Text and references to accompany NBMG Field Studies Map 14

GEOLOGY OF THE HOT SPRINGS PEAK QUADRANGLE AND THE SOUTHEASTERN PART OF THE LITTLE POVERTY QUADRANGLE, HUMBOLDT COUNTY, NEVADA

by
A. Elizabeth Jones

INTRODUCTION

The Hot Springs Peak Quadrangle and the southeastern part of the Little Poverty Quadrangle in Humboldt County, Nevada, cover the northern end of the Hot Springs Range, northeast of Winnemucca. The map area lies at the northwestern edge of a region of exposure of Paleozoic and lower Mesozoic rocks. The areas to the west and north are covered with Mesozoic sedimentary and Tertiary volcanic rocks. Stratigraphic and structural relations in and among the Paleozoic and lower Mesozoic rocks exposed in these quadrangles reveal important information about the tectonic history of these rocks. These relations add constraints to the understanding of the complex tectonic history of this region. Figure 1 shows the structural relations among the major tectonic units exposed in the Hot Springs Peak and Little Poverty Quadrangles.

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. Two Paleozoic terranes are exposed in these quadrangles. The Dutch Flat terrane includes the Late Cambrian Paradise Valley Chert, a Late Cambrian limestone, and the Late Devonian Harmony Formation. The Golconda terrane (Jones, 1991a) includes the Mississippian Home Ranch subterrane, the Mississippian through Permian Poverty Peak subterrane, the Permian Poverty Peak melange, the Permian Golconda melange, and possibly a Permian unit of phyllite and shale. Mesozoic rocks exposed in the area are part of the Triassic-Jurassic Jungo terrane (Silberling and others, 1987), and include the Auld Lang Syne Group and the Little Poverty limestone. Cenozoic rocks include Tertiary vesicular basaltic andesite, Tertiary porphyritic rhyolite, and several generations of Quaternary alluvium. The Tertiary volcanic rocks overlie all of the terranes and provide the minimum age of assembling of the various terranes into their present configuration.

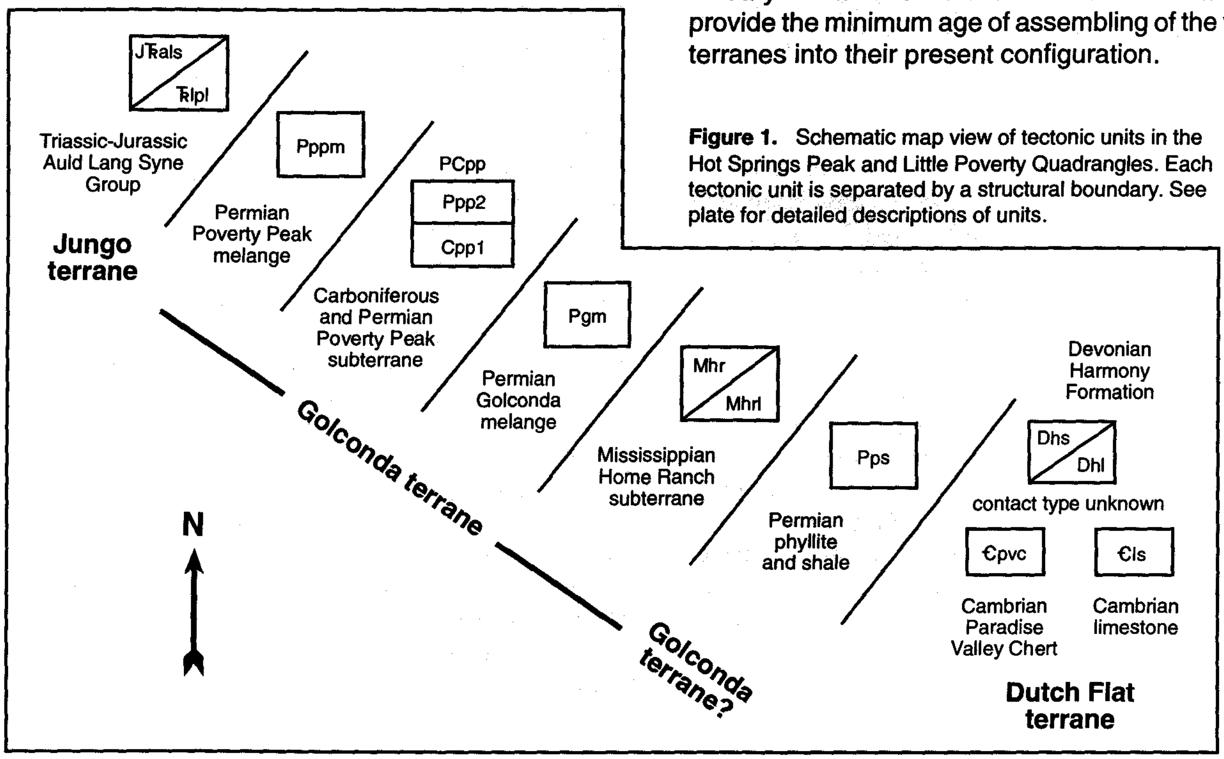

Figure 1. Schematic map view of tectonic units in the Hot Springs Peak and Little Poverty Quadrangles. Each tectonic unit is separated by a structural boundary. See plate for detailed descriptions of units.

Beds of the Paradise Valley Chert and the Harmony Formation are folded together in the Dutch Flat terrane and lie adjacent to the upper Paleozoic subterranes of the Golconda terrane along a high angle, mostly obscured structure. The contact between the Permian phyllite and shale and the Harmony Formation is covered by Tertiary basalt. The Home Ranch subterrane is faulted above the Permian phyllite and shale along a gently warped low-angle structure. The Golconda subterranes are separated from each other and from the melange units by generally steeply northwest-dipping, northeast-striking structural contacts. The Paleozoic rocks are separated from the Mesozoic Jungo terrane to the northwest by a poorly exposed, moderately west-dipping structure. The Paleozoic and Mesozoic units are overlain by Tertiary and Quaternary volcanic and sedimentary rocks. Tertiary and Quaternary high-angle structures have created minor offsets in many units, and occur with several distinct orientations across the area.

