An Alternative Hypothesis for the Mid-Paleozoic Antler Orogeny in Nevada

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)

An Alternative Hypothesis for the Mid-Paleozoic Antler Orogeny in Nevada

By Keith B. Ketner

Abstract

A great volume of Mississippian orogenic deposits supports the concept of a mid-Paleozoic orogeny in Nevada, and the existence and timing of that event are not questioned here. The nature of the orogeny is problematic, however, and new ideas are called for. The cause of the Antler orogeny, long ascribed to plate convergence, is here attributed to left-lateral north-south strike-slip faulting in northwestern Nevada. The stratigraphic evidence originally provided in support of an associated regional thrust fault, the Roberts Mountains thrust, is now known to be invalid, and abundant, detailed map evidence testifies to post-Antler ages of virtually all large folds and thrust faults in the region. The Antler orogeny was not characterized by obduction of the Roberts Mountains allochthon; rocks composing the "allochthon" essentially were deposited in situ. Instead, the orogeny was characterized by appearance of an elongate north-northeast-trending uplift through central Nevada and by two parallel flanking depressions. The eastern depression was the Antler foreland trough, into which sediments flowed from both east and west in the Mississippian. The western depression was the Antler hinterland trough into which sediments also flowed from both east and west during the Mississippian. West of the hinterland trough, across a left-lateral strike-slip fault, an exotic landmass originally attached to the northwestern part of the North American continent was moved southward 1700 km along a strike-slip fault. An array of isolated blocks of shelf carbonate rocks, long thought to be autochthonous exposures in windows of the Roberts Mountains allochthon, is proposed here as an array of gravity-driven slide blocks dislodged from the shelf, probably initiated by the Late Devonian Alamo impact event.

Introduction

The essential and still current concept of the Antler orogeny and its linkage to the Roberts Mountains thrust was published more than a half century ago by Roberts and others (1958), but its roots go back much farther to the field work of H.G. Ferguson, S.W. Muller and R.J. Roberts, most of which was done in the 1940s. Those consummate field geologists mapped a tremendous area of rugged mountains in reconnaissance fashion and their maps are still useful. In retrospect, however, they may have been too prone to invoke extensive thrust faults when a better understanding of the stratigraphy was needed, and that tendency has continued to affect interpretations of the geology of Nevada.

In Nevada, a north-trending carbonate shelf of Ordovician to Devonian age gives way westward through a transition zone to an expanse of dark, siliceous sedimentary rocks, termed the western facies (figs. 1, 2). The western facies domain is dotted with bodies of carbonate shelf strata. Between 1970 and 1992 numerous journal articles described the Antler orogeny as a process involving plate convergence by which the Roberts Mountains allochthon composed of the western facies rocks was obducted from an ocean basin onto the adjacent part of the carbonate shelf via the Roberts Mountains thrust (for example, Moores, 1970; Burchfiel and Davis, 1972; Dickinson, 1977; Miller and others, 1984; Burchfiel and others, 1992). Scattered blocks of shelf carbonate rocks within the western facies domain were regarded as exposures of the shelf in windows of the allochthon.

The purpose of this report is to cite evidence that concepts developed in early publications, including the classic paper by Roberts and others (1958), were based largely on erroneous stratigraphy and to offer a new conceptual framework for consideration. The essence of the new framework is that (1) left-lateral strike-slip faulting along the western margin of the North American continent, rather than plate convergence, was the engine of Paleozoic tectonics in the region; (2) the Roberts Mountains allochthon, as such, does not exist, and the Ordovician to Devonian western facies rocks were deposited essentially in situ; and (3) blocks of shelf carbonate rocks earlier thought to be exposures in windows of the Roberts Mountains allochthon are slide blocks from the carbonate shelf. The slide blocks probably were dislodged by the Alamo impact event of Late Devonian age. These concepts together constitute a working hypothesis based on field observations.

Origin of Tectonic Concepts—Antler Orogeny and Roberts Mountains Thrust

Roberts (1949) introduced the term Antler orogeny in an abstract as follows: "The earliest orogeny, here named the Antler orogeny … took place during Mississippian (?) and early Pennsylvanian time." That abstract was followed in 1951 by his geologic map of the Antler Peak quadrangle in the text of which he described the Antler orogeny in detail and somewhat refined the age span of the orogeny: "During the Antler orogeny formations in Battle Mountain ranging in age from Ordovician to Mississippian (?) were complexly folded and faulted. As these rocks are unconformably overlain by the Battle Formation of Early Pennsylvanian (Des Moines) age, the orogeny probably took place during the Late Mississippian. The orogeny may have continued into Early Pennsylvanian, however, for the coarse conglomerates of the Battle Formation indicate derivation from a rugged highland area" (Roberts, 1951).

