Text and references to accompany NBMG Field Studies Map 13

# GEOLOGY OF THE DELVADA SPRING QUADRANGLE, HUMBOLDT COUNTY, NEVADA

*by*
A. Elizabeth Jones

## INTRODUCTION

The Delvada Spring 7.5' Quadrangle in Humboldt County, Nevada, covers the southern end of the Hot Springs Range and a small part of the Osgood Mountains northeast of Winnemucca. The map area lies at the western edge of a large area of exposure of Paleozoic rocks that are surrounded by Mesozoic and Cenozoic igneous and sedimentary rocks. The stratigraphic and structural relations among the Paleozoic rocks exposed in this quadrangle add important constraints to our understanding of the complex tectonic history of this region.

The Paleozoic rocks exposed in this quadrangle are structurally complex, and their geologic and tectonic relations to each other remain incompletely understood. Figure 1 is a diagram that illustrates the structural and tectonic relations of these different units as they are interpreted from evidence in the Delvada Spring Quadrangle. The structural complexity and lack of stratigraphic continuity among the different rock units in this area make it most practical to treat them as distinct tectonostratigraphic units, or terranes. Three Paleozoic terranes are exposed in this quadrangle. The oldest rocks in the area, the Proterozoic to Early Cambrian Osgood Mountains Quartzite and the Cambrian-Ordovician Preble Formation, are grouped together into the Hogshead Canyon terrane. These units have been informally referred to as the "Osgood terrane" elsewhere (Jones, 1991; Madden-McGuire and Marsh, 1991). The Late Cambrian Paradise Valley Chert, a Cambrian limestone (exposed in the Hot Springs Peak Quadrangle to the north) and the Late Devonian Harmony Formation are grouped together and referred to as the Dutch Flat terrane, and the Ordovician Valmy Formation is also known as the Getchell terrane, in keeping with the nomenclature of Madden-McGuire and Marsh (1991). Cretaceous(?) granite and dacite, Tertiary vesicular basalt, Tertiary or Quaternary older alluvium, and Quaternary alluvium are the only younger rocks that either intrude into or cover over the Paleozoic sequences across the quadrangle.

The Osgood Mountains Quartzite and the Preble Formation occur in depositional contact in quadrangles to the east in the Osgood Mountains, and therefore they are grouped together into the Hogshead terrane, even though their contacts are covered in the Delvada Spring Quadrangle. The alluvium of Eden Valley covers the contact between the Valmy Formation (the Getchell terrane) and the Hogshead Canyon terrane and so the stratigraphic and structural relations between them are unknown. Beds of the Paradise Valley Chert and the Harmony Formation are folded together in the Hot Springs Range, and hence are included together in the Dutch Flat terrane, although the contact relation between them remains obscure. The Dutch Flat terrane is separated from rocks of the Valmy Formation by northeast- and north-striking high-angle structures. Mesozoic igneous rocks in this quadrangle intrude the Harmony Formation in small plugs along the crest and western side of the Hot Springs Range. Tertiary and Quaternary volcanic and sedimentary rocks overlie the Paleozoic rocks in both the Hot Springs Range and the Osgood Mountains.

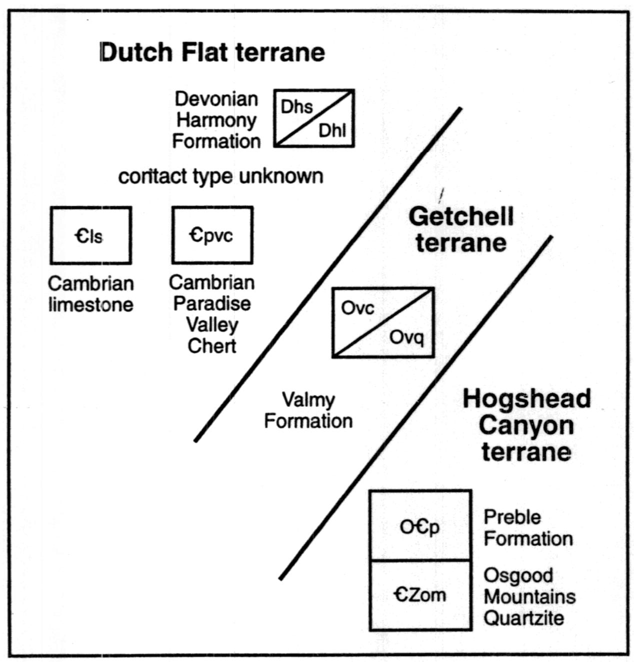


**Figure 1.** Schematic map view of tectonic units in the Delvada Spring Quadrangle, Humboldt County, Nevada. Each tectonic unit is separated by a structural boundary. See plate for detailed descriptions of units.