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

STRUCTURAL ANALYSIS

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 (fig. 2). 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 that intrudes the Harmony Formation exposed at Dutch Flat in the Delvada Spring Quadrangle.

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. 2d). Poles to bedding in the Paradise Valley Chert plot along a similar great circle as poles to bedding in the Harmony Formation (fig. 3). 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.

Golconda Terrane

Structural data from rocks of the Golconda terrane exposed in the Hot Springs Peak and Little Poverty Quadrangles reveal a complex structural history for these rocks described in detail in Jones (1991b) (fig. 4). Vertical to slightly northwest-dipping foliation defines the steeply east-vergent axial surface (fig. 4b) that is measured throughout the Golconda terrane in the Hot Springs Range. The carbonate beds of the Home Ranch subterrane show northeast trending and plunging tight to open folds, tens to hundreds of meters across that are overturned toward the southeast. Biostratigraphic sections across Poverty Peak I subterrane in the Little Poverty Quadrangle (table 1) indicate a progressive younging to both the southeast and the northwest, suggesting an overall antiformal structure for this subterrane. Steeply west- to vertically dipping chert beds and foliations striking northeast indicate pervasive southeast-vergent isoclinal folding of the Poverty Peak subterrane. The structure in the rocks of Poverty Peak II subterrane is identical to that in rocks of Poverty Peak I, except that the more massive and competent beds show larger scale tight to isoclinal folds and greater scatter in orientation. The subterranes of the Golconda terrane are separated from each other by post-Late Pennsylvanian or Early Permian melange units. The Poverty Peak subterrane is separated from the Home Ranch subterrane to the southeast by the Golconda melange, and bounded on the northwest by the Poverty Peak melange. The predominant northeast-trending foliation in the Golconda melange and the Poverty Peak melange parallels the structures that separate it from adjacent subterranes. The fabric within the melange units is also similar in orientation to the folding and shearing within the Home Ranch and Poverty Peak subterranes.

Together, the structural data from the different units of the Golconda terrane exposed in the Hot Springs Range define an overall northeast-trending and -plunging fold axis orientation (fig. 4a). They also indicate a steep eastward vergence of the deformation. The age of this deformation in the Hot Springs Range can only be constrained to pre-Tertiary.

The low-angle structure that emplaces the Home Ranch subterrane over the Permian phyllite and shale is constrained only to post-Late Permian and pre-Tertiary in age. It has been offset by Tertiary and/or Quaternary high angle fault movement in several places. Relative sense or amount of movement along this structure is unknown, but the present trace of the low-angle structure indicates that it has been gently folded. No evidence has been collected in the Hot Springs Range that indicates whether movement along this structure has been contractional or extensional in nature or if movement was related to deformation within the Golconda terrane temporally or kinematically.

Table 1. Age data from the Hot Springs Peak and Little Poverty 7.5' Quadrangles

Subterrane or Formation	Sample	Rock Type	Fossil	Species	Age	Identifier
Jungo terrane						
Little Poverty Limestone	87-SHS-001 (Mes. 33330)	limestone	conodont	*Epigondolella* sp. indet.	Karnian-Norian (Late Triassic)	Anita Harris, USGS
Little Poverty Limestone	88-SHS-004 (Mes. 33356)	limestone	conodont	*Epigondolella* sp. indet. *Xaniognathus* sp. indet.	Late Triassic	Anita Harris, USGS
Little Poverty Limestone	88-SHS-007	limestone	echinoids, gastropods, brachiopod, corals	*Giganticidaris* n. sp., *Triadocidarid* n. gen., n. sp., *Lentilancidema* n. sp., *Hespirocirus* sp., *Spondylospira* sp., *Liostrea* sp.	probably late Karnian (Late Triassic)	Tim Flemming
Golconda terrane						
Dry Hills (Golconda melange block)	87-SHS-087	green chert	radiolarian	*Albaillella indensis; Albaillella undulata, Archocyrtium petrushevskajae*	Osagean to early Meramecian (Middle Mississippian)	Elizabeth Jones
Dry Hills (Golconda melange block)	88-SHS-045	black chert	radiolarian	*Albaillella indensis?; Archocyrtium* sp.	Osagean to early Meramecian (Middle Mississippian)	Elizabeth Jones
Dry Hills (Golconda melange block)	88-SHS-047	gray-green chert	radiolarian	*Albaillella indensis; Albaillella undulata*	Osagean (Early Mississippian)	Elizabeth Jones
Golconda melange block	87-SHS-067	green-black cherty tuff	radiolarian	*Albaillella indensis; Albaillella undulata; Archocyrtium* sp.	Osagean to early Meramecian (Middle Mississippian)	Elizabeth Jones
Golconda melange block	88-SHS-018	black chert	radiolarian	*Tetratormentum* sp.	late Meramecian to Chesterian (Late Miss. to Early Penn.)	Elizabeth Jones
Golconda melange block	88-SHS-038	dark green chert	radiolarian	*Archocyrtium* sp.	Late Devonian to early Meramecian (early Late Miss.)	Elizabeth Jones
Golconda melange block	88-AEHS-061	black chert	conodont	*Neogondolella* sp., *Neogondolella idahoensis* (Youngquist, Hawley & Miller)	middle to late Leonardian (late Early Permian)	Anita Harris, Bruce Wardlaw, USGS
Golconda melange block	88-AEHS-062	red chert	radiolarian	*Archocyrtium* sp.	Late Devonian through Early Miss.	Elizabeth Jones
Home Ranch	87-SHS-096 (30838-PC)	limestone	conodont	*Hindeodus* aff. *H. crassidentatus* (Branson & Mehl); *Polygnathus* sp. indet.	late Kinderhookian-Osagean (Early Mississippian)	Anita Harris, USGS
Home Ranch (Golconda melange block)	88-SHS-050	limestone	conodont	*Hindeodus* sp. indet.; gnathodid; *Polygnathus* sp. indet.	late? Kinderhookian-Osagean (Early Mississippian)	Anita Harris, USGS
Home Ranch	88-AEHS-063	limestone	bryozoan	in place bryozoans	Mississippian	unident.
Home Ranch	88-AEHS-071 (30860-PC)	limestone	conodont	*Polygnathus* aff. sp. *communis* Branson & Mehl; *Polygnathus bischoffi* Rhodes, Austin, & Druce; *P. mehli* group	Early Mississippian	Anita Harris, USGS
Poverty Peak I	86-JHS-002	red chert	radiolarian	*Albaillella aliceria*, n. sp., *Albaillella triangularis,* Latentifistula sp. B, *Scharfenbergia concentrica, Scharfenbergia plenospongiosa, Tetratormentum tailleurense*	late Meramecian through early Morrowan (Late Mississippian to Early Pennsylvanian)	Elizabeth Jones
Poverty Peak I	87-SHS-010	green chert	radiolarian	Latentifistulid B, *Tetratormentum talihinaensis*	late Meramecian through Chesterian (Late Mississippian)	Elizabeth Jones
Poverty Peak I	87-SHS-011A	red chert	radiolarian	*Tetratormentum B, Tetratormentum buckensis, Tetratormentum haeckeli, Tetratormentum tailleurense, Tetratormentum talihinaensis*	late Meramecian to Desmoinesian (Late Mississippian to Late Pennsylvanian)	Elizabeth Jones

