Text to accompany Nevada Bureau of Mines and Geology Map 160

Geologic Map of the Central Butte Range, White Pine County, Nevada

by Bruce R. Otto

The Butte Range lies in the western part of White Pine County, Nevada. Sides (1966) first mapped the central part of the range. Hose and Blake (1976) incorporated Sides' mapping in their compilation of White Pine County geology. The author completed the mapping presented herein in 1995 as part of a regional exploration program, and thanks Placer Dome Exploration, Inc. for permission to publish this work. The map includes the southern half of the Cabin Springs Quadrangle, all of the McBrides Sheep Well Quadrangle, and the northern quarter of the Dickinson Well Quadrangle.

STRATIGRAPHY

Strata exposed in the Butte Range define a regional north-trending synclinorium. The lowest exposed strata consist of clastic sediments of the Diamond Peak Formation. Upper Paleozoic carbonates from the Ely Limestone through the Arcturus Formation form most of the range. No Mesozoic strata occur in the mapped area. Intermittently distributed Tertiary-age clastic sediments and volcanic rocks overlie the Paleozoic section unconformably. The following description of map units progresses downward from the top of the section.

Quaternary

Alluvial deposits undifferentiated (Qal)
Unconsolidated valley-filling gravel, playa-lake deposits, and dry-drainage-filling gravels form this unit. It includes talus aprons and alluvial fan deposits along the western range front.

Tertiary

Mafic lavas (Tb)
Basaltic lavas occur in the northern part of the map area in a relict west-northwest-trending graben. The lavas are probably part of a regional sequence dated at 39 Ma (C. Nutt, personal commun.). The sequence is one of the youngest rock units in the mapped area, and has a minimum thickness of 500 m. The lavas lie above a thin sequence of unlithified stream gravels and unconformably on the Arcturus Formation.

The prominently exposed, cliff-forming basalt lavas lie unconformably on Paleozoic lithologies and disconformably on gravels of unit Tg. The groundmass is microcrystalline to glassy, and where present, euhedral plagioclase laths up to 1 cm long and subordinate subhedral to euhedral pyroxene comprise the phenocryst population. The unit is brown to reddish brown on weathered surfaces and dark charcoal gray to black on fresh surfaces.

Silicic vent (Tr)
A 200-m-long and 50-m-wide silicic rhyolite vent or subvolcanic feeder pipe occurs in the southwestern corner of Section 24, T22N, R59E, along a prominent west-northwest-trending normal fault. The elliptical planimetric shape elongate along this fault indicates that this occurrence may be Eocene or younger because this fault also controls the distribution of 39-Ma mafic lavas and subjacent gravels. The age relationship with the mafic lava flows of unit Tb is unknown.

Recessive-weathering rocks that do not crop out form the vent. They develop anomalously white clay-rich soil that includes angular fragments of altered Paleozoic rocks. The unit consists of a groundmass of rock flour, shattered euhedral quartz crystals and subordinate broken biotite euhedra. The exposed part of the vent crosscuts adjacent strata; if an effusive carapace was originally present, erosion has removed it.

Unlithified Tertiary sediments (Tg)
A thin sequence of poorly exposed, unconsolidated stream gravels underlies the basaltic lavas of unit Tb. They are restricted to the same graben as the lavas, and have a limited distribution, suggesting that they were restricted to a channel within the graben. The clasts in the gravels were derived from local Paleozoic strata and are restricted to a small part of the relict west-northwest-trending graben in Section 19, T22N, R60E. Similar gravel occurrences mapped in the south were correlated with the northern occurrences based on lithologic similarity.

The unit includes recessive, unconsolidated fluvial and colluvial accumulations of gravel derived dominantly from a local Paleozoic source terrain. It is Eocene or older because it occurs below 39-Ma mafic lava flows (date from C. Nutt, personal commun.). Where fluvial, the sediments include locally derived lithologies that range from sand fraction to moderately well rounded 0.5-m clasts. Most of the clasts are in the size range of 20 to 30 cm. The colluvial gravels are derived from the same source terrain; they are unsorted, poorly rounded, and form

plateaus of fanglomerate that can be distinguished from presently forming Quaternary fanglomerate by their deeply dissected geomorphic signature and their stratigraphic position relative to the lavas.

Paleozoic Strata

Hose and Blake (1976) correlated the Paleozoic strata exposed in the Butte Range with the Diamond Peak, Ely, Rib Hill, and Arcturus formations and the Park City group. My mapping confirms these correlations and subdivides the Ely, Rib Hill, and Arcturus formations into local, informal lithostratigraphic facies. I have included much of what they called Rib Hill in the Arcturus Formation, and have subdivided the Arcturus into five informal lithostratigraphic members. This was done because these strata formed within a single progradational carbonate platform-reef complex that rests in part on a post-Ely erosional surface. I have correlated their undivided Park City Group strata with my upper member of the Arcturus Formation because of the continuity of depositional environments with underlying strata.

Arcturus Formation (Pa)

I have subdivided the Arcturus Formation into five lithotypes. These included a basal clastic transitional unit (Pat_1), a platform carbonate sequence unit (Pap), an upper transitional unit (Pat_2), a shallow-slope fore-reef turbidite sequence unit (Paf), and a reef complex (unit Par). Hose and Blake (1976) mapped the lower transitional strata of unit Pat_1 as part of the Rib Hill Sandstone. The platform sequence and overlying strata (units Pap, Pat_2, and Paf) were recognized as the Arcturus Formation (Plate 1 from Hose and Blake, 1976). I have maintained this correlation, but have subdivided the units based on variations in composition, bedding thickness, bedforms, fossil content, and depositional enviroment. Units Pat_2 and Paf possibly correlate with the Kaibab and Plympton Formations of the Park City Group, and unit Par may correlate with the Gerster Formation. I have chosen not to make these correlations because these strata are lithologically different from published descriptions of the Park City Group, they have different fossil populations, they represent different depositional environments, and they fit nicely into the depositional framework represented by the Arcturus exposed in the Butte Range.

***Reef facies* (Par)**

The highest exposed Paleozoic unit in the map area is a thick accumulation of fossiliferous limestone that is restricted to the southern and central part of the map area. Hose and Blake (1976) mapped this unit as Park City Group. I have mapped these strata as the upper member of the Arcturus Formation, however, based on the presence of abundant spirifer brachiopods and elongate chert nodules; they may correlate regionally with the Gerster Formation, the uppermost formation of the Park City Group. The unit probably formed in a restricted carbonate shelf environment with local reef buildups. It occurs in the cores of synclinal folds and is everywhere allochthonous because of fold-induced bedding-plane slippage along reverse faults (discussed in structure section). Platform carbonates of unit Pap, calcarenites of Pat_1, and thin-bedded limestone of unit Paf structurally underlie this unit.

