoclinally folded and contains abundant buff, tan and gray, calcareous, fine-grained sandstone units and 1- to 5-m-thick gray to tan chert horizons interbedded with gray and green shale and fine-grained sandstone. Another diagnostic horizon of unit DScs is a black, knobby 1- to 2-m-thick limestone commonly in contact with bedded gray limestone and dolomite, common in hills north and south of Mack Creek (fig. 3). Approximate thickness of a synformally folded sequence of rocks that crop out north of Mack Creek in sec. 7, T33N, R50E is >600 m.

Undifferentiated limestone units (Dl) above the Dunphy thrust are interbedded with horizons in DScs and Dcs. Many occurrences are not mapped. The limestones commonly are 2-m-thick, gray to black, and layered to massive, particularly in unit Dcs. Within the DScs unit gray limestone is interbedded with chert and black, knobby, 1- to 2-m-thick limestone commonly is in contact with bedded, gray limestone and dolomite specifically in hills north and south of Mack Creek.

Table 1. Stratigraphic section of rocks above the Dunphy thrust (Dcs)

Rock types	Map thickness (m)	Total thickness (m)
THRUST FAULT		
siliceous, black and gray, bedded shale and chert	~400	~300 m
FAULT?		
black, massive- to medium-bedded chert	~150	~125
bedded, siliceous, gray shale and black chert	~50	~50
chert-pebble conglomerate	~30	~25
bedded, gray to white shale, chert, and limestone	~400	~300
DUNPHY THRUST FAULT		
		TOTAL ~800

Rocks below the Dunphy thrust (Silurian or younger)

The rocks below the Dunphy thrust are assigned a Devonian or younger age on the basis of radiolarians assigned to the Entactinid superzone of Noble and Aitchison (2000). This fauna includes *Trilonche* and *Ceratoikiscum*. In addition, samples containing fragments of *Holoekiscus* are assigned a Famennian age. The conodonts *Polygnathus sp.* and *P. linguiformis* give a Middle Devonian, Emsian through Givetian age (M. Kurka, written commun., 1998). Parts of the sequence have lithologic similarities to both the upper parts of the Silurian Elder Sandstone and the Devonian Slaven Chert of Gilluly and Gates (1965) in the Battle Mountain area.

The main rock types are an upper sequence of sandstone, shale, black, banded chert, dolomitic sandstone, and limestone and a lower sequence dominated by poorly bedded, fragmental green to black orbicular chert. The rocks are distinguished by poor fissility, bedding, and layering compared to rocks above the Dunphy thrust. Tectonism and folding have disturbed the stratigraphic succession in most areas in the east-central part of Bobs Flat Quadrangle, but the thickness from two parts of an intact section in the western parts of the quadrangle was inferred across a northeast fault (fig. 3, table 2, and table 3).

Assuming that these two stratigraphic sections are intact and faulted extensions of each other, the total exposed thickness of rocks below the Dunphy thrust would be between 1,600 and 1,875 m. Several lithologic units are present in this sequence and most commonly are represented by chert, sandy dolomite, quartzite, limestone, and locally interbedded (coeval?) quartz-feldspar porphyry.

Chert and undivided rocks (Dch) below the Dunphy thrust consist of poorly-bedded breccia-textured, locally tightly folded, green, gray and black chert with abundant centimeter-scale, rounded to elongated, interbedded green to brownish pink blebs, and orbicules and flattened, or flame-