Table 1. Age data from the Hot Springs Peak and Little Poverty 7.5' Quadrangles (continued)

Subterrane or Formation	Sample	Rock Type	Fossil	Species	Age	Identifier
Golconda terrane (continued)						
Poverty Peak I	87-SHS-013	green chert	radiolarian	*Albaillella A, Albaillella indensis* type, *Albaillella undulata, Latentifistula longabrachia, Scharfenbergia concentrica*	latest Osagean to early Meramecian (late Early to early Late Mississippian)	Elizabeth Jones
Poverty Peak I	87-SHS-015	greenish white chert	radiolarian	*Nazarofella gracilis, Scharfenbergia concentrica, Scharfenbergia ruestae, Tetratormentum gordoni, Tetratormentum haeckeli, Tetratormentum kennetti,* n. sp., *Tetratormentum ruestae, Tetratormentum tailleurense, Tetratormentum talihinaensis*	late Meramecian through Chesterian (Late Mississippian)	Elizabeth Jones
Poverty Peak I	87-SHS-016	dk. red chert	radiolarian	Latentifistulid arm	late Osagean through Wolfcampian (late Early Mississippian through Early Permian)	Elizabeth Jones
Poverty Peak I	87-SHS-017	red chert	radiolarian	Latentifistulid A, *Ormistonella robusta, Polyfistula* sp., *Pseudoalbaillella lomentaria, Pseudoalbaillella nodosa, Pseudoalbaillella simplex* type, *Pseudoalbaillella u-forma, Sossonella klaumannensis,* n. gen., n. sp.	Missourian through Wolfcampian (Late Pennsylvanian through Early Permian)	Elizabeth Jones
Poverty Peak I	87-SHS-030	red chert	radiolarian	*Scharfenbergia plenospongiosa*	Chesterian through early Morrowan (Late Mississippian through Early Pennsylvanian)	Elizabeth Jones
Poverty Peak I	87-SHS-031	red chert	radiolarian	*Tetratormentum tailleurense*	late Meramecian through early Morrowan (Late Mississippian through Early Pennsylvanian)	Elizabeth Jones
Poverty Peak I	87-SHS-033	red chert	radiolarian	Latentifistulid D, Latentifistulid F	late Morrowan through Wolfcampian (Early Pennslyvanian through Early Permian)	Elizabeth Jones
Poverty Peak I	87-SHS-039	red chert	radiolarian	*Tetratormentum haeckeli, Tetratormentum kennetti,* n. sp., *Tetratormentum tailleurense*	late Meramecian through early Morrowan (Late Mississippian through Early Pennsylvanian)	Elizabeth Jones
Poverty Peak I	87-SHS-040	green chert	radiolarian	*Scharfenbergia concentrica, Scarfenbergia plenospongiosa, Scharfenbergia ruestae, Tetratormentum haeckeli, Tetratormentum tailleurense*	late Meramecian through early Morrowan (Late Mississippian through Early Pennsylvanian)	Elizabeth Jones
Poverty Peak I	87-SHS-042	red & green chert	radiolarian	*Albaillella A, Albaillella indensis, Latentifistula longabrachia* arms	latest Osagean through early Meramecian (Mid-Mississippian)	Elizabeth Jones
Poverty Peak I	87-SHS-043	red chert	radiolarian	Latentifistulid E, Latentifistulid F, *Scharfenbergia concentrica, Tetratormentum gordoni, Tetratormentum ruestae, Tetratormentum tailleurense, Tetratormentum talihinaensis*	late Meramecian through early Morrowan (Late Mississippian through Early Pennsylvanian)	Elizabeth Jones
Poverty Peak I	87-SHS-044	dark grey chert	radiolarian	Latentifistulid B, Latentifistulid F, *Tetratormentum B, Tetratormentum kennetti*	late Meramecian through early Morrowan (Late Mississippian through Early Pennsylvanian)	Elizabeth Jones
Poverty Peak I	87-SHS-052	red chert	radiolarian	Latentifistulid A	Chesterian through Desmoinesian (Late Mississippian through Mid-Pennsylvanian)	Elizabeth Jones

Golconda terrane (continued)