In a subsequent, very influential paper, Roberts and others (1958) further refined the age of the Antler orogeny (p. 2,817) as follows: "This belt is now known to have been the locus of intense folding and faulting during the Antler orogeny in latest Devonian or Early Mississippian time ..." That age range was confirmed in a widely quoted paper by Silberling and Roberts (1962, p. 5): "During the Late Devonian or Early Mississippian ... the Antler orogenic belt was intensely folded and faulted, and during Mississippian time the Roberts Mountains thrust sheet was emplaced." The effect of this revision was to exclude the evidence in the Antler Peak quadrangle cited above for a Late Mississippian to mid-Pennsylvanian age on which the concept of the Antler orogeny originally had been based and to establish the conventional age of that orogeny as Late Devonian to Early Mississippian.

How the Roberts Mountains Thrust Came to be Related to the Antler Orogeny

It is somewhat unclear how the Roberts Mountains thrust, originally confined to the Roberts Mountains area and originally determined to be of post-Paleozoic age by Merriam and Anderson (1942), became connected with the Antler orogeny of Late Devonian to Early Mississippian age. The following discussion attempts to determine when and how this linkage took place.

An abstract by Roberts and Lehner (1955) appears to be the first published expression of the later widespread belief that the Roberts Mountains thrust was of mid-Paleozoic age rather than of post-Paleozoic age as originally determined by Merriam and Anderson (1942). Roberts and Lehner presented what they thought was convincing evidence based on stratigraphic relations in the Piñon Range, before that range was mapped by Smith and Ketner (1978). "The thrusting was originally considered to be Laramide, but near Carlin, Nev., conglomerate and limestone of Pennsylvanian age rest unconformably upon rocks of both the eastern and western facies" (Roberts and Lehner, 1955). Thus, in the view of Roberts and Lehner (1955), the thrusting began in the Pennsylvanian or before, and in that abstract, Roberts and Lehner implied that the stratigraphic relations, as they interpreted them in the Carlin area, trumped evidence of age from the type area in the Roberts Mountains. They apparently believed that any thrust fault that juxtaposed contrasting facies of Paleozoic rocks, as in the Roberts Mountains, could be termed the Roberts Mountains thrust—even if the apparent age of the rocks differed widely from the age of thrusting as determined in the type area. Three years later Roberts and others (1958, p. 2,813) described this assumed linkage as follows: "A belt along the 116º–118º meridians—the Antler orogenic belt—was the locus of intense folding and faulting that culminated in the Roberts Mountains thrust fault in Late Devonian or Early Mississippian time."

The regional evidence for a Late Devonian to Early Mississippian age of the Antler orogeny cited by Roberts and others (1958) is valid; abundant conglomeratic strata of Mississippian age constitute ample evidence of an important orogenic event. But their assertion of a linkage between thrust faulting, by whatever name, and the Antler orogeny is much less convincing as indicated in the following discussion.

Roberts and others (1958, p. 2,852) listed "five areas which give specific evidence about the age of the thrusting and related orogeny ..." In that statement the authors indicated that the thrusting and the orogeny were related and implied that evidence relating to the age of one is evidence for the age of both. Their first example from Antler Peak correctly cites an angular unconformity below the Middle Pennsylvanian Battle Conglomerate but does not explain how it is related to mid-Paleozoic thrusting. Their second example near Mountain City, Nev., was based on preliminary data supplied by students, some of which is now known to be invalid. For example, the unit said to be depositionally overlapping a "major fault" is, itself, underlain by a fault (Ketner, 2007). Their third example, from an area south of Carlin, Nev., in the Piñon Range, refers to an exposure of Lower Mississippian conglomerate lying on both the autochthon and Silurian shale of the allochthon. This third example and similar statements on pages 2,839 and 2,840 (Roberts and others, 1958) were based on miscorrelations without benefit of adequate fossil collections. Based on fossils, Smith and Ketner (1978) mapped as Permian the "Mississippian" conglomerate and the "Silurian" strata cited by Roberts and others. The fourth and fifth examples from Roberts and others (1958) rely on lithic correlation of nonfossiliferous conglomerates. None of these five examples constitute clear evidence for the age of thrusting or a link between the Roberts Mountains thrust, or any major thrust, and the Antler orogeny. In the 1950s, very little of the geology of Nevada had been mapped in detail, and structural interpretations were based on reconnaissance mapping and short visits to widely scattered exposures, often with reliance on lithic correlations without the benefit of fossil collections.