The Arcturus reef strata occur throughout the southern part of the mapped area in the Dickinson Well Quadrangle, and at higher elevations in the southern half of the McBrides Sheep Well Quadrangle, primarily in the cores of synclines. Cliff-forming bioclastic limestone composes the unit. Bedding is generally massive with internal 1- to 5-cm-thick depositional units that are lenticular and undulatory. The fossil component is commonly greater than 30%, and includes abundant and pervasive brachiopods, crinoids, gastropods, and sponges(?) that act as a framework for micritic mud. The sponge-like biotas are 2 to 3 cm in diameter, approximately 10 to 20 cm long, and locally contain hollow centers. They commonly branch into two tubes in an up section direction. They occur both in a growth position normal to bedding, and parallel to bedding. Local accumulations of colony corals and bryozoans also occur but are not common. Locally abundant crinoid stem fragments range up to 2 cm in diameter. None of the fossils show preferential orientations from current reworking. The unit typically weathers cream, buff or tan on weathered surfaces and is cream, tan, or light gray on fresh surfaces. It comprises the highest Paleozoic strata exposed in the area so its total thickness is not known because of erosion; its minimum thickness is 1200 m.

***Fore-reef facies* (Paf)**

The fore-reef facies is restricted to the central and northern parts of the map area. Regional thickness variations are not known because the top of the unit throughout the map area is tectonic. Because it does not occur in the south, I assume that it thickens from south to north, similar to other Arcturus strata. The lateral and vertical facies distribution of adjacent strata suggests that unit Paf formed in a seaward albeit distal setting relative to the Arcturus reef facies. The internal lithologic character is homogeneous throughout its distribution; it consists of low-energy, thin-bedded limestone and calcarenite. Bedding is generally planar but locally includes starved current ripples. Where measured, these ripples show a consistent flow direction from south to north. These current and bedding data indicate deposition on a low-angle slope starved of significant clastic material in a sub-wave base environment.

The Paf facies represents a fore-reef environment that progresses from proximal in the south to distal in the north. In southerly exposures, the fossils occur in thin mud-matrix debris flows separated by nonfossiliferous, thin planar-bedded limestone and calcarenite. Fossils with elongated shells (straight-shelled nautiloid - *Michelinoceroida*) are consistently oriented into a N10–20ºE flow direction, and the unit includes local thick accumulations of gastropod coquina. To the north the same

fossil assemblage occurs in the same lithotype, but are not restricted to debris flows; they are randomly oriented and occur evenly disseminated in the strata. Their more evenly disseminated occurrence and lack of current-parallel orientation suggest that the northerly exposures represent the depocenter of the debris flows in a distal and flatter sub-wave base environment. This change takes place somewhere in the vicinity of Sections 1 and 2, T22N, R59E.

The sub-wave base environment indicated by the fore-reef strata of Paf shows that an extensional tectonic event occurred that was large enough to lower the underlying intratidal platform carbonates of Pap to a sub-wave base environment in a short period of time. The transitional unit, Pat_2 may record the onset of this tectonic event.

This recessive unit of laminated to thin-bedded calcarenite and sandy limestone occurs extensively throughout the central and northern parts of the map area but does not occur in the south, where unit Par lies depositionally above unit Pap. It consists of 1 to 3 cm thick beds with laminated mud parting surfaces. Beds are generally planar but locally include unidirectional asymmetric current ripples. Strongly current-oriented straight-shelled nautiloids occur in southerly exposures but are randomly oriented to the north. The clastic component comprises well-rounded terrigenous, carbonate-cemented quartz sand with a grain size of 80 to 120 microns.

The basal part of this unit contains a distinctive biological population that I used to identify the unit throughout the map area. It contains well preserved pseudoplanispiral gastropods (*Amphiscapha*?), orthostrophic type conispiral gastropods (*Murchisonia*?), straight-shelled nautiloids (*Michelinoceroidia*?), ammonoids (*Goniatites*?), and brachiopods. In southerly exposures they occur as localized thin bioclastic debris flows scattered intermittently through a thin-bedded to laminated limestone sequence; to the north they occur at the same lithostratigraphic level but are more evenly scattered through laminated and thin-bedded lime mud.

The unit weathers to medium, light-brown or yellowish brown, and is medium brown to light gray on fresh surfaces. It has a minimum thickness of 500 m. The last occurrence of massive micrite beds of unit Pap defines the unit's gradational base. The top is everywhere tectonic; altered limestone of unit Pap occurs as moderate-displacement thrust sheets that terminate the top of the unit.

***Upper transitional facies* (Pat_2)**

The upper transitional facies, similar in lithologic character and depositional environment to the lower transitional facies (Pat_1), occurs in the northern part of the map area. These northerly exposures show a change in depositional environment from underlying intratidal platform carbonates of unit Pap to overlying sub-wave base strata of unit Paf. In the south, Pat_2 is absent and the reef facies (Par) lies in depositional continuum with the platform carbonates of unit Pap. This suggests that a greater amount of tectonically induced basin subsidence occurred in the north relative to the south.

Unit Pat_2 occurs only in the northern part of the map area and, where present, is not everywhere mapped as a distinct facies due to a lack of adequate exposure. Where not separately mapped it is included as the basal part of unit Paf. Lithologies intermediate between the fore-reef facies (Paf) and the platform facies (Pap) compose this moderately recessive unit. Carbonate-cemented quartz sandstone, bioclastic limestone, and massive micrite form the primary lithologies. Local massive micrite beds stand out in strong relief while the calcarenite forms recessive subcrop. The unit progresses upward from medium to thick beds of massive micrite separated by thin-bedded sandy partings at the base progressively to thin-bedded calcarenite.

The unit typically does not contain fossils except local accumulations of crinoid stem fragments. Its color is variable: the massive micrite beds are light to medium gray on fresh and weathered surfaces while the calcarenite is generally pastel brown to light tan on weathered surfaces and medium to light gray-brown on fresh surfaces. The sharp lower contact is based on the first occurrence of calcarenite beds between massive micrite beds. The upper contact is gradational over 30 to 50 m and based on the last occurrence of massive micrite beds. Thickness of the unit ranges from 0 (non-deposition) to approximately 100 m.