Poverty Peak I	87-SHS-069	red chert	radiolarian	*Albaillella?* sp. indet.; *Archocyrtium?* sp. indet.	Kinderhookian to early Meramecian (Mississippian)	Elizabeth Jones
Poverty Peak I	88-SHS-015	red chert	radiolarian	Latentifistulid F, *Scharfenbergia concentrica*	Chesterian through Wolfcampian (Late Miss. through Early Permian)	Elizabeth Jones
Poverty Peak I	88-SHS-016	red chert	radiolarian	*Scharfenbergia concentrica*	latest Osagean through Leonardian (Early Miss. through Early Permian)	Elizabeth Jones
Poverty Peak I	89-AEHS-004	green chert	radiolarian	*Latentifistula longabrachia* Jones	latest Osagean to Chesterian (Mississippian)	Elizabeth Jones
Poverty Peak I	89-AEHS-005	red chert	radiolarian	*Tetratormentum* sp. indet.	late Meramecian to early Morrowan (Late Miss. to Early Penn.)	Elizabeth Jones
Poverty Peak I	89-AEHS-007	red chert	radiolarian	Latentifistulid, g. & sp. indet.	late Morrowan to Virgillian? (Pennsylvanian)	Elizabeth Jones
Poverty Peak II	87-SHS-036 (30872-PC)	calcarenite	conodont	*Neogondolella guijioensis, Neostreptognathodus exsculptus, Sweetognathus?* sp., *Sweetina* sp., *Xaniognathus* sp.	early Artinskian (late Early Permian)	Anita Harris
Poverty Peak melange block	87-SHS-002	red chert	radiolarian	Latentifistulid C, Latentifistulid E, *Pseudoalbaillella simplex* type, *Quinqueremis robusta*	Missourian through Wolfcampian (Late Penn. through Early Permian)	Elizabeth Jones
Poverty Peak melange block	87-SHS-003	red chert	radiolarian	Latentifistulid D, *Nazarovelli gracilis, Ormisonella* sp., *Pseudoalbaillella annulata, Pseudoalbaillella longicornis, Pseudoalbaillella sakmarensis, Pseudoalbaillella scalprata, Pseudoalbaillella u-forma* type, *Sossonella klaumannensis*	Missourian through Wolfcampian (Late Penn. through Early Permian)	Elizabeth Jones
Poverty Peak melange block	87-SHS-021	red chert	radiolarian	*Pseudoalbaillella* sp.	late Morrowan through Leonardian (Pennsylvanian through Early Permian)	Elizabeth Jones
Poverty Peak melange block	87-SHS-022	chert clast in breccia	radiolarian	*Pseudoalbaillella* sp., *Scharfenbergia concentrica?, Sossonella klaumannensis* n. gen., n. sp.	Missourian through Wolfcampian (Late Penn. through Early Permian)	Elizabeth Jones
Poverty Peak melange block	87-SHS-024	red chert	radiolarian	Latentifistulid D, *Ormistonella* sp., *Pseudoalbaillella u-forma* type, *Quinqueremis robusta, Sossonella klaumannensis*	Missourian through Wolfcampian (Late Penn. through Early Permian)	Elizabeth Jones
Poverty Peak melange block	87-SHS-029	red chert	radiolarian	*Deflandrella manica, Latentifistula A,* Latentifistulid D, Latentifistulid F, Latentifistulid G, *Pseudoalbaillella G, Pseudoalbaillella longicornis, Pseudoalbaillella nodosa, Pseudoalbaillella scalprata, Pseudoalbaillella u-forma* type	Missourian through Wolfcampian (Late Penn. through Early Permian)	Elizabeth Jones
Poverty Peak melange block	87-SHS-045	red chert	radiolarian	Latentifistulid D, *Pseudoalbaillella* sp., *Scharfenbergia concentrica*	late Morrowan through Wolfcampian (Pennsylvanian through Early Permian)	Elizabeth Jones
Poverty Peak melange block	87-SHS-048	red chert	radiolarian	*Pseudoalbaillella globosa* type, *Pseudoalbaillella lomentaria, Pseudoalbaillella scalprata, Pseudoalbaillella* sp. X	early Leonardian (late Early Permian)	Elizabeth Jones
Poverty Peak melange block	87-SHS-061	red chert	radiolarian	Ormistonellid?, *Tetratormentum* B type	Chesterian through Desmoinesian (Late Mississippian through Early Pennsylvanian)	Elizabeth Jones
Poverty Peak melange block	87-SHS-062	green chert	radiolarian	Latentifistulid D, Latentifistulid F, *Scharfenbergia concentrica, Sossonella klaumannensis* n. gen., n. sp.	late Morrowan through Leonardian (Pennsylvanian through Early Permian)	Elizabeth Jones
Poverty Peak melange block	87-SHS-071	red chert	radiolarian	*Latentifistula patagilaterala, Pseudoalbaillella aidensis; Ps. longicornis; Ps. scalprata; Ps. simplex*	Wolfcampian (Early Permian)	Elizabeth Jones

Table 1. Age data from the Hot Springs Peak and Little Poverty 7.5' Quadrangles (continued)

