Paleozoic tectonic domains of Nevada: An interpretive discussion to accompany the geologic map of Nevada

A. Elizabeth Jones Crafford
GeoLogic, 9501 Nettleton Drive, Anchorage, Alaska 99507, USA

ABSTRACT

The Paleozoic geologic history of Nevada can be viewed in terms of tectonic domains derived from the newly interpreted digital geologic map of Nevada. These domains reveal that Paleozoic tectonic events were shaped by complex interactions between the continental margin in Nevada and accreted terranes outboard of the margin.

Ten domains are described. They include lower Paleozoic domains based on paleogeographic facies, the Carbonate Shelf, Slope and Basin domains; the Nolan Belt domain, a structurally complex domain that includes Precambrian and lower Paleozoic slope and basin facies rocks; the Dutch Flat domain, an Upper Devonian feldspathic sandstone of exotic origin; an Upper Devonian to Lower Pennsylvanian siliciclastic Foreland basin domain resting conformably over the Shelf domain; the Pennsylvanian and Permian siliciclastic and carbonate Antler Overlap domain, which sits unconformably over all of the older domains; the Golconda domain of deformed upper Paleozoic oceanic, carbonate and siliciclastic rocks, which is faulted over the Antler Overlap domain; the upper Paleozoic and Mesozoic volcanioclastic Black Rock-Jackson domain; and numerous carbonate, siliciclastic, and volcanioclastic Mesozoic terranes and assemblages that were either accreted to the margin or deposited unconformably over previously accreted Paleozoic terranes.

Interpretations of these domains define multiple, distinct, lower Paleozoic tectonic environments. They suggest that the “Antler Orogeny” can be reinterpreted as a sequence of tectonic events involving deformation of the margin and the accretion of multiple terranes to the margin over an extended period from the Late Devonian to the Early Pennsylvanian in a complex transpressive tectonic regime. Some of the accreted terranes contain rocks unlike those from the adjacent margin or other terranes and suggest they are far traveled. A change in the plate boundary configuration in the Middle Pennsylvanian led to the development of a new margin that reflected the effects of a new plate boundary farther to the west. Accretion to the margin of upper Paleozoic oceanic terranes at the close of the Paleozoic redefined the margin once again as it changed from a transpressive accretion regime to a true backarc plate tectonic setting in the Mesozoic. East-vergent and west-vergent, thick-skinned thrusting and exhumation coupled with significant translation of components of Mesozoic and older terranes rearranged the Paleozoic rocks of the shelf and earlier accreted terranes during Jurassic and Cretaceous time. Viewing the geologic history of the region in the context of terrane accretion provides new insight into the complex processes that shaped the continental margin of western North America.

Keywords: Nevada, Tectonic, Paleozoic, Antler, terrane

INTRODUCTION

The purpose of this paper is to present a new viewpoint of the Paleozoic and Mesozoic geologic history in Nevada using tectonic domains derived from the newly interpreted digital geologic map of Nevada (Crafford, 2007). The new map provides detailed descriptions of how each local rock unit or formation was grouped into a regional geologic unit. This paper attempts to group those regional geologic units into tectonic domains and to discuss the significance of those domains relative to the geodynamic evolution of the region. The tectonic domains are each defined by a combination of stratigraphic, lithologic, facies, and structural characteristics of the regional geologic units, and not generally by any single feature. The purpose of creating the tectonic domains is to help characterize and distinguish groups of rocks by the distinct tectonic histories that have (or have not) impacted them.

Traditional interpretations of Paleozoic tectonic events in Nevada have primarily relied on pre-plate tectonic or early plate tectonic ideas of displacement of the Earth’s crust that do not necessarily address the complexity of structural and stratigraphic evidence that has been observed since they were first proposed (Brueckner and Snyder, 1985; Burchfiel and Davis, 1972, 1975; Burchfiel and Royden, 1991; Miller et al., 1984; Roberts et al., 1958; Speed, 1979; Speed and Sleep, 1982). Specifically, ideas of terrane accretion and displacement have only been applied either very generally to the Paleozoic and Mesozoic rocks within Nevada (Dickinson and Gehrels, 2000; Geissman et al., 1984; Silberling et al., 1987; Silberling et al., 1992), or to a few specific terranes (Blome and Reed, 1995; Darby et al., 2000; Gehrels and Dickinson, 2000; Gehrels et al., 2000a; Gehrels et al., 2000b; Gehrels et al., 1995; Harwood and Murchey, 1990; Jones, 1990; Ketchum et al., 2005; Madden-McGuire and Marsh, 1991a; Smith and Gehrels, 1994). The two primary tectonic events of the Paleozoic, the Antler and Sonoma orogenies, are discussed in detail in this paper together with evidence for other less well known Paleozoic tectonic events. The “Antler Orogeny” (Roberts, 1951) refers to the folding and faulting of pre-Pennsylvanian rocks that is observed throughout northern Nevada and is generally considered to be Late Devonian and Mississippian in age. The “Sonoma Orogeny” (Silberling and Roberts, 1962) has been defined as a Late Permian to Early Triassic tectonic event that deformed Upper Paleozoic oceanic facies rocks and emplaced them over the Upper Paleozoic margin of northern Nevada.

The observations derived from viewing the Paleozoic and Mesozoic geology of Nevada as regional tectonic domains pose more questions than they answer, but they also demonstrate that early models of tectonic events affecting
Paleozoic rocks in the region can benefit from being analyzed in the context of terrane accretion, and that important components of these events can be enhanced and updated. Defining domains helps to provide a spatial context for the various rock units. How the natures of the boundaries of the domains are interpreted provides important constraints on the timing and orientation of tectonic events affecting the different domains and the margin. Understanding tectonic relations between the various terranes and the margin is necessary for the geology to be an effective predictive tool for resource exploration and regional tectonic synthesis.

The terminology “tectonic domain” is explicitly intended to encompass the variety of geologic entities including stratigraphic sequences, assemblages, and terranes, deliberately utilized and described in detail on the new geologic map (Crafford, 2007); but it is also meant to distinguish “domains” as interpretive groupings derived from the more explicit geologic groupings used on the map. On the map, traditional stratigraphic units are grouped into sequences; “terrace” is used in the classic sense for fault-bounded geologic entities of regional extent, each characterized by a geologic history that is different from the histories of contiguous terranes (Jones et al., 1983); and “assemblage” is used for a group of related rock units within a terrace, or for a unit (or units) that has a known basement but is geographically isolated and lithologically and (or) structurally distinct from other coeval rocks. “Assemblage” is also used for grouping rock units that have been historically interpreted as geologically related to each other, but the relationship is unclear based on existing geologic data. In many cases, a specific tectonic domain is synonymous with a particular terrace or assemblage, and in other circumstances, the domain represents a grouping of these entities.

**DOMAIN DESCRIPTIONS**

Roberts et al. (1958) chose to categorize lower Paleozoic rocks of Nevada into essentially three domains, an “eastern” or “carbonate” assemblage, a “western” or “siliceous” assemblage and a “transitional” assemblage. Debate centered on whether the “transitional” assemblage had more affinity with the eastern or the western assemblages. In the context of a plate tectonic framework for the geologic history, these assemblages can be recast in the form of domains that relate in specific ways to the tectonic environment where they formed. Domains can be defined primarily by the paleogeographic setting of the rocks (where that can be reasonably defined), or by groupings of terranes or assemblages that reflect a combination of tectonic setting and specific structural history. The pre-Tertiary rocks in Nevada can be grouped into a number of tectonic domains. Each domain is defined in terms of the rocks included, its spatial extent, the nature of its boundaries, and how it was impacted by various tectonic events. Ten domains are discussed below. In this paper, Mesozoic terranes and assemblages are grouped into a single domain and are not discussed in detail.

The geologic units described on the new map (Crafford, 2007) utilize stratigraphic nomenclature as well as informal assemblages and terranes. In many cases, there is a one-to-one correlation between an assemblage or terrace described on the new geologic map, and a tectonic “domain” described in this paper. In other cases, a tectonic domain represents a group of assemblages or stratigraphic units on the map. The text that accompanies the map describes all of the geologic units and their groupings as sequences, assemblages, or terranes in detail (Crafford, 2007), and is not covered in this paper. Table 1 lists each tectonic domain, the correlative units from Crafford (2007), and a brief description of the nature of the boundaries and extents of the tectonic domains. The distribution of the tectonic domains displayed in the figures with this paper represents a simplified grouping of rock units from Crafford (2007). The actual exposure of the rock units from the map is shown within the extent of the domain. Since such a large area of Nevada is covered by younger volcanic rocks and alluvium, the simplified distribution of the domain is intended as a reasonable extrapolation of the extent of the occurrence of the actual units included in the domain underneath Tertiary and Quaternary cover.

An ArcGIS project that contains shape files of all the tectonic domains discussed here accompanies this paper.1 By viewing the project while reading the paper, the reader can turn on and off various domains as desired to complement the printed figures. These shape files can also be incorporated into the new digital map (Crafford, 2007) and compared with the actual geologic data in much greater detail.

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1 The file 00108_NevadaDomains.zip is a complete ArcGIS project with an .mxd file and all supporting data files. ArcView is needed to open the .mxd file. If you are viewing the PDF of this paper or reading it offline, please visit http://dx.doi.org/10.1130/GES00108.S1 or the full-text article on www.gsajournals.org to access NevadaDomains.zip.

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**Lower Paleozoic Shelf Domain**

This domain is defined by the sequence of passive margin carbonate shelf rocks exposed in the eastern half of Nevada (Cook and Corboy, 2004), sitting depositionally on Proterozoic North American basement (Fig. 1). It is distinguished from other tectonic domains by its relative lack of Paleozoic deformation east of its western boundary, its well-defined carbonate platform paleogeographic setting, and its unequivocal stratigraphic link to the autochthonous coeval rocks of the Colorado Plateau.

**Rocks**

This domain comprises Devonian through Cambrian carbonate shelf facies rocks including limestone, dolomite, sandstone, shale, and quartzite. It is similar to the “eastern assemblage” of Roberts et al. (1958) and the “carbonate assemblage” of Stewart and Carlson (1978). The rock units from the map (Crafford, 2007) that are included in the Lower Paleozoic Shelf domain are the Devonian through Cambrian units of the Carbonate Shelf Sequence including the undivided and metamorphosed equivalent rocks (Table 1).