***Platform facies* (Pap)**

The platform carbonate facies occurs throughout the map area. It displays laterally extensive, amalgamated, medium- to thick-bedded carbonate. Northerly exposures of this generally lithologically homogeneous unit have a greater amount of interbedded calcareous sand.

Local accumulations of pebble conglomerates occur in the upper portion of the unit in the central and southern part of the map area. Hose and Blake (1976) mapped these conglomerates as part of the Triassic section. The conglomerates form thin to medium planar beds that are typically reverse graded. The clasts are mostly chert and quartzite and are in carbonate-matrix support. These textural features suggest a subaqueous environment of deposition, probably from storm-generated turbidites. Their stratigraphic position and this depositional environment indicate that the conglomerates represent a proximal (nearer shore) equivalent of the transitional unit Pat_2.

The platform carbonates of unit Pap have a highly variable thickness. Regionally the unit displays a four-fold increase in thickness from south to north. In the South, the platform carbonates lie conformably above the Rib Hill Sandstone and, in one area, disconformably on the Ely Limestone. Northerly exposures lie conformably above a thick accumulation of the Pat_1 transitional strata.

The depositional pattern displayed by thickness changes and facies distributions of this unit indicate an unprotected high-energy carbonate shelf environment that

prograded from south to north. This facies represents a period of relative tectonic stability during which the shelf passively subsided, causing the systematic thickness change.

The unit occurs throughout the map area but is best exposed in the middle to northern part. The cliff-forming unit of medium- to thick-bedded or massive micrite generally shows no bed forms. It locally includes concentrations of 200–300 micron quartz sand grains floating in a carbonate matrix, but is otherwise strictly micrite or a recrystallized equivalent. The upper half of the unit contains local accumulations of graded, thin- to medium-bedded carbonate-matrix, conglomeratic turbidites. Clasts in the conglomerates are composed mostly of well-rounded quartzite and chert that range up to 2 cm in diameter. Much of the original rock texture is destroyed by partial to total dolomitization. The dolomitic parts of the unit form highly resistant, white to light-gray outcrops. Due to masking by later epigenetic silicification, the distribution of dolomite recrystallization was not mapped.

The unit contains a sparse and highly fragmented fossil population that locally includes fusilinids, brachiopods, and crinoid stems. The fusilinids are generally restricted to near the top of the unit. It ranges from light gray to near white. The base of the unit is sharp, defined by the last occurrence of Rib Hill-type sands. The upper contact is defined by the first occurrence of calcarenite of Pat_2 or where absent, fine-grained calcarenites of Paf. The unit is everywhere present in the area mapped and ranges from 200 m to over 500 m thick.

It lies conformably on the Rib Hill Sandstone or the transitional facies of Pat_1; locally it interfingers with the Pat_1 transitional unit. Where Pr and Pat_1 are not present, Pap lies disconformably on the Ely Limestone and is separated by a 20- to 30-m-thick intraformational breccia.

***Lower transitional facies* (Pat_1)**

The transitional facies of unit Pat_1 represents a different depositional environment than that of the Rib Hill Sandstone. I have defined the base of the Pat_1 section by the first occurrence of bioclastic crinoidal limestone beds that form much of the section. The supratidal and intratidal environments represented by Rib Hill strata give way to a slope-deposited subtidal environment during deposition of Pat_1, suggesting that the area subsided during deposition of the upper part of the Rib Hill sands. This newly formed subtidal environment represents the inception of an Arcturus slope-platform-reef complex. The Pat_1 section thickens rapidly from south to north, suggesting that the depositional system formed in a tectonically active environment. The distribution of the Pat_1 facies indicates a structural control of the basin by west-northwest-trending, north-side-down normal faults. I have inferred two such fault systems based on thickness and facies changes; one tracks through Sections 2, 3, 4, 9, 10 and 11, T21N, R59E, the other through Sections 1, 2, 11 and 12, T22N, R59E. Both locations include faults with Tertiary north-side-down offset.

The unit occurs in abundance in the northern third of the McBrides Sheep Well Quadrangle and to the north; it thins to the south. Thin- to medium-bedded calcarenite, carbonate-cemented fine-grained quartz sandstone, and thin-bedded to laminated limestone form this recessive unit with lithologies similar to unit Pat_2. It contains locally extensive accumulations of crinoidal limestone. Where present, the crinoids form over 80% of the rock; individual stem fragments range in diameter to over 3 cm, which make it distinct from other crinoidal limestones in the section.

The unit generally weathers light brown to yellow and is medium-brown to medium-gray on fresh surfaces. The crinoidal limestone is typically light gray on both weathered and fresh surfaces. Thicknesses range from 0 to more than 600 m. Its base is gradational with and commonly indistinguishable from the underlying Rib Hill Sandstone; the top contact is sharp with the overlying unit Pap. I included it in the Arcturus Formation because much of the thicker parts of unit Pat_1 show lateral facies transitions into the thick-bedded carbonates of Pap.

Rib Hill Sandstone (Pr)

The Rib Hill Sandstone occurs intermittently throughout the map area but generally thickens and is more abundant to the north. The erratic distribution of the unit indicates syndepositional faulting that locally exposed underlying strata to erosion. The great variations in thickness of the underlying Ely Limestone also suggest that the Rib Hill sands represent a significant period of erosion. The unit represents a high-energy, supratidal to intratidal environment of deposition with a significant component of terrigenous quartz sand. Beach and eolian processes probably influenced the Rib Hill sands. Interpreted this way, non-deposition of Rib Hill sands accurately shows regions that were subaerially exposed during upper-Ely to pre-Arcturus time, and helps explain the great variations in Ely Limestone thickness. One such area occurs in Sections 21 and 28, T21N R59E, where rocks of the Arcturus platform facies lie disconformably on Ely Limestone with no intervening sands.

The map definition between the Rib Hill Sandstone and unit Pat_1 is problematic because the two have similar lithologies and they commonly occur together. The Rib Hill Sandstone occurs either below the Pap facies without intervening Pat_1 strata or underneath Pat_1. Where both the Rib Hill and Pat_1 are present, strata of Pat_1 occur as a vertical continuation of the Rib Hill Sandstone and as a lateral facies of Pap. This relationship demonstrates that the Pat_1 unit is part of the Arcturus depositional system, whereas the Rib Hill may not be. Both lithotypes include fine-grained calcarenite, but Pat_1 also includes significant accumulations of strongly bioclastic crinoidal limestone. Where possible I have distinguished the two based on the presence or absence of the bioclastic beds. Where indistinguishable the upper part of the Rib Hill Sandstone may represent the basal part of Pat_1, or vice versa.