Ten years after Roberts and others (1958), Smith and Ketner (1968) described specific stratigraphic relations in the Piñon Range indicating that a thrust fault, which they identified as the Roberts Mountains thrust, was of latest Devonian to earliest Mississippian age. At the time, the authors considered this to be the best evidence for major thrusting of mid-Paleozoic age, but that evidence was invalidated by Ketner and Smith (1982) as described below.

Conventional Theories of the Antler Orogeny and Roberts Mountains Thrust as Effects of Plate Convergence

Over a period of 22 years numerous reports relating the Antler orogeny and Roberts Mountains thrust to plate convergence have been published in various journals, and because their basic tenets have been widely accepted, they are here termed the conventional theories. The following discussion attempts to distill the more influential reports. The earliest effort to relate plate tectonics specifically to the Antler orogeny was provided by E.M. Moores (1970): "A collision of this continental margin with a subduction zone dipping away from it in late Devonian-early Mississippian time … resulted in deformation of the pre-existing continental marginal rocks in the Antler Orogeny." Two principal contrasting tectonic hypotheses were presented in various journals between 1972 and 1992. A hypothesis based on east-dipping subduction involved back-arc partial closure over an east-dipping subduction zone to account for the Antler orogeny. A second hypothesis involved collision of the continent with an island arc above a west-dipping subduction zone. Several other less-influential hypotheses have been proposed (see Nilsen and Stewart, 1980).

Burchfiel and Davis (1972) presented the first detailed paper that explained the Antler orogeny and the Roberts Mountains thrust in terms of the subduction aspect of plate tectonic theory, stating: "... the paleogeography of this part of the Cordilleran geosyncline probably consisted of an offshore island complex separated from the continental slope and shelf by a small ocean basin of behind-the-arc type. Initial regional deformation within the Cordilleran geosyncline—the Mid-Paleozoic Antler orogeny—was characterized by the eastward displacement (Roberts Mountains thrust) of eugeosynclinal units from within the small ocean basin over miogeosynclinal strata deposited on the continental shelf." In that paper, Burchfiel and Davis set the parameters for future discussions of the nature and origins of the Antler orogeny and associated thrusts. Their basic concept of east-dipping subduction was reflected in modified form by others, including Miller and others (1984).

Dickinson (1977) and Dickinson and others (1983) argued for an opposing theory, that west-dipping subduction and arc-continent collision were the fundamental processes. They stated in the abstract of their 1983 report that "The Roberts Mountains allochthon was probably the subduction complex or accretionary prism of an intra-oceanic Antler arc-trench system that faced east (west-dipping), with subduction downward to the west. Its emplacement by thrusting over the Cordilleran miogeoclinal terrane of lower Paleozoic strata occurred in earliest Mississippian time during an inferred arc-continent collision that began in latest Devonian time and is termed the Antler orogeny." This was followed by papers offering modified versions of the same theory including those by Johnson and Pendergast (1981), Speed and Sleep (1982), and Speed and others (1988).

Finally, Burchfiel and others (1992) reviewed the two conventional theories and supplied what they thought were relevant data from the Mediterranean region. With that publication, the series of numerous papers (spanning 22 years) relating the Antler orogeny to plate convergence and subduction seems to have ended with general acceptance of the concept of plate convergence but with a lack of consensus as to whether west-dipping or east-dipping subduction was involved.

Problems with the Conventional Theories

The coexistence of two distinct hypotheses for many years without development of a consensus on the fundamental question of the direction of subduction suggests that neither theory has hit upon the right concept. Fundamental aspects of both ideas are undermined by stratigraphic relations that have come to light since those theories were first conceived. Not only is the link between the Antler orogeny and major thrusting denied by these stratigraphic relations, but the very existence of an allochthon is questioned.

Upon critical examination, the linkage between the Antler orogeny and the Roberts Mountains thrust is not supported by a significant body of field observations. After applying new stratigraphic data and re-examining older interpretations of relations in the Piñon Range, Ketner and Smith (1982) began to question their own evidence for their previously held belief that the Roberts Mountains thrust was of mid-Paleozoic age. They stated that "One interpretation of these new data suggests that in the Piñon Range, where a mid-Paleozoic age for the (Roberts Mountains) thrust was most convincingly displayed, the overlap assemblage actually may have been cut by a major thrust that juxtaposed contrasting facies of Mississippian rocks. If so, the principal evidence used to date the (Roberts Mountains) thrust is compromised, and the time has come for an agonizing reappraisal of all evidence bearing on the question." Further, "The most plausible conclusion from the relations in the Piñon Range and neighboring areas as here interpreted is that the western facies rocks of the Piñon

Range are part of a widespread allochthon that reached its present position following the close of the Paleozoic." Stratigraphic evidence in the Piñon Range for thrust faults involving strata as young as Early Mississippian cited by Johnson and Pendergast (1981) is significant, but the ages of those faults were not determined.