**Extent and Boundaries**

The extent of the Lower Paleozoic Shelf domain is shown in Figure 1. The northern boundary of the domain trends east-west across central Elko County. The western boundary trends northeasterly in north-central Nevada and then bends toward the southeast near the Lander-Nye County boundary. To the south, it bends abruptly westward in southermmost Nye County and continues south and west from there into California. This domain extends eastward into Utah along most of Nevada’s eastern border and southward until Proterozoic basement crops out in southermmost Nevada.

**Tectonic Events**

Paleozoic, Mesozoic, and Cenozoic age thrusting and exhumation from both contractional and extensional tectonics have blurred the original autochthonous stratigraphic western boundary of this domain (Coats and Riva, 1983; Johnson and Pendergast, 1981; Johnson and Visconti, 1992; Kettner and Smith, 1982; McFarlane, 1997; McKee, 1976b; Riva, 1970). In the southern parts of the state, the faulting of lower Paleozoic rocks generally involves Mesozoic rocks, demonstrating a Mesozoic or younger age.
<table>
<thead>
<tr>
<th>Tectonic domain</th>
<th>Units from Crafford (2007)</th>
<th>Nature of spatial and geologic boundaries and structures</th>
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| Lower Paleozoic Shelf           | Carbonate Shelf Sequence (CSS)—Dc, Dcd, DSc, SOc, Ocq, OCc, Cc Undivided CSS: DCc, DOcm, Ocqm, OCcm | Eastern and southern boundaries grade stratigraphically into Colorado plateau.  
Northern and northwestern boundaries are mostly Paleozoic and Mesozoic structural imbrications with other rocks, rare depositional sequences with Slope domain.  
Southwestern boundary may be a Mesozoic truncation.  |
| Slope                           | Slope assemblage—MDst, DST, DOts  
Vinini Formation  
Comus Formation | Eastern boundary is both a depositional sequence and fault imbrications with Shelf domain and fault imbrications with Foreland Basin domain.  
Western boundary is imbricated with Shelf and Basin domain rocks, and truncated by the Nolan Belt.  
Southwestern boundary is possibly a Mesozoic truncation.  
Outliers could be distinct terranes or displaced fragments.  |
| Basin                           | Basin assemblage—DCs, Ss  
Valmy Formation | Eastern boundary is structural imbrication with Slope, Shelf, and Foreland Basin domain rocks.  
Overlain unconformably by rocks of the Antler Overlap domain throughout area.  
Western boundary generally covered.  
Southwestern boundary may be Mesozoic truncation?  |
| Nolan Belt                      | Nolan Belt—OCtd, Ctd, CZq  
Preble Formation | Basement below quartzite is unknown. Eastern boundary is usually covered, generally a high-angle structure where exposed.  
Western boundary is a high-angle shear zone or structurally overridden by Basin domain or Dutch Flat terrane.  
Unconformably overlain by rocks of the Antler Overlap domain.  |
| Dutch Flat                      | Dutch Flat terrane—DF  
Synonymous with Harmony Formation | Basement unknown. All boundaries structural or covered. Thrust over Basin domain at Battle Mountain, refolded and faulted with Paleozoic and Triassic rocks in the Sonoma Range. Unconformably overlain by the Antler Overlap domain.  |
| Foreland Basin                  | Foreland Basin assemblage—lPMcl, MDcl  
Webb Formation  
Newark Valley sequence | Overlies carbonate rocks of the lower Paleozoic Carbonate Shelf domain.  
Unconformably overlain by the Antler Overlap domain. Structural imbrication with Shelf, Slope, and Basin domain rocks at its western edge makes distinction difficult.  |
| Antler Overlap                  | Siliciclastic Overlap assemblage—TRAcl, Pacl, PiPaci  
Battle Formation  
Candelaria Formation | Rests unconformably over Basin, Slope, Foreland Basin, Nolan Belt, and Dutch Flat domains and Upper Paleozoic Carbonate Shelf rocks. Commonly is footwall to Golconda thrust.  |
| Golconda                        | Golconda terrane and Home Ranch subterrane—GC, GChr | All boundaries structural or covered. Structurally emplaced over the Antler Overlap domain on Golconda thrust. Unconformably overlain by Lower Triassic volcanic and carbonate rocks.  |
| Black Rock-Jackson              | Black Rock–Jackson terrane—BRJ | All boundaries structural and/or covered. Accretion happened after deformation in adjacent Mesozoic terranes. Distinct stratigraphy and structure from partly coeval Golconda terrane.  |
| Mesozoic terranes and assemblages | Walker Lake terrane—WPN, WPL, WLB; Sand Springs terrane—SAS;  
Quartz Mountain terrane—QM; Jungo terrane, JC; Gold Range assemblage—JTRgor; Humboldt assemblage—JTRs, TRc, TRkv;  
Metavolcanic rocks—JTRv | Generally structurally emplaced after Middle Jurassic time. Affected by major strike-slip displacement in Jurassic and Cretaceous tectonic events.  |
Figure 1. Extent of lower Paleozoic Shelf domain with outcrops shown. Refer to Craford (2007) for detailed explanation of geologic units.
for most faulting (Burchfi el and Davis, 1972; Burchfi el et al., 1974; Burchfi el et al., 1970; Carr, 1983) in that region. In central and east central Nevada, a paucity of Mesozoic sedimentary rocks makes it difficult to distinguish the effects of Paleozoic tectonism versus younger folding events on these rocks, but evidence suggests that they have been primarily affected by multiple episodes of Mesozoic deformation (Armstrong, 1968; Camilleri and Chamberlain, 1997; Hudec, 1992; McKee, 1976b).

**Discussion**

Much of the present distribution and exposure of the rocks of the Lower Paleozoic Shelf domain (apart from Tertiary and Quaternary cover) is the result of exhumation of the Paleozoic shelf by Mesozoic and Tertiary age thrusting and extension. Imbrication of the rocks of this Shelf domain with rocks of both the Slope and Basin domains, discussed below, has been documented (Fig. 2) in the Snake Mountains (McFarlane, 1997), the Independence Mountains (Kerr, 1962), the Tuscarora Mountains (Peters, 1997a, 1997c), the Shoshone Range (Gilluly and Gates, 1965), the Roberts Mountains (Murphy et al., 1978), the Toiyabe Range (Means, 1962; Stewart and McKee, 1966; Stewart and Palmer, 1967), and the Toquima Range (McKee, 1997b). Some of this faulting is interpreted as relating to Paleozoic (Antler) events between Upper Devonian and Middle Pennsylvanian time (McFarlane, 1997; Silberling et al., 1997), and elsewhere it has been inferred to be younger (Coats and Riva, 1983; Kettner, 1984; Kettner et al., 1993; Murphy et al., 1978), although actual age constraints are notably rare. The Middle Pennsylvanian unconformity that defines the deformation associated with the Antler Orogeny lies above Foreland Basin domain rocks that depositionally overlie the Shelf domain (Crafford, 2007; Trexler et al., 2004). It is therefore reasonable to infer involvement of the western edge of the Shelf domain in Upper Devonian to pre-Middle Pennsylvanian folding and thrusting (Silberling et al., 1997), but it is also clear that Mesozoic thrusting has subsequently imbricated rocks of these domains together as well (Coats and Riva, 1983; Kettner and Smith, 1982; Oversby, 1972; Riva, 1970).

In a few places in the area of overlap of the Shelf and Slope domains, slope facies rocks of the Slope domain are part of Ordovician, Silurian, and Devonian depositional sequences that include carbonate rocks of the Shelf domain (Crafford, 2007), and therefore depositional sequences that include rocks of the Shelf domain are often characterized by a continuous stratigraphic sequence of rocks deposited during the lower Paleozoic, unless the entire block has been rotated as one. In contrast, in southwestern Lander County, the western boundary of the domain turns toward the northeast at its northern end, and in a few localized outliers to the northwest and south. Nearly all of the extent of the Slope domain overlaps exposures of Ordovician and younger rocks of the Shelf domain. The southwestern edge of the primary exposures of the Slope domain coincides with the southwestern edge of the Shelf domain, trending southeast across the regional facies changes in the rocks. Four outliers of rocks that are generally lithologically consistent with Slope domain rocks are shown as isolated areas west and south of the main area of exposure. Only the southernmost is depositional with Shelf domain rocks. In a number of cases, rocks are not well distinguished between the Slope and Basin domains, and there is significant uncertainty as to which group to assign them.

**Tectonic Events**

Late Devonian to pre-Middle Pennsylvanian generally east-vergent, large-scale folding and thrusting is present throughout this domain (Finney and Perry, 1991; Finney et al., 1993; Madden-McGuire and Marsh, 1991a; Noble and Finney, 1999; Thoreson et al., 2000). In the Tuscarora Mountains, thrusting is interpreted to be late Paleozoic (Theodore et al., 1998). East-vergent, post-Early Triassic folding, thrusting, and exhumation have affected these rocks in the central part of the state (Bartley, 1990; Bartley and Gleason, 1987; Cameron and Chamberlain, 1988; Carpenter et al., 1993; Coats and Riva, 1983).

**Discussion**

Most, but not all of the contacts between rocks of the Slope domain and the rocks of the Shelf domain are structural (Crafford, 2007), as discussed above. The few depositional contacts help to define an important link between these two domains. In a number of places, the Slope and Basin domain rocks have not been adequately distinguished from each other due primarily to the structural complexity of the rocks. Another difficult distinction is between the Upper Devonian and Lower Mississippian Slope domain rocks and the coeval rocks of the Foreland Basin domain discussed below (Silberling et al., 1997). Regional mapping has not distinguished them in a consistent way. The
Figure 2. Lower Paleozoic Shelf, Slope, and Basin domains. Outcrop of Lower Paleozoic Shelf domain shown. Locations mentioned in text.
Figure 3. Extent of Slope domain and Lower Paleozoic Shelf domain. Outcrop of Slope domain shown. Locations mentioned in text.
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Overlay of the western third of the Shelf domain and the Slope domain (Fig. 3) is indicative of both the tectonic interlayering of these domains and the migration over time during the lower Paleozoic of the shelf-slope break (Cook and Corboy, 2004), as discussed above. The southeast-trending, southwestern edge of the domain is suggestive of a truncation or structural break similar to that observed in the Shelf domain rocks. Rocks of the Slope domain are imbricated with rocks of the Shelf, Basin, and the Foreland Basin domains (Fig. 4) (Silberling et al., 1997, see references under Shelf domain discussion as well).