Table 1. Age data from the Delvada Spring 7.5' Quadrangle

| Terrane and Formation | Sample | Rock Type | Fossil | Species | Age | Identifier |
|---|---|---|---|---|---|---|
| **Dutch Flat terrane** | | | | | | |
| Harmony Formation | 91-DS-002 | turbiditic limestone | barren | | not determined | J. Repetski, USGS |
| Harmony Formation | 93-DS-001 | turbiditic limestone | conodont | post-Ordovician free blade of P element, CAI 5.5 indet. brachiopod fragments | post-Ordovician | J. Repetski, USGS |
| Harmony Formation | 93-DS-002 (12529-SD) | turbiditic limestone | conodont | cf. *Ozarkodina* sp. Pa element *Palmatolepis* sp. indet. Pa element, CAI 5.5-6 | Late Devonian | J. Repetski, USGS |
| Harmony Formation | 94-DS-001 | turbiditic limestone | indet. spicule or sclerites | | not determined | J. Repetski, USGS |
| Harmony Formation | 94-DS-002 | turbiditic limestone | barren | | not determined | J. Repetski, USGS |

Age data are listed in table 1 and stratigraphic and age relations are described in the unit descriptions on the plate. The important structural characteristics of each terrane are described below. Local constraints on structures and rock units are compared with regional constraints and discussed in a regional tectonic context.

## STRUCTURAL ANALYSIS

### Hogshead Canyon Terrane

A Schmidt net stereo plot of 16 bedding measurements from the Osgood Mountains Quartzite in the Osgood Mountains in the southeastern part of the quadrangle reveals a great circle plot of poles to bedding that define a S50°W, gently southwest plunging fold axis (fig. 2). The uniform consistency of the quartzite beds prevented facing direction measurements, but the relative abundance of points identifying west dipping beds of quartzite suggest that the folds may be overturned toward the southeast. Additional measurements are required before more definitive conclusions can be drawn from this small data set. The age of this folding is only constrained to pre-Tertiary in the Delvada Spring Quadrangle.

The Osgood Mountains Quartzite is separated from the Preble Formation in this quadrangle by Tertiary and Quaternary stream deposits, but depositional contacts between these units are exposed on the east side of the Osgood Mountains (Hotz and Willden, 1964). The Preble Formation is faulted against an expanse of Tertiary basalt that covers older rocks of the Osgood Mountains in the rest of the Delvada Spring Quadrangle.

### Getchell Terrane

Near-vertically plunging folds can be measured in the chert and quartzite beds of the Ordovician Valmy Formation, exposed at the eastern edge of the Hot Springs Range in the Delvada Spring Quadrangle. The scatter of the poles to these steeply dipping beds that plot along the perimeter of a Schmidt Equal Area stereonet indicate the complexity and nonuniformity of the folding in these rocks (fig. 3). The age of the folding of the Valmy Formation in the Delvada Spring Quadrangle is constrained only to pre-Tertiary.

A series of Tertiary and Quaternary high-angle faults striking northeast and north have disrupted and juxtaposed the Valmy Formation against the Harmony Formation. The pre-Tertiary structural and stratigraphic relation between these units is unknown.