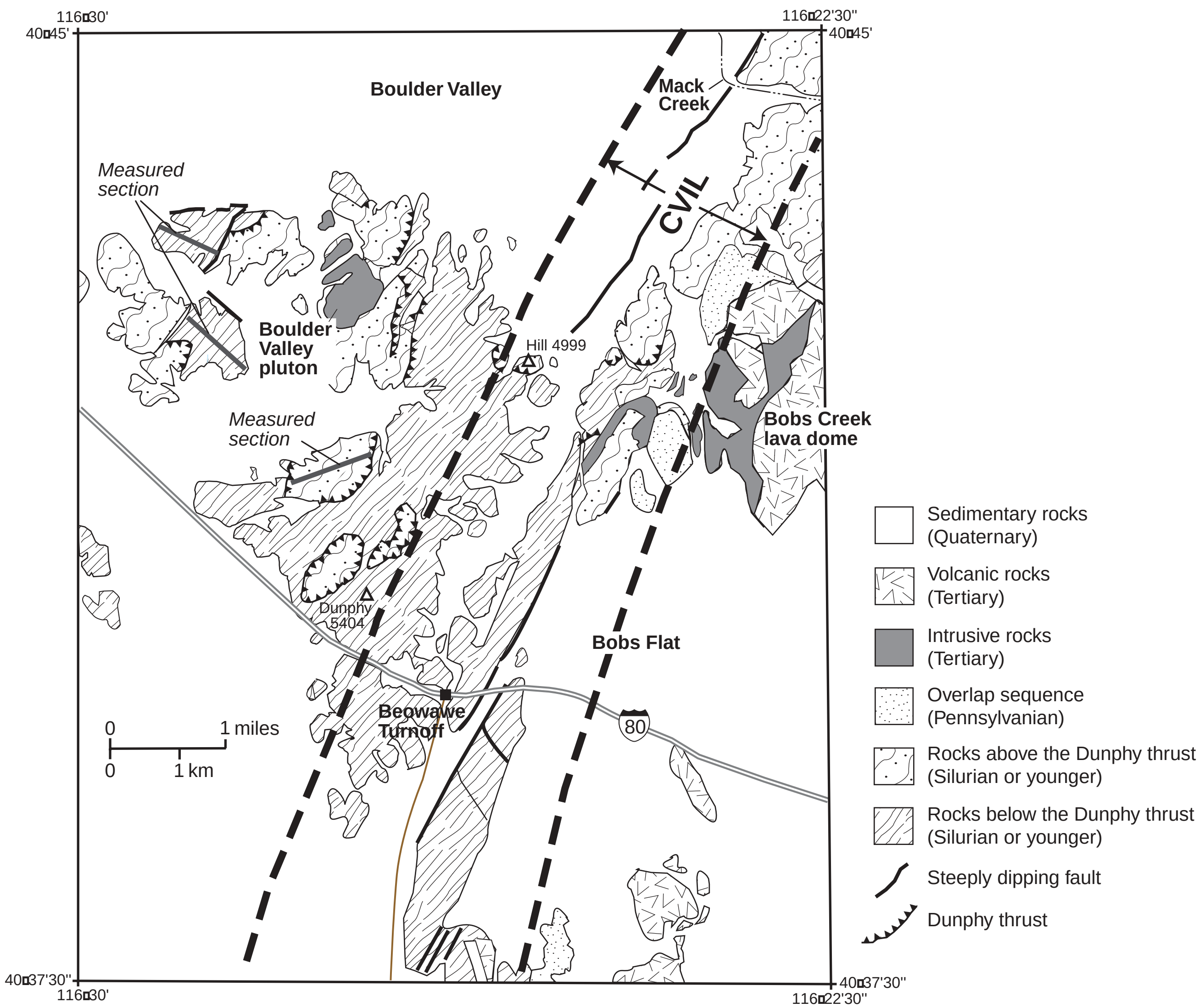

Figure 3. Simplified geology of Bobs Flat Quadrangle showing location of place names mentioned in text.

like, amorphous, light gray, light creamy green, to black nodules. Horizons locally contain bedded and radiolarian-bearing, massive black, gray, and tan cherts and tan to orange sandy dolomite, sandstone, green-gray phyllite, gray limestone, and black to gray shale. The unit commonly contains tight mesoscopic and megascopic folds, and it is tectonized and locally brecciated.

Table 2. Stratigraphic section of rocks below the Dunphy thrust in secs. 19 and 20, T33 N, R49E from west to east

Rock types	Map thickness (m)	True thickness (m)
FAULT		
siliceous, hard massive brown to maroon quartzite (Dq)	~400	~300
layered limestone; black and gray, banded chert; gray, black, and maroon shale (Dsd)	~50–150	~50–125
fine-grained, tan, dolomitic sandstone; banded black chert; minor shale; and limestone (Dsd)	~350–650	~275–450
FAULT		
		TOTAL ~625–875

Table 3. Stratigraphic section (continued from above) in secs. 29 and 30, T33N, R49E from west to east. (Note Dsd/Dch contact)

Rock types	Map thickness (m)	True thickness (m)
FAULT		
massive, poorly bedded, dolomitic sandstone (Dsd)	~30	~50
massive to bedded to layered limestone and black chert with minor shale and dolomitic fine-grained sandstone (Dsd)	~250	~250
tan, poorly bedded, dolomitic sandstone; calcareous sandstone; sandy dolomite; banded black chert; bedded and layered limestone (Dsd)	~175	~125
bedded limestone and tan to gray shale (Dls)	~75	~50
poorly bedded, orbicular, green, gray, black brown, and gray chert. Massive to interbedded with tan dolomitic sandstone (Dch)	~650	~450
END OF OUTCROP		
		TOTAL ~925

A second package of rocks (Dsd) probably overlies the chert unit (Dch). It consists of as much as 1,000 m of sandy dolomite, calcareous sandstone, shale, chert, limestone, and quartzite. Dolomite, dolomitic sandstone, and sandy dolomitic shale are gray to tan to orange with fine- to medium-grained, rounded quartz grains. Dolomite is transitional to tan to green gray dolomitic shale, sandstone, and phyllonite. Limestone (Dls) is gray weathering, massive to layered or fine-bedded, black, and locally micritic and it is interbedded with black to dark gray chert, dolomite, black cherty shale, and mudstone.

Quartzite (Dq) is massive and dark gray to light maroon and hard. It consists of well-sorted, rounded, medium- to fine-grained detrital quartz grains in a silicified matrix. The largest exposure is a 300-m-thick layer in NE¼ sec. 19, T33N, R49E. Other occurrences are less than 1 m thick. Some exposures of the hard quartzite are jasperoidal and may have been derived from silicification of dolomitic and calcareous sandstone.