Subterrane or Formation	Sample	Rock Type	Fossil	Species	Age	Identifier
Golconda terrane (continued)						
Poverty Peak melange block	87-SHS-072	red chert	radiolarian	*Pseudoalbaillella longicornis?; Ps. simplex,* Ormistonellid	Wolfcampian? (Early Permian)	Elizabeth Jones
Poverty Peak melange block	87-SHS-073	green chert	radiolarian	Latentifistulid; Ormistonellid; *Pseudoalbaillella elegans; Ps. simplex* type	Wolfcampian (Early Permian)	Elizabeth Jones
Poverty Peak melange block	87-SHS-074	red chert	radiolarian	Latentifistulid; Ormistonellid; *Pseudoalbaillella u-forma* type; *Scharfenbergia concentrica?*	late Morrowan to Wolfcampian (Late Pennsylvanian to Early Permian)	Elizabeth Jones
Poverty Peak melange block	88-SHS-009	red chert	radiolarian	Latentifistulid F, Ormistonellid, *Pseudoalbaillella* sp., *Scharfenbergia concentrica*	late Morrowan through Wolfcampian (Pennsylvanian through Early Permian)	Elizabeth Jones
Poverty Peak melange block	88-SHS-012	red chert	radiolarian	Latentifistulid arms, *Pseudoalbaillella elegans, Pseudoalbaillella lomentaria*	Wolfcampian? (Early Permian)	Elizabeth Jones
Poverty Peak melange block	88-SHS-017	red chert	radiolarian	Latentifistulid D	late Morrowan through Wolfcampian (Pennsylvanian through Early Permian)	Elizabeth Jones
Poverty Peak melange block	88-SHS-024	red chert	radiolarian	Latentifistulid D	late Morrowan through Wolfcampian (Pennsylvanian through Early Permian)	Elizabeth Jones
Poverty Peak melange block	88-SHS-026	red chert	radiolarian	Albaillellid, Latentifistulid D, *Nazarovella?*	late Morrowan through Wolfcampian (Pennsylvanian through Early Permian)	Elizabeth Jones
Poverty Peak melange block	88-SHS-028	red chert	radiolarian	*Latentifistula impella?; L. plenospongiosa?; Nazarovella; Pseudoalbaillella longicornis; Ps. scalprata; Tormentum* sp.,	Leonardian? (late Early Permian)	Elizabeth Jones
Permian phyllite and shale	88-AEHS-066	black cherty siltstone	radiolarian	*Albaillella indensis* type; *Albaillella undulata*	Osagean to early Meramecian (Middle Mississippian)	Elizabeth Jones
Permian phyllite and shale	88-AEHS-068	limestone	conodont	*Neogondolella gracilis* (Clark and Ethington); *Neogondolella* sp. indet.; *Neostreptognathodus sulcoplicatus* (Youngquist, Hawley and Miller); *Xaniognathus* sp. indet.	latest Leonardian (latest Early Permian)	Anita Harris, USGS
Dutch Flat terrane						
Harmony Formation	93-HSP-001	turbiditic limestone	barren			John Repetski, USGS
Harmony Formation	94-HSP-001 limestone	turbiditic	barren			John Repetski, USGS
Harmony Formation	94-HSP-002 limestone	turbiditic	barren			John Repetski, USGS
Harmony Formation	94-HSP-003	siliceous argillite	not processed			
Cambrian Limestone	94-HSP-004 (11053-CO)	fine-grained micritic limestone	protoconodonts, paraconodonts, euconodonts, phosphatic brachiopods, trilobites *incertae sedis*	*Phakelodus elongatus* An; *Furnishina* sp.; *Proacodus* sp., cf. *P. pulcherodus* (An); *Prooneotodus gallatini* (Muller); *Proconodontus?* sp.; Acrotretids; *Angulotreta; Pseudagnostus?; Chancelloria*	early Late Cambrian basal Steptoean (Aphelaspis Zone)	John Repetski, USGS, A.R. Palmer, USGS

Permian phyllite and shale. The distribution of foliations in the Permian phyllite and shale unit indicates that it has had a complex structural history. Foliations of very different orientations were measured and suggest a polyphase, non-coaxial structural history for these rocks. North-northeast trending, east-dipping crenulation cleavage refolds an earlier foliation that is parallel to bedding. Steeply dipping foliations do not have a consistent sense of vergence and are only constrained in age to pre-Tertiary. The contact between the Permian phyllite and shale and the Harmony Formation is obscured by Tertiary basaltic andesite and lack of exposure. The contact trends northeasterly, roughly subparallel to the structures that separate the Golconda subterranes from each other. The age of the structure is pre-Tertiary and it may have served as the locus of future Tertiary volcanism.

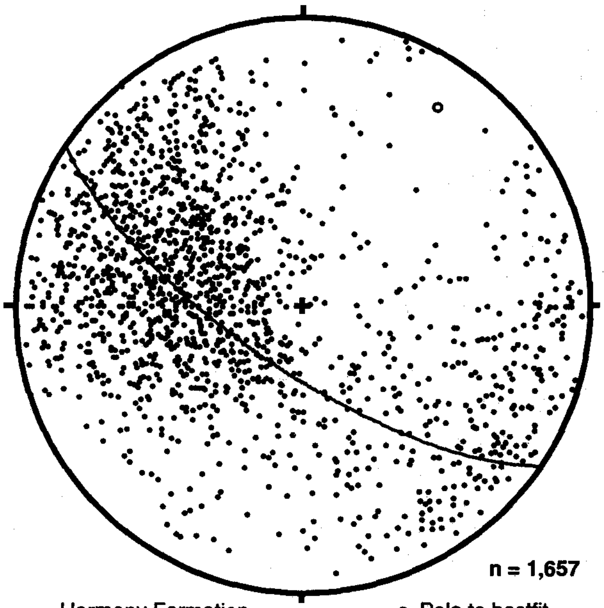

Figure 2a. Bedding plane measurements in the Harmony Formation across the Hot Springs Range.

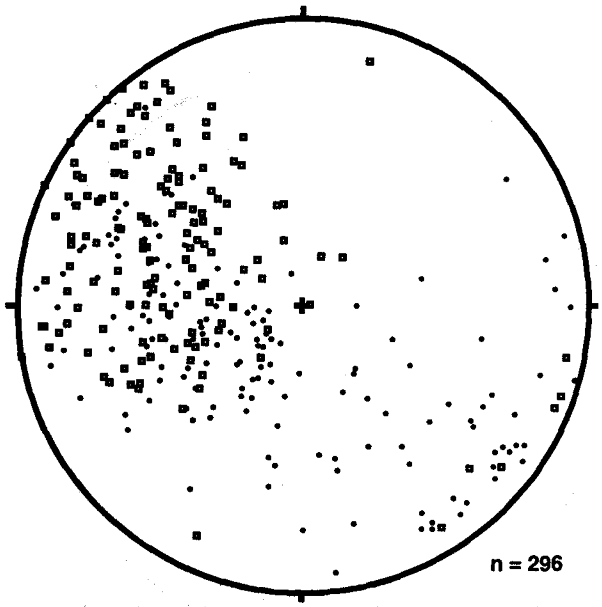

Figure 2c. Bedding plane measurements of upright vs. overturned beds in the Harmony Formation.