The outliers of rocks assigned to the Slope domain in the Osgood Mountains and in Nye County (Fig. 3) may represent fragments of slope rocks that were displaced from the margin during either Paleozoic or Mesozoic time. Alternatively, they may be slope facies rocks unrelated to the margin of Nevada and represent fragments of similar facies from distinct accreted terranes (Madden-McGuire and Marsh, 1991a, 1991b).

The abundant gold resources of Nevada are strongly concentrated in rocks of the Slope domain (Cook and Corboy, 2004; Crafford, 2005, 2007). A small number of these auriferous rocks are in depositional contact with Carbonate Shelf sequence rocks (the Shelf domain), but most are in imbricate fault slices between the rocks of Basin and Shelf domains (Peters, 1997a, 1997b, 1997c).

The current distribution of Slope domain rocks is the result of faulting and folding caused by more than one Paleozoic tectonic episode (Silberling et al., 1997; Theodore et al., 1998; Theodore et al., 2003) and at least one and more likely two distinct Mesozoic tectonic events (see references above) addressed further in the discussion and regional synthesis section of this paper. These tectonic imbrications are superimposed on an original stratigraphic distribution of slope facies rocks.

Basin Domain

The Basin domain (Fig. 5) is defined by its predominance of lithologic components derived from a basin facies environment—the presence of significant lithology not derived from the Nevada region of the continental margin; and a moderate to strongly deformed, generally east-vergent structural style. It is a composite domain consisting of several poorly defined tectonic elements.

Rocks

Upper Devonian through Upper Cambrian shale, chert, argillite, quartzite, greenstone, basalt, limestone, and Silurian feldspathic sandstone and siltstone are the characteristic lithologic components of this domain. The rock units from the geologic map (Crafford, 2007) that are included in this domain are those of the Basin assemblage (Table 1) discussed in Crafford (2007).

Extent and Boundaries

The Basin domain (Fig. 5) overlaps extensively with and is poorly differentiated from the Slope domain in some areas. The primary area of exposure forms a north-to-northeast-trending belt in the center of the state that trends sharply eastward in northern Elko County and ends abruptly at its southern edge at the Lander-Nye County boundary. Outliers of the Basin domain are exposed to the north, west, and southwest and are separated from other exposures of similar rocks to the east by rocks of the Nolan Belt (see next section) and younger Paleozoic rocks. All of the boundaries of the Basin domain are structural.

Tectonic Events

At the type locality of the Antler Orogeny at Battle Mountain, Devonian through Ordovician rocks of the Basin domain and the Dutch Flat terrane (the Harmony Formation) are both unconformably overlain by a Middle Pennsylvanian conglomerate (Roberts, 1951). The Basin domain is also structurally overlain by the Upper Devonian Dutch Flat terrane (the Harmony Formation) (Roberts, 1964). The folding in the Basin domain rocks is complex but generally suggests an east-directed Paleozoic transport direction (Evans and Theodore, 1978; Peters, 1997a, 1997b, 1997c; Theodore et al., 2003). In the Sonoma and East Ranges, the Basin domain is additionally faulted over and folded with Middle and Upper Triassic carbonates (Gilluly, 1967; Silberling, 1975; Stahl, 1989) in generally west-vergent structures. Detailed structural relations studied in the Roberts Mountains (Murphy et al., 1978; Murphy et al., 1984; Noble and Finney, 1999) and elsewhere demonstrate that multiple phases of Paleozoic and Mesozoic deformation have affected rocks of the Basin domain, and that the oldest permissible age for the imbrication of the rocks within the domain is Late Devonian (Silberling et al., 1997) but is not well constrained.

Discussion

The Basin domain represents a subset of the “western facies” rocks described by Roberts et al. (1958) or the “siliceous” grouping of Stewart and Carlson (1978). The Basin domain consists of a wide variety of lithologies including Silurian feldspathic rocks that were not derived from the now adjacent North American margin (Gehrels et al., 2000b; Girty et al., 1985), and basaltic rocks formed as seamounts and mid-ocean crust (Leslie et al., 1991; Watkins and Browne, 1989). This suggests that parts of the Basin domain may consist of a number of distinct, possibly far-traveled accreted terranes (Wright and Wyld, 2006).

The Basin domain is clearly “allochthonous” in a traditional sense, but to describe it solely as the “upper plate” of a regional thrust fault, the Roberts Mountains thrust (Roberts et al., 1958), is no longer a geologically defensible interpretation of its tectonic history or the process by which the rocks were emplaced in their present position. The rocks of the Basin domain are repeatedly imbricated with rocks of the Slope, Shelf, and Foreland Basin domains (Noble and Finney, 1999; Silberling et al., 1997; Theodore et al., 1998). Significant lateral movement of rocks was indeed a far-reaching geologic concept of the 1950’s geosynclinal world. It was the foresight of the originators of the idea (Merriam and Anderson, 1942; Nolan et al., 1956) that helped lead to our understanding of plate tectonics and the idea that pieces of the Earth’s crust have indeed moved enormous distances (not just tens of kilometers) around the planet in the processes of formation and accretion (Coney et al., 1980).

The geologic evidence for the unconformity between the rocks of the Basin domain and the Antler Overlap domain that defines the Antler Orogeny is robust (Doebrich, 1994, 1995; Roberts, 1951, 1964; Theodore, 1991, 1994; Theodore et al., 1994)—the youngest deformed rocks are Upper Devonian or possibly even Lower Mississippian (Boundy-Sanders et al., 1999; Coles and Snyder, 1985). The oldest unconformity overlap is Middle Pennsylvanian (Roberts, 1964), and this relationship can be observed regionally in many places across Nevada (Dott, 1955; Hotz and Willden, 1964; Larson and Riva, 1963; McFarlane, 1997; McKee, 1972; Riva, 1970; Theodore et al., 2003; Trexler et al., 2004).

Large regions of the Basin domain consist of basaltic, tuffaceous rocks, and deep-water cherts and argillites. These rocks likely formed in an ocean basin of unknown size and were subsequently accreted to the western margin of North America through a series of tectonic events. Whether this was the result of arc-related tectonism as suggested by early workers (Burchfiel and Davis, 1972, 1975; Speed and Sleep, 1982) or transpressional strike-slip plate movements as suggested by others (Eisbacher, 1983), or a combination of these events, remains to be determined. The scattered outliers of rocks included in the Basin domain that are outboard (west) of younger accreted terranes like Dutch Flat and Golconda demonstrate that the rocks of the Basin domain have been further disrupted.

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Figure 4. Slope, Basin, Shelf, and Foreland Basin domains. Outcrop of Slope domain shown.
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Figure 5. Extent of Basin domain with Slope and Lower Paleozoic Shelf domains. Outcrop of Basin domain shown.

Colored areas show actual outcrop. See Crafford (2007) for list of units and complete descriptions.

Legend

- Lower Paleozoic Shelf Domain
- Slope Domain
- Basin Domain

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and dislocated by younger Upper Paleozoic and Mesozoic tectonic events.

Nolan Belt Domain

Lower Paleozoic rocks that share affinity to a continental margin but demonstrate unusual structural characteristics form a discrete belt west and northwest of displaced rocks of the Slope and Basin domains (Fig. 6). Earlier maps and interpretations included these rocks in either “transitional” or “silecous” groupings (Roberts et al., 1958; Stewart, 1980; Stewart and Carlson, 1978). They are different from the other lower Paleozoic rocks in a number of important ways that warrant distinction as a separate group (Crafford, 2007; Crafford and Grauch, 2002). These rocks have structural characteristics of an accreted terrane; that is, they exhibit complex polyphase deformation and metamorphism distinct from adjacent, coeval rocks, but also appear to have stratigraphic ties to a craton that suggest they have not traveled great distances laterally from a continental margin. This does not preclude the idea that rocks of this domain may have traveled great distances longitudinally along or around the continental margin.

The origin of the name for this belt of rocks is for T.B. Nolan, whose early paper defined many of these rocks as part of an important “geanticline” during the later Paleozoic (Nolan, 1928). This was long before such concepts had any grounding in modern tectonic understanding, and prior to recognition of the magnitude of displacement that has affected adjacent Paleozoic rocks and terranes. Detailed discussions of the distinguishing characteristics of the Nolan belt are provided in Crafford (2007, p. 33) and discussed in Crafford and Grauch (2002). To summarize, the Nolan belt is characterized by (1) the presence of Precambrian quartzite conformably underlying the Cambrian and younger rocks (mapped as several different named units), (2) the unusual pre-Pennsylvanian, west-vergent polyphase deformation affecting these rocks, distinct from the deformation in much of the Basin and Slope domains, (3) the regional metamorphic character of the rocks—they are much higher grade than the other domains, and (4) the more slope facies character of the rocks relative to the rocks of the locally adjacent Basin domain.

Rocks

Strongly deformed Precambrian to Cambrian quartzite and Cambrian and Ordovician (and younger?) schist, phyllite, shale, chert, quartzite, and thin bedded limestone are the principal rock types found within the Nolan Belt domain. The Cambrian section lies conformably on Precambrian-Cambrian quartzite. In a few cases, Cambrian phyllite and shale have been separately recognized (Decker, 1962; Ehman, 1985; Ferguson and Cathcart, 1954; Means, 1962), but in most places they are intimately deformed together with Ordovician phyllite, schist, shale, and chert and are not distinguished separately on regional maps. The age relations between the Ordovician rocks deformed within the Nolan belt and the Ordovician rocks of the Basin domain are not well constrained, but they are inferred to be partly coeval based on limited data (Churkin and Kay, 1967; Finney et al., 1993; Madden-McGuire, 1991; Madden-McGuire and Palmer, 1990; Ross and Berry, 1963). The rock units included in this domain are referred to as the Nolan Belt (Table 1) on the geologic map (Crafford, 2007).