Detailed geologic mapping in several localities across north-central Nevada indicates that the ages of virtually all large folds and related thrust faults are much younger than the Antler orogeny. Detailed maps that would provide similarly strong evidence of a mid-Paleozoic age of the Roberts Mountains thrust are notably scarce. Evidence for a younger age consists of Paleozoic rocks, including western facies strata that have been thrust over folded Permian, Triassic, Jurassic, and Eocene strata. If this evidence relating to the age of thrust faults and major folds had been available in the 1950s, a mid-Paleozoic age for the Roberts Mountains thrust probably would not have been proposed and certainly would not have been widely accepted. Locations of mapped geologic evidence in Nevada are shown on figure 1 (as numbers 4 through 13) and are here described in abbreviated form:

4. Upper Triassic rocks overturned and thrust-faulted in the Humboldt Range (Silberling and Wallace, 1967; Wallace and others, 1969);
5. Upper Triassic rocks overturned in the East Range (Whitebread, 1978, 1994);
6. Upper Triassic strata, overturned and thrust-faulted in the Sonoma Range (Gilluly, 1967);
7. Triassic rocks overturned and thrust-faulted in the Pine Forest Range (Smith, 1973);
8. Jurassic strata strongly folded in the Cortez Mountains (Muffler, 1964; Ketner and Smith, 1974; Ketner and Alpha, 1992);
9. Lower Triassic units strongly folded and overthrust by Paleozoic rocks in the Adobe Range (Ketner and Ross, 1983, 1990);
10. Isoclinally folded Permian units overthrust by Mississippian rocks in the Peko Hills (Ketner and Evans, 1988);
11. Eocene folded and overthrust by Paleozoic strata in the Elko Hills and Piñon Range (Ketner, 1985, 1990a; Ketner and Alpha, 1992);
12. Lower Triassic rocks folded and overthrust by Paleozoic strata at Mount Ichabod (Ketner, 1990b; Ketner, Murchey, and others, 1993, 1996);
13. Permian, and probable Triassic, rocks, folded and thrust-faulted in the Northern Shoshone Range (Gilluly and Gates, 1965).