Rounded, 80- to 120-micrometer quartz sand grains form the recessive, thin- to medium-bedded, calcite-cemented sandstone of the Rib Hill Sandstone. The unit consists of amalgamated beds that are generally massive but locally show internal planar laminations and asymmetric current ripples. Fossils are generally absent, though some locations in the northern part of the McBrides Sheep Well Quadrangle contain basal crinoidal limestone, which causes difficulty in separating this unit from Pat_1.

Weathered surfaces show colors that vary between hematitic red, yellow ochre, and pastel brown; it is medium brown to brown gray on fresh surfaces. Where present, the unit lies disconformably above the Ely Limestone with a sharp basal contact. The top contact is sharp where overlain by unit Pap, but gradational where overlain by unit Pat_1. I used the first occurrence of bioclastic limestone beds to define the overlying base of unit Pat_1. Thicknesses vary from non-deposition to ±100 m. The large thickness described by Hose and Blake (1976) was derived from their inclusion of my Pat_1 unit into their Rib Hill Sandstone.

Ely Limestone (lPe)

The Ely Limestone occurs along much of the western flank of the Butte Range. I broke the unit into two litho-stratigraphic units, a platform facies (lPep) and a reef facies (lPer). The subdivision is based on the presence and mode of occurrence of fossils and on bedding characteristics.

***Platform facies* (lPep)**

Throughout most of its extent the platform facies is a monotonous sequence of medium- to thick-planar-bedded micrite. It has a variable thickness due in part to post-Ely erosion. The fossil population is limited to a few percent of the rock and includes highly fragmented crinoids with subordinate brachiopods and fusilinids. The fragmented nature of the fossil population and the bedding characteristics suggest a high-energy unrestricted shelf environment.

Platform-faces strata of the Ely occur throughout the map area. Bold, outcrop-forming, medium to thick, planar-bedded micritic limestone forms a distinctive ledge-and-slope topography. The generally thick to amalgamated micrite beds do not show sedimentary textures except for local planar laminations. It contains abundant and distinctive concentrations of bedding parallel chert. The chert generally displays irregular and diffuse upper and lower margins. Individual chert beds are on average 2–5 cm thick and represent up to 30% of most outcrops. I used the presence of significant chert to distinguish this unit from the platform carbonates of unit Pap.

The unit contains a sparse fossil population of highly fragmented crinoid stems, brachiopods, and locally, corals and fusilinids. The unit weathers to medium to light gray on weathered surfaces and is medium gray to locally dark gray on fresh surfaces. The units lower contact grades downward to the Diamond Peak Formation over less than 10 m. Rib Hill sands or the platform facies of the Arcturus Formation (Pap) occur sharply above the erosional upper contact. An intraformational breccia occurs within the Ely where the Rib Hill Sandstone is not present. Thickness of the unit varies greatly from 300 m to more than 800 m.

***Reef facies* (lPer)**

A reef facies of the Ely Limestone occurs in Sections 25, 26, 27, 34 and 35, T22N, R59E. The interpretation as a reef is based on up to 30% fossils, many of which occur in their growth position, in massive cliff-forming beds. The fossils include crinoids, brachiopods, framework corals, bryozoans, and sponges. The reef facies grades rapidly south along strike to the planar beds of the platform facies. The transitional zone between the two facies shows a marked thickness change; the reef facies has a minimum thickness of 800 m. Immediately south (±1 km), the platform carbonates have a thickness of less than 300 m. Two explanations could account for the thickness variation; it could be original, or it could be due to unidentified structures. There are no recognized faults cutting the intervening strata that can explain the variation (see Sections 3 and 4, T21N, R59E and Section 34, T22N, R59E). The former is most plausible as both the upper and lower contacts of both facies are exposed and faults, if present, should be visible because the section is well exposed. The thinned part of the platform sequence is overlain by a thick sequence of Pat_1, indicating that the area may have been subject to extensive erosion during Rib Hill time.

The occurrence of the reef facies is restricted to the northern part of the McBrides Sheep Well Quadrangle. It is a bold, cliff-forming unit lithologically similar in most respects to the platform facies. Differences include a greater diversity and abundance of fossils, and significantly greater bed thicknesses. The fossils, some of which are in their growth position, include an abundance of brachiopods, bryozoans, corals, sponges(?), and crinoids. The lower contact with the Diamond Peak Formation is gradational over less than 10 m; transitional facies of unit Pat_1 lies above the sharp upper contact. Thickness of the unit is at least 800 m.

Diamond Peak Formation (Mdp)

Strata of the Diamond Peak Formation are exposed in foothills along both sides of Long Valley. The formation contains a sand- and silt-dominant facies and a conglomerate-dominant facies. The base of the unit is unexposed; the top is gradational over 10 m or less to the Ely Limestone. The gradation is marked by a systematic upward increase in strongly cross-bedded and resedimented clastic carbonate beds within siliciclastic detrital beds, thence to primary carbonate beds of the Ely.

Sandstone and siltstone beds dominate the sand facies, but the unit locally includes conglomerate lenses. This facies is composed of amalgamated medium- to thick-bedded planar sandstone and interbedded siltstone. It

commonly displays cross beds and asymmetric current ripples. Measurements of bed forms such as ripple marks and flute casts demonstrate a current-flow direction generally to the southwest.

The conglomerate facies is composed of channelized lenses of quartzite- and chert-pebble conglomerate. Individual lenses range up to 1 km in length and tens of meters thick. The Lenses are commonly stacked and amalgamated. Depositional units within the lenses show reverse and bidirectional grading. In the bidirectional graded depositional units the conglomeratic base shows clast support of all cobbles. The cobble-rich base grades systematically upward to a planar-bedded sandy interior, thence to a conglomeratic top. The top conglomerate is different from the base in that it shows sand support of cobbles. These textures and unit morphologies indicate deposition from subaqueous channeled, high-clast-concentration turbidites. Their overall geometry suggests a generally east-west elongation.

The sand facies is generally more recessive than the conglomerate facies but both stand out locally with good outcrop. The sand consists of medium- to coarse-grained quartz with local pebbles of quartzite, chert, and locally, fossilized wood fragments. Asymmetric current ripples are the dominant bedform where present, but most of the unit is planar laminated. Several measurements of current ripples indicate a transport direction of southwest.

The conglomerate facies consists of well-rounded pebble to cobble size quartzite and chert fragments in a fine-grained sand to mud matrix. The conglomerate occurs as lenses within finer grained material and as amalgamated beds. Most depositional units show either reverse or bidirectional grading.