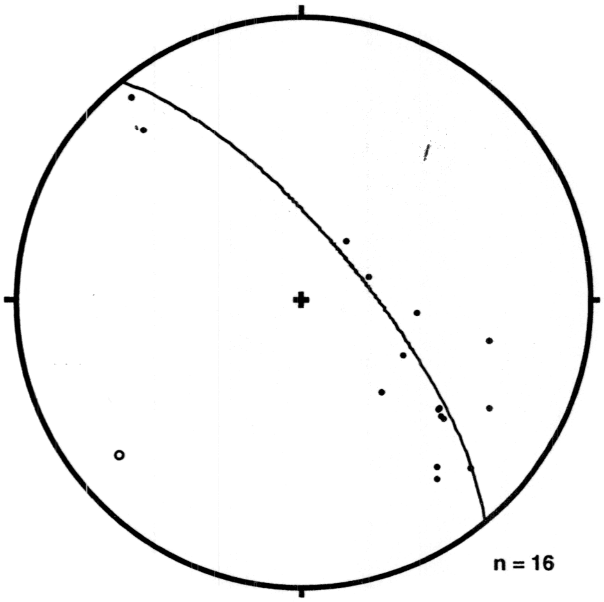


**Figure 2.** Bedding plane measurements from the Osgood Mountains Quartzite outcropping on the western edge of the Osgood Mountains in the Delvada Spring Quadrangle.

## Dutch Flat Terrane

The structural data set for the Harmony Formation collected in the Hot Springs Peak and Delvada Spring Quadrangles consists of over 1,600 bedding measurements, nearly 300 of which include positively defined facing directions (figs. 4a, b, c). Schmidt Equal Area Plots of poles to bedding confirm the report by (Hotz and Willden, 1964) that beds of the Harmony Formation are overturned toward the west (Jones, 1993). The age of the folding in the Harmony Formation is only constrained in the Hot Springs Range to pre-Cretaceous(?), or to the age of the granitic plug exposed at Dutch Flat that intrudes the Harmony Formation.

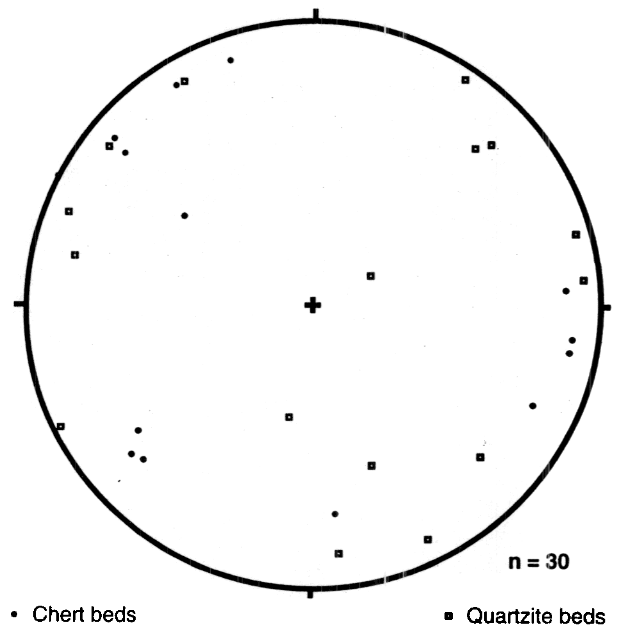


**Figure 3.** Bedding plane measurements from the Valmy Formation on the southeast side of the Hot Springs Range.

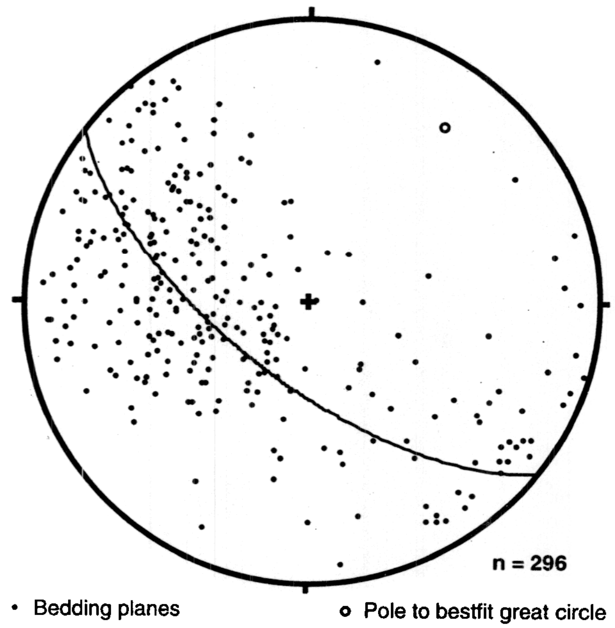


**Figure 4b.** Bedding plane measurements in the Harmony Formation where the facing direction could be confidently determined.

