AN ABSTRACT OF THE THESIS OF

Roger Stephen Sans for the degree of Master of Science in Geology presented on May 22, 1985. Title: Origin of Devonian Rock Units in the Southern Fish Creek Range, Nye County, Nevada

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In the southern Fish Creek Range, Nye County Nevada, Devonian rocks are found overlying younger rocks. These Devonian units are allochthonous blocks that slid by gravity into their present positions.

The allochthonous blocks represent several different provenances commonly found to the west and northwest of the area. The blocks include Denay Limestone, a stromatoporoid-bearing limestone, Beacon Peak Dolomite, Oxyoke Canyon Formation, and undetermined limestone and mudstone. During the Late Devonian these units were incorporated into the Roberts Mountains allochthon as it added outer-shelf carbonates then inner-shelf carbonate and

clastic rocks to its base by an eastward-stepping mechanism.

The Devonian blocks of the thesis area are large blocks that detached from the front of the moving Roberts Mountains allochthon and slid eastward into the Mississippian foreland trough.

Origin of Devonian Rock Units in the Southern Fish Creek Range, Nye County, Nevada

by

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ORIGIN OF DEVONIAN ROCK UNITS IN THE SOUTHERN FISH CREEK RANGE, NYE COUNTY, NEVADA

INTRODUCTION

Purpose

The name "Cockalorum Wash Formation" was proposed by C. W. Merriam (1973) for a varied sequence of rocks exposed in the southern Fish Creek Range. It included both Devonian and Mississippian rocks.The Devonian rocks appear to be exotic when compared to known paleogeography.

An abstract and talk given to the Geological Society of America meeting at Salt Lake City (Poole _et al_., 1983), interprets one outcrop in the Fish Creek Range of southern Eureka County, previously mapped as questionable Cockalorum Wash Formation (Hose, 1978), to be composed of Upper Devonian Woodruff Formation and Lower Mississippian Webb Formation. The rocks are thought to compose a slide block that detached from the front of the Roberts Mountains allochthon and was then deposited in the Antler flysch trough (Poole _et al_., 1983).

At the inception of this project, the principal geologic map of the southern Fish Creek Range was a U.S. Geological Survey Open-File Geologic Map (Hose, 1978) showing the location of outcrops assigned to the Cockalorum Wash Formation, but which did not delineate the separate rock units within the formation. Since that time, a more complete map has been published (Hose, 1983). In this later map, the formation name "Cockalorum Wash" was abandoned and the rocks were reassigned to other formations.

The primary objective of this thesis is directed toward answering three questions which arise from the above work. (1) Are the former Cockalorum Wash Formation rocks also allochthonous blocks, analogous to the rocks described by Poole et al. (1983)? (2) Are there other units represented within the thesis area that are similarly derived? (3) If there are allochthonous blocks in the southern Fish Creek Range what provenances do they represent?

Location and Accessibility

The study area is located approximately thirty miles south-southwest of Eureka, Nevada in the southern Fish Creek Range (Fig. 1). The northern boundary of the study area coincides with the Eureka-Nye county boundary. The southern boundary of the area is approximately three-quarters of a mile to the south of Willow Creek. The

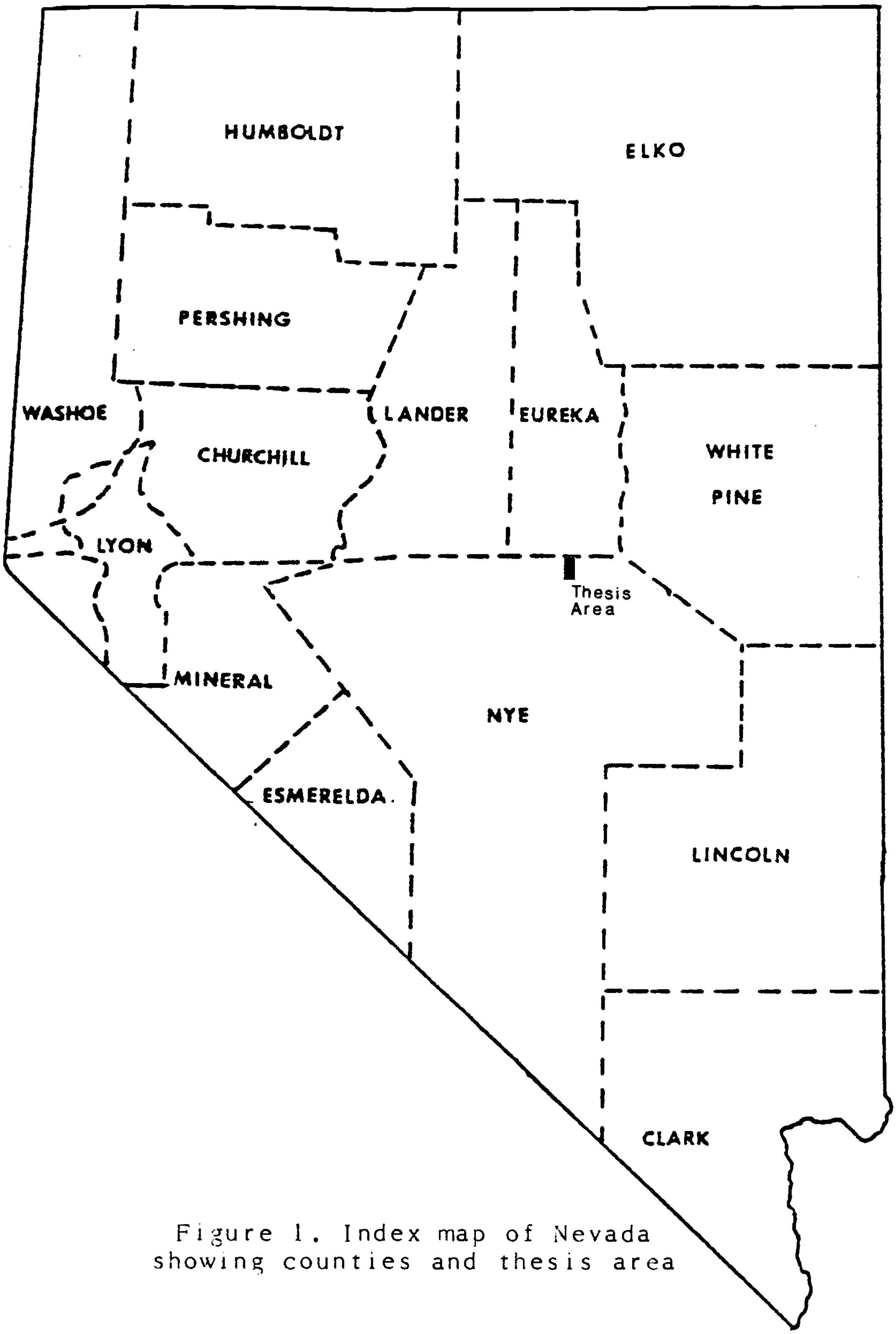

Figure 1. Index map of Nevada showing counties and thesis area

eastern and western boundaries are located within areas of valley fill flanking the Fish Creek Range.

The thesis area can be reached by following Highway 20 (the road to Duckwater Indian Reservation) south out of Eureka for approximately 20 miles, to the junction with the road to Snowball Ranch. Following Snowball Ranch road approximately 10 miles brings one to the area.

The road to Snowball Ranch cuts diagonally through the study area and brings one within a short walking distance to most of the outcrops. Additional access is provided by mining roads.

Acknowledgements

There are numerous people who have contributed to this thesis by giving me advice and information, moral support, and/or retreat from the pressures of the work. I am greatful to them all.

There are a few that I am exceptionally indebted to. My parents and grandmother were unfailing in both their emotional and financial support. Dr. Johnson offered the right proportions of guidance, geological insights, humor, empathy, and friendship. I am also greatful to him for the financial support he was able to provide. Claudia Regier exhibited skill and patience in her conodont work and gave

me both technical instruction and friendship. Mark Darrach suffered the tedious journey to Nevada and back, accepting Nevada geology, canned meals, a little liquor, and my gratitude as payment. Dr. M. A. Murphy was quite helpful to me during my field season. The Friday Tea Group, Marlene Halford and Bob Mow each offered me sanctuary whenever I needed it. To all of you, I am thankful.

Previous Work

Merriam (1967) mapped in the Cockalorum Wash quadrangle for 12 miles along the axis of the Fish Creek Range. He noted Devonian marine rocks and also probable land-laid or estuarine facies rocks that he thought to be partly equivalent to the Woodruff Formation of Smith and Ketner (1975). Merriam (1973) later applied the name Cockalorum Wash Formation to this coralline limestone, shale, siltstone, and sandstone sequence. These rocks crop out discontinuosly in the southern Fish Creek Range, between Cockalorum Wash and Willow Creek. Merriam's (1973) reconnaissance map of the area left many questions as to the nature of the contacts between the mapped units and what the stratigraphic relationships of those units are.

Hose (1978) showed the location of Cockalorum Wash Formation outcrops on a preliminary map of the Cockalorum

Wash quadrangle, but he did not delineate the separate rock units within the formation.