Extent and Boundaries

The Nolan Belt domain crops out in four distinctive areas that together form a sinuous, north-south belt through the center of the state (Fig. 6). The northern end of the belt located in northern Elko County trends northeastward through the Bull Run Mountains and the Copper Mountains (the Mountain City block) (Bushnell, 1967; Coash and Hoare, 1967; Coats, 1964; Decker, 1962; Ehman, 1985). There is a significant gap produced by cover rocks from there southwest to north-central Nevada, where it crops out in the distinctive Osgood block in the Osgood Mountains (Crafford, 2000a; Hotz and Wilden, 1964), Edna Mountain (Erickson and Marsh, 1974a, 1974b), the Sonoma Range (Gilluly, 1967), and the East Range (Whitebread, 1994). Some of the Cambrian phyllite are exposed in the Shoshone Range (Gilluly and Gates, 1965), and more extensive exposures crop out to the south in the Toiyabe Range (Gilluly and Cathcart, 1954; McKee, 1976a; Means, 1962; Steward and McKee, 1968; Washburn, 1970) and at the southern end of the Toquima Range near Manhattan (Shawe, 1995). Metamorphosed and deformed lower Paleozoic rocks depositionally overlying Precambrian rocks are well exposed in Esmeralda County trending westward into California (Crafford, 2007). Whether they should be assigned to the Nolan Belt or another domain is uncertain. All of the boundaries of the Nolan Belt domain are structural (Table 1).

Tectonic Events

The rocks of this domain have been affected by pre-Middle Pennsylvanian metamorphism, deformation, and exhumation quite distinct from the deformation measured in rocks of the Basin and Slope domains (Crafford and Grauch, 2002; Erickson and Marsh, 1974a; Madden-McGuire and Marsh, 1991a). While the Paleozoic deformation in the Basin and Slope domains is primarily east-vergent, the pervasive deformation in the Nolan Belt domain is distinctly west-vergent. Limited evidence suggests it has also been affected by east-vergent deformation that may be similar to that in the Basin domain (Means, 1962; Oldow, 1984b). Additionally, in a few places these rocks have also been involved in west-vergent Mesozoic folding and thrusting (Gilluly, 1967; Hotz and Wilden, 1964; Silberling, 1975; Stahl, 1989; Whitebread, 1994).

Importantly, rocks of the Antler Overlap domain unconformably overlie both the rocks of the Nolan Belt domain and those of the Basin and Slope domains (Ehman, 1985; Erickson and Marsh, 1974b, 1974c; Hotz and Wilden, 1964), indicating that deformation in the Nolan Belt and that in the combined Slope and Basin domains predates the Middle Pennsylvanian and that these rocks were juxtaposed in their positions relative to each other by that time.

Discussion

The nature of the unusual complex polyphase deformation in the Nolan belt has been locally observed for some time (Boskis and Schweickert, 2001; Crafford and Grauch, 2002, and references therein); Ehman, 1985; Erickson and Marsh, 1974b, 1974c; Madden-McGuire and Marsh, 1991a; Means, 1962) but not incorporated into a regional tectonic framework. Whether the youngest age of rocks deformed in this domain is Ordovician, Silurian, or Devonian also is not well constrained. These are critical factors in understanding and more clearly defining this domain. Northern portions of the Nolan belt in the Osgood Mountains (the Osgood block) and the Bull Run Mountains (the Mountain City block) are outboard (west) of large areas of exposure of the significantly younger Golconda terrane (Fig. 7). Additional exposures of the Basin domain and Golconda terrane crop out still farther west. These observations require relative tectonic displacements between these rocks that are likely related to Jurassic or younger west-vergent folding and thrusting (Stahl, 1989, 1992) or exhumation.

The origins of the Nolan Belt domain are unclear. The domain could represent an exhumed part of the continental margin that was once deeply buried, or it could represent a distinct accreted terrane, derived originally from somewhere along the North American margin, deformed in tectonic events not necessarily related to its present position, and subsequently accreted to the margin in a transpressional tectonic setting (Crafford, 2000b). Regardless of which scenario is best supported by the geologic data, the Nolan Belt has numerous characteristics that define it as a distinct tectonostratigraphic block.

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Figure 6. Extent of Nolan Belt with Basin, Slope, and Lower Paleozoic Shelf domains. Outcrop of Nolan Belt shown. Question mark means domain assignment is uncertain. Places mentioned in text.
Figure 7. Golconda terrane shown with Nolan Belt, Basin, Slope, and Lower Paleozoic Shelf domains. Outcrop of Nolan Belt shown. Question mark means domain assignment is uncertain. Places mentioned in text.
Dutch Flat Domain

The Dutch Flat domain is distinguished by its unusual coarse-grained feldspathic sandstone lithology that is unknown elsewhere in the Great Basin (Fig. 8). Its Late Devonian age is constrained by conodont fragments recovered from turbiditic, quartzose, limestone horizons interbedded with the feldspathic sandstone found in the Hot Springs Range in Humboldt County (Jones, 1997a).

Rocks

Rocks of the Dutch Flat domain are composed of feldspathic sandstone, silstone, shale and turbiditic limestone. It is traditionally referred to as the Harmony Formation. The terrane and domain are synonymous. The age of the Harmony Formation has been enigmatic since its first description. It was originally interpreted as Mississippian (?) because of its position unconformably beneath Pennsylvanian conglomerate at Battle Mountain (Ferguson et al., 1952; Roberts, 1951). Cambrian fossils were later found in the Osgood Mountains and in the Hot Springs Range in close proximity to the unusual feldspathic sandstone and became the most commonly assumed age (Hotz and Willden, 1964; Stewart and Suczek, 1977). The Cambrian fossils have since been recognized to be part of a structurally disrupted upper Paleozoic package (Jones, 1991b, 1997a; Jones et al., 1978; McCollum and McCollum, 1991), and may have been derived from the Nolan Belt. Verification of Ordovician microfossils recovered from the Harmony Formation in the Sonoma Range (Madden-McGuire et al., 1991) revealed they were unfounded (Madden-McGuire, 1993, personal commun.). In 1994, a single Late Devonian *Pulmatolepis* sp. conodont was recovered from a calcareous turbidite interbedded with the feldspathic sandstone in the Hot Springs Range (Jones, 1997a). Subsequently, post-Ordovician conodont fragments also recovered from the Hot Springs Range have confirmed that the unit is clearly post-Ordovician in age (Ketner et al., 2005). This domain is referred to as the Dutch Flat terrane on the geologic map (Crafford, 2007) (Table 1).

Extent and Boundaries

The Dutch Flat terrane (Fig. 8), more commonly known as the Harmony Formation, is only exposed in north-central Nevada at Battle Mountain (Roberts, 1964), in the Hot Springs Range north of Winnemucca (Jones, 1997a, 1997b), the Sonoma Range (Gilluly, 1967; Silberling, 1975), and in a small area in the East Range in Pershing County (Ferguson et al., 1951; Whitebread, 1994). However, fragments of feldspathic debris for which the Harmony Formation is the only plausible source turn up in places across a large area of northern Nevada from the Foreland Basin domain to the Golconda terrane (Ketner et al., 2005). All known boundaries of the Dutch Flat terrane are structural.

Tectonic Events

The Harmony Formation is unconformably overlain by the Middle Pennsylvanian Battle Formation of the Antler Overlap domain at the type locality of the Antler Orogeny at Battle Mountain (Roberts, 1951). The folding in the Harmony Formation at Battle Mountain has been reported to be similar to the folding in the rocks of the Basin domain (Evans and Theodore, 1978). However, in the Hot Springs Range, the Harmony Formation has been involved in a folding event that has overturned many folds westward (Jones, 1993, 1997a). In the Sonoma Range, the Harmony Formation is also thrust westward over Triassic rocks (Gilluly, 1967; Silberling, 1975; Stahl, 1987, 1989) suggesting that the west-vergent folding in the Harmony in the Hot Springs Range is likely related to the Jurassic Winnemucca fold and thrust belt (Speed et al., 1982; Stahl, 1992) or an even younger deformation event.

Discussion

While the unusual feldspathic characteristics of this unit have been recognized for many years (Roberts, 1951), the source of the feldspar has remained elusive and subject to varying interpretations (Jones, 1997a; Ketner et al., 2005; Roberts et al., 1958; Rowell et al., 1979; Smith and Gehrels, 1994; Stewart and Suczek, 1977; Wallin, 1990). Early workers included the Harmony Formation in the “transitional” assemblage (Roberts et al., 1958), a group of rocks that did not fit well into either the “eastern carbonate” or “western siliceous” assemblages. Zircon data indicate that some of the Harmony Formation was derived from an exotic source not near its present location (Dickinson and Gehrels, 2000; Gehrels et al., 2000b; Smith and Gehrels, 1994; Wallin, 1990). Its age and lithology require that its impact (literally and figuratively) on the continental margin did not begin until the end of the Devonian at the earliest. It is interpreted to be faulted over rocks of the Basin domain (the Valmy Formation) at Battle Mountain, and both it and the Valmy Formation at Battle Mountain are unconformably overlain by the Middle Pennsylvanian Battle Formation of the Antler Overlap domain (Roberts, 1964). This relationship at Battle Mountain is the “type locality” of the Antler Orogeny (Roberts, 1951), thus defining the accretion of the Dutch Flat terrane as an integral component of this tectonic event.

Because of its unusual lithologic characteristics, the Harmony Formation is considered an exotic accreted terrane that was emplaced against lower Paleozoic Basin domain (and/or Nolan Belt) rocks between Late Devonian and Middle Pennsylvanian time. The Harmony Formation originally mapped in the Osgood Mountains associated with Cambrian rocks (Hotz and Willden, 1964) consists of house-size blocks of feldspathic sandstone in a large mélangé-like shear zone. Blocks of Cambrian limestone are also present in the mélangé (Jones, 1991b). The matrix of the mélangé contains Pennsylvanian radiolarians (McCollum and McCollum, 1991), suggesting additional upper Paleozoic disruption of the Dutch Flat terrane, possibly related to accretion of the Golconda terrane. The distinct structural characteristics of the Harmony Formation in different locales also indicate significant upper Paleozoic and Mesozoic disruption of various parts of the terrane since its original emplacement.

Foreland Basin Domain

The Foreland Basin domain is distinguished by the thick sequence of Lower Pennsylvanian through Upper Devonian hemipelagic, carbonate, and clastic rocks deposited over rocks of the Lower Paleozoic Shelf domain (Fig. 9). It is interpreted as a series of eastward-migrating, flexural-loading, foredeep and back bulge deposits (Goebel, 1991). At its western edge, these rocks are involved in mid-Paleozoic folding and thrusting related to the Antler orogeny (Silberling et al., 1997).