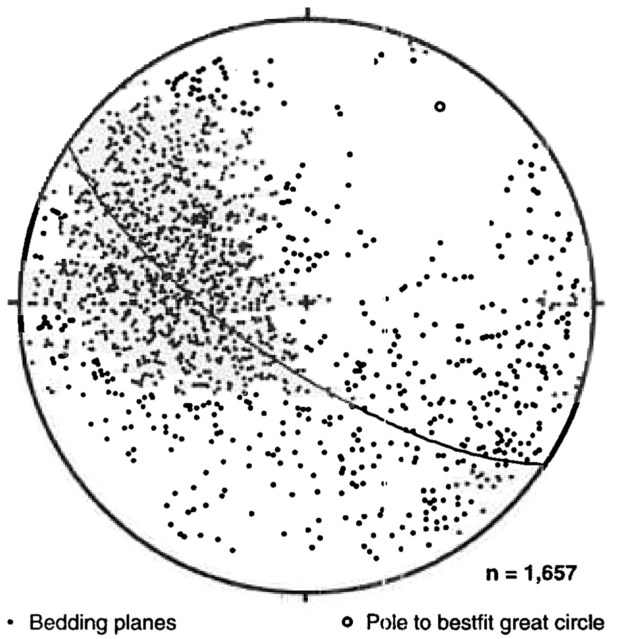


**Figure 4a.** Bedding plane measurements in the Harmony Formation across the Hot Springs Range.

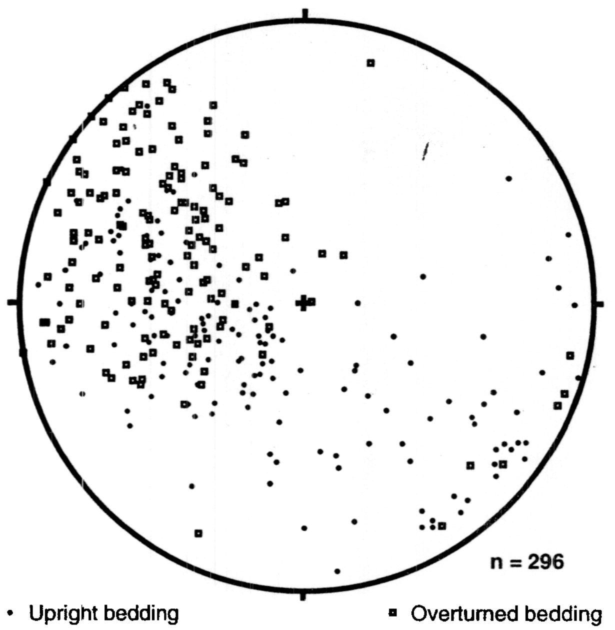


**Figure 4c.** Bedding plane measurements of upright vs. overturned beds in the Harmony Formation.

Large, 5- to 20-m tight folds characterize the thickly bedded sandstone of the Harmony Formation. The orientation of beds in the Harmony Formation defines a northeast-plunging fold axis, with the folds overturned toward the northwest. Foliations in the Harmony Formation define a northeast-striking northwest-vergent axial surface (fig. 4d). Poles to bedding in the Paradise Valley Chert plot along a similar great circle as poles to bedding in the Harmony Formation (fig. 5). Although the data set is smaller and the scatter greater, it supports the interpretation that the two units were affected by the same folding event.