Volcanic rocks, geochemically intermediate, mainly quartz-feldspar porphyry (Dv), are interlayered with chert and crop out in SE¼ sec. 33, T33N, R49E, where they are tan to black and commonly have either a brecciated or layered texture. Thickness is variable between 2 and 100 m. These rocks are intensely tectonized, similar to the surrounding sedimentary rocks, which suggests they formed as volcanic flows during deposition of the chert or where injected prior to tectonism as dikes or sills.

Sedimentary rocks of the late Paleozoic overlap assemblage

Sedimentary rocks of the overlap assemblage are part of an autochthonous, clastic foreland sequence related to late Antler orogeny or the Humboldt orogeny (Ketner, 1977). Exposures of these rocks in the north and south part of the Bobs Flat Quadrangle have age similarities to the Pennsylvanian age Tomera and Moleen Formations of Dott (1955) on the basis of fossil fragments of the conodont juvenile *Idiognathoides spp.*, which gives a Pennsylvanian Morrowan or Atokan age (M. Kurka, written commun., 1998). The units crop out between the rocks of the Roberts Mountain allocation and Eocene volcanic rocks, but they are mostly covered by Quaternary alluvial deposits (fig. 3). Although the contacts with underlying rocks are portrayed as stratigraphic on the accompaiΩing map, conformable contacts were not observed and several of the contacts are tectonized. The exposed stratigraphic thickness in sec. 24, R49E, T33N and sec. 19, T33N, R50E is less than 200 m.

Rocks with lithologic similarities to the Moleen Formation consist of massive dolomite, chert, platy dolomitic shale (IPsc), and 1- to 5-m-thick beds of sandstone and conglomerate (IPd). These rocks are most common in the north part of Bobs Flat Quadrangle where they underlie low hills. Dolomite is tan to creamy white, hard, poorly bedded, and locally silicified, with low, pitted, knobby outcrops. It contains sparse conodonts and 3-cm-long, 3-mm-diameter black ammonites.

Exposures of ℙsc in the southern part of the quadrangle have lithologic similarities mostly to the Tomera Formation, mainly on the basis of the lack of dolomite. These exposures are composed of thick-bedded sandstone and conglomerate that are interlayered with shale. In both the northern and southern exposures, the sandstone and conglomerate horizons contain 0.25- to 5-m-thick, silicified, yellow-brown to dark-brown, bold, hard outcrops of rounded quartzite pebble conglomerate that formed channels in mudstone, shale, and fine- to medium-grained quartzite. The sandstone and conglomerate horizons form high, bold outcrops where silicified and low, tan to light-gray outcrops where unsilicified.

The poorly exposed parts of the basal contact of the overlap sequence rocks with the cherty rocks above the Dunphy thrust are marked by low-angle faults and shear zones. This suggests that the overlap sequence of rocks may be allochthonous or an angular unconformity.

Igneous Rocks

Plutonic rocks of both Mesozoic and Tertiary age intrude the Paleozoic sedimentary rocks in the Bobs Flat Quadrangle as plutons and dikes. Rocks assigned to the Mesozoic are rare, whereas Tertiary intrusive and extrusive rocks form larger bodies and are spatially and temporally linked to the large Eocene Emigrant Pass volcanic field to the east of Bobs Flat (Henry and Faulds, 1999).

Mafic (lamprophyre?) dikes (Jurassic?)

Mafic (lamprophyre?) dikes form 0.5-m-wide, weathered, steep-dipping bodies exposed in the upper road cuts on the north side of Beowawe Turnoff (fig. 3), and they also may have air photographic expressions as dark lineaments along northeast-striking faults along the ridge in NW¼ sec. 2, T32N, R49E and SW¼ sec. 35, T33N, R49E. The rocks are foliated and massive, medium to fine grained, and green to gray, and contain local phlogopite phenocrysts. The dikes are assigned to the Jurassic on the basis of similarity to well-dated dikes of similar lithology along the Carlin trend (Teal and Jackson, 1997).

Granodiorite (Mesozoic?)

Granodiorite (Mzg) of unknown age is assigned to the Mesozoic on the basis of equigranular textural similarities to the Jurassic Goldstrike stock, 35 km to the north-northeast, and the Cretaceous Richmond stock, 25 km to the northeast, described by Evans (1980). The rock is medium-grained, equigranular granodiorite, and it contains quartz, plagioclase, K-feldspar, and biotite in weathered outcrops over an area of 15 by 3 m in the valley bottom in sec. 33, T33N, R49E. The granodiorite contains centimeter- to decimeter-scale, white, smooth, orbicular, aplitic nodules. The surface extent of granodiorite under colluvium is probably less than 100 m because contact metamorphism of the surrounding Paleozoic rocks is not apparent.

Intrusive rocks (late Eocene)

Intrusive rocks are assigned to the late Eocene in the Bobs Flat Quadrangle on the basis of $^{40}Ar/^{39}Ar$ dates (see table 4) and on their similarity and association with rocks of Eocene age in the volcanic field to the east in the Emigrant Pass Quadrangle. The rocks are present in two centers: the Boulder Valley pluton in the center of the quadrangle, and in dikes in and adjacent to the Eocene volcanic rocks in the northeast part of the quadrangle (fig. 3). Both occurrences have similar petrochemical and mineralogical composition and have been classified on the basis of hand specimen and thin section petrology as rhyodacite and dacite, although petrochemically they are more similar to andesite and trachyandesite. The rocks in the Boulder Valley pluton are relatively homogenous in texture and mineralogy, but dike rocks to the east have a number of varieties that interlayer with or are similar to some volcanic units, and therefore may represent the feeder parts of a lava-dome complex.