Rocks

A sequence of Lower Pennsylvanian through Upper Devonian silstone, limestone, shale, sandstone, and conglomerate rests concordantly on Upper Devonian carbonate of the Lower Paleozoic Shelf domain and is included in this study in the Foreland Basin domain (Brew, 1971; Poole and Sandberg, 1991). These rocks are unconformably overlain by rocks of the Antler Overlap domain (Dott, 1955; Trexler et al., 2004). On the geologic map (Crafford, 2007), the rocks that are included in this domain are referred to as the Foreland Basin assemblage (Table 1).

Extent and Boundaries

The western boundary of the Foreland Basin domain is very abrupt (Fig. 9) and closely follows the eastern edge of the Slope domain along a small area of overlap. The distribution of Foreland Basin domain rocks extends far to the east all the way to the Nevada-Utah border (Poole and Sandberg, 1977, 1991) and beyond. On

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Figure 8. Extent of Dutch Flat domain shown with Nolan Belt, Basin, Slope, and Lower Paleozoic Shelf domains. Outcrop of Dutch Flat terrane shown. Places mentioned in text.
Figure 9. Extent of Foreland Basin domain shown with Slope and Lower Paleozoic Shelf domains. Outcrop of Foreland Basin domain shown.
its northern edge, the boundary veers sharply eastward in northern Elko County, mimicking the other Paleozoic domain boundaries in that area (Crafford, 2007). To the south, the Foreland Basin domain narrows to a northeast-trending belt across western Lincoln County. Similar to Lower Paleozoic Shelf domain rocks, its trend takes a sharp turn to the west in southern Nye County. Foreland Basin domain rocks are only present in the far northwestern corner of Clark County in southernmost Nevada. An outlier of these rocks is also mapped in the Cactus Range of southern Nye County (Cornwall, 1972; Ekren et al., 1971).

**Tectonic Events**

Foreland Basin domain rocks have been involved in Paleozoic and Mesozoic folding and thrusting. The dramatic change in facies from the lower Paleozoic Shelf domain to the deposits of the Foreland Basin domain beginning in Late Devonian time is strong stratigraphic evidence for initiation of a Late Devonian tectonic event affecting the margin at this time (Goebel, 1991; Poole and Sandberg, 1977; Silberling et al., 1995; Silberling et al., 1997; Speed and Sleep, 1982). Studies of the structural characteristics of these Upper Devonian and Mississippian rocks have demonstrated that they are imbricated with older shelf, slope, and basin facies rocks near the western boundary of exposure of the Foreland Basin domain (Johnson and Visconti, 1992; McFarlane, 1997; Murphy et al., 1978; Murphy et al., 1984; Silberling et al., 1997; Smith and Ketner, 1977; Trexler and Cashman, 1991). The age of this faulting and the interpretation of which rocks belong in which domain have changed significantly over time (Ketner and Smith, 1982; Silberling et al., 1997; Smith and Ketner, 1968, 1978) and remain confusing. The impact of Mesozoic and younger structures on these rocks has not commonly been recognized but may be significant (Cameron and Chamberlain, 1988; Gilbert and Taylor, 2001; Nett, 1997; Smith, 1984). Unconformities are interpreted within the Upper Devonian slope and basin facies rocks (Murphy et al., 1984), but the domain association of those rocks is unclear, and they are structurally bounded (Silberling et al., 1997). Interpretations of most boundaries as faulted or not can only be constrained by biostratigraphic evidence.

**Discussion**

The abrupt change in stratigraphy of the Upper Devonian continental margin has long been interpreted as the initiation of a tectonic event that has been attributed to the Antler Orogeny (Goebel, 1991; Poole, 1974; Speed and Sleep, 1982). While tectonism is the most plausible explanation for the important changes in lithology at this time, the association with the Antler Orogeny as it was originally defined at Battle Mountain is not as straightforward as it is often assumed to be. Early workers attributed creation of the “Antler Foreland Basin” to the shedding of debris off the “Antler Highland” (Poole, 1974) into an “exogeosynclinal trough.” The general principle of a foreland basin forming as a result of tectonism to the west (Goebel, 1991; Speed and Sleep, 1982) has withstood geologic cross-examination (Silberling and Nichols, 1991; Silberling et al., 1995; Silberling et al., 1997), but the details of the nature and timing of the tectonic event(s) and the components that were accreted are still not well constrained. The regional tectonic relations that support the idea that the Foreland Basin domain formed as a response to the multiple tectonic events defining the Antler Orogeny are: (1) The narrow overlap and subparallel association of the western boundary of the Foreland Basin domain and the eastern boundary of the Slope domain; (2) the greatest thickness of Foreland Basin domain rocks is near its western edge (Poole and Sandberg, 1977); (3) the source rocks of the Foreland Basin domain primarily include rocks of the Basin and Slope (and other?) domains to the west (Harbaugh and Dickinson, 1981; Poole, 1974); (4) rocks of the Basin, Slope, Shelf, and Foreland Basin domains are all imbricated together along the Slope/Foreland Basin boundary (Jansa and Speed, 1993; Silberling et al., 1997); and (5) the rocks of the Foreland Basin domain are unconformably overlain by the Antler Overlap domain rocks. The Antler Overlap domain appears to be quite variable. It has been involved in important localized Mesozoic folding and thrusting in a number of places (Hotz and Willden, 1964; Ketner and Alpha, 1992; Ketner and Ross, 1990; Riva, 1970). Deformation within the Antler Overlap domain has placed Permian rocks directly on underlying folded Basin domain and Nolan belt rocks or unconformably on older Pennsylvanian and Lower Permian Antler Overlap domain rocks (Erickson and Marsh, 1974a, 1974b, 1974c; Trexler et al., 2004; Trexler et al., 1991; Villa et al., 2007), indicating that these rocks record changes within an active upper Paleozoic tectonic regime.

**Antler Overlap Domain**

The Permian and Pennsylvanian Antler Overlap domain is characterized by the irregular distribution of siliciclastic and carbonate rocks that reflect local source areas across a large region (Fig. 10). Five distinct lower Paleozoic domains are overlain unconformably or disconformably by rocks of this domain. Important unconformities also exist within the rocks of the domain.

**Rocks**

The Antler Overlap domain consists of Lower Triassic through Middle Pennsylvanian conglomerate, sandstone, siltstone, and limestone. It unconformably overlies rocks of the Foreland Basin domain, the Slope domain, the Basin domain, the Nolan belt, and the Dutch Flat terrane. These rocks were not deposited directly on the lower Paleozoic Shelf domain but are unconformably overlying the Pennsylvanian Ely Limestone in White Pine County, part of the Upper Paleozoic Shelf domain. On the geologic map (Crafford, 2007), these rocks are referred to as the siliciclastic overlap assemblage (Table 1).

**Extent and Boundaries**

Exposures of the Antler Overlap domain are widely scattered across central Nevada (Fig. 10) and are discontinuous, but their stratigraphic relations across the area are surprisingly consistent. It crops out as far northeast as the Snake Mountains and the HD Range, as far northwest as the Osgood Mountains, and south into northern Nye County (Crafford, 2007). Only the southwestern-most exposure in the Candelaria Hills includes Lower Triassic rocks in Mineral and Esmeralda Counties.
Figure 10. Extent of Antler Overlap domain shown with Dutch Flat domain, Nolan Belt, Basin, Slope, Lower Paleozoic Shelf, and Foreland Basin domains. Outcrop of Antler Overlap domain shown with places mentioned in text.
Many other distinct lithologic sequences have been identified within the Golconda terrane (Erickson and Marsh, 1974a; Jones, 1991a; Miller et al., 1984; Murchey, 1990), but they are difficult to correlate on a regional scale.

**Extent and Boundaries**

North and west of Ordovician through Lower Mississippian rocks of the Basin and Slope domains, rocks of the Golconda terrane and Home Ranch subterrane are distributed in three distinct areas (Crafford, 2007) (Figs. 7 and 11): (1) in northern Elko County at the northern end of the Independence Mountains and eastward; (2) in a large area in north-central Nevada near Golconda in the Sonoma, Tobin, and East Ranges, at Battle Mountain and Edna Mountain, and in the Shoshone Range, with outliers to the north in the Hot Springs Range and the Osgood Mountains; and (3) in west-central Nevada in the Toiyabe Range, the Pilot and Excelsior Mountains, and areas in between. The lithology and structural characteristics of each of these areas have similarities that warrant grouping them overall in the same terrane, although at a more localized level there may be significant distinctions. The Home Ranch subterrane is found in the northernmost Independence Mountains, the Hot Springs Range, the Osgood Mountains, and the northernmost East Range, where its outcrops are shown in a distinct color.

**Tectonic Events**

Pervasive deformation of rocks unconformably overlain by relatively undeformed Lower Triassic rocks is a defining characteristic of the Golconda terrane, and was described long ago as the Sonoma Orogeny (Silberling and Roberts, 1962). The deformation has regional variabil-

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The Golconda domain is characterized by thick, deformed sequences of upper Paleozoic basin facies rocks (Fig. 11). These rocks are commonly bounded below by a regional thrust fault that emplaces them over coeval carbonate and clastic rocks of the Antler Overlap domain. Lower Triassic volcanic and carbonate rocks unconformably overlie the rocks of the Golconda terrane.

**Rocks**

The Golconda domain includes rocks ranging from Late Permian through Latest Devonian in age. Rock types include a wide range of lithologies from basalt and andesite to shale, argillite, and radiolarian chert, and even siliciclastic and carbonate facies as well. On the geologic map (Crafford, 2007), the rock units that are included in this domain are referred to as the Golconda terrane and the Home Ranch subterrane of the Golconda terrane (Table 1). The Home Ranch subterrane is restricted to Mississippian in age, and is characterized by basalt, limestone and olistostromal debris flows suggestive of deposition in a seamount setting (Jones, 1991a, 1997b).