Stewart (1980) noted the similarities between the Cockalorum Wash and Woodruff Formations, but also noted that coralline limestone has not been reported in the Woodruff. He concluded that the Cockalorum Wash Formation was an anomalous outer shelf unit.

Johnson and Pendergast (1981) suggested that parts of the Cockalorum Wash Formation were equivalent to the Pilot Shale. They also cited M. A. Murphy (oral communication, 1980) as suggesting that the Cockalorum Wash Formation might be tectonically interleaved. Poole et al. (1983) interpreted an outcrop previously mapped as questionable Cockalorum Wash Formation to be composed of Woodruff Formation and Webb Formation in a slide block that detached from the front of the Roberts Mountains allochthon. A final version of Hose's map (Hose, 1983) was published after the mapping work for this thesis had been completed. Hose's later map abandons the formation name Cockalorum Wash and shows the lithologic units reassigned to the Devils Gate, Pilot Shale, Woodruff, Antelope Range, and Webb formations.

The works cited above comprise essentially all the work done specifically on the geology of the field area for this thesis. There are several regional studies that include this area within their scope. Matti et al. (1975)

prepared a palinspastic map showing the regional distribution of lithofacies in the Cordilleran geosyncline of Nevada and California during the latest Silurian to earliest Devonian. Matti and McKee (1977) mapped the paleogeography for central Nevada from the Silurian to the Lower Devonian. Johnson and Sandberg (1977) interpreted the stratigraphy of the western United States from the Lower through the Middle Devonian. Sandberg and Poole (1977) accomplished a similar task for the western United States from the Middle Devonian through the latest Devonian. Sandberg et al. (1983) interpreted the geologic history of the Overthrust Belt region of the western United States from Middle Devonian to Late Mississippian. In each of these studies, however, the interpretations made were based on the extrapolation of data collected primarily to the north, northwest, and northeast of the thesis area.

Terminology

Both Dunham (1962) and Folk (1962) have been used for carbonate classification. Folk's classification is intended to reflect the different physical energy in the depositional environment of the carbonates classified. The use of Folk's roots (eg. sparite, micrite) and modifiers (eg. bio-, pel-, oo-) convey a succinct description of the rock classified. Dunham's terminology is applied when classifying dolomite or limestones that prove to be mostly recrystallized.

The terminology for stratification is taken from McKee and Weir (1953). In their terms to describe stratification laminated is 2mm. to 1 cm. thick (about 0.08 to 0.5 in.), very thin-bedded is 1 to 5 cm. thick (about 0.5 to 2 in.), thin-bedded is 5 to 60 cm. thick (about 2 in. to 2 ft.), thick-bedded is 60 to 120 cm. thick (about 2 to 4 ft.), and very thick-bedded is greater than 120 cm. thick.

Methods of Investigation

Field work was begun July 7, 1983, and concluded October 15, 1983.

A base map of the study area with a scale of 4 inches to the mile (1:15,840) was prepared from the enlargement of a 1:62,500 U.S. Geological Survey topographic map of the Cockalorum Wash quadrangle.

Most of the mapping was done on the ground, but some of the Tertiary sediment and Mississippian sandstone was mapped initially by plotting the contacts on aerial photographs and then transferring the contacts to the base map. Contacts were then verified in the field. This approach was taken in areas of low relief (less than 80 feet of vertical relief) thus taking advantage of the vertical exaggeration inherent in viewing aerial photographs.

Samples representative of each lithology found were collected. From these, 18 thin-sections were made for petrographic analysis.

Samples weighing between 5 and 10 kilograms (11 to 22 lbs.) each were collected for conodonts. These samples were split then dissolved in formic acid. The residues were picked for conodonts by Claudia Regier.

Two collections, one composed of conodonts and brachiopods and the other of conodonts only were made by C. W. Merriam in 1964. These were collected from the southern end of the hill east of Willow Creek Ranch. These were obtained on loan from the U. S. National Museum, Natural History.

Identification and age determination of most of the conodonts was by Dr. Gilbert Klapper of the University of Iowa. One collection was examined by Dr. C. A. Sandberg, of the U.S. Geological Survey, Denver. Brachiopods were identified by Dr. J. G. Johnson of Oregon State University.

GEOLOGIC SETTING

During the Early Devonian, present-day Nevada formed a part of the north-northeast-trending Cordilleran geosyncline (Fig. 2). This was the dominant geological feature controlling early and middle Paleozoic sedimentation in the western United States. The geosyncline probably was the result of deposition along a passive margin which was formed by late Precambrian riffting (Stewart, 1972, 1976). This is analogous to the present-day Atlantic margin. Ordovician to Devonian history of the geosyncline may represent a broad continental shelf bordered on the west by a marginal basin and an island arc system (Burchfield and Davis, 1972; Churkin, 1974).

Early and middle Paleozoic deposition within the Cordilleran geosyncline can be assigned to three distinct, sub-parallel lithofacies belts (Roberts et al., 1958): (1) a miogeosynclinal belt (shelf deposits) in the east, composed of dolomite, limestone, and quartz arenite; (2) a transitional belt composed of a limestone clastic suite; and (3) a eugeosynclinal belt in the west, composed of deep-water limestone, mudstone, chert, and volcanic rocks.

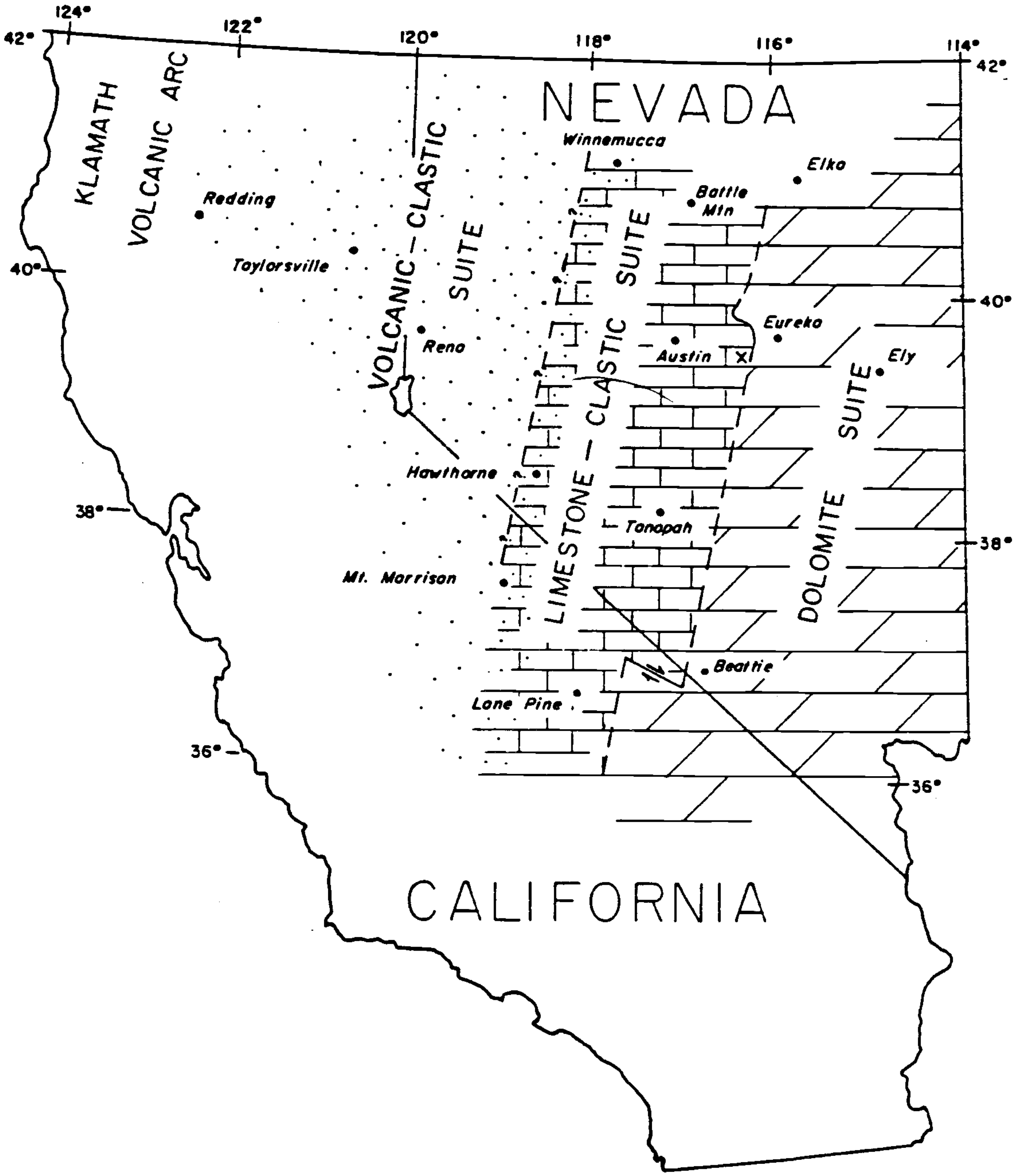

Figure 2. Diagram showing distribution of lithofacies in Cordilleran geosyncline (Matti et al., 1975)

From Late Silurian to Early Mississippian there were eleven major transgressive-regressive cycles (Johnson and Murphy, 1984). One effect of these cycles was the shifting of the dolomite front of the miogeosynclinal belt in response to the transgressive-regressive cycles (Johnson and Murphy, 1984). The shifts of the dolomite front reflected shifts of the carbonate shelf-edge. The shifts were not exactly corresponding, however. During extensive onlap the dolomite front retreated cratonward of the carbonate shelf while during times of regression the dolomite front shifted basinward of the carbonate shelf (Johnson and Murphy, 1984).