STRUCTURE

Upper Paleozoic Structure

Abrupt thickness changes, vertical sedimentation patterns, and facies distributions suggest that syndepositional structure may have influenced deposition of upper Paleozoic strata in the Butte Range. The facies tracks of these strata indicate a West-northwest trending structural control. The facies changes mapped in the Ely, Rib Hill, and Arcturus formations indicate extensional tectonism that continually deepened the basin within which shallow sedimentation kept pace. The vertically stacked facies transitions define the presence of two north-deepening depositional margins.

Southern depositional margin

The oldest, largest, and southernmost of these margins is located in the northern half of the McBrides Sheep Well Quadrangle. It is a broad and diffuse zone covering a south to north distance of approximately 6 km. The margin is first expressed in the Ely Limestone, between the platform carbonate facies (lPep) and the reef facies (lPer). This abrupt and localized transition shows a nearly three-fold increase in thickness (300 to 800 m) from the platform facies (lPep) in the south to the reef facies (lPer) in the north. Though constructional development of the reef facies probably explains the increased thickness, coeval subsidence likely provided the depositional framework. Mapped faults in this area generally trend west-northwest, and may follow the original depositional structural axis.

Other facies transitions in the Rib Hill and Arcturus formations demonstrate the presence of this margin as well. South of the margin, the Rib Hill Sandstone occurs between the Ely and the platform facies of the Arcturus without intervening Pat_1 transitional lithologies. Transitional strata of Pat_1 increase from non-deposition to over 1000 m thickness in less than 2 strike km from south to north. Across this margin at higher stratigraphic levels, the Arcturus platform facies increases from 300 m to nearly 1000 m, the Pat_2 facies increases from non-deposition to 100 m, and the fore-reef facies increases from non-deposition to over 500 m. A northward-thickening accumulation of channeled calcareous sandstone occurs between the upper part of the Arcturus platform strata (Pap) and the lower part of the overlying Pat_2 unit in Section 23, T22N, R59E. These facies changes occur across a N65˚W-trending fault that also controls the distribution of Tertiary lavas and a rhyolitic vent, demonstrating intermittently continuous activity through time on the west-northwest structures. The Arcturus reef facies is restricted to the area south of the margin, above “Ely Island,” a term I coined to define an area in Sections 21 and 28, T21N, R59E in which an unconformity occurs between the Ely and the Arcturus formations. The Rib Hill Sandstone flanks the island, and shows that the Ely Limestone was subaerially exposed and eroded in Rib Hill (post-Ely – pre-Arcturus) time. The Arcturus reef may have been restricted to this positive area because of greater water depths to the north. The combined facies and thickness changes across the north margin suggest a total subsidence of at least 2800 m during deposition of the Ely, Rib Hill, and Arcturus formations.

Northern depositional margin

The northern margin is located in the south central part of the Cabin Springs Quadrangle, 5 km north of the southern margin. Thickened transitional strata of unit Pat_1 and thinned transitional strata of unit Pat_2 define the margin. Older strata that may aid in defining this margin are not exposed. A west-northwest-trending normal fault bisects the facies transitions and may proxy for the original structural control on deposition of these facies.

Thinning of unit Pat_2 from south to north in Sections 23, 13 and 12, T22N R59E, suggests that this area may have been a depocenter perched between the two sedimentary margins. Randomly oriented fossils in the overlying fore-reef strata of unit Paf indicate deposition on a flat surface rather than a slope as oriented fossils indicate in strata to the south.

Folds

Regional folds

Strata in the Butte Range form a regional-scale north-trending synclinorium. This regional feature has a wavelength over 20 km and amplitude over 4 km. The distribution of Ely and Arcturus strata and regional bedding dips define the "Butte" synclinorium. Strata along the western flank of the Butte Range dip an average of 30ºE and equivalent strata on the eastern flank dip similarly west; strata of the Arcturus Formation occupy the interior of the structure. The axis of the synclinorium is horizontal through most of its length, and strikes generally north-south. In the area of the southern depositional margin the axis of the syncline plunges approximately 20ºS. In this area there are a series of secondary thrust faults, described below, that cut Ely and Arcturus strata.

Map-scale folds

Parasitically folded Arcturus strata in the interior of the synclinorium define a structural style visible at a 1:24,000 scale. The chevron style internal folds generally show a flexural slip to brittle style of deformation. They have amplitudes of 500 to 1000 m and wavelengths of 1500 to 2000 m. The limbs typically dip 20 to 30º, and the axial planes, where not vertical, verge slightly east. These geometries define relatively open folds that have intra-limb angles greater than 120º. The folds are locally disharmonic and much tighter, particularly in the areas of facies transitions. In these areas the section displays well-developed axial-planar spaced cleavage and local stratigraphic overturning.

Faults

Thrust faults and faulted disharmonic folds

Major structures in the Butte Range display a unique style that formed by a combination of folding and coeval reverse faulting. The folds are locally very tight, boxy and disharmonic, particularly within the areas of significant facies changes. Where this occurs, reverse faulting within fold interiors dominates the structural fabric. The generally bedding-parallel thrust faults have a curviplanar shape that conforms to the shape of the syncline. The faults display bi-directional dips; those on the west side of folds dip east and those on the east side dip west. The opposing limbs of fault surfaces connect across the fold axes forming a helicoidal surface. The dips of the west and east segments shallow into the keel of the fold and merge into one structure that completely encloses the allochthonous hanging-wall block. The axis of the faults parallels the axis of the synclines. The faults show reverse movement in a direction normal to stratigraphic strike. Strata in the hanging wall to the faults on the on the west side were displaced upward to the west, and correlative strata on the east side were displaced upward to the east.

Several of these folds with detached interiors occur in the southern part of the McBrides Sheep Well and the northern part of the Dickinson Well Quadrangles. They displace rocks of the Arcturus platform (Pap) and reef (Par) facies up both east and west, over younger rocks of the fore-reef facies (Paf). The level of erosion in the northern-most of these occurrences is deep enough to expose the axis of the allochthonous fold interior. This relationship is exposed in discontinuous but good outcrop in the center of section 14, T21N, R59E, where the entire curviplanar fault surface apexes. This relationship shows that the faults are isolated within the core of the regional syncline and not rooted into a larger, regional thrust fault at depth.