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**Discussion**

The variety of lithologies and the large age span of these rocks intimately imbricated together suggest that the Golconda terrane is made up of rocks formed in many depositional settings in and around an upper Paleozoic paleo-Pacific ocean of unknown size. With the exception of the Home Ranch subterrane, lithologic and biostratigraphic data from the Golconda terrane have not been regionally analyzed to distinguish other age-specific lithologic groupings that have been locally identified (Murchey, 1982; Murchey, 1990). Parts of the Golconda terrane are likely far traveled, while others clearly formed in proximity to a continental margin evidenced by deposition of siliciclastic material (Moore et al., 2000; Speed, 1979).

A number of structural and biostratigraphic studies have demonstrated the structural complexity of this terrane (Babaie, 1987; Brueckner and Snyder, 1985; Fagan, 1962; Jones, 1991a; Jones and Jones, 1991a; Little, 1987; Miller et al., 1981; Miller et al., 1984; Murchey, 1990; Riley et al., 2000; Schweickert and Lahren, 1987; Silberling and Roberts, 1962; Speed, 1979; Stewart et al., 1977; Stewart et al., 1986). The pervasive deformation characterized by steeply dipping structures and large belts of melange (Jones, 1991a, 1997b) within the terrane suggests proximity to a long-lived tectonic boundary that involved significant relative displacement of its components. Explanations for the origins of the deformation in the Golconda terrane have included microplate collisions, subsiding arcs, and translational plate boundaries (Brueckner and Snyder, 1985; Burchfi el and Davis, 1975; Jones, 1991a, 1991b; Miller et al., 1982; Speed, 1977, 1979). The bounding structure of the terrane as it is observed today, however, has minimal deformation in the lower plate and is a regionally characteristic thrust fault, suggesting it may relate to only the final
Figure 11. Extent of Golconda and Black Rock-Jackson domains shown with Antler Overlap and Nolan Belt domains. Outcrops of Golconda and Black Rock-Jackson terranes shown with places mentioned in text. The outcrops of the Home Ranch subterrane are those shown in gray in the far northern Independence Mountains, the Hot Springs Range, the Osgood Mountains, and the northwesternmost outcrops in the East Range.
emplacement of the terrane. This reinforces the idea that significant displacement within the terrane occurred when parts of it may have been far from the margin, and that the margin was not directly involved until a final emplacement event that may have occurred significantly later than the deformation within the terrane.

**Black Rock-Jackson Domain**

The Black Rock-Jackson domain (Silberling et al., 1992) is distinguished from coeval upper Paleozoic and lower Mesozoic rocks in Nevada by its lithologic correlation to terranes to the west in California, and its distinct Mesozoic deformation history (Fig. 11).

**Rocks**

This composite terrane consists of two sequences. Mid-Triassic to upper Paleozoic chert, siltstone, shale, sandstone, and tuffaceous and volcaniclastic rocks that formed in an oceanic-basin and island-arc setting were originally assigned to the Black Rock terrane. A mid-Jurassic to Upper Triassic sequence of volcanogenic and volcanic rocks was originally assigned to the Jackson terrane (Blome and Reed, 1995; Jones, 1990; Quinn et al., 1997; Russell, 1984; Silberling et al., 1992; Wyld, 1990). Rocks of this domain have affinities to correlative rocks in the Eastern Klamath and northern Sierra terranes, and not to the North American margin or the Golconda terrane (Jones, 1990; Skinner and Wilde, 1966). On the geologic map (Crafford, 2007), the rocks of this domain are referred to as the Black Rock-Jackson terrane (Table 1).

**Extent and Boundaries**

These rocks are exposed in far northwestern Nevada in southern Washoe, Humboldt, and Pershing Counties (Fig. 11) primarily in the Pine Forest Range, the Jackson Mountains, and the Granite Range.

**Tectonic Events**

Parts of the Black Rock terrane can be interpreted as the base of the Jackson terrane, but they are generally structurally juxtaposed throughout the region (Silberling et al., 1987). The Permian rocks of the Black Rock terrane are coeval with Permian rocks of the Golconda terrane but do not exhibit the characteristic deformation assigned to the Sonoma Orogeny (Jones, 1990). This implies that they were located far from rocks of the Golconda terrane during this time (Jones, 1990). The deformation of the rocks of the Black Rock-Jackson terrane has been shown to be Mesozoic (Russell, 1984; Wyld, 1990; Wyld et al., 1996). The Black Rock-Jackson terrane did not accrete to the margin until Jurassic or Cretaceous time (Wyld et al., 1996).

**Discussion**

The Black Rock-Jackson terrane contains an important sequence of Permian carbonate rocks that have distinct non-North American faunal assemblages and a stratigraphic sequence that ties them to coeval rocks in the Klamath Mountains in California (Blome and Reed, 1995; Darby et al., 2000; Jones, 1990; Russell, 1984; Skinner and Wilde, 1966; Wyld, 1990). Geologic evidence supports the paleogeographic interpretation that during the Permian these rocks were far from rocks of the Golconda terrane and North America and that their subsequent accretion did not occur until the Jurassic or later (Darby et al., 2000; Wyld, 2000). Exposures of the Black Rock terrane at the southern end of the Blik Creek Mountains are deemed to represent one of the world’s few, deep-water, Permian-Triassic boundaries (Sperling and Ingle, 2006).

**Mesozoic Terranes and Assemblages Domain**

The Mesozoic terranes and assemblages discussed in Crafford (2007) are grouped in this paper as a single domain and are not described in detail. Their presence outboard of the Paleozoic rocks discussed above precludes a direct genetic relationship (Jones, 1990; Wyld et al., 2006) between Paleozoic rocks of northern and central Nevada and Paleozoic rocks now located outboard of these terranes in the Sierra Nevada of California.

**Rocks**

Lower Jurassic to Middle Triassic carbonate, volcaniclastic, siliciclastic, and volcanic rocks of numerous accreted terranes, assemblages, and volcanic rocks are included in this domain (Crafford, 2007). All of the Mesozoic rocks on the geologic map (Crafford, 2007) except for the Cratonal Sequence (Triassic and Jurassic rocks in eastern Nevada, see map) are considered together (Table 1).

**Extent and Boundaries**

Most of the pre-Tertiary rocks exposed in the western third of northern Nevada are included in this domain (Fig. 12).

**Tectonic Events**

Jurassic and Cretaceous tectonic events were responsible for the deformation and accretion of Mesozoic terranes (Oldow, 1983, 1984a; Oldow and Bartel, 1987; Oldow et al., 1993; Wyld, 2002) in northwestern and west-central Nevada. While significant progress has been made in identifying distinct terranes that have differing structural and stratigraphic histories, the overall picture of when these terranes arrived, and the nature of their total displacement relative to each other and the autochthonous part of the Mesozoic margin is variably constrained (Wyld, 2000; Wyld et al., 1996; Wyld et al., 2006). Clearly the initiation of the arc complex in the Sierra Nevada at the end of the Triassic had a defining impact on reshaping the Mesozoic margin in Nevada and influenced how these terranes were subsequently deformed and displaced in a backarc setting (Burchfiel and Davis, 1981; Busby-Spera et al., 1990; Dickinson, 1981; Schweickert, 1978).

**Discussion**

The details of the Jurassic and Cretaceous accretion of the Mesozoic terranes are outside the scope of this paper, but the impact of these events on older rocks needs to be carefully considered when interpreting Paleozoic tectonic events. The role of Mesozoic tectonism in rearranging the older rocks is significant, regionally heterogeneous, and generally overlooked in the interpretation of the history of the Paleozoic rocks. Three distinct structural components of Mesozoic tectonism have affected Paleozoic rocks across Nevada—east-vergent folding and thrusting (of multiple orientations; for example, Armstrong, 1968; Camilleri and Chamberlain, 1997; Ketner and Alpha, 1992; Zamudio and Atkinson, 1995), west-vergent folding and thrusting (Gilluly, 1967; Stahl, 1989, 1992), and strike-slip displacement (Oldow and格尔, 1987; Oldow et al., 1993; Schweickert and Lahren, 1990; Wyld et al., 2006). In particular, the idea that major strike-slip faults or shear zones have rearranged and displaced significant portions of the Paleozoic margin since late Paleozoic time needs to be carefully considered. Evidence for such events has been demonstrated and/or postulated (Burchfiel and Davis, 1972; Lahren and Schweickert, 1989; McCollum, 1985; Schweickert and Lahren, 1990; Stevens et al., 1991; Stewart et al., 1986; Walker, 1988; Wyld et al., 2006; Wyld and Wright, 2001) in a number of places in the eastern Sierra and western Nevada. Incorporation of the effects of the Mesozoic accretion and displacement events on the Paleozoic domains is necessary to establish the overall tectonic evolution of the region (discussed below).

**DISCUSSION AND REGIONAL SYNTHESIS**

The geologic problem of the close juxtaposition of distinct basin and shelf facies Ordovician rocks was recognized many years ago in the
Legend

- Black Rock-Jackson terrane
- Humboldt assemblage
- Jungo terrane
- Gold Range assemblage
- Metavolcanic rocks
- Jurassic felsic volcanic rocks
- Quartz Mountain terrane
- Sand Springs terrane
- Walker Lake terrane, Luning-Berlin assemblage
- Walker Lake terrane, Pamlico-Lodi assemblage
- Walker Lake terrane, Pine Nut assemblage

Colored areas show actual outcrop. See Crafford (2007) for list of units and complete descriptions.