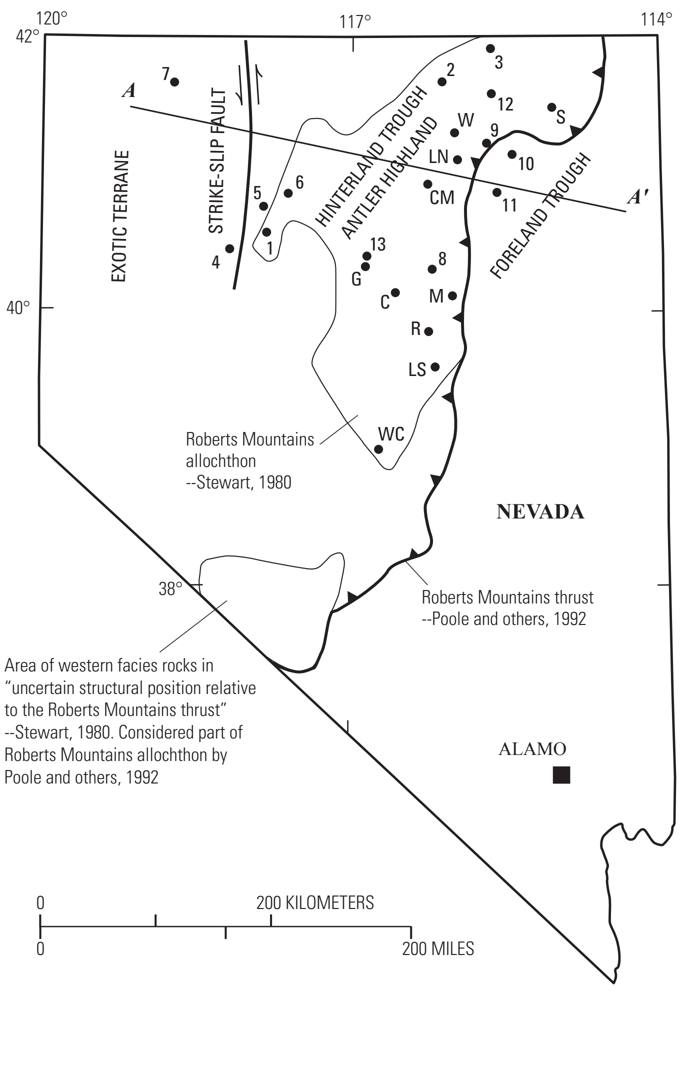

Figure 1. Outline of Nevada showing the Roberts Mountains allochthon according to Stewart (1980) and the Roberts Mountains thrust according to Poole and others (1992). Numbers 1, 2, and 3 indicate localities where the Ordovician Valmy Formation is in observed depositional contact with autochthonous Cambrian carbonate rocks. Numbers 4 to 13, cited in the text, indicate localities where detailed geologic mapping demonstrates strong folding and thrusting of post-Antler age. Letters designate prominent isolated exposures of shelf carbonate scattered in the western facies domain: S-Stormy Mountain; W-Wheeler Mountain; LN-Lone Mountain (north); CM-Carlin Mine; G-Goat Ridge; C-Cortez; M-Mineral Hill; R-Roberts Mountains; LS-Lone Mountain (south); and WC-Wildcat Peak. The central Antler highland and flanking troughs represent conditions in the Late Devonian and Mississippian. Line *A–A′* shows location of the generalized north-central Nevada cross section of figure 2.

In the East Range, the Bull Run Mountains, and the Rowland-Bearpaw Mountain area (Nevada sites 1, 2, 3, respectively; fig. 1), the Ordovician Valmy Formation, an essential component of the western facies assemblage and Roberts Mountains allochthon, lies with well-exposed gradational, depositional contacts on a sequence of autochthonous rocks including cross-bedded Cambrian sandstone overlain by Cambrian limestone-shale turbidite as shown on the left side of figure 2. In the East Range and Rowland-Bearpaw Mountain areas, the Valmy Formation is overlain disconformably by Mississippian to Permian strata, and in the northernmost Bull Run Mountains, it is overlain approximately concordantly, but with an obscure contact, by Upper Mississippian and younger rocks (Ketner, 1998a, 2008; Ketner, Ehman and others, 1993; Ketner and others, 1995). The entire Roberts Mountains "allochthon" lies south and east of these localities as shown in figure 1. The conventional theories would require the allochthon to pass completely over these three localities before deposition of the Mississippian and younger units without leaving any evidence of its passage.

The Harmony Formation of the Antler hinterland trough is of Late Devonian to Mississippian age (Ketner and others, 2005; Ketner, 2008). The coarse-grained arkosic components and large olistoliths of this formation must have been derived from a nearby landmass to the west as argued by Ketner and others (2005) and outlined below. This paleogeographic situation is incompatible with hypotheses that require a volcanic arc to the west of the allochthon.

Other weaknesses of the conventional theories have been cited by the authors themselves. These include absence of a volcanic arc, volcanic sediments, or oceanic crust in the western facies assemblage, and the lack of granitic intrusive rocks of subduction age.

An Alternative Hypothesis for the Antler Orogeny

It is impossible to reconcile the two conventional theories with the problems cited above. The linkage between the Antler orogeny and the Roberts Mountains thrust, the mechanism of plate convergence and subduction, and the concept of an allochthon of regional extent are the flaws of the conventional theories.

A new hypothesis without those components is required. The Antler orogeny, as here conceived as a working hypothesis, consisted of the formation in the Late Devonian and Early Mississippian of a central uplift and two flanking parallel troughs oriented in a north-northeast direction through much of Nevada. This hypothesis is a reversion to similar