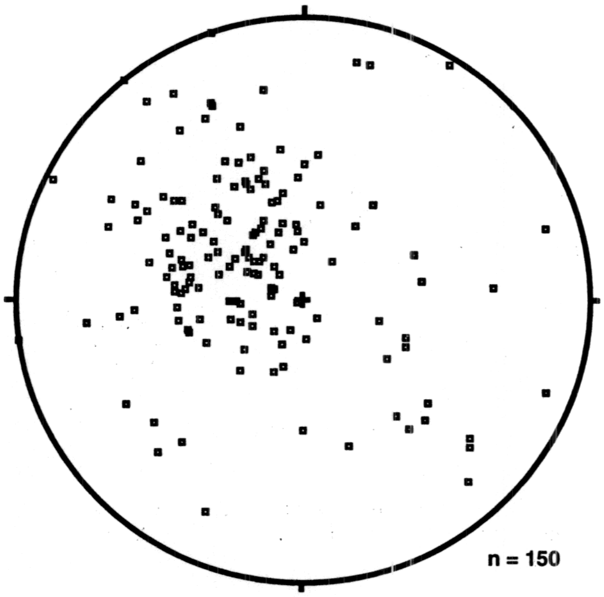


**Figure 4d.** Foliations in the Harmony Formation.

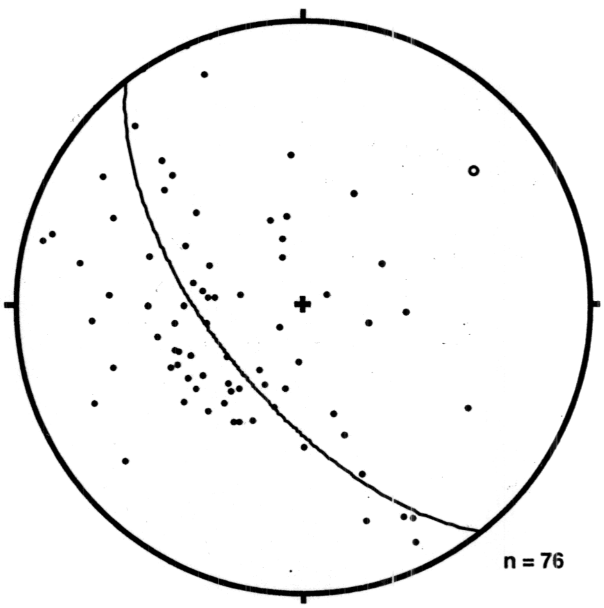


**Figure 5.** Bedding plane measurements in the Paradise Valley Chert from across the Hot Springs Range.

## Cenozoic Structure

A well-developed set of north-northwest-striking steeply dipping quartz breccia veins extend north and south from the granitic plug exposed in the Dutch Flat mining district in the southwestern part of the quadrangle. Gold, silver, and mercury mineralization associated with these veins has been reported by Hotz and Willden (1964) and has been mined intermittently over the years.

Four distinct sets of high-angle Cenozoic structures with different orientations can be observed across the Hot Springs Range. Only a few of them can be observed to offset rock units on the ground. Detailed air photo analysis, however, reveals a complex sequence of faulting events. Sets of high angle structures with the following orientations can be observed: N-S, N40-50°W, N25-45°E, and N55-75°E. Recent Quaternary movement is apparent on the N25-45°E structures in the Delvada Spring Quadrangle and on N40-50°W structures in the Hot Springs Peak Quadrangle to the north.

North-striking high-angle faults are sparsely scattered, and are best seen at the far northern and southern ends of the range. The most prominent north-south structure in the Delvada Spring Quadrangle is located at Delvada Spring where it appears to be offset by northwest-striking faults.

Northwest-striking high angle faults form several prominent canyons in the Delvada Spring Quadrangle including Sodarisi Canyon, Browns Canyon, and several unnamed drainages. They appear to offset north-striking faults and to truncate east-northeast-striking faults. They are also offset by other east-northeast structures and north northeast structures. Structures of this same orientation are visible on air photos across the range, however they can rarely be observed to offset rock units.

Northeast-striking structures in the Delvada Spring Quadrangle show evidence for recent movement in the center of Eden Valley, and at the far northern end of the range. There are many fewer northeast-striking faults in the Delvada Spring Quadrangle than in the quadrangles to the north where the rocks of the Golconda terrane have a prominent northeast fabric. This preexisting fabric has clearly influenced the presence and orientation of these younger structures. Tertiary basalt in this quadrangle shows fractures with many orientations, a strong indication that recent activity has occurred on several different structural trends.

East-northeast high-angle structures are more common in the center and southern parts of the range in the Delvada Spring Quadrangle than they are at the northern end. The east-northeast structures appear to rotate northward at the east side of the range where they merge with the structure in Eden Valley. They give the appearance of the structural rotation that would be expected in a left-lateral shear zone bounded by northeast-striking faults on either side of the Hot Springs Range.