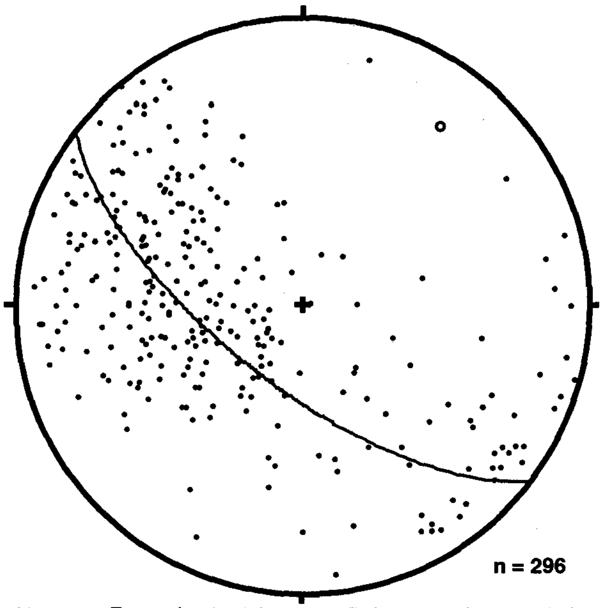

Figure 2b. Bedding plane measurements in the Harmony Formation where the facing direction could be confidently determined.

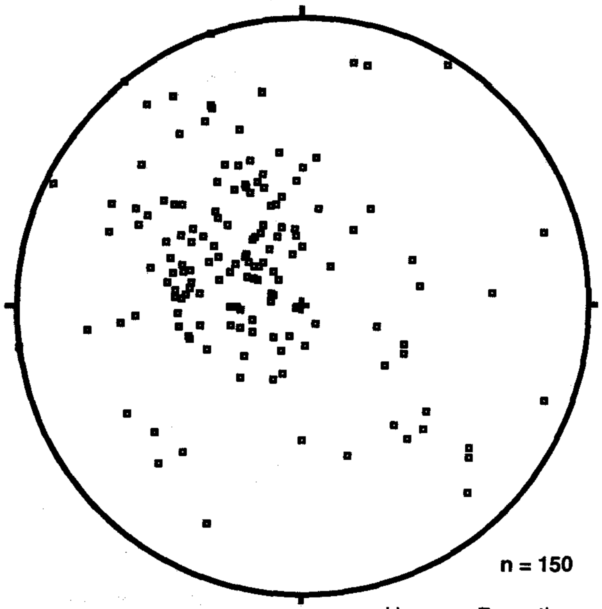

Figure 2d. Foliations in the Harmony Formation.

Jungo Terrane

Beds of the Auld Lang Syne Group and the limestone of Little Poverty are tightly folded and cleaved. Bedding dips steeply to the east and west, and strikes east-northeast. The youngest age data collected for these rocks in the Hot Springs Range are Late Triassic, but the Auld Lang Syne Group is known to be as young as Jurassic in the Santa Rosa Mountains to the west. This indicates that the folding in this terrane is Jurassic or younger. Limited structural data collected in the Hot Springs Range suggest a slightly different structural orientation within these rocks as compared with the structure in the Golconda terrane (Jones, 1991a).

Within the Jungo terrane, the contact between the Auld Lang Syne Group and the limestone of Little Poverty is covered by Tertiary or Quaternary alluvium and Tertiary volcanic rocks. The Jungo terrane is separated from the Golconda terrane by a moderately west-dipping, poorly exposed structure that trends northeast at the northwestern edge of the range. It juxtaposes the Auld Lang Syne Group against blocks of serpentine and basalt in the Poverty Peak melange and it places the Little Poverty limestone over gabbro, serpentine and basalt in the Poverty Peak melange.

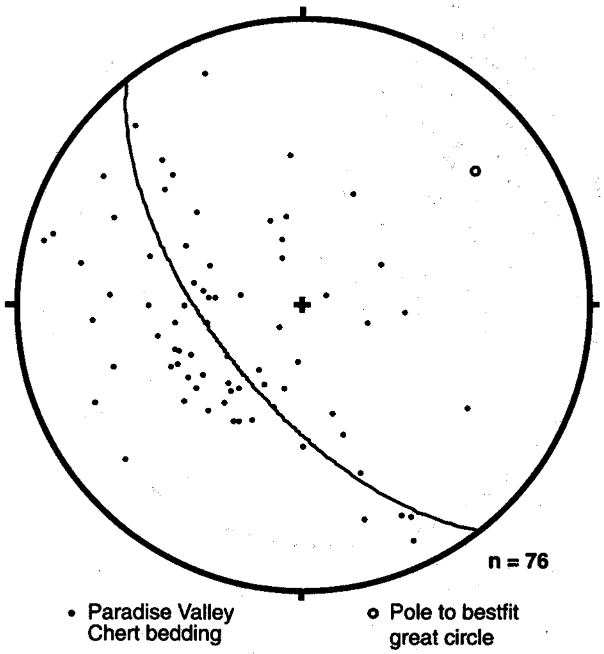

Figure 3. Bedding plane measurements in the Paradise Valley Chert.

CENOZOIC STRUCTURE

Four distinct sets of high-angle 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. Quaternary movement is apparent on the N25-45°E and N40-50°W structures.

A north-striking high-angle fault offsets the Poverty Peak melange, Poverty Peak subterrane and the Golconda melange approximately 360 m with a right lateral sense of movement at the northern end of the range. An older Tertiary or Quaternary alluvial fan shedding from the locus of this structure suggests it may be one of the older Cenozoic faults in the area.