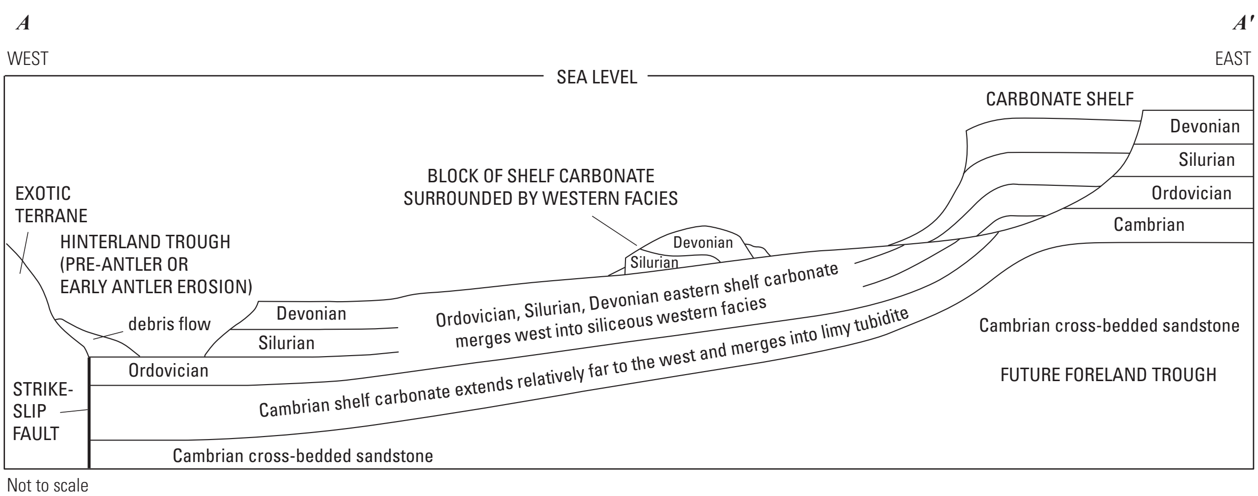

Figure 2. Generalized east-west cross section across north-central Nevada showing early Late Devonian (early Frasnian) relations at the time of Alamo impact. Not drawn to scale. The relations depicted here were modified by Late Paleozoic, Mesozoic, and Cenozoic events which partially buried blocks of carbonate shelf rock, creating the illusion of windows. Notable features include these: the carbonate shelf stands higher than the western facies domain; Lower to Middle Cambrian cross-bedded sandstone underlies the entire Paleozoic sequence; Middle to Upper Cambrian shallow-water shelf carbonate rocks are very extensive relative to the Ordovician to Devonian shelf rocks, ultimately giving way westward to turbidite deposits mainly composed of carbonate; Ordovician to Devonian shallow-water shelf carbonates give way westward through a transitional zone to siliceous rocks of the western facies domain; the contact between the western facies rocks and the immediately underlying Cambrian rocks, composed largely of carbonate, is depositional; Devonian and Silurian strata in the most westerly exposures of the western facies domain were eroded in a pre-Antler or early Antler event, leaving only the Cambrian rocks overlain by the Ordovician Valmy Formation, which is partly covered by debris flows. The debris flows emanated from an exotic continental fragment across a left-lateral strike-slip fault.

early concepts (Nolan, 1928; Roberts, 1968). Evidence for this paleogeographic landscape is the distribution and composition of Upper Devonian to Mississippian sediments that filled the foreland and hinterland troughs. The presence in the foreland trough of such deposits derived from both east and west is well known (Stewart, 1980). Deposits include quartzite and chert clasts from the central highlands and carbonate clasts from the shelf to the east. Formations include the easterly-sourced Tripon Pass Limestone and westerly-sourced Diamond Peak Formation and other units. Upper Devonian to Mississippian deposits of the hinterland trough also include deposits derived from both east and west. Those include quartzite and chert clasts from the central highlands and arkosic deposits and olistostromes (debris flows) from a western source (Ketner, 2008). Formations include the Harmony Formation and lower parts of the Inskip Formation and Havallah sequence (Ketner, 2008).

The age of the earliest deposits eroded from the central uplift can be used to date the onset of the Antler orogeny. The best-dated of these are the Pilot Shale, Woodruff Formation, and certain correlative unnamed deposits of north-central Nevada (fig. 3). The earliest dated beds of these stratigraphic units are of Frasnian age, early Late Devonian (Sandberg and others, 2003; Ketner, 1998b; Ketner and Ross, 1990).

Left-Lateral Strike-Slip Faulting as a Cause of the Antler Orogeny

With the rise of plate tectonic concepts in the 1960s it was inevitable that those principles would be applied to the stratigraphic and structural features of Nevada as those features were understood at the time. The emphasis placed by nearly everyone who has written on the subject, however, was on plate convergence. Here, I propose that another aspect of plate tectonics, namely left-lateral strike-slip faulting along an uneven track, could be the engine that generally drove Paleozoic tectonics in Nevada, and specifically drove the Antler orogeny. Evidence for a strike-slip fault along the western margin of the continent mainly is in the presence of arkosic deposits as discussed below.

Given the existence of a strike-slip fault and postulating an irregular track, the upper-Precambrian and lower-Paleozoic sequence at the continental margin in Nevada could have been subjected either to horizontal compression or tension. Compression certainly, and tension possibly, could have resulted in the formation of the central uplift and flanking troughs. The principles involved have been well-documented with respect to the San Andreas Fault system (Crowell, 1974).