Dacite (Td) is a porphyritic hornblende-biotite-feldspar-quartz intrusive rock that forms the Boulder Valley pluton in secs. 21 and 28, T33N, R49E and a 100- to 300-m-thick dike in sec. 35, T33N, R49E. The second dike-like body strikes northeast into an irregular-shaped plug and is gradational into rhyodacite (Trd) rocks to the east. Several 0.5- to 1-m-thick dikes also are present along the northeast-trending ridge between Beowawe Turnoff (fig. 3) and sec. 26, T33N, R49E.

Rhyodacite (Trd) is equigranular, medium-grained, porphyritic, and forms isolated outcrops that protrude through Quaternary alluvium (Qai) in sec. 25, T33N, R49E. The rhyodacite is texturally and mineralogically transitional between the dacite body to the west and the volcanic rocks to east that it intrudes. Rhyodacite contains biotite, plagioclase, K-feldspar, quartz, and rare hornblende, and it also contains local vitrophyre-bearing breccia bodies on its southern margins (NE¼ sec. 36, T33N, R49E). Vitrophyric zones are designated as Tvv, as are vitrophyric parts of the volcanic flows, but may represent carapace breccia in the

Table 4. $^{40}Ar/^{39}Ar$ Ages of Tertiary Intrusions

Sample	Rock type	N Latitude	W Longitude	Mineral	Age Method	n, %^{39}Ar*	Age (Ma)	±1σ
H98-1	porphyritic dacite dike	40° 41.60'	116° 24.80'	hornblende	plateau	10, 95.1	37.40	0.18
EM-N2	porphyritic dacite intrusion	40° 42.72'	116° 27.24'	hornblende	plateau	4, 62.8	37.87	0.21

* n and %^{39}Ar = number of steps and percent ^{39}Ar in plateau

Data from C.D. Henry and M.W. Ressel. Monitor: FCT-1, Fish Canyon sanidine, 27.84 Ma. Sample H98-1 analyzed at the New Mexico Geochronology Research Laboratory; sample EM-N2 analyzed at the Nevada Isotope Geochronology Laboratory rhyodacite. Near the volcanic rocks, rhyodacite locally is foliated and contains zones that are hornblende-rich and locally are indistinguishable in hand specimen from medium-grained dacitic volcanic rock.

Volcanic rocks (late Eocene)

Intermediate composition volcanic rocks of late Eocene age crop out on the northern and southern parts of Bobs Flat (fig. 3) and have been subdivided, on the basis of grain size, into vitrophyre (Tvv), fine-grained (Tvfg), and medium-grained (Tvmg) units. The rocks in the northern exposures are spatially and temporally associated with intrusive dacite dikes and with plutons in the west.

Vitrophyre and volcanic glass and breccia units (Tvv) consist of black, concoidally fractured material in 5- to 30-m-thick flows. Volcanic glass also forms blebs and disseminations in the groundmass of volcanic rocks. The chilled margins of intrusive units Td and Trd also are vitrophyric and are included in this unit (NW¼ sec. 30, T33N, R50E). Vitrophyre also is present in auto intrusive breccia bodies that have 0.5- to 2.0-cm-wide, subangular clasts of dacite and Paleozoic wall rock in a vitrophyric matrix (NE¼ sec. 36, T33N, R49E). The section on the accompanying map interprets this breccia body as an intrusive breccia, but it may also be interpreted as a carapace breccia transitional between the intrusive rocks to the west and the volcanic rocks to the east.

Fine-grained andesite volcanic flows (Tvfg) are aphanitic, black to pink, hard, rarely porphyritic (hornblende, plagioclase), locally layered or foliated. These rocks are the western extension of rocks interpreted by Henry and Faulds (1999) to be the 4- to 5-km-diameter Bob Creek lava dome [36.82 ± 0.4 Ma (sanidine) and 37.19 ± 0.10 Ma (hornblende)]; C. Henry, oral commun., 1999].

Medium- to fine-grained andesite-dacite volcanic flow rocks (Tvmg) are layered and flow foliated, commonly with brecciated or vitrophyric bases or locally contain 1- to 5-mm-thick internal or lateral layers of vitrophyre. Two main occurrences are interlayered with hypabyssal intrusive rhyodacite in sec. 30, T33N, R50E and south of Interstate 80 in secs. 13 and 24, T32N, R49E. These rocks are part of the Eocene Emigrant Pass volcanic field to the east in the Emigrant Pass Quadrangle. The Tvmg rocks in the northeast part of Bobs Flat Quadrangle are equivalent to a series of porphyritic dacite of the Mack Creek lava sequence of Henry and Faulds (1999). The Tvmg rocks in the south part of Bobs Flat Quadrangle may be equivalent to coarse hornblende andesite of the Primeaux lava sequence described by Henry and Faulds (1999), or may represent outflow of the Mack Creek lava sequence along a north-trending late Eocene valley.