The largest of the transgressions, the Taghanic onlap, began in the Givetian (Johnson, 1970). The waters of the Taghanic onlap inundated the cratonic interior far beyond Great Basin boundaries, shifting the dolomite front eastward several hundreds of miles (Johnson, 1971; Johnson and Sandberg, 1977). This onlap was synchronous with the Acadian orogeny which resulted from the closing of the northern Proto-Atlantic ocean (Johnson, 1971; Sandberg et al., 1983).

During late Frasnian time, the deposition of slope and western shelf limestones began to abate, clastics from an emerging western source began to appear, and the Pilot basin began to form on what was previously inner continental shelf. These events were in response to foreland epeirogeny related to the Antler orogeny (Johnson, 1971; Sandberg and Poole, 1977; Johnson and Pendergast, 1980, Sandberg et al., 1983).

The primary structural feature of the Antler orogeny is the Roberts Mountains thrust. From Late Devonian to earliest Mississippian the eugeosynclinal assemblage of the Roberts Mountains allochthon was thrust relatively eastward, riding over and deforming the slope and westernmost shelf deposits of the miogeosyncline (Roberts, 1972; Stewart and Poole, 1974, Johnson and Pendergast, 1981; Speed and Sleep, 1982, Sandberg et al., 1983).

East of the allochthon, during late Kinderhookian time, a flysch trough began to form (Poole, 1974). This was in response to the incipient subduction of continental crust (Johnson and Pendergast, 1981; Speed and Sleep, 1982). Flysch trough deposition was composed of deep-water hemipelagic sediment and allodapic limestones. At some locales, the allochthon overrode these deposits (Pendergast, 1981; Johnson and Pendergast, 1981). By the early Osagean, the deep-water sediments deposited in the flysch trough began to give way to the coarser, shallower water clastics that are characteristic of molasse (Harbaugh and Dickinson, 1981). This is believed to have been the result of isostatic uplift which compensated for the earlier incipient subduction of continental crust (Johnson and Pendergast, 1981).

The main pulse of the Antler orogeny was probably concluded in the early Mississippian. Repeated post-orogenic uplift probably continued throughout the late Paleozoic (Stewart, 1980, p.55).

Siliclastics from the Antler highland were shed eastward into central Nevada through the Pennsylvanian and into the Permian (Stewart, 1980, p. 53). The detritus contributed to the Pennsylvanian and Permian sandy limestones of the thesis area.

There is no evidence of deposition within the thesis area from the Late Permian to the Early Cretaceous. During the Late Permian and Triassic, compressional upwarping in central Nevada occurred in response to the Sonoma orogeny (Collinson et al., 1976). The erosion of this upland contributed to the diminution of the Pennsylvanian and Permian rocks within the area. The upland is thought to have been largely destroyed by the Late Triassic. Post-Sonoma tectonism, however, resulted in locallized uplifts through the Jurassic and into the Cretaceous (Stewart, 1980, p. 76, 77). This could account for the non-deposition and erosion during this time within the thesis area.

The next significant deposition to effect the thesis area was the deposition of Cretaceous conglomerate. The conglomerate represents deposition in fresh-water basins characterized by crustal instability (Nolan, 1962). The Cretaceous topography may have resembled present day basin and range topography and may reflect an early stage of basin-range structure (Roberts et al., 1967).

The most recent geologic events represented within the thesis area are the Tertiary volcanics and volcanic sediments and the high-angle, north-northeast-trending normal faulting responsible for the Basin and Range topography of present day Nevada.

SILURIAN DOLOMITE

An outcrop of a light tan-gray dolomite at the southernmost end of the thesis area is unlike any of the dolomites elsewhere whithin the area. Samples collected with the hope of finding conodonts yielded no fossils. Hose (1983), however, collected conodonts which indicated a latest Early Silurian age for the unit. He suggested that the unit is approximately equivalent to the Laketown Dolomite, a central and eastern Nevada unit deposited in a shoal-water environment during the Silurian (Sheehan, 1980).

ALLOCHTHONOUS BLOCKS

Introduction

Merriam (1973) applied the name Cockalorum Wash Formation to a coralline limestone, shale, siltstone, and sandstone that crops out discontinuously in the southern Fish Creek Range between Cockalorum Wash and Willow Creek. Field evidence suggests that the limestone and mudstone assigned to the Cockalorum Wash Formation are allochthonous blocks that were thrust or slid by gravity into their present position. A similar style of emplacement is indicated for all of the Devonian rocks of the thesis area. In each case Devonian rocks are sitting on rocks of younger age. These Devonian rocks form a north-trending, narrow linear belt of allochthonous blocks. The text to follow describes the blocks and, where sufficent evidence exists, identifies the provenance.

Beacon Peak and Oxyoke Canyon Blocks

Description

A block composed of massive dolomite conformably overlain by quartzite is found at County Line Ridge.

Another block, smaller but similarly composed, caps both Quartzite Hill and Middle Hill. At Nyeka Peak, the quartzite alone forms the cap.

The dolomite is a light tan to light gray color. It is finely crystalline and shows no sign of bedding. Thin sections show the dolomite to contain from 10 percent to 60 percent quartz sand grains.

The quartzite is a massive, well-indurated unit. In handsample the individual quartz grains cannot be distinguished. Fresh surfaces of the rock are a light gray color. Exposed surfaces weather to a yellowish-gray or a pink color (Fig. 3).

In thin-section the quartzite is seen to be fine- to very fine-grained. Approximately 85 percent of the rock is framework and 95 percent of that is composed of quartz grains. The grains are sub-angular to sub-rounded and they are well sorted. Quartz overgrowths are common. Pressure solution is indicated by the occurrence of sutured grain boundaries. The matrix is dolomite (Fig. 4).

Provenance and Age

The dolomite was identified by Hose (1978, 1983) as Beacon Peak Dolomite. Hose _et al_. (1982) arrived at an age range of uppermost Silurian to Lower Devonian for the Beacon Peak Dolomite, but they included Lone Mountain

Figure 3. Quartzite; Oxyoke Canyon Formation

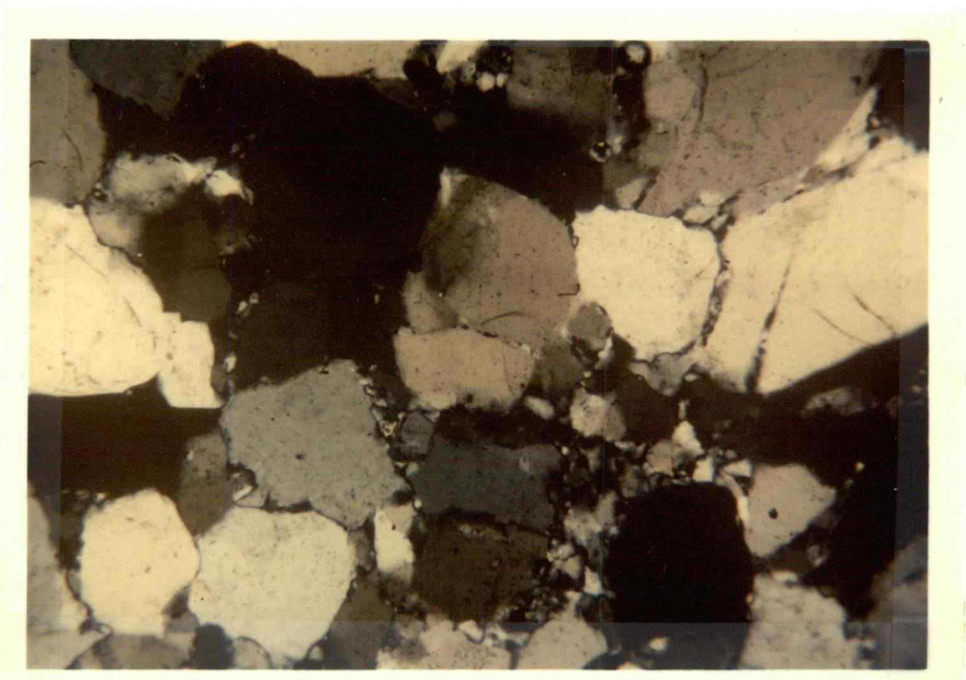

Figure 4. Photomicrograph of quartzite; Oxyoke Canyon Formation.

Dolomite in that unit. A sample, SS124, collected from the quartzite-dolomite block at County Line Ridge, yielded conodonts that could have been deposited within this time range (Klapper, written commun., 1984). The blocks composed of both dolomite and quartzite will be referred to as Oxyoke-Beacon Peak blocks on the basis of the age correlation of the dolomite.