Figure 12. Extent of Mesozoic terranes and assemblages shown with outcrop.
of rocks has been debated since it was first proposed that imbricated together different facies
prominent in middle Paleozoic tectonics in Nevada has become embedded as a defi ning feature of mid-Paleo-
needed insight into the second problem as perceived by Nolan and others of why there were different facies, but it also complicated the simplistic explanation that a single thrust fault was the mechanism that brought them together.
Over the years, the idea of a single, regional thrust fault as a defi ning feature of mid-Paleozoic tectonism in Nevada has become embedded in the geologic consciousness of many Nevada geoscientists. The age(s) of the regional faulting that imbricated together different facies of rocks has been debated since it was fi rst proposed (Ketner and Smith, 1982; Merriam and Anderson, 1942; Roberts et al., 1958; Silberling et al., 1997; Smith and Ketner, 1968) and is still diffi cult to constrain. While the contrast in facies of similar age rocks over a large region of Nevada is real, the circumstances of that juxtaposition are not adequately explained by a single regional thrust fault. Contributing factors to the present distribution of rocks include the interplay of an original continental slope environment and multiple tectonic episodes, during both the Paleozoic and the Mesozoic that brought these rocks together. These tectonic events involved multidirectional folding and thrusting in a zone of structural weakness created by rapid changes in facies across a small area along the margin. The driving mechanism that created this tectonic setting was the accretion of terranes along plate boundaries farther to the west. It is the fi rst problem that Nolan and others deemed solved—the juxtaposition of different facies rocks—not the second, of why they exist in the fi rst place, which, in fact, still challenges our geologic understanding of this complex region.
Early tectonic models that were invoked to explain the Antler Orogeny used the accretion of a Devonian arc as the tectonic mechanism to either close a backarc basin and emplace the basin and slope facies rocks onto the margin (Burchfiel and Davis, 1972) or to emplace an accretionary prism in front of a subsiding arc (Speed and Sleep, 1982). The arc-related rocks in the Paleozoic terranes in the Sierra Nevada of California (Hanson et al. 1988; Harwood, 1992) were inferred to be the remnants of the Devonian arc. Obstacles exist to these interpretations. The western third of Nevada consists of upper Paleozoic and Mesozoic terranes (Fig. 12) that were not emplaced until Mesozoic time (Oldow, 1983, 1984a; Silberling, 1973; Silberling and Roberts, 1962; Speed, 1979), thus their pre-Mesozoic locations, and the locations of any terranes now west of them, are largely unconstrained. The Early Triassic margin of North America in northern Nevada was west of Winnemucca just outboard of the Golconda terrane (Fig. 11). The location of Paleozoic terranes that are now in northwestern Nevada (the Black Rock-Jackson terrane) is considered by some to have been thousands of kilometers from western North America during the Permian (Jones, 1990; Stevens et al., 1991; Stevens et al., 1990) based on distinct faunal provinces (Skinner and Wilde, 1966) and the lack of correlation of the geology. While this is disputed by others (Darcy et al., 2000; Gehrels et al., 2000a; Wyld, 2000), there is no compelling body of geologic data that uniquely links Paleozoic rocks of the Sierra Nevada to the continental margin of Nevada, in spite of general similarities of basin-derived rocks (Harwood and Murchey, 1990). Fragments of arc-related rocks that are present in the Golconda and Dutch Flat terranes could have been derived from several accreted terranes that are now dispersed along the western North American margin from Mexico to Alaska.
Another obstacle to the early tectonic models for the Antler Orogeny is that structural data suggest upper Paleozoic and Mesozoic rocks in western Nevada and California were displaced tens or hundreds of kilometers (or more) along strike-slip faults at various times ranging from the late Paleozoic to the Cretaceous (Lahren and Schweickert, 1989; Oldow et al., 1993; Schweickert and Lahren, 1990; Walker, 1988; Wyld et al., 2006; Wyld and Wright, 2001). Until the recognition of the felspathic Harmony Formation as Upper Devonian (Jones, 1997a), no arc-related rocks of appropriate age in Nevada could be assigned to the subsided arc of Speed and Sleep (1982). Direct evidence is still lacking for an arc as the accretionary force behind the tectonics of the Antler Orogeny in the same way that large Jurassic and Cretaceous plutons in the Sierra Nevada and Nevada define the Mesozoic arc setting of the region (Burchfi el and Davis, 1972; Hamilton, 1969). Burchfi el and Royden (1991) proposed a model attempting to address the lack of age-appropriate, arc-derived material in Nevada, and while some components of their model, especially the ideas of extension in a basin offshore of the margin, are valid, it overlooks important relations among Paleozoic rocks in northern Nevada (Jones, 1991b, p. 217–219). An interpretation that is more consistent with the geologic data as presented on the new map (Crafford, 2007) is that both the Antler and Sonoma Orogenies and other Paleozoic tectonic events that resulted in the deformation and emplacement of Paleozoic rocks in Nevada were caused by the accretion of distinct terranes (Madden-McGuire and Marsh, 1991a) along one or more transpressive plate boundaries (Eibach, 1983; Jones, 1991b) prior to the initiation of subduction and arc-volcanism in the Mesozoic.

**Pre-Late Devonian Tectonism**

Pre-Late Devonian tectonism is not recorded in rocks of the Lower Paleozoic Shelf domain. Constraints are poor for the location of rocks of the Basin and Slope domains relative to the margin of western North America during their time of formation from the Late Cambrian through the Middle Devonian, but these rocks do show evidence for pre-Late Devonian tectonism. Some rocks of the Slope domain received influxes of quartzose sediment derived from a continental margin that correlate with quartzose sediment deposition in the Shelf domain during this time (Finney and Perry, 1991; Miller and Larue, 1983). This fact has been used to suggest that the “Roberts Mountains allochthon” is not an exotic terrane (Finney and Perry, 1991), and was located close to the Nevada continental margin in Ordovician time. However, recognition of the structural complexity within rocks assigned to the Slope and Basin domains (Noble and Finney, 1999) as well as the presence of other sediment derived from multiple sources (Gehrels and Dickinson, 2000; Walin, 1990) within the Basin domain, supports the idea that the rocks with potentially locally derived quartzose sediment may be structurally imbricated with rocks that have traveled great distances before their accretion to the margin. Additionally, quartzose sediment was deposited along a great length of the western North American continental margin during the Ordovician (Gehrels et al., 1995; Ketner, 1986), and thus its presence in the Basin and Slope domain rocks does not rule out significant movement of terranes subparallel to the margin.

Lower Paleozoic igneous rocks diagnostic of several different tectonic environments are
Late Devonian to Middle Pennsylvanian “Antler” Tectonism

The dramatic paleogeographic change on the continental margin from carbonate-dominated stratigraphy to siliciclastic-dominated stratigraphy during the Late Devonian marked the transition from the Lower Paleozoic Shelf domain to the Foreland Basin domain and signaled the beginning of a tectonic influence on the continental margin. While flexural warping from tectonic loading is a viable model for foreland basin formation (Goebel, 1991; Silberling et al., 1997), several types of tectonic events—extensional, compressional, or translational—could generate the topographic relief required for the erosion of siliciclastic material into a foreland basin. According to Johnson and Visconti (1992) and Murphy et al. (1984), evidence for post-Early Mississippian faulting in the Roberts Mountains is well constrained. Upper Devonian rocks also show evidence of stratigraphic disruption (Murphy et al., 1984), and can be interpreted to be part of a pre-Early Mississippian faulting event (Silberling et al., 1997, p. 177–179). Smith and Ketner (1968) interpreted the Lower Mississippian Webb Formation as a unit that postdated thrusting, while Johnson and Visconti (1992) and Ketner and Smith (1982) show that Mississippian rocks mapped as the Webb (included in this study in the Foreland Basin domain) are actually involved in the faulting. Thus, rocks as young as Mississippian are involved in faulting. In the Pinion Range, the Late Mississippian Newark Valley sequence (Trexler and Cashman, 1991; Trexler and Nitchman, 1990) of the Foreland Basin domain unconformably overlies Upper Devonian rocks assigned to the Slope Domain and Lower Mississippian rocks assigned to the Foreland Basin domain (Silberling et al., 1997, p. 177–179, Fig. 12).

The regional Middle Pennsylvania unconformity at the base of the Antler Overlap domain defines a significant change in the tectonic setting of the region, and demonstrates that the rocks of the Basin, Slope, Nolan belt, Dutch Flat, and Foreland Basin domains were in some sort of relative juxtaposition by that time. Beneath that unconformity, rocks of these domains exhibit at least three different tectonic histories.

The youngest age of rocks deformed in the Nolan Belt is not well constrained. There are rocks younger than Ordovician in the regions mapped as part of the Nolan Belt (Crafford, 2007), but whether their relation to the older rocks is structural or stratigraphic is not clear (Stewart and Palmer, 1967). The youngest rocks involved in the Nolan belt deformation could be as old as Ordovician, or they could be as young as Devonian. This would make the broadest age range for the deformation within the belt Ordovician to Middle Pennsylvanian. The west-vergent, pre-Middle Pennsylvanian deformation and exhumation of the Nolan Belt may predate the east-vergent, pre-Middle Pennsylvanian deformation in the Basin and Slope domains. Evidence for this is found in the Osgood and Mountain City blocks of the Nolan Belt (Fig. 6) and the Candelaria region of Mineral and Esmeralda Counties, where Basin domain rocks are faulted directly over deformed and metamorphosed Cambrian and Ordovician Nolan belt phyllite and shale (Crafford and Grauch, 2002). In the northern Osgood Mountains, this structure is unconformably overlain by Pennsylvanian rocks of the Antler Overlap domain (Jones, 1991b). Means (1962), however, argued that the polyphase deformation in the rocks in the Tertiary Range, included in this study in the Nolan Belt, could be as young as Jurassic, and therefore possibly post-dated the east-vergent structures in the rocks.

The presence of the structurally bounded Dutch Flat terrane in Humboldt, Pershing, and Lander Counties (Fig. 8) requires displacement of this terrane from its point of origin and accretion of it to the rocks of the Basin domain between Late Devonian and Middle Pennsylvanian time. At Battle Mountain, the Harmony Formation is interpreted as thrust over the Valmy Formation of the Basin domain along the DeWitt Thrust (Roberts, 1964), suggesting this event postdates the folding and thrusting within the Basin domain. Both units are then unconformably overlain by the rocks of the Antler Overlap domain. How close the Harmony Formation and the Valmy Formation at Battle Mountain were to the continental margin when they were juxtaposed is constrained only by the regional distribution of the unconformably overlying Antler Overlap domain (Fig. 10).

Numerous scenarios could explain the sequence of events affecting these rocks as they relate to the “Antler Orogeny.” The deformation in the Nolan Belt could be either an unrelated preexisting deformation that was already part of the rocks, or could have formed during the accretion and/or uplift of the Nolan Belt. The age is constrained only from post-Ordovician to pre-Middle Pennsylvanian. The Dutch Flat terrane structurally overlies the Basin domain at Battle Mountain (Roberts, 1964). The accretion of the Dutch Flat terrane may therefore have been a partial mechanism for the deformation in the underlying Basin and Slope domains, but the Dutch Flat terrane is not big enough to have caused the deformation known throughout the Basin and Slope domains, unless it was once much larger and much of it has been removed.
Mesozoic Tectonism

Mesozoic tectonism resulting from plate convergence to the west (Oldow et al., 1984) led to the accretion of Paleozoic and Mesozoic terranes in western Nevada and California (Oldow, 1984a; Wyld, 2002). However, the impact of this tectonism on the older rocks to the east has long been difficult to constrain in spite of its importance. The biggest obstacle to understanding the affect of the Mesozoic tectonism on the Paleozoic rocks is the lack of Mesozoic sedimentary rocks in the north-central and eastern regions of Nevada. Nonetheless, certain geometric constraints of different domains imply substantial movement during the Mesozoic of important components of Paleozone domains.