Ash and lacustrine deposits (Miocene?)

Ash and lacustrine deposits (Tal) are present as white to earthy brown, porous, bedded deposits stratigraphically below old alluvial fans (Qao) in sec. 22, T32N, R49E. The unit may be part of lacustrine deposits to the south and may correlate with deposits of Miocene lavas, tuffs and tuffaceous sedimentary rocks to the northeast in the Emigrant Pass Quadrangle (Henry and Faulds, 1999). A large component of white crystal sand (probably resulting from weathering of these deposits) is present as material in younger eolian deposits (Qs), in soils on alluvial deposits (Qai), (Qaff), and in some fluvial deposits (Qfh_1 and Qfh_2).

Quaternary Surficial Deposits

Surficial, generally unconsolidated, deposits cover a majority of the Bobs Flat Quadrangle and consist of fluvial deposits of the Humboldt River in the southwest part of the area and alluvial fan and mixed colluvial deposits in the rest of the area. Stream channels contain alluvial material, and many of the hills have small colluvial and eolian deposits.

Fluvial deposits of the Humboldt River (Holocene to Pleistocene)

Fluvial deposits of the Humboldt River have been divided into three ages of deposit (Qfh_3, Qfh_2, and Qfh_1) on the basis of location and crosscutting relations among river channels and oxbow lakes. They contain unconsolidated silt, sand, and rounded cobbles. Old Humboldt River deposits (Qfh_3) are assigned a Holocene to Pleistocene? age and flank intermediate age deposits (Qfh_2) to the northeast. They are covered by older alluvial fan deposits (Qao) on their north parts and contain remnant channels and oxbow lakes. Intermediate-age (Holocene?) Humboldt River deposits (Qfh_2) flank younger deposits (Qfh_1) or are present as remnant islands. Oxbow channels typically are truncated by young Humboldt River deposits (Qfh_1) that are present in active stream channels and oxbow lakes.

Alluvial fan deposits (Quaternary)

Alluvial fan deposits have been divided into three ages (Qao, Qai, and Qay) on the basis of crosscutting relations, degree of erosion, and form. Most alluvial fans are composed of silt, sand, and rounded cobbles. Old alluvial fan deposits of Holocene and Pleistocene(?) age (Qao) are typically remnants of large composite fans and sheets that have been indurated and eroded, and they locally are filled with younger (Qai) deposits. The fans are soil covered and locally consolidated with caliche, calcrete, and jasperoid near their bases. Alluvial fan deposits north and south of I-80 in Bobs Flat contain volcanic material on the east side and chert material on the west side. Other deposits in Humboldt River Valley and in Boulder Valley contain chert and some volcanic rock cobbles and pebbles.

Intermediate-age Quaternary alluvial fan deposits (Qai) are mixed with local Holocene and Pleistocene colluvial deposits (Qc) in areas that fill smaller valleys adjacent to ridges and side drainages in hills. Intermediate-age alluvial fan deposits also are soil covered and contain unsorted, unconsolidated silt, sand, and round to angular cobbles.

Locally intermediate-age alluvial fan deposits are contained in, and contain reworked material from, old alluvial fan deposits. Chert cobbles are most common in western areas and in Boulder Valley, whereas volcanic rock cobbles are more common in Bobs Flat, where older alluvial fans have been eroded and reworked. Young, recent, or active fan deposits (Qay) are present at the mouths of drainages along hill fronts. The south part of a large fan is present at the mouth of Mack Creek that extends northward into the Rodeo Creek SW Quadrangle. Younger alluvial fans also contain unconsolidated, unsorted sand and partly rounded to angular sheet wash deposits and are most common as 200-m-wide discrete fans along the central northeast-trending ridge system that extended north and south across Beowawe Turnoff on Interstate 80.

Colluvium, alluvium and eolian deposits (Quaternary)

Colluvium and talus of Quaternary age (Qc) is present as loose debris in the upper parts of drainages. The units locally are weathered and transitional to alluvial fan deposits. Young stream deposits and basinal flood plain deposits (Qal) are composed of unconsolidated sand and rounded cobbles and are transitional to younger fan fringe (Qaff) deposits. These fan fringe deposits are present on the down slopes of both older and younger alluvial fans in the larger flat valleys and include and provide a transition to valley fill, stream, and flood plain deposits. Eolian deposits (Qs) also are present as local exposures of unconsolidated white to tan sand, particularly on western-facing slopes and valleys.

STRUCTURAL GEOLOGY

The structural evolution of rocks in the Bobs Flat Quadrangle spans the Paleozoic through the Cenozoic and consists of both ductile and brittle styles of deformation due both to compression and extension. These events imparted a strong northeast-trending grain that was reactivated during a number of deformation events. Silicification and quartz veining along many planar structures formed linear zones of jasperoidal rocks and silicified breccias. Jurassic lamprophyre and Eocene dacite dikes also intruded some of these structures. Structural elements present in the Bobs Flat Quadrangle consist of structural mélange, foliation, jointing, phyllonite, folds, thrusts, and NNE-, NW- and NS-striking brittle faults. Flow foliation also is present in the volcanic rocks.