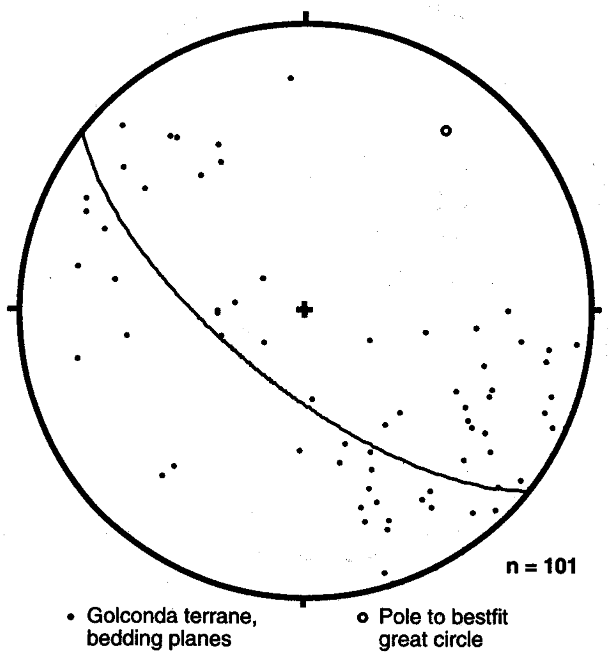

Figure 4a. Bedding plane measurements from the Golconda terrane in the Hot Springs Range.

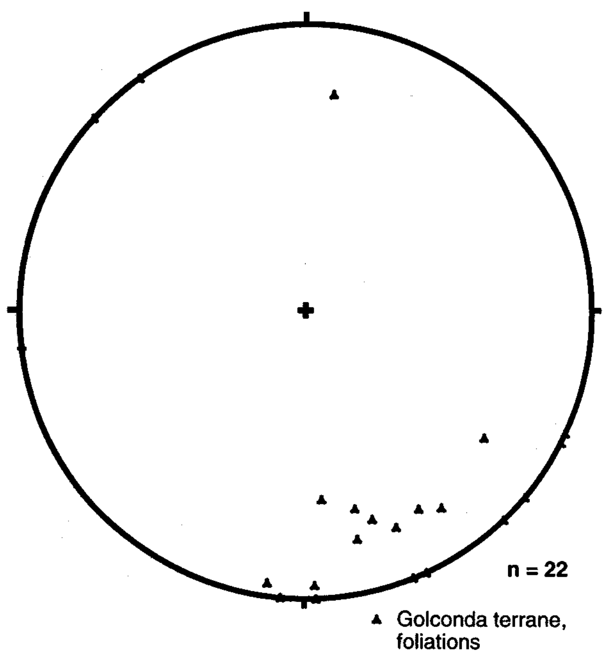

Figure 4b. Foliation measurements from the Golconda terrane in the Hot Springs Range.

Northwest-striking high-angle faults offset the Poverty Peak melange and subterrane at the northwest edge of the range. Structures of this same orientation are visible on air photos across the range but they can rarely be observed to offset rock units. Their age relative to the north-striking high-angle fault is unknown. They are truncated in many cases by north-northeast-striking faults, indicating later movement on the latter. An exception is found at the southwest end of the northern part of the range where a recent northwest-striking quaternary fault has truncated the end of the range there. This movement postdates the north-northeast-striking faults in that area. The presence of this set of northwest-striking faults in this area may be linked to the extensive mercury mineralization that has been intermittently mined on the northwestern side of the range at the Kahill Mine.

Several prominent northeast striking structures in these two quadrangles show evidence for recent movement, especially along the northwesternmost range front. The abundance of high-angle, north-northeast faults and fractures, as seen in air photos, can be attributed to the presence of the strong north-northeast-trending fabric — bedding and foliation— in the Paleozoic rocks of the Golconda terrane. This preexisting fabric has clearly influenced the presence and orientation of these younger structures. There are fewer north-northeast-striking faults farther south in the range where only the Harmony Formation is exposed. Fractures with this north-northeast trend can also be observed in the Tertiary basalt, a strong indication that this set of structures has been active very recently.

East-northeast high-angle structures are less visible at the far northern end of the range, but can be seen in air photos in the center of the range and to the south in the Delvada Spring Quadrangle. Near Stewart Gap, at least two major drainages share this orientation. The east-northeast structures may offset the northwest structures, but the evidence for this is not conclusive.

High-angle Quaternary faults, fractures and shear zones with minor to no offset are common throughout the quadrangles. 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

Structural evidence for three different pre-Cenozoic tectonic events as well as Tertiary Basin and Range extension is well preserved in the rocks exposed in the northern Hot Springs Range. Northwest vergent folding in the Harmony Formation of the Dutch Flat terrane, northeast striking foliations in the Golconda terrane, and east-northeast striking bedding and foliations in the Jungo terrane are each evidence that three separate, discrete tectonic events have affected the different Paleozoic and Mesozoic rocks exposed in the Hot Springs Range.

Dutch Flat Terrane

The northwest-vergent orientation of the folds in the Dutch Flat terrane is distinct from that recorded in any other Paleozoic terrane in northern Nevada. This structural evidence indicates that the Harmony Formation and hence the Dutch Flat terrane were *not* involved in east-vergent deformation during the middle Paleozoic Antler Orogeny that affected volumes of oceanic-derived Lower Paleozoic rocks throughout northern Nevada. Likewise, the structural evidence collected from the Harmony also indicates that it was not affected by the east-directed tectonism (the Sonoma Orogeny) that deformed the upper Paleozoic rocks in the Golconda terrane at the northern end of the range and elsewhere. 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 collected in the Delvada Spring Quadrangle (Jones, 1997) suggests that the Harmony Formation was being deposited at a time when it is commonly interpreted that the Antler Orogeny was accreting Ordovician to 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 suggests 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.

Golconda Terrane

The south-east vergent deformation in the upper Paleozoic rocks of the Golconda terrane is very distinct from the northwest-vergent folding in the Harmony Formation. There is no evidence of the west-vergent folding observed in the Harmony Formation in the Golconda terrane. These two units are separated by the polyphase-deformed Permian phyllite and shale, several high-angle structures, and Tertiary basalt.