Simultaneous folding and reverse faulting probably formed from flexural slip on a grand scale that resulted from a lack of room within the core of the developing syncline. The faults allow the axial part of the fold to migrate up and out of the interior after the compressional strength of the rock has been exceeded and brittle deformation becomes dominant (see cross sections). The vertical distribution of this deformational style defines a diffuse boundary between folding and brittle deformation. The total amount of displacement is not known, but a vertical transport distance of 1000 to 2000 m would explain the observed geometries. Rocks involved in this deformation typically show intense stratabound brecciation and alteration within hanging wall lithologies (described below). I have mapped similar structures in the White Pine Range, east of Illipah Reservoir.

Tertiary Structure

Normal faults

Three faults that show normal movement were mapped in the southern half of the Cabin Springs and the northern part of the McBrides Sheep Well Quadrangles. All cut through areas of major facies transitions and show north-side-down and/or left-slip strike displacement. This style of movement could have been created from true left-slip movement, dip-normal movement, or a combination of both. The faults control the distribution of 39-Ma(?) lavas, demonstrating a Tertiary age of movement. The present day topographic profile present along the crest of the Butte Range in a north-south section indicates that these faults control topography.

Alteration and Mineralization

Stratabound dolomitization

Pervasive stratabound dolomitization occurs within the platform carbonates of unit Pap. The texture-destructive dolomitization masks all primary bedforms in these strata. It is restricted to the platform facies that lie south of the southern depositional margin. The age of dolomitization is not constrained except that it is post-depositional and pre-silicification.

Stratabound silicification, recrystallization and bleaching

Silicified, recrystallized and strongly bleached rocks occur intermittently throughout the map area, and are formationally restricted to the platform facies of the Arcturus Formation. This type of alteration is superimposed on the dolomitized rocks and is spatially associated with the detached-interior fold and thrust fault system. The most intense silicification and pervasive bleaching generally occurs in the brecciated hanging walls of the larger-displacement thrust faults, and is strongest near the base of individual thrust sheets.

The quartz is generally chalcedonic and intricately bedding controlled, though crosscutting replacement veins are typically present. Where bedding controlled, the chalcedony follows bedding surfaces precisely; coarsely crystalline dolomite typically composes the intervening nonsilicified beds. The quartz, where discordant to bedding, always cuts the dolomite. Unaltered and unconsolidated Tertiary gravels occur as a channel filling sequence that cut into the altered carbonate strata. This brackets the silicification and bleaching to an age older than the overlying 39-Ma(?) Tertiary section.

Jasperoids

Locally developed jasperoid bodies occur in the Arcturus section. Unlike the formationally restricted chalcedony, the jasperoid cuts and generally destroys bedding and all bedding characteristics. It is spatially associated with west-northwest-trending normal faults and with the rhyolite vent breccia exposed in Section 24, T22N, R59E. The rhyolite is probably Eocene because of its association with west-northwest normal faults that control the distribution of the 39-Ma lavas. Although there are no empirical grounds to temporally dissociate the two types of silicification these spatial associations suggest that the jasperoid development is Eocene and the formationally restricted style of silicification is associated with the earlier (Laramide?) thrust faulting.

Annealed carbonate fault breccias

Healed fault breccias occur along faults of any style that cut the carbonate section. Strong bleaching, recrystallized textures, and a pervasive planar fabric at an angle to bedding define the breccias. Unlike most fault breccias, these recrystallized breccias commonly form outcrops and stand out in relief.

CONCLUSIONS

Mapped structures, facies transitions, thickness changes, and alteration patterns define two west-northwest-trending structural zones that have been active since at least Mississippian time. Faults that form the zone controlled the distribution of facies in all strata present during Pennsylvanian through Permian time. They formed a shelf-to-slope depositional environment into which the Ely and Arcturus formations were deposited. The margin has a long-axis trend that parallels west-northwest-trending Tertiary faults.

The west-northwest faults were active in the Mesozoic and (in part) controlled the style and distribution of Laramide compressional structures and related alteration systems. They also controlled the distribution of Tertiary volcanic and sedimentary strata, Tertiary silicic vents, and related alteration systems. Tertiary movement of the faults formed a west-northwest-trending graben that occurs as a dissected present-day topographic feature. The topographically lowest area within the Tertiary graben coincides with the late Paleozoic slope facies. Such a pervasive association of the many structural and stratigraphic elements through time suggests that the west-northwest fault system may be a deep-seated, through-going basement structural fabric.

REFERENCES

Hose, R.K. and Blake, M.C., 1976, Geology and mineral resources of White Pine County, Nevada: Nevada Bureau of Mines and Geology Bulletin 85, 113 p.

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GEOLOGIC MAP OF THE CENTRAL BUTTE RANGE, WHITE PINE COUNTY, NEVADA

Bruce R. Otto
2008

Qal **Alluvial deposits undifferentiated** Includes pediment talus aprons, gravel accumulations in dry washes and vegetated playa lake deposits.

VOLCANIC ROCKS

Tb **Mafic lavas (Tertiary)** Occurs only in the northern half of the map area in a relict west-northwest-trending graben. Well-exposed, cliff-forming basaltic lavas. Groundmass is microcrystalline to glassy. Euhedral plagioclase laths up to 1 cm long and subordinate subhedral to euhedral pyroxene comprise the phenocryst population. Brown to reddish brown on weathered surfaces, dark charcoal gray to black on fresh surfaces. Lies unconformably on Paleozoic rocks and disconformably on gravels of unit Tg. Represents the youngest unit in the mapped area; over 500 m thickness remains preserved.

Tr **Silicic vent (Tertiary)** Occurs only in the SW¼ Section 24, T22N, R59E. Recessive, non-outcropping unit consisting of angular fragments of altered Paleozoic rock in a groundmass of rock-flour, shattered euhedral quartz crystals and subordinate broken biotite euhedra. Forms anomalously white clay-rich soil. Vent is entirely crosscutting, and apparently did not develop an effusive carapace.

SEDIMENTARY ROCKS

Tg **Unlithified Tertiary sediments** Restricted to a small part of a relict west-northwest-trending graben in the northern part of the mapped area. Includes recessive, unconsolidated fluvial and colluvial accumulations of gravel derived dominantly from a local Paleozoic source terrain. The unit is Eocene or older because it occurs below 39-Ma mafic lava flows (date from C. Nutt, personal commun.). Where fluvial, sediments include locally derived lithologies that range from sand fraction to moderately well-rounded 0.5-m-diameter clasts. Most of the clasts are in the size range of 20 to 30 cm. The colluvial gravels are derived from the same source terrain; they are unsorted, non-rounded, and form plateaus of fanglomerate that can be distinguished from presently forming Quaternary fanglomerate by their deeply dissected geomorphic signature and their stratigraphic position below the lavas.