Crescent Valley-Independence Lineament (CVIL)

The CVIL is defined by a N20°E- to N30°E-striking zone of planar geologic and geomorphologic features. The CVIL extends southwest from the Independence Mountains along the edge of the Tuscarora Mountains and through the Bobs Flat Quadrangle (Peters, 1998; 2000). It then continues south through Beowawe on the northeast side of Crescent Valley and may extend into Carico Lake Valley and farther to the southwest (fig. 1). The central parts of the CVIL constitute a 3- to 5-km wide zone that may be part of a much larger, composite 20-km-wide zone containing additional northeast-trending linear features. The CVIL also roughly marks the western edge of an 80-km-wide Tertiary basin between the Independence and Ruby Mountains (see also, Regnier, 1960; Stewart and Carlson, 1976; Solomon and others, 1979; Mueller, 1992).

The central part of the northeast-trending tectonic zone in the Bobs Flat Quadrangle was defined as part of the CVIL by Peters (1998) and is interpreted to be due to multiple events between the Paleozoic and Cenozoic. The orientation, nature, and geometric relations among tectonic fabrics and intrusive rocks constrain the timing of events along the CVIL. Most fold axes in Paleozoic rocks in north-central Nevada plunge at low angles to the northeast and southwest with fold axes and axial planes roughly parallel to the CVIL (Evans and Theodore, 1978; Oldow, 1984; Peters and Evans, 1995). The early tectonism associated with the CVIL is therefore presumed to be caused by regional Paleozoic tectonism (fig. 4).

In contrast, fold axes along the Carlin trend plunge at shallow angles to the northwest (Madrid and Bagby, 1986; Madrid, 1987; Peters, 1996, 1997a) and were postulated by Evans and Theodore (1978) to be due to Jurassic tectonism, which was synchronous with some tectonic events recognized by Ketner and Smith (1982), Ketner (1987) and Thorman and others (1991a) in northeastern Nevada. This implies that the original northeast-trending tectonic fabric in the CVIL may predate the Jurassic. Younger geologic events also are present along the CVIL in the Bobs Flat Quadrangle.

Tectonic Mélange

Rock types near and in the CVIL in Bobs Flat Quadrangle in rocks below the Dunphy thrust contain fabrics that are typical of tectonic mélange zones (see Peters, 1996, 1997a, 1998). Mélange is a mappable body of fragmented and mixed rock, with phacoidal shapes, in a scaly and shaly matrix, commonly called clast-in-matrix rock or brokenite (Raymond, l984a, b). The chaotic nature of mélange is caused by either sedimentary or tectonic processes that produce fragmentation, mixing, disruption, and dismemberment. Although the laws of lateral continuity and superposition are not generally applicable in mélange (Hsu, l968), the mélange in Bobs Flat Quadrangle retains symmetrical linear fabrics that trend northeast, parallel to fold axes in the region, which is compatible with formation under uniform tectonic stress (Peters, 1996).

The best exposure of tectonic mélange is exposed in the 500-m-long road cut along the west-bound lane of Interstate 80 near Beowawe Turnoff (fig. 3) (sec. 10, T32N, R49E). Deformed rocks include laminated pelitic chert, massive chert, silty and calcareous sandstone, and massive dolomitic, fine-grained sandstone. Bedding was dismembered and transposed such that competent layers, which are 1 to 100 cm thick, were broken or deformed into phacoids in a matrix of irregularly cleaved shale or clast-in-matrix rock. Strain in the tectonized rocks was concentrated in the incompetent, pelitic matrix of the clast-in-matrix rock, which contains blocks of undeformed, thick-bedded locally deformed chert and massive dolomitic sandstone as much as 2 m long.

Foliation

Foliation, jointing, phyllonite, and cleavage are present in the chert, sandstone, and shale of the rocks below the Dunphy thrust along the 100-m-wide northeast-trending mélange zone and to a lesser extent in similar rocks in the hills to the west. Bedding planes in these rocks, which manifest poor original bedding, were further obscured by these planar fabrics. This planar fabric has a steep westerly dip and includes axial planes of mesoscopic folds and shear cleavage (fig. 4). Joints, silicified breccia zones, and gouge overprinted these fabrics. Thus, these northeast-trending, planar, parallel fabrics resulted from several different episodes of deformation.

Foliation mainly is present in the rocks below the Dunphy thrust along the tectonized CVIL zone as steep-dipping, locally vein-filled north-striking joints, composite sheeted axial planes of folds, and as phyllonite and cleavage. Foliation strikes dominantly to the northeast-southwest and dips steeply to the west and east, with a statistical overall dip of about 80° west (fig. 4). The northwest and southeast margins of the 3- to 5-km-wide foliated zone contain intense shear zones, faults, and pods of breccia that are oriented parallel to the foliation; some may be coeval with the foliation and some may be older than younger brittle faulting and brecciation.