Merriam (1973) tentatively identified the quartzite blocks as belonging to the Oxyoke Canyon Formation. Hose, (1978, 1983) made the same assignment. The similarity in lithology in both handsample and thin-section between the quartzite blocks and the Oxyoke Canyon Formation supports these conclusions. Further support for this assignment rests in the stratigraphic relationship of the quartzite depositionally overlying the dolomite. This is consistent with the stratigraphic relationship found elsewhere in central Nevada where the Oxyoke Canyon Formation depositionally overlies the Beacon Peak Dolomite. At Nyeka Peak where the quartzite alone forms the cap, the block is referred to as the Oxyoke Canyon Block.

No fossils have been found within the Oxyoke Canyon block. Brachiopods and conodonts of Emsian to Eifelian age have been collected within the Sadler Ranch Formation where it intertongues with the Oxyoke Canyon Formation at Union Mountain, in the Pinyon Range (Kendall *et al*. 1983).

Denay Blocks

Description

The discontinuous limestone and underlying mudstone identified by Merriam (1973) as Cockalorum Wash Formation is more accurately described as a number of individual blocks composed of limestone with underlying mudstone.

The mudstone ranges in thickness from approximately ten feet at Reef Hill to a hundred and fifty feet at Coral Ridge. The color of the mudstone varies as a result of hydrothermal alteration. The unaltered rock is a dark gray color; the altered rock can be either a light-gray to white or an orange-red color.

The mudstone readily crumbles into pebble-sized chips. Intact mudstone is exposed, however, in the numerous trenches that have been bulldozed in the exploration for vanadium. The mudstone bedding exposed in the walls of these exploration trenches is highly deformed, fractured, and sheared.

The overlying limestone is highly variable in texture, bedding, and faunal content. It has been so thoroughly disrupted that any interpretation of statigraphic position within the limestone section must be purely speculative. Such variability is best exemplified at Reef Hill.

At Reef Hill, Merriam's (1973) type section for the Cockalorum Wash Formation, the limestone unit appears to be an amalgamation of several limestone blocks derived from different environments of formation. At the top of Reef Hill there is a dark brown, laminated micritic, flaggy to platy limestone. These beds contain no macrofossils. North, approximately 45 meters along strike, the bedding disappears; the rocks are massive tan limestone lacking macrofossils. On the southeast flank of Reef Hill, there is a tan, non-laminated, thin-bedded limestone containing macrofossils, silicified coral heads, and crinoid stems (Figs. 5 & 6).

None of the other limestone-mudstone blocks within the area show as much variability as that found at Reef Hill. There is, however, a degree of variability within and between most of these blocks. South of Willow Creek, there is a large outcrop of slabby, light-tan limestone with a platy dark-gray limestone intercalated. At Coral Ridge there is an extensive outcrop of slabby, light-tan limestone, massive dark-brown limestone (with fossils of corals, bryozoans, and crinoid stems) and dark-brown, laminated micritic limestone. At Horn Ridge, the limestone is a massive, gray-brown sandy limestone.

The variability of the limestone-mudstone blocks is not restricted simply to differences in limestone lithology. Conodonts collected from 9 different sites

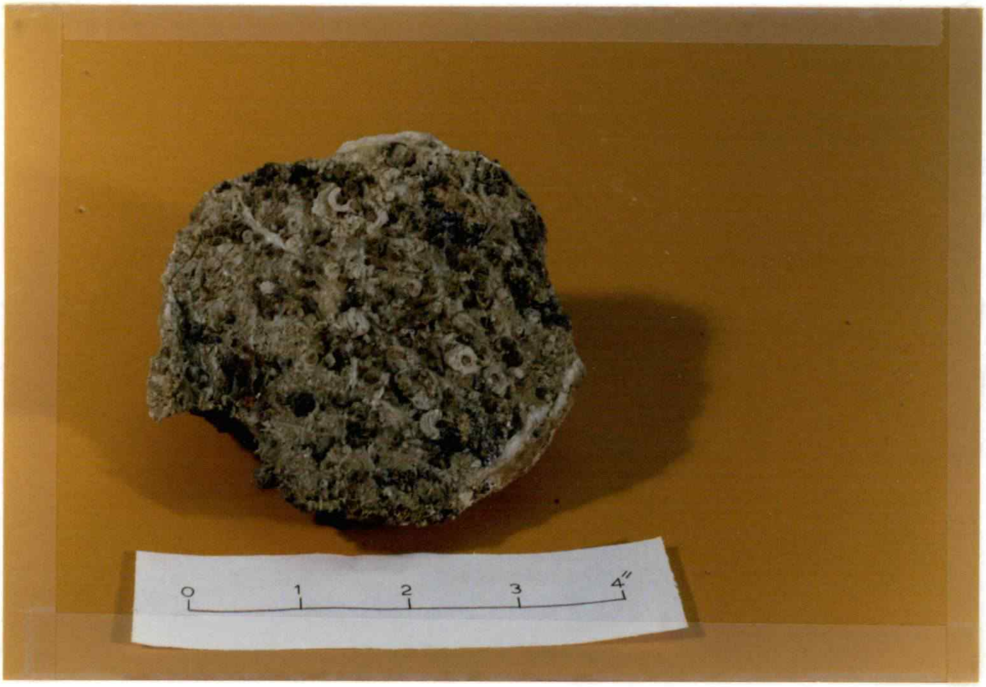

Figure 5. Crinoidal limestone; Denay block.

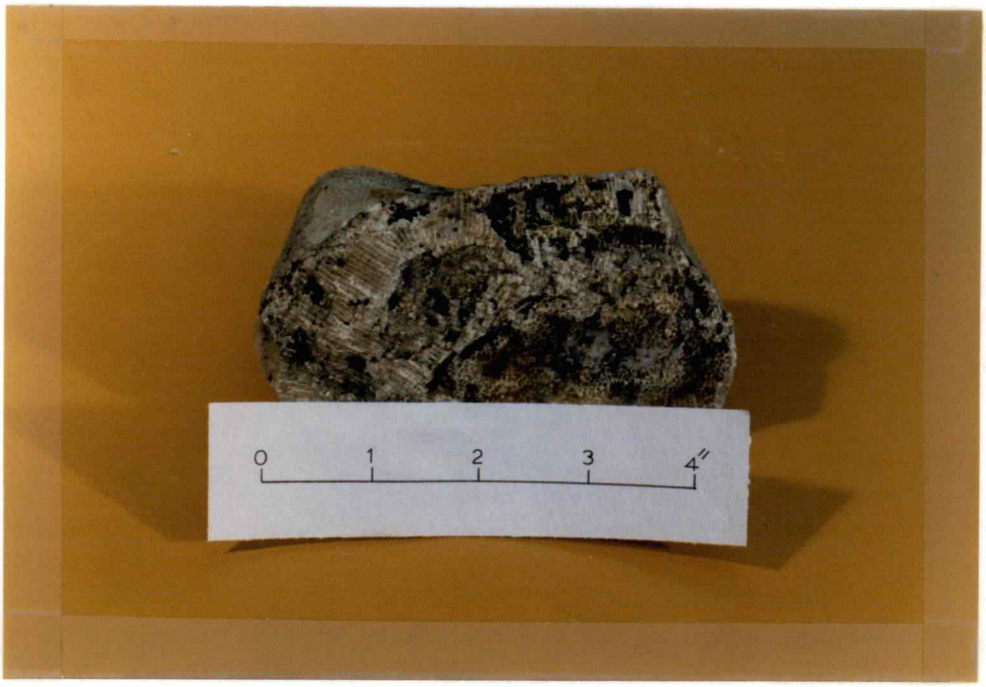

Figure 6. Favosite coral; Denay block.

indicate a variety of biofacies and ages of deposition for the limestone. This will be fully discussed in the following sections.

Age

Merriam (1973) collected corals from Reef Hill and Coral Ridge. These indicate a late Middle Devonian age for the limestone-mudstone blocks. As conodonts allow a greater age resolution than do corals, rock samples were collected for conodonts and these conodonts were identified by Dr. Gilbert Klapper.

Conodont collections from the limestone-mudstone blocks represent seven different conodont zones (Table 1). These extend from lower Middle Devonian to middle Upper Devonian. The discontinuous character of the limestone, the deformation and truncation of beds within the limestone blocks, and the localized absence of bedding have eradicated or obscured any sense of faunal succession.