Although late Precambrian rifting along the western margin of the North American plate (Stewart, 1972) is widely accepted, the present location of rifted parts of the continent is unknown. However, the location of part of the rifted margin appears to have been at the latitude of Nevada by the Late Devonian (Ketner and others, 2005) and is inferred to have arrived there by means of strike-slip faulting along the western margin of the continent. Part of the evidence for this is in the nature of coarse-grained Upper Devonian to Lower Mississippian arkosic strata in the hinterland trough (Ketner and others, 2005; Ketner, 2008). These arkosic strata are unique in Nevada and require a unique origin. The ages of zircon clasts from the strata indicate derivation from northwestern Canada according to Gehrels and others (2000). Moreover, large fossiliferous limestone olistoliths at the base of the arkosic strata were determined to have originated in northern Canada or elsewhere in northern latitudes far from Nevada (DeBrenne and others, 1990). The generally large

		Standard Conodont Zones			Detrital units considered to be early indications of Antler orogeny, Nevada
LOWER UPPER DEVONIAN	FRASNIAN	*Palmatolepis linguiformis*		UPPER (LATE) FRASNIAN	
		P. rhenana	Late		
			Early		Basal Antler orogenic deposits, southern Independence Mountains, Nev., (C.A. Sandberg, written commun., in Ketner, 1998b), and Adobe Range, Nev., (A.G. Harris, written commun., in Ketner and Ross, 1990)
		P. jamieae		MIDDLE FRASNIAN	
		P. hassi	Late		
			Early		Basal Pilot Shale (Sandberg and others, 2003)
		P. punctata			Alamo impact event (Sandberg and others, 2003), Nevada
		P. transitans		LOWER (EARLY) FRASNIAN	Basal Woodruff Formation (Sandberg and others, 2003)
		Mesotaxis falsiovalis	Late		
			Early		

Figure 3. Diagram of lower Upper Devonian standard conodont zones and timing of initial Antler orogenic deposits in relation to the Alamo impact event, Nevada.

size of clasts in both arkosic material and olistostromes indicates a nearby source; the arkosic rocks commonly are composed of coarse sand and small-pebble conglomerate, and the dimensions of some of the carbonate olistoliths reach several meters. The source of the large clasts must have been close and just to the west of the Antler hinterland trough as argued by Ketner and others (2005).

The concept of major left-lateral strike-slip faulting along the western margin of North America is not a new concept. Eisbacher (1983) presented evidence of a Devonian-Mississippian sinistral fault extending from the Arctic to Nevada and beyond. Left-lateral faulting of uncertain age or ages in California and Mexico has been discussed widely (Anderson and others, 2005, and references therein).

Roberts Mountains “Allochthon” Essentially Autochthonous

I propose here that the Roberts Mountains allochthon is a mistaken concept, and that Ordovician to Devonian western facies deposits may be in depositional contact with autochthonous Cambrian units throughout the area commonly thought to be occupied by the allochthon. Although the western facies deposits are sliced internally by faults of various ages and underlain in places by low-angle faults, stratigraphic components are also clearly in depositional sequence with autochthonous Cambrian components of the continental margin in the East Range, Bull Run Mountains, and Rowland-Bearpaw Mountain areas as cited previously. In this interpretation, the eastern limit of the Roberts Mountains allochthon actually is the approximate eastern extent of the western facies rocks in their original depositional setting but modified by post-Antler tectonism. A deep drill hole anywhere in the western facies domain likely would penetrate faulted rocks of the Devonian to Ordovician western facies assemblage, Cambrian carbonate rocks, and finally Cambrian and older cross-bedded sandstone. Depositional emplacement of the western facies rocks is not an original idea; a large area of western facies strata in southwestern Nevada has been interpreted as autochthonous or parautochthonous, in concordant depositional sequence with autochthonous Cambrian strata composed partly of carbonate rocks (Stewart, 1980, p. 39). This accounts for the discrepancy in figure 1 between the extent of the Roberts Mountains allochthon according to Stewart (1980) and the greater, more conventional, extent indicated by Poole and others (1992).

Extending Stewart’s interpretation of stratigraphic relations in southwestern Nevada to central and northern Nevada leaves the concept of windows in the Roberts Mountains “allochthon” to be addressed. Based on the concept of an allochthon, the carbonate rocks exposed in the windows are thought (1) to be autochthonous parts of the shelf sequence, and (2) to prove the existence of an extensive allochthon underlain by the Roberts Mountains thrust.