Foliation is coplanar with and parallel to the axial planes of most of the northeast-trending, shallow-plunging folds in both the upper- and lower-plate rocks of the Dunphy thrust. Because foliation is prolific only in the rocks below the Dunphy thrust, the folding, thrusting and foliation, as well as mélange development, most likely predate the Dunphy thrust. Because folds and younger faults are parallel to these tectonic features in rocks above the Dunphy thrust, structures above and below the Dunphy thrust may have resulted from similar stress regimes or be the products of a long-lived stress regime that also involved thrusting. Reactivation of northeast-striking structural fabrics during subsequent tectonic events also would account for the parallel structures and fabrics in the rocks above and below the Dunphy thrust.

Folds

Fold axes in the Bobs Flat Quadrangle have strong, northeast-trending, near-horizontal linear plunges, both on the megascopic and mesoscopic scales. This northeast-trending fold orientation is present in rocks both above and below the Dunphy thrust (fig. 4). Large 100-m-wide complex folds are present in rocks above the Dunphy thrust, specifically near Dunphy BM 5404 and hills to the north (fig. 3). Mesoscopic folds also are common in rocks below the Dunphy thrust along the northeast-trending CVIL. Stereographic net analysis of fold axes demonstrate persistent northeast- or southwest-trending shallow-dipping fold plunges and steep-dipping northeast-striking fold axial planes and foliation (fig. 4). This set of fabrics is interpreted to have been produced during the Late Permian to Late Jurassic, during the Sonoma and Elko deformation events (Peters, 1998). Folds, transposed bedding, and shears imply local northeast-southwest shortening, internal strain, and possible dissolution along cleavage planes along the CVIL during that time.

Thrust Faults

Thrust faults are present in the Bobs Flat Quadrangle; the most pronounced thrust is the Dunphy thrust, which separates two tectonically and lithologically different packages of Devonian or younger rocks. In addition, the Pennsylvanian Tomera and Moleen Formations have poorly exposed, shallow-dipping tectonic contacts with the underlying Paleozoic units, suggesting the possibility of a second major thrust.

The Dunphy thrust has not been documented previously and is defined here as a shallow-dipping, locally imbricate structure that placed allochthonous Silurian or younger rocks, the Dunphy allochthon, on top of lithologically different semi-autochthonous Silurian(?) to Devonian or younger rocks. Both the upper and lower plates are presumed to be part of the Roberts Mountains allochthon of the Antler orogeny and to be underlain by the Roberts Mountains thrust. Depth to the Roberts Mountains thrust may be 900 to 1,200 m below the surface on the basis of thickness of the rocks above and below the Dunphy thrust. The boundary between the upper and lower plates and the locations of strands of the Dunphy thrust have been determined on the basis of lithology, on discordant bedding attitudes across the boundary, and by fault rocks and tectonized zones along the proposed thrust plane.

The best relatively undisturbed parts of the Dunphy thrust define a north-striking, 10–30° west-dipping structure that is exposed east of the Boulder Valley pluton in the north and crops out along ridges in sec. 33, T33N, R49E. Other occurrences of the Dunphy thrust include: (1) fault-bound exposures of juxtaposed upper- and lower-plate rocks west of the Boulder Valley pluton; (2) 0.5- to 1-km-wide oval-shaped klippe 3 to 4 km northwest of Beowawe Turnoff (fig. 3); and (3) faulted and folded areas along northeast-trending ridges in the north-central CVIL zone. The Eocene Boulder Valley pluton and coeval dacite dikes to the east cut parts of the Dunphy thrust.

The 200- and 400-m-thick Dunphy thrust zone consists of several individual tectonized strands separating upper and lower plate rocks. Some shallow-dipping strands of the thrust were down-dropped on strike-parallel steep-dipping faults that locally may have exaggerated the thickness of the Dunphy thrust zone. Elsewhere, the thrust zone contains 1- to 10-m-thick gray phyllonite composed of aphanitic consolidated olive-drab gouge. The zones also are marked by dense, microcrystalline, white, tan, and black silica flooding that crops out as jasperoid. Some zones 10 to 100 m into the upper-plate rocks are characterized by white 0.5- to 3-cm-thick planar quartz veinlets, which are present in both random stockwork arrays or in parallel, oriented, multiple, or conjugate patterns. Breccia, bleached zones, bedding parallel shears, and intense joint sets also are common in or near parts of the Dunphy thrust zone.

A tectonized contact is inferred to be present along the contact between Pennsylvanian overlap sequence rocks (units ℙsc and ℙd) and Devonian or younger rocks above the Dunphy thrust (unit Dsc). This relation is suggested by