Two samples collected from the limestone-mudstone blocks south of Willow Creek, samples SS126 and SS127, yielded conodonts which range in age from australis Zone to Lower varcus Subzone. A sample collected from Reef Hill, SS57, and one collected from Coral Hill, SS132, contained conodonts belonging to the kockelianus Zone. Sample SS82,

	Limestone blocks											
	57	132	126	127	82	65		89	66-26	64-5	60	27
Dvorakia klapperi	x											
Tortodus k. kockelianus	x	x										
P. trigonicus	x											
P. parawebbi	x	x	x	x								
P. l. linguiformis gamma	x					x		x				
P. pseudofoliatus	x				x							
P. angustipennatus	x											
O. raaschi	x			?								
P. l. linguiformis morph indet.		x										
O. brevis				?		x						
P. angusticostatus					?							
P. varcus group					x							
P. x. xylus						x						
P. timorensis						x						
I. obliquimarginatus						?						
P. cristatus								x				
P. dubius								x	x	x		
P. l. linguiformis epsilon								x				
P. ordinatus								x	cf.			
P. dengleri								?		x		
S. peracutus								x				
S. peracutus ?								x				
I. sp. aff. *I. symmetricus*								x				
Pa. disparilis								x				
Pa. disparalvea								x				
P. norrisi									x			
P. incompletus									?			
Pand. insita (multidenticulate)									x			
An. rotundiloba (early form)										x		
P. pennatus										x		
P. alatus										x	x	
P. webbi										x		
P. collieri										x		
O. sannemanni										x		
Pa. gigas											x	
Pa. linguiformis											?	
Pa. elegantula											x	
An. nodosa											x	
P. lodinensis											x	
P. brevis group											x	
cf. *"Nothognathella" sublaevis*												x
Pa. minuta ?												x
Pa. spp.											x	x
P. augustidiscus											x	
	kockelianus Zone		*australis* to L. *varcus* Subzone		*ensensis* to M. *varcus* Sz.	*varcus* Zone		*disparilis* Zone	Lm. *asymm.* Zone	L. *asymm.* Zone	U.-Um. *gigas* Zone	L. Famennian

Table 1. Collected conodont species assigned to conodont zones

collected from the north flank of Nyeka Peak, contained conodonts from the ensensis Zone to the Middle varcus Subzone. Sample SS65, from Coral Ridge, contained conodonts assigned to the varcus Zone. The disparilis Zone is represented by another sample collected from Reef Hill, SS89. Merriam, in 1964, collected two samples from the southern end of a limestone block south of Willow Creek; sample KV66-26 contains conodonts assigned to the Lowermost asymmetricus Zone and KV64-5, which contains conodonts assigned to the Lower asymmetricus Zone.

Provenance

The limestone of the limestone-mudstone blocks was interpreted by Hose (1983) to be Devils Gate Limestone. Evidence derived from conodonts collected from the blocks suggests otherwise.

The Devils Gate spans the upper part of the disparilis Zone to the Upper triangularis Zone (Johnson and Murphy, 1984). Six collections from the limestone-mudstone blocks, SS57, SS65, SS82, SS126, SS127, and SS132 (Table 1), represent four conodont zones that are too old to belong to the Devils Gate Formation.

Five other collections from the Denay blocks (Table 1) are of an age compatible with Devils Gate deposition. However, three of these collections belong to a biofacies not known in the shallow-water rocks of the lower Devils Gate (Johnson, written commun., 1984). Collection SS89 and two collections made by Merriam , KV66-26 and KV64-5, contain conodonts belonging to biofacies associated with an offshore marine environment (Johnson, oral commun., 1985). The two other collections that are age-compatible with the Devils Gate, SS60 and SS27, also indicate an offshore marine environment, but they are in accord with Devils Gate lithotopes of that age (Sandberg and Poole, 1977).

The offshore biofacies represented in the limestone-mudstone blocks is not found in the northwestern carbonate rock outcrops such as those at Devils Gate or Lone Mountain. This biofacies is known to the west in the Denay Limestone of the northern Antelope Range (Johnson _et al_., 1980). The older ages for the Denay blocks are also consistent with the age of the Denay Limestone. It is for these reasons that the limestone blocks are identified as Denay blocks.

Blocks of Undetermined Provenance

Stromatoporoid-bearing Blocks

A limestone block caps Lime Hill. Three smaller limestone blocks similar to the Lime Hill block are located just off the northwest flank of Lime Hill. The blocks are resistant and stand out in relief, forming rounded hills (Fig. 7). The rock is a light tan color which weathers to a gray-white. Weathered surfaces are extremely rough and dimpled. Fresh surfaces indicate that the limestone has been thoroughly recrystallized. Evidence of depositional texture is no longer apparent. Evidence of faunal content has all but disappeared. The limestone is composed of a homogeneous groundmass of interlocking calcite crystals; this is a crystalline carbonate, according to Dunham's (1962) classification.

The limestone blocks were initially identified by Merriam (1973) and later by Hose (1978, 1983) as Devils Gate Limestone. This identification was later confirmed by M. A. Murphy (oral commun., 1983). Murphy, when examining the northernmost block, noted that faintly preserved

Figure 7. Lime Hill capped by Stromatoporoid-bearing limestone.

stromatoporoids could be detected in relief on the weathered surfaces of the rock. The presence of the stromatoporoids could suggest that the blocks originated from a lower Devils Gate source. Another possible provenance for the limestone is the upper beds of the lower Denay Limestone (Johnson _et al_., 1980). This Denay unit is found immediately to the west of the thesis area within the northern Antelope Range.

As a result of the absence of other faunal data with which to correlate the limestone blocks, their provenance must here remain undetermined. The presence of stromatoporoids within the blocks does, however, indicate a shallow-water depositional environment.

Unidentified Blocks A Through F

Provenance has not been established for three other limestone and three mudstone blocks (labled A through F on the map). The easternmost limestone block, south of Willow Creek, block A, and the easternmost limestone block just north of Willow Creek, block B, seem indistinguishable in color, texture, and bedding from the massive tan limestone identified as composing the Denay blocks. The contacts of the undetermined limestone blocks are completely obscured by cover, but the proximity of the blocks to Denay blocks suggests that they are associated structurally. This evidence tempts one to conclude that the undetermined limestone blocks should be included as Denay blocks. Conodonts collected from these blocks do not support this interpretation.

Collection SS60, from block B, belongs to the Upper to Uppermost *gigas* Zone. Collection SS27, from block C, is in the lower Famennian. These blocks are younger than the youngest Denay, which was deposited during the early Frasnian (Johnson *et al*., 1980). The age of these two blocks is compatible with assignment to the Devils Gate Formation.

The ambiguity resulting from these blocks that resemble and appear to be structurally associated with Denay blocks, but are age compatible with the Devils Gate formation, requires that the blocks be viewed as having an undetermined provenance.

The third undetermined limestone block, block C, also resembles the Denay blocks, but no conodonts were collected from it. As a result, determining provenance would be completly arbitrary.

The undetermined mudstone blocks are labled D, E, and F. The mudstone appears to be identical to the mudstone of the Denay blocks. Like the mudstone of the Denay blocks, it is hydrothermally altered, it crumbles into pebble-sized chips, and bedding, where distinguishable, is highly contorted. The similarity suggests a Denay provinance. Once again, faunal evidence suggests otherwise. Hose (1983) found Angustidontus in blocks E and F. The age range of Angustidontus is Late Devonian to early Mississippian (Berdan, 1983). The Angustidontus mudstone is therefore too young to be a Denay block. Angustidontus is found in the Pilot Shale and in the Woodruff Formation.

The mudstone mapped previously as Cockalorum Wash Formation has occasionally been interpreted as being Woodruff Formation (Stewart and Poole, 1974; Poole, Sandberg, and Green, 1983); however, Hose (1983) identified blocks E and F as belonging to the Pilot Shale. As neither Pilot Shale nor Woodruff Formation can conclusively be determined as the provenance for these blocks, provenance will remain unidentified here.

Mudstone block D must also remain unidentified as to provenance. There have been no fossils found in block D nor is it in contact with limestone; its contact with the Antelope Range Formation is under cover. As a result, there is no stratigraphic context in which to place this block. The lithologic similarity of the mudstone with all other mudstone found within the area allows a conclusion that block D probably belongs to the Denay blocks or is of the same provenance as blocks E and F.

ANTELOPE RANGE FORMATION

Description

The Antelope Range Formation is an autochthonous sandstone unit found in the northern Antelope Range and southern Fish Creek Range. It is the lowest unit exposed within the study area north of Willow Creek.

The formaton was named and described by Hose et al. (1982). Their work focused on the outcrops found in the northern Antelope Range. The formation, at its type-locality, is composed primarily of a dark-yellowish-orange sandstone that is fine- to coarse-grained. This is succeeded up section by an indeterminate thickness of olive-gray to medium-gray silty shale with lenticular beds of sandstone and grit, some of which is conglomeratic (Hose, 1983).

Within the thesis area, the Antelope Range Formation is commonly a medium- to coarse-grained sandstone. In outcrops west of Coral Ridge, however, there is conglomerate within the unit. Though scarce, there are exposures of very fine-grained sandstone. The formation is thick-bedded to very thick-bedded and shows no cross-stratification. The orangish-red color of the formation makes it easily recognizable both in the field and on color aerial photographs.

Merriam (1973) described platy siltstone and sandstone in the lower 600 feet of his Devonian Cockalorum Wash Formation. Field investigation shows these clastic rocks to be in depositional contact with the underlying Antelope Range Formation, so they are interpreted here as being Antelope Range Formation sandstone. Above these, the Devonian rocks have been thrust or slid by gravity into place.