Allochthon Windows as Slide Blocks

Here I propose that the western margin of the carbonate shelf could have collapsed into the western facies domain in the early Late Devonian (Frasnian) and that blocks of Upper Cambrian to Devonian shelf rocks drifted, under the influence of gravity, into the relatively low-lying, deep-water western facies domain. Such slide blocks consistently have been identified as exposures of the autochthon in windows of the Roberts Mountains allochthon. A well-described example demonstrating the validity of the proposed process is in Alberta, Canada, where, in the early Late Devonian, large blocks of carbonate rocks clearly have spalled from the shelf and slid away from it into the adjacent relatively deep-water, siliceous domain (Cook and others, 1972).

If the alternative hypothesis is valid, the shelf collapse and formation of an array of slide blocks may have been caused by the Alamo impact event. This impact is a well-documented early Late Devonian event (Sandberg and others, 1997; Morrow and others, 2005) that had regional effects centered in southern Nevada, mainly north and west of the settlement of Alamo. Known effects included dislodgement of large blocks from the western margin of the carbonate shelf (Sandberg and others, 1997; Morrow and others, 2005). The age of the Alamo impact event is early Frasnian (Sandberg and others, 1997). The age of sediments overlapping one block displaced by the impact is slightly later in the Frasnian (C.A. Sandberg, written commun., 2011).

Problems of the Alternative Hypothesis

Although the alternative hypothesis is based on field studies and is considered here to better explain the geologic relations that characterize mid-Paleozoic tectonics in Nevada, it is not without problems. If the concept of strike-slip faulting and transport of a continental fragment to western Nevada from northwestern Canada is valid, why has the exotic terrane not been discovered? This is a serious problem for the alternative theory; an errant continental fragment should not be hard to find. However, it could still be present in western Nevada but covered by extensive Mesozoic and Cenozoic deposits, or transport could have continued southward and the fragment remain to be discovered. If the shelf rocks of the “windows” are actually slide blocks, where are the cavities from which they were spalled? Where are Cambrian rocks unconformably overlain by Late Devonian and Mississippian orogenic clastic strata? Such rocks have not been discovered but could be present under valley sediments of Cenozoic age. Why are slide blocks not everywhere surrounded by Devonian strata as shown on figure 2? A long history of intense folding and faulting extending from Late Paleozoic to the present presumably has masked the original structural relations and brought older strata into contact with the blocks.

In the Roberts Mountains (R on figure 1) certain strata, of Mississippian age and composed in part of clasts from the western facies rocks, are said to constitute part of the autochthon that was overridden by the Roberts Mountains allochthon (Murphy and others, 1978). If true, this would be a problem for the alternative hypothesis because it would imply that the western facies rocks were elevated, and gravity emplacement of slide blocks into the western facies domain would be impossible. The nature of the contact with underlying Devonian rocks, however, has been regarded by some observers as a fault and by others as debatable (Finney and others, 1993).

The Alamo impact took place in the early Frasnian (early Late Devonian), but when, exactly, were the slide blocks detached from their substrate? Until more data are available, one can only say that the two events are nearly contemporaneous.

Conclusions

Both the conventional theories based on plate convergence and the alternative hypothesis based on strike-slip faulting have serious defects. Those of the former include the erroneous assumptions that the Antler orogeny and Roberts Mountains thrust are linked, that the western facies assemblage is everywhere allochthonous, that the isolated blocks of shelf rocks prove the existence of an allochthon, and that the western facies assemblage was associated with a volcanic arc. Weaknesses of the alternative hypothesis principally include failure to identify both the location of the required exotic terrane and the sources of postulated slide blocks. I believe that defects of the alternative hypothesis are less damaging than those of the conventional theories. The defects of the alternative hypothesis can be explained away by attributing them to post-Devonian faulting, but the problems of the conventional theories cannot easily be resolved.

The effects of the Alamo impact may be more far-reaching than anyone has realized. Dislodgement of Upper Devonian shelf rocks in Alberta may be a consequence. Olistostromes, or debris flows, at the base of the Harmony Formation in the hinterland trough include large limestone olistoliths. The age of emplacement of those deposits must be early in the Late Devonian to Mississippian interval, the age range of the Harmony Formation. It is tempting to regard them as the westerly-derived equivalent of the easterly-derived slide blocks, but the available age data do not permit a close correlation.

Even more intriguing is the correlation between the onset of the Antler orogeny and the Alamo impact. If the onset of the Antler orogeny is determined approximately by the age of the earliest known orogenic deposits, the two events could be nearly coincident (fig. 3). Why would the onset of a tectonic event caused by strike-slip faulting, as argued here, and a meteoric impact just happen to take place in the same region and in the same narrow interval of time? In any event, the effects of both tectonic and cosmic events appear to be mingled inextricably in the Antler orogeny, which could explain why it is such a difficult problem and why there has been no consensus on its nature.

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