East-vergent and southeast-vergent Mesozoic thrusting is well documented in southern Nevada in the major thrust belts attributed to the Sevier Orogeny exposed in Clark County (Armstrong, 1968; Burchfiel and Davis, 1988; Burchfiel et al., 1970; Carr, 1983; Walker et al., 1990). Farther to the north in the central part of the state, east-vergent Mesozoic thrusting has also been demonstrated in spite of a paucity of exposure of Mesozoic rocks (Allmendinger et al., 1984; Bartley, 1990; Bartley et al., 1987; Cameron and Chamberlain, 1988; Camilleri and Chamberlain, 1997; Ketner and Smith, 1974, 1982; Lush et al., 1988; McGrew et al., 2000; Nolan et al., 1971; Thorman et al., 1991; Thorman et al., 1990). Even farther to the north in northern Elko County, the effects of east-vergent Mesozoic thrusting can still be documented (Coats and Riva, 1983; Ketner, 1984; Ketner et al., 1993). In many places, these thrust sheets have imbricated together previously thrust offshore sequences of Shelf, Slope, Basin, and Foreland Basin domain rocks (Murphy et al., 1978). Palinspastic reconstructions across the region (Saleeby and Busby-Spera, 1992) support the idea that these large thrust sheets have displacements on the order of a few to a few tens of kilometers of both horizontal and vertical displacement through the crust (Elison, 1991). Over the region, the thrusting occurred during various episodes from the Jurassic through the Cretaceous, although older thrusting cannot be ruled out.

An important feature of Mesozoic deformation in north-central Nevada that is often overlooked is the evidence for west-vergent thrusting (Coats, 1964; Gilluly, 1967; Speed et al., 1988; Stahl, 1987, 1989, 1992; Wallace and Silberling, 1964; Willden, 1961). While a number of studies have demonstrated the importance of this deformation in reconfiguring the Paleozoic domains of the area (Elison et al., 1986; Elison and Speed, 1989; Heck et al., 1986; Jones, 1993; Speed et al., 1982; Stahl and Speed, 1983;
Paleozoic Tectonic Domains of Nevada

Stahl and Speed, 1984), no synthesis has looked at the regional effect of this deformation. The area where it is best documented is around Winnemucca in the East and Sonoma Ranges and in the Osgood Mountains (Jones, 1991b; Stahl, 1989). Both the Osgood block and the Mountain City block of the Nolan belt have significant exposures of the Golconda terrane on both sides of the blocks (Figs. 7 and 11). Regional relations indicate that the Golconda terrane overrode the Antler Overlap rocks eastward by Early Triassic time (Crafford, 2007). Thrust faulting of Cambrian phyllite of the Nolan belt in the Osgood Mountains places these rocks westward over Permian rocks of the Antler Overlap domain (Hotz and Wilden, 1964; Jones, 1991b). While the actual age constraints of this thrusting are post-Permian to Tertiary, it is most consistent with the regional data that the Jurassic and/or younger west-vergent deformation documented in the Sonoma and East Ranges is part of a larger regional system that moved thick crustal sequences tens of kilometers westward.

Strike-slip displacement in the western Cordillera during Mesozoic deformation before the Sierran arc has been suggested by others (McCollum, 1985) and documented in several places. Evidence for Jurassic sinistral displacement of tens of kilometers (Oldow, 1983; Silberling and John, 1989) and Early Cretaceous dextral displacement of even greater magnitude have been proposed (Bushby-Spera and Saleeby, 1990; Lahren and Schweickert, 1989; Schweickert and Lahren, 1990; Wyld et al., 2006; Wyld and Wright, 2001). The domain analysis in this paper brings to light an interesting discontinuity that may be related to Jurassic or younger displacement (Fig. 13). The lower Paleozoic Shelf domain, the Basin domain, and the Slope domain all have a truncation at the southwestern edge of the main area of exposure that trends southeast across northern Nye County across the depositional facies recorded in the Shelf domain (Figs. 2, 4, and 5). To the south and west of this boundary, there are no exposures of Shelf domain rocks, only isolated exposures of Slope and Basin domain rocks, and rocks of the Nolan belt (Fig. 6). A possible explanation for this abrupt boundary is a truncation along a Mesozoic (Jurassic?) strike-slip fault. The isolated exposures of Basin and Slope domain rocks southwest of the structure can be explained as displaced fragments that were remobilized during a Mesozoic strike-slip event.

This boundary is parallel to the Pine Nut fault system (Oldow, 1983; Oldow and Gelber, 1987; Oldow et al., 1993) located 150 km to the northwest (Fig. 13). The eastern boundary of the Pine Nut assemblage of Oldow (1984a) (the Pine Nut assemblage of the Walker Lake terrane of Crafford [2007]) is interpreted as a fault, with significant strike-slip motion (Oldow, 1984a). Its location is constrained by the boundaries of the Pine Nut assemblage and the Sand Springs terrane (Fig. 13), and it also separates regions with significantly different structural histories (Oldow, 1984a). A major, brittle shear zone exposed along the east flank of the Wassuk Range is interpreted to be an exhumed part of the fault system (Oldow et al., 1993). It is inferred to be part of the Mojave-Snow Lake fault by others (Schweickert and Lahren, 1990). It seems reasonable to propose that the truncation boundary of the Shelf and Slope domains southeast of the Pine Nut fault system could represent the southeastern edge of the zone of deformation and displacement found in the Mesozoic accreted terranes of the Luning fold and thrust belt (Oldow, 1984a) system. A kinematic model with simultaneous transcurrent and thrust displacements during transpressional deformation, as suggested by Oldow et al. (1993) for the Pine Nut fault could be applied equally well to this proposed structure. The amount of displacement is unconstrained but could be on the order of 100 km.

SUMMARY

Assigning rocks from the new geologic map of Nevada (Crafford, 2007) to tectonic domains that reflect their paleogeographic setting and their structural history provides new insight into specific tectonic events and how these events relate to the accretion of terranes and the deformation of the margin through time. Predictive models of the geologic framework useful for resource exploration require an understanding of this tectonic history that can best be achieved by iterative modeling of local geologic data into a regional geologic framework.

Important tectonic domains discussed in this paper include lower Paleozoic domains based on paleogeographic facies, the Carbonate Shelf, Slope, and Basin domains; the Nolan belt, a structurally complex domain that includes Pre cambrian and lower Paleozoic slope and basin facies rocks; the Dutch Flat terrane, an Upper Devonian feldspathic sandstone of exotic origin; an Upper Devonian to Lower Pennsylvanian siliciclastic Foreland Basin domain concordantly overlying the Shelf domain; the Pennsylvanian and Permian siliciclastic and carbonate Antler Overlap domain unconformably overlying the older domains; the Golconda terrane of deformed upper Paleozoic oceanic, carbonate, and siliciclastic rocks, which is faulted over the Antler Overlap domain; the upper Paleozoic and Mesozoic volcanioclastic Black Rock-Jackson terrane; and numerous carbonate, siliciclastic, and volcaniclastic Mesozoic terranes and assemblages that were either accreted to the margin or deposited unconformably over previously accreted Paleozoic terranes.

Mafic volcanism associated with seamounts and rifting is evidenced in the lower Paleozoic rocks of the Basin and Slope domains. Feldspathic sedimentary rocks indicating proximity to unknown arc-related sources are an important component of the Basin domain, indicating its relative mobility with respect to the lower Paleozoic Shelf domain. Exotic, coarse-grained, Upper Devonian feldspathic rocks of the Dutch Flat terrane now accreted to the Basin domain require a post-early Late Devonian and pre-Middle Pennsylvanian accretion event. Distinctive pre-Middle Pennsylvanian deformation in Cambrian and Ordovician slope and basin facies rocks defines the Nolan belt. It has a structural history different from the history recorded in the Basin and Slope domains. It may be an accreted terrane or a displaced section of the continental margin. The Antler Overlap domain ties the accretion and deformation of the Basin and Slope domains and the Dutch Flat terrane to the Nolan belt and the continental margin by the Middle Pennsylvanian.

Deformation recorded in the rocks of the Golconda terrane suggests involvement of these oceanic rocks in a long-lived plate boundary. Signatures of the tectonism associated with this boundary may be recorded in the rocks of the coeval Antler Overlap domain. The final accretion of the Golconda terrane to the margin took place at the close of the Paleozoic or early in the Mesozoic. Tectonism in the Mesozoic reflected the change of the margin from one of transpressional accretion of ocean basin terranes to a true backarc setting. This involved thick-skinned, east- and west-vergent folding and thrusting of Mesozoic and older rocks and significant displacement along transcurrent faults, all as a reflection of the kinematics of the plate boundaries located to the west.

The Paleozoic geologic history of Nevada can be viewed in terms of tectonic domains derived from the newly interpreted geologic map of Nevada (Crafford, 2007). These domains reveal that Paleozoic tectonic events in Nevada were shaped by complex interactions between the continental margin and accreted terranes outboard of the margin. The Paleozoic margin has also been modified by Mesozoic tectonic events in important, under-recognized ways. Better constraining our understanding of the complex relations of ancient orogenic belts provides a more refined picture of the geodynamic history of the Earth’s crust. It also serves to enhance and update our ever-evolving understanding of the rich geologic history of Nevada. This can
Figure 13. All domains shown with Mesozoic strike-slip faulting and proposed truncation.
Paleozoic Tectonic Domains of Nevada


Paleozoic Tectonic Domains of Nevada


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MANUSCRIPT RECEIVED 20 MARCH 2007
REVISED MANUSCRIPT RECEIVED 12 OCTOBER 2007
MANUSCRIPT ACCEPTED 16 OCTOBER 2007

Geosphere, February 2008