Thin sections of Antelope Range sandstone beds show compositions of 60 to 75 percent quartz, 20 to 30 percent chert, 1 to 5 percent feldspar, and 1 to 5 percent lithic fragments (Fig. 8). The lithics are primarily mudstone clasts. Matrix composes less than 5 percent of the rock. Applying Williams, Turner, and Gilbert's (1954) sandstone classification, the samples studied range from feldspathic to arkosic arenites. The rock is cemented by a combination of chert, quartz, and hematite. The hematite is responsible for the orangish-red color.

The presence of feldspar and mudstone lithic fragments indicates that the Antelope Range Formation is compositionally immature (Folk, 1951), the result of

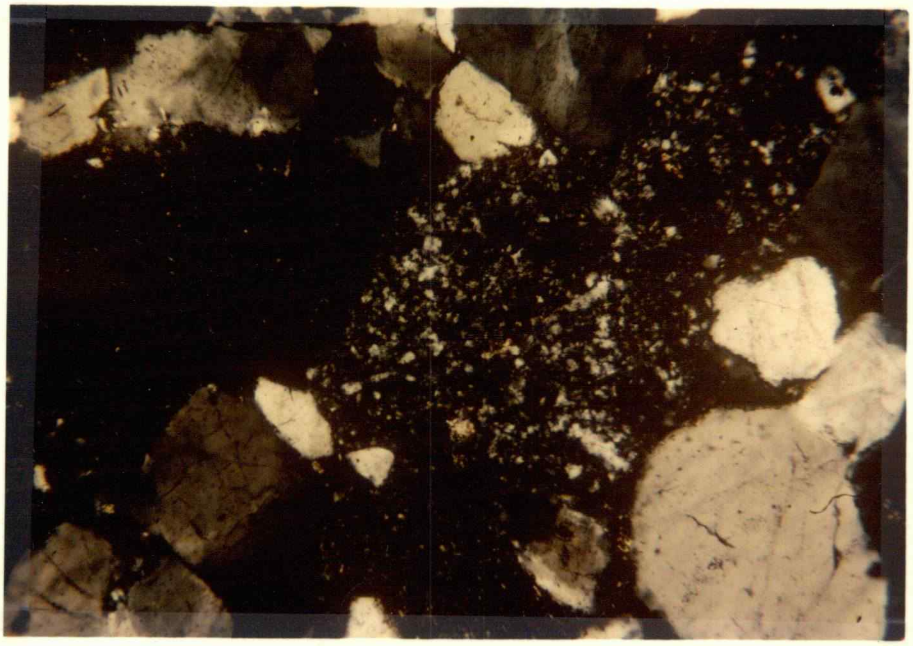

Figure 8. Photomicrograph of feldspathic arenite; Antelope Range Formation

deposition of the sediments relatively close to the source area.

The clasts range in roundness from angular to rounded; they are poorly sorted and there is less than 5 percent matrix. This describes a texturally submature rock indicative of a moderate- to low-energy depositional environment (Folk, 1951).

Age

No fossils were found within the research area with which to date the Antelope Range Formation. Foraminfera collected outside the area toward the bottom of the formation indicate an to early to middle Carboniferous age (Hose et al., 1982). With the exception of a few plant remains, no megafossils have been found within the Antelope Range Formation.

Depositional Environment

Hose et al. (1982) suggested an esturarine or deltaic environment for the Antelope Range Formation. This is based on the presence of plant remains and nearshore marine and nonmarine spores collected from within the unit. The textural immaturity of the rock, which indicates a low-energy environment of deposition, is consistent with this interpretation.

The tectonic setting for the Antelope Range Formation involved deposition in the Antler foreland basin (Harbaugh and Dickinson, 1981; Johnson and Pendergast, 1981). Deposition within such a basin would produce a deltaic environment of deposition (Harbaugh and Dickenson, 1980) consistant with the depositional environment proposed by Hose *et al*. (1982).

PENNSYLVANIAN SEDIMENTARY ROCKS

To the southwest of Horn Ridge is a small outcrop of a sandy limestone that appears to be in depositional contact with the underlying Antelope Range Formation. In thin section the rock proves to be a sandy foram biomicrite. Foraminifers and conodonts collected from the unit indicate an early Pennsylvanian age (Hose, 1983).

CARBON RIDGE FORMATION

Description

A tan silty limestone that crops out just south of Willow Creek has been identified by Hose (1983) as belonging to the Lower Permian Rib Hill Formation.The Rib Hill Formation (Pennebaker, 1932) is a sandstone and sandy limestone unit found in eastern Nevada.

J. G. Johnson (oral commun., 1984) suggested that this limestone might instead belong to the Carbon Ridge Formation. The proximity of known Carbon Ridge outcrops to the thesis area and the absence of Rib Hill Formation as far west as the Fish Creek Range supports this suggestion.

The Carbon Ridge Formation (Nolan et al., 1956) is found predominantly in Eureka County as far east as the Diamond Mountains and to the south as far as Eureka, Nevada. It is heterogeneous in lithologic character, composed of sandy limestone beds, sandstone, carbonaceous sandstones interbedded with sandy shale, and chert-pebble conglomerate.

The Carbon Ridge Formation, as it is represented within the thesis area, is a sparse biomicrite. In outcrop, the rock is thin-bedded and slabby. Fresh surfaces are light gray-brown; weathered surfaces are tan. The limestone contains fossils of brachiopods, gastropods, and unidentified straight spines. The other lithologies of the formation are not present.

Age

Easton *et al*. (1953) arrived at a Permian age for the Carbon Ridge Formation. The outcrop within the thesis area contained brachiopods that indicate a comparable age. Sample SS25 yielded a bilobed chonetid which may be *Chonetinella*, indicating Pennsylvanian to lower Permian (Johnson, written commun., 1984).

Depositional Environment

The Carbon Ridge Formation belongs in what Stewart (1980) refers to as the carbonate-terrigenous detrital province of the Permian. He explains that the detrital material that composes much of the formation was shed eastward from the former Antler highland into a shallow marine environment.

NEWARK CANYON FORMATION

Description

The Newark Canyon Formation (Nolan *et al*., 1956) crops out at County Line Ridge and forms the spine of Conglomerate Ridge (Fig. 9). The unit lies with angular unconformity upon the underlying Antelope Range Formation. At County Line Ridge, the Beacon Peak Dolomite has been transported over the Newark Canyon Formation.

The Newark Canyon Formation is a heterogeneous unit composed of siltstone, sandstone, conglomerate, and freshwater limestones. Within the study area, the unit is represented by conglomerate. It is composed primarily of rounded to well-rounded pebbles and cobbles. The clasts are mainly of chert and quartzite from the western facies of the Ordovician Vinini and Valmy Formations, along with a few clasts of Paleozoic limestone (Hose, 1983).

Age

Nolan *et al*. (1956) were able to arrive at an early Cretaceous age for the Newark Canyon Formation on the basis

Figure 9. Conglomerate Ridge; Newark Canyon Formation forms spine of ridge.

of gastropod and fish fossils. Hose (1983), collected ostracods, pollen and spores, and freshwater mollusks from various parts of the unit in the southern Fish Creek Range. These indicate an early Cretaceous age for the formation.

Depositional Environment

Fossils found within the Newark Canyon Formation indicate that deposition occurred in a fresh-water environment (Nolan *et al*., 1956; Hose, 1983). Evidence that the formation was deposited in a basin of highly variable relief has lead Nolan (1962) to conclude that the basin was undergoing crustal instability at the time of deposition. Roberts *et al*. (1967) suggested that the topography during Newark Canyon deposition may reflect an early stage of basin-range structure.

TERTIARY UNITS

Sheep Pass Formation

The Sheep Pass Formation of Winfrey (1960), described in the Egan Range, consists of a basal conglomerate overlain by limestone, silty limestone, mudstone, siltstone, shale, and sandstone. It is only the basal conglomerate that is found in the Fish Creek Range. Winfrey considered the Sheep Pass Formation to be Eocene in age. Fouch (1977) amended this to Paleocene and Eocene age.

Exposures of the Sheep Pass Formation within the study area are found on the east flank of the Fish Creek Range opposite Lime Hill and Nyeka Peak. The unit forms low rounded hills.

The conglomerate of the Sheep Pass Formation is moderately indurated and composed of sub-rounded to rounded pebbles and cobbles in clast-support. These clasts are derived from Paleozoic formations (Hose, 1983).

The conglomerate is believed to be the product of fluvial deposition in a broad internal drainage system (Stewart, 1980). Within the thesis area, the Sheep Pass Formation is in normal fault contact with the Cretaceous

Newark Canyon Formation and in depositional contact with an overlying Tertiary ash-flow tuff.

Tertiary Hypersthene Rhyodacite

Within the thesis area, there are a number of hypersthene rhyodacite outcrops. These are dark gray to black in color. Samples fracture conchoidally. They contain feldspar and hypersthene phenocrysts in a glassy groundmass (Hose, 1983). Hose (1983) dates these volcanics as Tertiary.