A small but distinct set of nearly east-west linear features occurs in air photos of the southeastern part of the quadrangle. It is unclear whether they represent a distinct fault set or a subset of another major set with a slightly different orientation.

High-angle Quaternary faults, fractures, and shear zones with minor to no offset are common throughout the Hot Springs Range. The lithologic uniformity and pervasive folding of the rocks often make it difficult to distinguish such structures. Where their orientation could not be reasonably constrained by either ground evidence or air photo evidence, they were not depicted on the map.

## TECTONIC INTERPRETATION

The contrasts of the structural characteristics among the three Paleozoic terranes exposed in the Delvada Spring Quadrangle require the recognition of multiple tectonic events that have not been incorporated into the tectonic history of this area. In all three terranes the beds are pervasively folded into plunging folds with dramatically different orientations. The divergent orientations of folding in each terrane do not support commonly accepted interpretations for their respective tectonic origins.

### Hogshead Canyon Terrane

The Osgood Mountains Quartzite is usually interpreted as an autochthonous or parautochthonous piece of the Paleozoic continental margin (Roberts and others, 1958). The southeastward-overturned southwest-plunging folds in the Osgood Mountains Quartzite demonstrate that at least in the Delvada Spring Quadrangle, this unit is no longer autochthonous. The folded beds of quartzite have presumably been detached from their original basement and moved southeastward. The amount of this movement is unconstrained.

This deformation may be related to east-vergent compression that occurred during either the Sonoman or Antler orogenies, or it may be the result of a Mesozoic compressive event. The fact that the Precambrian quartzite is now exposed also indicates that an extreme amount of uplift has occurred to bring this unit that was once presumably buried by the Paleozoic miogeocline to the surface. Any of the compressive or extensional events that have affected the western margin of the continent could have been in part responsible for this uplift. Future studies of more extensive exposure of the Osgood Mountains Quartzite in the Osgood Mountains will help to address whether the observed structures in the Delvada Spring Quadrangle are local, or indicative of a more regional structural characteristic.

### Getchell Terrane

The Valmy and Vinnini Formations are the principal rock units of the Roberts Mountains terrane. They are characterized elsewhere by east-vergent folding attributed to the middle Paleozoic Antler Orogeny that affected rocks of the Roberts Mountains terrane in many regions of north and central Nevada (Roberts and others, 1958; Evans and Theodore, 1978; Oldow, 1984). The Valmy Formation exposed in the Hot Springs Range is lithologically similar to the Valmy exposed in nearby mountain ranges, but the steeply plunging fold orientations of the Valmy Formation in the Hot Springs Range are not similar to orientations of the folds in the same rock unit reported from other areas. The most plausible explanation for this is that the Valmy Formation in the Hot Springs Range has been subject to an unknown amount of local rotation and/or refolding as a result of subsequent Mesozoic and Cenozoic tectonic activity. Regional studies similar to those done by Oldow (1984) and Evans and Theodore (1978) could help to quantify the amount and type of rotation or refolding that has affected these rocks.

### Dutch Flat Terrane

The northwest vergent orientation of the folds in Dutch Flat terrane is not only directly opposed to the folding orientation in the Osgood Mountains Quartzite, but it is distinct from that recorded in other Paleozoic terranes in northern Nevada. There is no geologic evidence in the Delvada Spring Quadrangle to suggest either overprinting of the west vergent structural fabric in the Harmony Formation by any east-vergent deformation or overprinting of an east-vergent Antler-type event by a west vergent structural fabric. This structural evidence indicates that the Harmony Formation and hence the Dutch Flat terrane was *not* involved in east-vergent deformation during the middle Paleozoic Antler Orogeny that affected volumes of oceanic-derived early Paleozoic rocks throughout northern Nevada. Since the age of the folding of the Harmony Formation in the Hot Springs Range can only be constrained as pre-Cretaceous, the west-vergent folding could be the result of either Mesozoic or Paleozoic tectonic events. At Battle Mountain, the early Pennsylvanian Antler Overlap sequence is reported to be depositional on the Harmony Formation (Roberts, 1964). If the Harmony Formation at Battle Mountain has the same structural history as the Harmony Formation in the Hot Springs Range, this could provide an upper age limit for this west vergent folding.