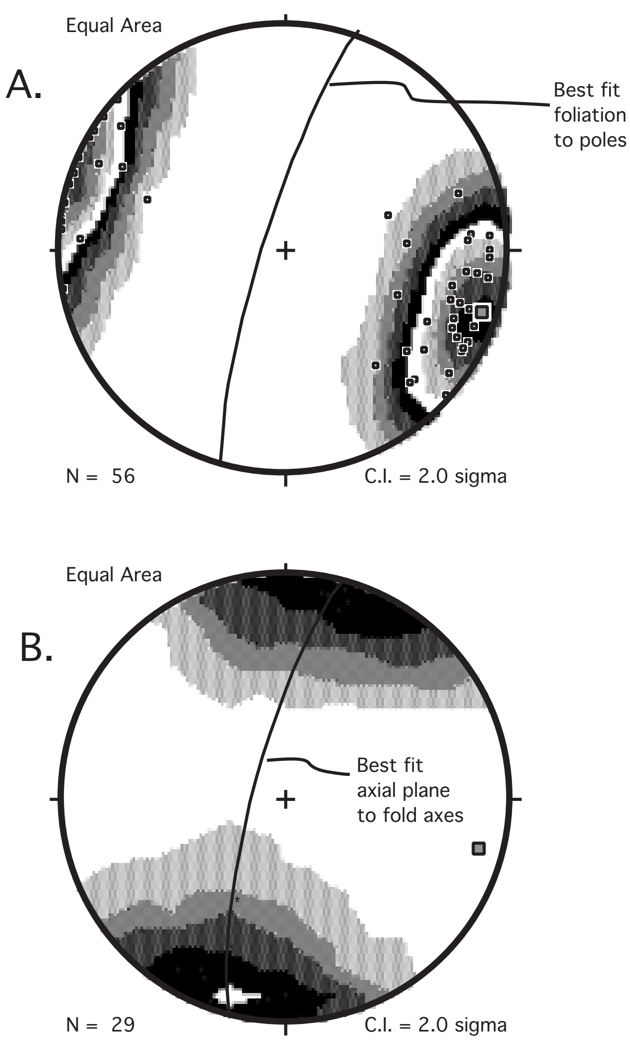

Figure 4. Stereographic equal area projections of foliation and fold axes at Bobs Flat Quadrangle. (A) Bobs Flat, Kamb contour of poles to foliation, with 2.0 sigma contour interval. Strike and dip of best fit great circle to poles is 197.6°, 81.0° W. Poles shown as open squares. (B) Bobs Flat, Kamb contour of fold axes, contour interval 2.0 sigma. Strike and dip of axial plane is 194.5°, 77.9° W. The foliation in the Bobs Flat area is parallel to the axial planes of the folds and is parallel to the strike of the CVIL.

local shallow-dipping tectonized fabrics along the contact between these two units in sec. 24, T33N, R49E. The tectonized contact crops out as a 1- to 2-m-wide gently dipping shear zone in the southwest part of sec. 23, T32N, R49E, at the contact between silicified rocks of unit ℙsc and rocks above the Dunphy thrust (see also, Peters, 1999).

Faults and Shear Zones

Faults and shear zones in the Bobs Flat Quadrangle have a number of orientations and represent several ages of movement. A dominant zone of steeply dipping, north-northeast-striking faults and shear zones of several ages is associated with the CVIL zone. In addition, north-, northwest- and east-striking faults also are present. Many faults have surface expressions as jasperoidal breccia bodies or iron-stained float. Fault traces are marked by vegetation or topographic disturbances or have aerial-photographic expressions. Lithologic offset also is present along parts of most of the fault traces.

Northeast-striking faults along the CVIL are marked by gouge, breccia, limonite, 1- to 2-m-wide zones of jasperoid, topographic expressions, and lineaments of dark soil on aerial photographs. Faults bound and traverse the two northeast-striking ridges, north and south of Beowawe Turnoff (fig. 3). This fault system is crosscut and locally filled by Eocene dacite dikes, but some faults also cut Quaternary alluvial fan deposits (Qai, Qao), indicating that fault movement both predated and was reactivated multiple times during the Cenozoic. Additional northeast-striking faults offset sandstone and limestone units in the central (sec. 34, T33N, R49E and secs. 3 and 4, T32N, R49E) and western (secs. 20 and 30, T33N, R49E) hills of Bobs Flat Quadrangle. Northeast-striking faults parallel foliation and fold axial planes along the CVIL (fig. 4) and also may have been active as shear zones during the formation of these fabrics. Brittle reactivation and silicification in early Eocene, Miocene(?) and Quaternary times most likely has obscured evidence of these prior faulting events.

Faults striking east-northeast are present in the west-central part of the quadrangle (secs. 32 and 33, T33N, R49E). These faults are along strike and possibly represent eastern extensions of faults in Miocene volcanic rocks in the Argenta Rim to the west (see also, Stewart and McKee, 1977).

North-striking faults are present in the east-central part of the quadrangle and extend south of the Boulder Valley pluton. These faults follow stream valley bottoms and saddles or are inferred from aerial photographic traces and offset of the Dunphy thrust, where they down-drop the upper- and lower-late contacts to the east (secs. 21 and 28, T33N, R49E). Outcrops contain iron-stained breccia, local gouge, and silicification. Faults with similar strikes also are present locally in the west part of the quadrangle.

Northwest-striking faults traverse the central part of the quadrangle in two main swarms. To the northwest, these faults are present in the central part of the area and truncate a klippe of rocks above the Dunphy thrust. To the southeast, northwest-striking faults cut Eocene volcanic rocks and show expression in air photographs in the older Quaternary alluvial deposits (Qao).

East-striking faults are present along the range front north and west of the Boulder Valley pluton where they cut older Quaternary alluvial deposits. They also crop out as jasperoidal breccia bodies along quartzite (unit Dq) in rocks below the Dunphy thrust.

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