Arcturus Formation (Permian)

Par **Reef facies** Occurs as cliff-forming outcrops in the cores of synclines in the southern part of the map area and at high elevations in the northern part. Bedding is generally massive with internal 1- to 5-cm-thick lenticular and undulatory depositional units. The fossil component is generally greater than 30%, and includes abundant and pervasive brachiopods, crinoids, gastropods, and sponges(?) that act as a framework for micritic mud. The sponge-like biota are 2–3 cm in diameter, approximately 10–20 cm long, and locally contain hollow centers. They commonly branch into two tubes in an upward direction. They occur both normal to bedding in a growth position, and parallel to bedding. Local accumulations of colony corals and bryozoans also occur but are not common. Crinoid stem fragments are locally abundant and range up to 2 cm in diameter. None of the fossils show preferential orientations from current reworking. Cream to buff or tan on weathered surfaces, cream, tan, or light gray on fresh surfaces. The base of the unit lies conformably on the Platform facies (Pap). The unit is the highest Paleozoic strata exposed in the area so its total thickness is unknown because of erosion; its minimum thickness is 1200 m.

Paf **Fore-reef facies** Distributed extensively throughout the northern half of the map area; does not occur in the South where unit Par lies directly above unit Pap. Recessive unit of laminated to thin-bedded calcarenite and sandy limestone. Consists of 1- to 3-cm-thick beds with laminated mud parting surfaces. Beds are generally planar but locally include unidirectional asymmetric current ripples. Straight-shelled nautiloids are strongly current oriented in southerly exposures and randomly oriented to the north. The clastic component comprises well-rounded terrigenous, carbonate-cemented quartz sand with a grain size of 80 to 120 micrometers. Basal part of unit contains a distinctive biological population that I used to identify the unit regionally. It contains well preserved pseudoplanispiral gastropods (*Amphiscapha*?), orthostrophic type conispiral gastropods (*Murchisonia*?), straight-shelled nautiloids (*Michelinoceroidia*?), ammonoids (*Goniatites*?), and brachiopods. In southerly exposures they occur as localized thin bioclastic debris flows scattered intermittently through a thin-bedded to laminated limestone sequence; to the north they occur at the same lithostratigraphic level but are more evenly scattered in laminated and thin-bedded lime mud.

Medium to light brown or yellowish brown on weathered surfaces, medium brown to light gray on fresh surfaces. Unit has a minimum thickness of 500 m. Its base is gradational, and is best defined by the last occurrence of massive micrite beds of unit Pap. The top is everywhere tectonic; altered Pap limestone occurs as thrust sheets that terminate the top of unit Paf.

Pat_2 **Upper transitional facies** This unit is present only in the northern part of the map area; where present it is not everywhere mapped as a distinct facies due to a lack of adequate exposure. Where not separately mapped it is included as the basal part of unit Paf. Moderately recessive unit composed of lithologies intermediate between the fore-reef facies (Paf) and the platform facies (Pap), including carbonate-cemented quartz sandstone, bioclastic limestone, and massive micrite; massive micrite stands out in strong relief; the calcarenite is recessive. Unit progresses from medium to thick beds of massive micrite separated by thin-bedded sandy partings at the base systematically upward to entirely thin-bedded calcarenite. The unit typically does not contain fossils except local accumulations of crinoid stem fragments. Color is variable: the massive micrite beds are light to medium gray on fresh and weathered surfaces; the calcarenite is generally pastel brown to light tan on weathered surfaces and medium to light gray-brown on fresh surfaces. The lower contact is sharp and is based on the first occurrence of calcarenite beds between massive micrite beds; the upper contact is gradational over 30 to 50 m and is based on the last occurrence of massive micrite beds. The unit ranges from 0- to 100-m-thick.

Pap **Platform facies** Occurs throughout the map area but is best exposed in the middle to northern part of the area. Cliff-forming unit of medium- to thick-bedded or massive micrite. Beds are generally massive and show no bed forms. Locally includes concentrations of 200- to 300-micrometer quartz sand grains floating in a carbonate matrix, but is otherwise strictly micrite or a recrystallized equivalent. Local accumulations of thin- to medium-bedded carbonate-matrix, graded conglomeratic turbidites occur in the upper half of the unit. Clasts in the conglomerates are composed mostly of quartzite and chert; they are well rounded and range up to 2 cm in diameter. Much of the original rock texture is destroyed by partial to total dolomitization. The dolomitic parts of the unit form highly resistant, white to very light gray outcrops. The distribution of dolomite was not mapped due to masking by later epigenetic silicification. Contains a sparse and highly fragmented fossil population locally, including fusulinids, brachiopods and crinoid stems. The fusulinids are generally restricted to near the top of the unit. The base of the unit is sharp, defined by the last occurrence of Rib Hill-type sands. The upper contact is defined by the first occurrence of thin-bedded calcarenite of Pat_2 or Paf. The unit is present throughout the mapped area and ranges from 200 m to over 500 m thick. It lies conformably on the Rib Hill Sandstone or the Pat_1 transitional facies; locally it interfingers with the Pat_1 transitional unit. Where Pr and Pat_1 are not present, Pap lies disconformably on the Ely limestone and is separated by a 20- to 30-m-thick intraformational breccia.

Symbology (per FGDC-STD-013-2006)

Contact Solid where certain and location accurate, short-dashed where inferred.

Fault Solid where certain and location accurate, short-dashed where inferred. Ball on downthrown side.

Thrust fault Solid where certain and location accurate. Sawteeth on upper plate.

Shoreline cliff Solid where certain and location accurate, dashed where inferred; queried if identity or existence uncertain. Hachures point down cliff.

Anticline Solid where certain and location accurate.

Syncline Solid where certain and location accurate.

Pat_1 **Lower transitional facies** Occurs in abundance in northern third of McBrides Sheep Well Quadrangle and to north; pinches out to south. Recessive unit with similar lithologies to unit Pat_2: thin- to medium-bedded calcarenite, carbonate-cemented fine-grained quartz sandstone, and thin-bedded to laminated limestone. Contains locally extensive accumulations of crinoidal limestone. Where present, the crinoids form over 80% of the rock; individual stem fragments range in diameter to over 3 cm, which makes this unit distinct from other crinoidal limestones in the section. Generally light-brown to yellow on weathered surfaces and medium-brown to medium-gray on fresh surfaces. The crinoidal limestone is typically light gray on both weathered and fresh surfaces. Thickness ranges from 0 to over 600 m. Its base is gradational (commonly indistinguishable) with the underlying Rib Hill Sandstone; the top contact is sharp with the overlying Pap unit. Much of the thicker parts of unit Pat_1 show lateral facies transitions into the thick-bedded carbonates of Pap, which is why I include it in the Arcturus Formation.