Roberts and others (1958) and Hotz and Willden (1964) interpreted the Harmony Formation as part of the "transitional assemblage." These rocks were believed to have been deposited in a setting midway between the "eastern" carbonate assemblage and the "western" oceanic assemblage (hence the term "transitional") and to have been deformed and moved eastward during the middle Paleozoic Antler Orogeny. Several lines of evidence indicate alternative interpretations that are more appropriate for these rocks. First, the lack of constraints for a source area for the unusual lithology of the Harmony Formation (Wallin, 1990; Smith and Gehrels, 1994; Gehrels and Dickinson, 1995) indicate that it may have originally formed far from its present location. Second, the new age data from the Harmony Formation presented here suggest that the Harmony Formation was being deposited at a time when it is commonly interpreted that the Antler Orogeny was accreting Ordovician and Devonian terranes to the North American continent. And thirdly, the unusual structural history of these rocks indicates that they were not near the locus of east-vergent deformation of the Antler Orogeny during the middle of the Paleozoic. Two alternatives can explain these observations. One alternative is that the Dutch Flat terrane is an accreted terrane which became part of the western North American continental margin after the Late Devonian, and arrived with a preexisting structural fabric (the west-verging folds). This would require an accretion mechanism such as translation that did not significantly disrupt or alter the internal structural fabric of the terrane. Alternatively, these rocks could have been involved in a pre-Cretaceous deformation episode within western North America (at a presently unknown location) that displaced them relatively westward from their original point of deposition, causing west-vergent deformation in the process. In either case, these rocks were neither involved in nor affected by an east-vergent Antler Orogeny as has been traditionally interpreted. While post-Paleozoic rotation of the Harmony Formation may have influenced the present orientation of bedding, there is no structural evidence that the southern two-thirds of the Hot Springs Range has been rotated in a stress regime markedly different from that affecting other ranges of northern Nevada where Paleozoic rocks are exposed. Ongoing studies to recover additional age data, and compare the structural and stratigraphic characteristics of the Harmony Formation exposed in the Hot Springs Range with the other exposures in northern Nevada may help to differentiate between alternative hypotheses for the origin and structural history of this enigmatic formation.

## CONCLUSION

Regional stratigraphic evidence has argued that the ages of folding of the Paleozoic rocks in the different terranes exposed in the Delvada Spring Quadrangle may be pre-Pennsylvanian. Multiple Paleozoic tectonic events with different vergence directions of folding in the different terranes can be inferred as sources of the structures observed in these rocks. However, extensive Mesozoic deformation has also been recognized across the region (Silberling and Roberts, 1962; Oldow, 1984; Stahl, 1987, 1989), and therefore cannot be precluded as a source of many observed structures. Modification of our understanding of the Antler Orogeny as the only east-vergent tectonic event affecting early Paleozoic rocks of northern Nevada is necessary. Two important conclusions can be drawn from the structural information collected from the Paleozoic rocks in the terranes of the Delvada Spring Quadrangle. First, the tectonic events that led to deformation in the Harmony Formation were distinct from the deformation that affected the other Paleozoic terranes in the quadrangle, and second, the events that subsequently structurally juxtaposed the Paleozoic terranes are not demonstrably related, in this quadrangle, to the deformation within the different units.

Four distinct orientations of Tertiary and Quaternary high-angle faults can be measured in the Hot Springs Range as N-S, N40-50°W, N25-45°E, and N55-75°E. Quaternary movement is apparent on both the N25-45°E and N40-50°W structures. The number of different orientations of Cenozoic structures indicates that the complex Cenozoic structural history in these mountains involved several different stress regimes over time.

Paleozoic, Mesozoic and Cenozoic tectonic events similar to those interpreted in the Hot Springs Range are represented by analogous structures and styles of deformation exposed in mountain ranges across north-central Nevada. This indicates that the structural geology displayed in the Delvada Spring Quadrangle represents not only localized geologic events, but also regional tectonic events that played fundamental roles in shaping this part of the western margin of North America during the Phanerozoic.

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