The structural data presented above for the Golconda terrane (fig. 4) closely match the axial surface and fold axis data presented by other workers (Miller and others, 1982, fig. 5B; Miller and others, 1984, fig. 7A,B; Brueckner and Snyder, 1985, fig. 10A,B) that have been attributed to the Sonoma Orogeny. Although no pre-Tertiary age constraints for this deformation are preserved in the Hot Springs Range, rocks of the Golconda terrane in the Tobin Range with this same style and orientation of deformation are unconformably overlain by Early Triassic volcanic and volcaniclastic rocks (Silberling and Roberts, 1962), and provide an upper age constraint for this characteristic deformation. While an interpretation of a Sonoman age (Late Permian-Early Triassic) for the deformation of the Golconda rocks in the Hot Springs range is consistent with regional tectonic evidence, the presence of Mesozoic deformation in these rocks can not be precluded.

The presence of clasts from the different subterranes in the melange units of the Golconda terrane suggests that the melanges formed as large shear zones while the subterranes were being brought together, or accreted, during the Late Permian or Early Triassic. The distinct lithologic and age characteristics of the different subterranes juxtaposed along these structures require significant amounts of relative movement between each of these units before they were brought together. The Mississippian rocks of the Home Ranch subterrane probably formed in an offshore, oceanic seamount setting (Jones, 1991a; Jones and Jones, 1991). They are now situated relatively "inboard" from the younger continental-margin derived Permian calcarenitic Poverty Peak II rocks. In contrast, the ocean-spreading-center-derived rocks in the Permian Poverty Peak melange and Poverty Peak I subterrane are outboard of the Permian calcarenitic Poverty Peak unit II, as would be expected in a compressive accretionary system, to which the Sonoma Orogeny is generally attributed (Speed, 1979; Brueckner and Snyder, 1985). Because the subterranes and melanges are not arranged in a specific east to west sequence that reflects paleogeographic settings that formed farther and farther away from a continental margin, the relative movement between these subterranes could not have been purely west to east shortening, but must have included a significant component of translation along with the compression. The result of this transpressive accretion process would be discrete blocks of rocks of different ages with differing paleogeographic origins separated by broad zones of intense disruption, as is observed in the Golconda terrane in the Hot Springs Range and the Osgood Mountains. All of the melange zones observed to date contain fossils as young as Permian, indicating the maximum age when these units formed. A model of a protracted transpressive accretion event that culminated at the end of the Permian or Early Triassic time with obduction onto the continental margin would fit the observations of the structural and stratigraphic characteristics of the Golconda terrane in the Hot Springs Range and elsewhere.

Permian phyllite and shale. The multiphase deformation that has affected the Permian phyllite and shale can be interpreted as the result of multiple effects from both the late Paleozoic-Early Triassic accretion of the Golconda terrane and subsequent Mesozoic tectonism. If the Permian phyllite and shale is part of the Golconda terrane, then the boundary of accretion between the Golconda terrane and the Harmony Formation could be represented by the obscure high-angle contact between the Permian phyllite and shale and the Harmony Formation. The fact that this contact is poorly exposed and is obscured by younger Tertiary volcanism may suggest that it represents a major boundary along which multiple episodes of tectonic activity have been localized. The low angle contact between the Home Ranch subterrane and the Permian phyllite and shale could represent a zone of imbricate thrusting that resulted from the obduction of the Golconda terrane against phyllite and shale, or it could be the result of a much later, unrelated Mesozoic event. The compression that later gently folded this contact could be responsible for the uplift that now exposes the Permian phyllite and shale underneath the Home Ranch subterrane. Whether or not the Permian phyllite and shale originated as a piece of the western North American continental margin or is a translocated piece of the Golconda terrane, its juxtaposition between the Dutch Flat terrane and the other units of the Golconda terrane and its pervasive deformation imply that it has been profoundly affected by major post-Late Permian tectonic events.

Jungo Terrane

The Triassic and Jurassic rocks of the Jungo terrane were affected by yet another major tectonic event, which produced a strong east-northeast fabric in these rocks. It is not clear whether or not this fabric is also present in the adjacent rocks of the Golconda terrane, but it is not present in the Dutch Flat terrane. A post-mid-Jurassic tectonic event was responsible for the accretion of and deformation observed in the Jungo terrane. The structure that separates the Jungo terrane from the Golconda terrane correlates with the Fencemaker thrust of Oldow (1984), and represents the boundary of a major belt of regional Mesozoic terrane accretion.

Cenozoic Structures

Tertiary and Quaternary extension reactivated many older structures and created new ones along zones of preferred orientations that were closest to the directions of minimum stress during the extension. The presence of discrete sets of Tertiary and Quaternary structures with differing orientations indicate that multiple stress regimes with several different orientations have existed during Tertiary and Quaternary time. The most recent direction of extension in the Hot Springs Range is N40-50°W, normal to the high-angle range-bounding Quaternary faults.

CONCLUSION

Three distinct pre-Tertiary tectonic events are recorded in the rocks and structures exposed in the Hot Springs Peak Quadrangle and the southeastern part of the Little Poverty Quadrangle; 1) northwest-vergent pre-Cretaceous folding in the Harmony Formation, 2) southeast directed post-Late Permian folding and faulting in the Golconda terrane, and 3) post mid-Jurassic compression with a possible east-northeast axis of maximum compression in the Jungo terrane. The boundary between the Permian phyllite and shale and the Dutch Flat terrane could be as old as latest Permian or Early Triassic. The emplacement of the Home Ranch subterrane over the Permian phyllite and shale is a post-Late Permian event, and was followed by a younger folding event. The emplacement of the Jungo terrane against the Golconda terrane is a post-mid-Jurassic event.

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. Recent 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 Hot Spring Peak and Little Poverty Quadrangles 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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