Pr **Rib Hill Sandstone (Permian, Leonardian?)** Occurs intermittently throughout map area, but generally thickens and is more abundant to north. Recessive, talus-forming unit of thin- to medium-bedded calcite-cemented sandstone. Composed of rounded quartz sand grains with a uniform 80–120 micron size. Unit consists of amalgamated beds that are generally massive but locally show internal planar laminations and asymmetric current ripples. Fossils are generally absent, though some locations in the northern part of the McBrides Sheep Well Quadrangle have a basal crinoidal limestone, which presents difficulty in separating this unit from Pat_1. Color varies between hematitic red, yellow ochre, and pastel brown on weathered surfaces; it is medium brown to brown gray on fresh surfaces. Lies disconformably above the Ely Limestone. The basal contact is sharp; the top contact is sharp where overlain by unit Pap, but is gradational where overlain by unit Pat_1. I use the first occurrence of bioclastic limestone beds to define the overlying base of the unit Pat_1. Thicknesses vary from non-deposition to ±100 m. The large thicknesses described by Hose and Blake (1976) are derived from their inclusion of my Pat_1 unit into their Rib Hill.

Ely Limestone (Pennsylvanian)

IPep **Platform facies (Desmoinesian?)** Occurs throughout the map area. Bold, outcrop-forming unit of medium to thick, planar-bedded micritic limestone that forms a distinctive ledge-and-slope topography. Micrite beds are generally thick to amalgamated and do not show sedimentary textures except for local planar laminations. Contains abundant and distinctive concentrations of chert. The chert is bedding parallel, generally displays irregular and diffuse upper and lower margins, averages 2–5 cm thick, and represents up to 30% of most outcrops. I used the presence of significant chert to distinguish this unit from the platform carbonates of unit Pap. Contains a sparse fossil population of highly fragmented crinoid stems, brachiopods, and locally, corals and fusulinids. Medium to light gray on weathered surfaces, medium gray to locally dark gray on fresh surfaces. The lower contact with the Diamond Peak Formation is gradational over less than 10 m; the upper contact is an erosional surface, above which is either the Rib Hill Sandstone or the platform facies of the Arcturus Formation (Pap). An intraformational breccia occurs within the Ely where the Rib Hill Sandstone is not present. Thickness of the unit varies greatly from 300 m to more than 800 m.

IPer **Reef facies** Occurrence is restricted to the northern part of the McBrides Sheep Well Quadrangle. Bold, cliff-forming limestone unit that is lithologically similar in most respects with the platform facies. Differences include a greater diversity and abundance of fossils, and a significantly greater bed thickness. The fossils, some of which are in their growth position, include an abundance of brachiopods, bryozoans, corals, sponges(?), and crinoids. The lower contact with the Diamond Peak Formation is gradational over less than 10 m; the upper contact is sharp with the Pat_1 transitional facies. Thickness of the unit is at least 800 m.

Mdp **Diamond Peak Formation (Mississippian)** Occurs in the foothills along the west flank of the Butte Range. Represents lowest exposed unit in map area. Composed of two subfacies that were not mapped separately. Sand/silt facies is generally more recessive than the conglomerate facies; both stand out locally with good outcrop. The base of the unit is not exposed; the top is gradational over 10 m or less to the Ely Limestone. The gradation is marked by a systematic increase in strongly crossbedded and resedimented clastic carbonate beds within siliciclastic detrital beds, thence to primary carbonate beds of the Ely. The conglomerates consist of well rounded pebble to cobble size quartzite and chert fragments in a fine-sand to mud matrix. The conglomerate occurs as lenses within finer grained material and as amalgamated lenses. Most depositional units show either reverse or bidirectional grading. The sandstones consist of medium- to coarse-grained quartz sand with local pebbles of quartzite, chert, and locally, fossilized wood fragments. Asymmetric current ripples are the dominant bedform where present, but most of the unit is planar laminated. Several measurements of the current ripples indicate a transport direction of S20°–30°W (Shallow well area, Sunshine Well NW Quadrangle).

ALTERATION

Stratabound dolomitization, silicification, recrystallization and bleaching Occurs within the platform carbonate of unit Pap. Texture destructive; alteration has destroyed features and has masked all bed forms. Restricted to southern half of mapped area. Silicification and bleaching overprints the dolomite and is spatially associated with thrust faults. The most intensely developed portions generally occur in the brecciated hanging walls of the larger displacement faults and is strongest near the base of individual thrust sheets. The silicification is chalcedonic and bedding controlled, though crosscutting replacement veins are generally present. Where bedding is the primary control, the chalcedony follows bedding precisely; intervening nonsilicified beds are composed of coarsely crystalline dolomite. Where discordant to bedding the quartz always cuts the dolomite. Unaltered and unconsolidated gravels of unit Tg occur as a channel-filling sequence that was cut into the altered carbonate strata, demonstrating that alteration is older than 39 Ma.

Intensely developed breccia Generally associated with thrust faults, and hosted by strongly altered platform carbonate of unit Pap.

See accompanying text for references and descriptions of structure and stratigraphy.

Strike and dip of beds

45 Inclined 80 Overturned

Fracture cleavage

40 Inclined

Brachiopod **Fusulinid**

Crinoid **Gastropod**

7.5' quadrangles

1	2	3
4	5	6
7	8	9

1 Long Valley Slough
2 Cabin Spring
3 Cow Camp
4 Sunshine Well NW
5 McBrides Sheep Well
6 White Sage Well
7 Sunshine Well
8 Dickenson Well
9 Thirtymile Ranch

Map boundary

Scale 1:48,000

0 1 2 kilometers

0 1 2 miles

0 5,000 10,000 feet

CONTOUR INTERVAL 20 FEET

Base map: Adapted from U.S. Geological Survey Cabin Spring, Dickenson Well, McBrides Sheep Well 7.5' quadrangles

Projection: Universal Transverse Mercator, Zone 11, North American Datum 1927 (m)

Nevada Bureau of Mines and Geology
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Nevada Bureau of Mines and Geology
University of Nevada, Reno / 178
Reno, Nevada 89557-0178
ph. (775) 784-6691, ext. 2
www.nbmg.unr.edu; nbmgsales@unr.edu

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