Tertiary Ignimbrite

On the eastern flank of the Fish Creek Range, within the thesis area, are two rhyolitic ignimbrites. To the south near Cobble Hill is a white, moderately welded ignimbrite with abundant feldspar and biotite phenocrysts. Farther north, to the east of Lime Hill is a pink, moderately welded ignimbrite with white pumice fragments and feldspar and quartz phenocrysts. Hose (1983) reports a K-Ar age of 32.5 m.y. for these.

Tertiary Jasperoid

A single outcrop of Tertiary jasperoid is located approximately 1/4 of a mile south of Horn Ridge. This rock is thought to be brecciated limestone that has been replaced by silica (Hose, 1983). It is redish-brown in color.

Tertiary Sedimentary Rocks

Exposed in the valley-fill deposits to the west of the Fish Creek Range are numerous low-relief outcrops of sedimentary rocks. These are fine- to coarse-grained tuffaceous sandstones. They are light tan to white in color and are composed of glass shards, pumice and volcanic lithic fragments, and clasts of chert and quartz. Many of the pumice fragments and glass shards have altered to a light-tan clay which composes as much as 30 percent of the rock. Soft-sedimentary structure is rare though one can occasionally find evidence of horizontal bedding. Hose (1983) characterizes the sandstones as Tertiary lake and pond deposits.

STRUCTURE

Thrust Faults

Evidence of Devonian units thrust upon Mississippian molasse is recognized the length of the thesis area. This should not, however, be interpreted as evidence of emplacement of a single thrust sheet. What is instead proposed is that each of the discontinuous Devonian blocks represents an individual slide block that was detached from the Roberts Mountains allochthon and then slid eastward to its depositional site in the Antler foreland basin. This is the same mechanism proposed by Poole et al. (1983) to explain the presence of another Devonian block, located in the southern Fish Creek Range to the north of the thesis area.

The Oxyoke-Beacon Peak block at County Line Ridge has undergone at least two episodes of eastward shift. The block was initially emplaced somewhere to the west of its present locale by the means previously described. Normal faulting, some time after deposition of the Cretaceous Newark Canyon Formation, resulted in an eastward dipping uplift. The Devonian block then slid by gravity to its present position above the Cretaceous conglomerate.

The Devonian blocks are composed of outer-shelf carbonate and inner-shelf carbonate and clastic rocks. These units were incorporated into the allochthon as it stepped eastward in a thrust process described by Murphy et al. (1984). Ordovician western-assemblage rocks were thrust eastward to overlie Devonian outer-shelf rocks. Thrusting then continued below the Devonian rocks. Subsequent thrusting along this fault plane moved the allochthon, composed of Devonian outer-shelf rocks overlain by Ordovician western-assemblage rocks, eastward to overlie Devonian inner-shelf rocks (Fig. 10). Thrusting then continued below the Devonian inner-shelf rocks resulting in farther eastward emplacement of the allochthon.

Normal Faults

There are a number of relatively small, high-angle normal faults that trend north-south within the thesis area. Two of these stand out due to their greater length and greater offset. One is located on the east flank of the Fish Creek Range, opposite Nyeka Peak and Lime Hill. This

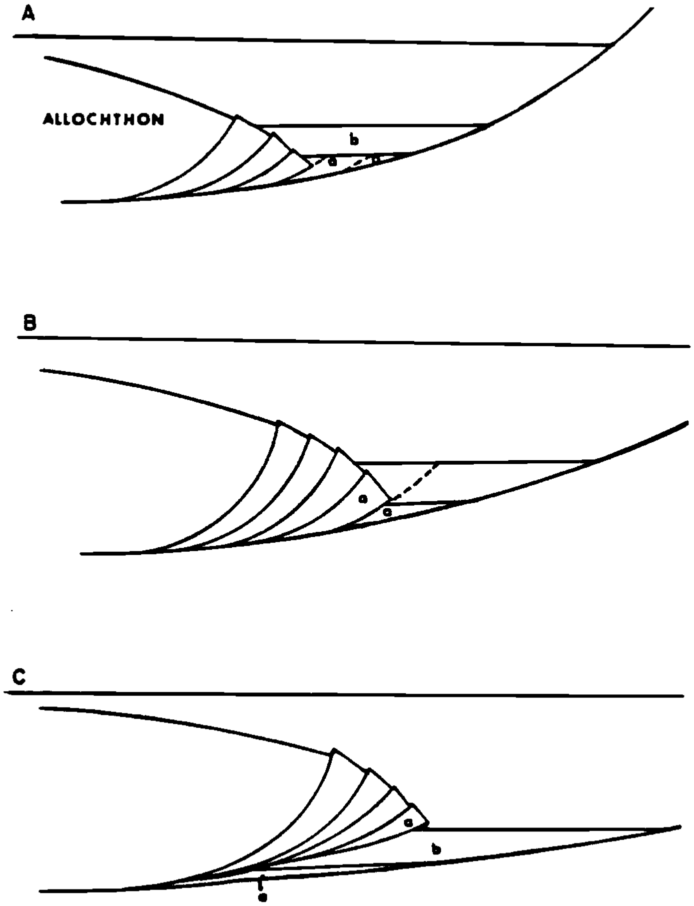

Figure 10 Diagram of east-stepping allochthon.

A) Deposition of unit b in front of allochthon.
B) Thrust plane cuts through a and b.
C) Continued thrusting results in the accretion of a to the bottom of allochthon which is then thrust over b.

fault brings Cretaceous Newark Canyon Formation in contact with Tertiary units. It is downthrown on the east side. The fault extends north to County Line Ridge where it is truncated by another of the relatively large faults located in the area.

County Line Ridge is cut by the other large fault of the thesis area. The fault extends the entire length of the ridge and brings Oxyoke Canyon Sandstone in contact with Beacon Peak Dolomite. The fault is downthrown on the west.

The normal faults of the area are all assumed to be related to the Miocene tensional regime responsible for Basin and Range faulting. Defense for this assumption rests primarily on the evidence of one of the faults cutting Eocene rocks.

Folds

There are no large-scale folds within the area. There are small, tight folds related to the emplacement of the Devonian blocks, however. Uniform dip directions to the west, found in the Antelope Range Formation in the northernmost exposure and the southern exposures, are related to block faulting rather than to folding.

GEOLOGIC HISTORY

The thesis area during the Silurian and Devonian was located within the middle carbonate belt of the continental shelf (Robison, 1960). Sedimentation consisted of miogeosynclinal deposits of shallow-water limestone and dolomite on a passive continental margin (Stewart and Poole, 1974; Johnson and Murphy, 1984). This lithotope is represented by the Lower Silurian Dolomite located at the southernmost extent of the Fish Creek Range.

To the west, during the Frasnian, a west-dipping subduction zone formed in oceanic crust (Fig. 11B) (Johnson and Pendergast, 1981). Eugeoclinal sediments were underthrust by the subducted slab and telescoped to form an accretionary wedge as oceanic crust was consumed (Johnson and Pendergast, 1981). This process continued for approximately 10 to 12 m.y., forming the Roberts Mountains allochthon (Fig. 11C) (Johnson and Pendergast, 1981). Underthrusting continued for another 11 to 13 m.y. (Johnson and Pendergast, 1981), pushing the Ordovician and Devonian eugeoclinal strata of the allochthon eastward over Late Devonian and early Mississippian units.

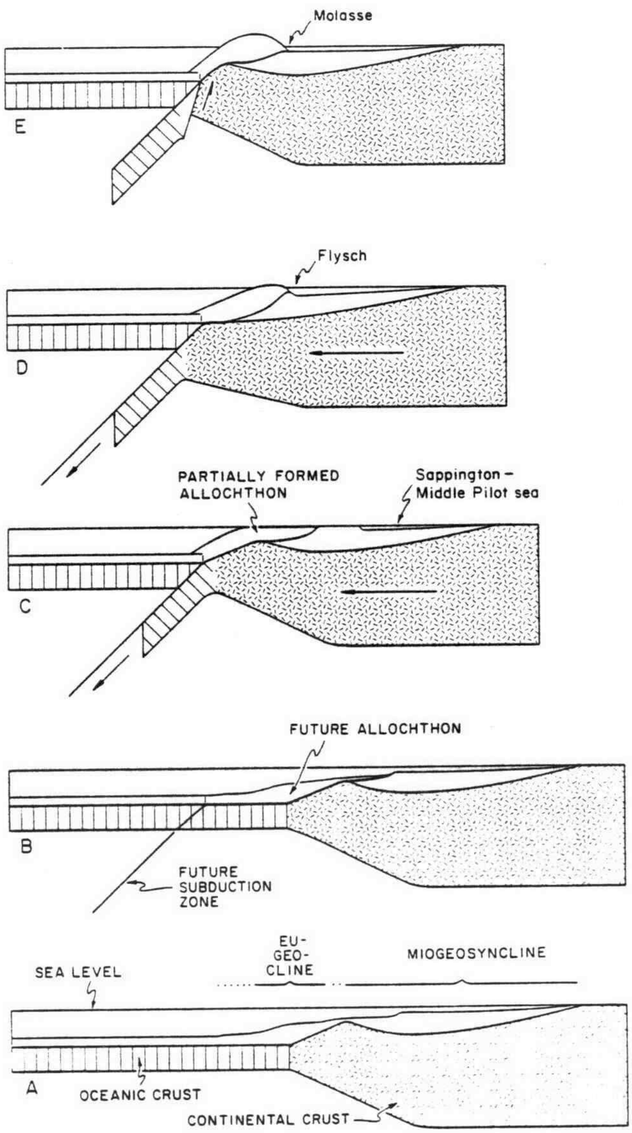

Figure 11. Diagram showing emplacement of the Roberts Mountain Allochthon

A) Prethrust lithofacies.
B) Location of future structural elements related to Roberts Mountain thrust.
C) Initial emplacement of partially formed allochthon.
D) Incipiant subduction of continental crust initiates formation of flysch trough.
E) Isostatic uplift results in molasse deposition.
(Johnson and Pendergast, 1981)

Once oceanic crust was entirely consumed, incipient subduction of continental crust followed (Fig. 11D). This initiated the formation of a flysch trough east of the allochthon and resulted in the uplift of the already-elevated allochthon (Johnson, 1975; Johnson and Pendergast, 1981).

Deposition in the flysch trough began in mid-Kinderhookian and continued into the early Osagean. Initial deposits were primarily deep water, hemipelagic sediments and allodapic beds. Later deposition was much coarser, consisting of silts, sandstones, and conglomerates derived from erosion of the exposed Roberts Mountains allochthon (Johnson and Pendergast, 1981). From late Meramecian time, into the early Pennsylvanian, shallowing-upward tendencies prevailed, and molasse was deposited (Fig. 11E) (Wilson and Laule, 1979; Harbaugh and Dickinson, 1981; Johnson and Pendergast, 1981). The deposition of molasse is thought to have resulted from the isostatic uplift which compensated for the incipient subduction of continental crust (Johnson and Pendergast, 1981). These molasse deposits are represented by the Antelope Range Formation in the thesis area.

Prior to the emplacement of the Roberts Mountains allochthon, as molasse deposition continued, large blocks detached from the front of the moving allochthon and slid eastward into the shallowing Mississippian trough.

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APPENDIX

CONODONT COLLECTIONS AND LOCALITIES

All but one of the following conodont collections were identified by Gilbert Klapper, 1984. The conodonts of collection SS25 were identified by C. A. Sandberg. Brachiopods were identified by J. G. Johnson.

Collections KV64-5 and KV66-26 were made by C. W. Merriam in 1964. These were obtained on loan from the U. S. National Museum, Natural History.

All sample locales are within the south-central part of the Cockalorum Wash quadrangle in the southern Fish Creek Range, Nevada.

Sample: SS25

Location: South flank of Willow Ck., 2,350 ft. E of SW cor. of section 19, T14N, R52E.

indet. dalmanellid sp.
indet. bilobed chonetid sp. with entral sulcus
indet. chonetid sp.
indet. productid sp.
long, straight spines, detached, parallel
indet. gastropod sp.
Streptognathodus sp.
indet. conodont sp.

Age: Probably lower Permian, based on the conodonts.

Sample: SS26

Location: Approx. 858 ft. N, 1,584 ft. W of SE cor. of sec 19, T14N, R52E, Elev. 6,920 ft.

Dvorakia klapperi
indet. ramiform elements

Age: Lower-Middle Devonian.

Sample: SS27

Location: Approx. 924 ft. N, 924 ft. W of SE cor of sec 19, T14N, R52E, Elev. 9,860 ft.

Palmatolepis minuta?
Pa. sp. indet.
cf. "*Nothognathella*" *sublaevis*
Polygnathus sp. indet.

Age: Lower Famennian.

Sample: SS57

Location: Located in non-surveyed area, 132 ft. N, 9,636 ft. E of NE cor. of sec. 1, T14N, R51E, Elev. 6,860 ft.

Tortodus k. kockelianus
P. trigonicus
P. parawebbi
P. l. linguiformis gamma morph.
P. pseudofoliatus
P. angustipennatus
Ozarkodina raaschi
Belodella sp.
Dvorakia klapperi
Neopanderodus sp.

Age: *kockelianus* Zone.

Sample: SS58

Location: Approx. 1,716 ft. S, 1,980 ft. W of NW cor. of sec. 19, T14N, R52E, Elev. 6,890 ft.

Polygnathus sp. indet.
indet. ramiform elements

Age: probably Middle Devonian.

Sample: SS60

Location: Approx. 1,056 ft. S, 924 ft. W of NE cor. of sec. 19, T14N, R52E, Elev. 6,940 ft.

Palmatolepis gigas
Pa. linguiformis?
Pa. elegantula Wang & Ziegler
Pa. spp. indet.
Ancyrodella nodosa
Polygnathus lodinensis Polsler
P. brevis Group
P. alatus
P. spp. indet.
Ozarkodina sp.
Pelekysgnathus sp.
Belodella sp.

Age: Upper or Uppermost gigas Zone.

Sample: SS61

Location: Approx. 1,558 ft. S, 1,320 ft. W of NE cor. of sec. 19, T14N, R52E, Elev. 6,960 ft.

Polygnathus sp. indet.
Indet. ramiform & platform fragments

Age: Middle-Upper Devonian.

Sample: SS65

Location: Approx. 198 ft. N, 1,122 ft. W of SE cor. of sec. 18, T14N, R52E, Elev. 6,960 ft.

P. l. linguiformis gamma morph.
P. x. xylus
P. sp. indet.
I. obliquimarginatus?
I. sp. indet.
O. brevis
Belodella sp.

Age: varcus Zone.

Sample: SS82

Location: Located in non-surveyed area, 4,092 ft. N, 10,692 ft. E of NE cor. of sec. 1, T14N, R51E, Elev. 6,920 ft.

Polygnathus _pseudofoliatus_
_P._ _angusticostatus?_
_P._ sp. indet.
_P._ _varcus_ Group (juveniles)
Icriodus sp.indet.
Ozarkodina sp.

Age: _ensensis_ Zone - Middle _varcus_ Subzone.

Sample: SS89

Location: Approx. 726 ft. W of NE cor. of sec. 5, T14N, R52E, Elev. 6,840 ft.

Polygnathus _cristatus_
_P._ _dubius_
_P._ _pennatus_
_P._ _alatus_
_P._ _webbi_
_P._ _collieri_
_P._ _dengleri?_
_O._ _sannemanni_
_I._ sp.

Age: _disparilis_ Zone (lower part).

Sample: SS124

Location: Located in non-sureveyed area, 12,144 ft. E, 7,788 ft. N of NE cor. of sec. 1 in T14N, R52E, Elev. 6,720 ft.

Ozarkodina _excavata_ _excavata_
(_Pa._ element + 2 fragments of ramiform elements)
Panderodus sp.

Age: Probably Silurian (Wenlockian - Pridolian); maximum range = Wenlockian - Lower Devonian.

Sample: SS125

Location: Approx. 2,310 ft. N, 1,914 ft. E of SW cor. of sec. 19, T14N, R52E, Elev. 6,840 ft.

Belodella sp.
indet. ramiform elements

Age: Probably Silurian - Lower Devonian.

Sample: SS126

Location: Approx. 1,122 ft. N, 1,386 ft. E of SW cor. of sec. 19, T14N, R52E, Elev. 6,900 ft.

Polygnathus parawebbi
Belodella sp.

Age: *australis* Zone - Lower *varcus* Subzone.

Sample: SS127

Location: Approx. 1,320 ft. S, 2,240 ft. W of NE cor. of sec. 30, T14N, R52E, Elev. 6,900 ft.

P. parawebbi
Pb element of *O. brevis* or *O. raaschi*
indet. ramiforms

Age: *australis* Zone - Lower *varcus* Subzone.

Sample: SS 132

Location: Approx. 264 ft. S, 1,056 ft. W of NE cor. of sec. 19, T14N, R52E, Elev. 6,960 ft.

Tortodus k. kockelianus
P. parawebbi
P. l. linguiformis morph. indet.
Belodella sp.
Panderodus sp.

Age: *kockelianus* Zone.

Sample: KV 64-5 of C. W. Merriam 7/20/64

Location: Hills east of Willow Creek Ranch, south end, sec. 19, T14N, R52E.

Ancyrodella rotundiloba (early form)
Ancyrodella rotundiloba (form indet.)
P. dubius
P. pennatus
P. alatus
P. webbi
P. collieri
P. dengleri
O. sannemanni
I. sp.
Schizophoria sp.
Ladogioides cf. pax
Radiatrypa sp.
Athyris sp.
Ambocoelia sp.
Ladjia? sp.
Tecnocyrtina? sp.
"Favosites"

Note: *Tecnocyrtina* fauna

Age: Lower *asymmetricus* Zone.

Sample: KV 66-26 of C. W. Merriam 7/20/64

Location: Hills east of Willow Creek Ranch south end, sec. 19, T14N, R52E.

Polygnathus norrisi
P. dubius
P. incompletus?
P. cf. *ordinatus*
Pandorinellina insita (multidenticulate)
Belodella sp.

Age: Lowermost *asymmetricus* Zone.