Cambrian Stratigraphy of the Wendover Area, Utah and Nevada

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Cambrian Stratigraphy of the Wendover Area, Utah and Nevada

By LINDA B. McCOLLUM and DAVID M. MILLER

New lithofacies of Cambrian strata in the northeastern Great Basin are assigned to nineteen formations, ten of them new

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Cambrian Stratigraphy of the Wendover Area, Utah and Nevada

By Linda B. McCollum[1] *and* David M. Miller

Abstract

A Cambrian stratal sequence, approximately 4,000 meters thick, is exposed in the Toano Range, Pilot Range, Goshute Mountains, and Silver Island Mountains along the northern Utah/Nevada state line. This sequence is divided into 19 formations, 10 of which are newly proposed herein. Newly described formations are the Lower and Middle Cambrian Killian Springs Formation; the Middle Cambrian Toano Limestone, Clifside Limestone, Morgan Pass Formation, and Decoy Limestone; the Middle and Upper Cambrian Shafter Formation; and the Upper Cambrian Oasis Formation, Lion Spring Limestone, Ola Sandstone, and Goshute Limestone. In addition, the Late Proterozoic and Lower Cambrian Prospect Mountain Quartzite; the Middle Cambrian Trippe Limestone; the Upper Cambrian Lamb Dolomite, Big Horse Limestone, Candland Formation, Johns Wash Limestone, Corset Spring Shale, and Dunderberg Shale; and the Upper Cambrian and Lower Ordovician Notch Peak Formation are present in the Wendover region.

The new nomenclature reflects substantial lithologic differences, particularly in the Middle to Upper Cambrian strata, of the Wendover region compared with other stratigraphic sections in the Great Basin. Complex facies patterns within the Middle to Upper Cambrian sequence, and subsequent structural telescoping of strata by the Pilot Peak detachment fault, require a dual and partially equivalent formational nomenclature. In addition, the Dunderberg Shale in the Toano Range and Goshute Mountains is temporally equivalent to the Candland Formation, Johns Wash Limestone, and Corset Spring Shale in the Pilot Range and Silver Island Mountains.

A wide range of depositional environments is recorded by the Cambrian sequence in the Wendover region. Braided alluvial-plain to shallow-marine clastic strata of the Prospect Mountain Quartzite are conformably overlain by prodelta and basinal, mixed clastic strata of the Killian Springs Formation. The overlying Toano Limestone was deposited on a northwest-facing, distally steepened carbonate ramp. The Clifside Limestone represents an algally dominated carbonate platform that prograded northwestward.

A mixed clastic and carbonate environment developed across the carbonate platform during deposition of the Morgan Pass Formation. The cessation of clastic input resulted in deposition of the Decoy Limestone, followed by a widespread marine transgression, which resulted in drowning of the outer platform. Cosmopolitan agnostoid trilobites in thin-bedded limestone and calcareous siltstone of the Shafter Formation indicate an open-marine environment outboard of the carbonate-platform deposits of the Lamb Dolomite. The carbonate platform again prograded completely across the region, and mixed limestone, dolomite, and sandstone accumulated. The Big Horse Limestone to the north, the Oasis Formation to the west, and the Lion Spring Limestone, Ola Sandstone, and Goshute Limestone to the south reflect these changes.

The Candland Formation and Dunderberg Shale record the last major regional transgression of the Cambrian and the return of open-marine conditions. A carbonate platform became reestablished with the deposition of the Johns Wash Limestone and the overlying Corset Spring Shale. That carbonate platform continued throughout the region with deposition of the Notch Peak Formation.

INTRODUCTION

Cambrian rocks are exposed in more than a dozen mountain ranges in the northern Great Basin (fig. 1). Near the town of Wendover, astride the Utah/Nevada border, Cambrian strata crop out over much of the Toano Range both north and south of Silver Zone Pass, at the junction of the Toano Range and the Goshute Mountains, in the southern and central Pilot Range, and in the central and northern Silver Island Mountains (fig. 2). Although a complete, continuous Cambrian section is not preserved at any one locality, a composite section of strata has an aggregate thickness of approximately 4,000 m. A complete, although structurally thinned, section was recently discovered by Phyllis Camilleri (unpub. mapping, 1990) in the Pequop Mountains 15 km west of the Toano Range.

Cambrian sections exposed in the Wendover region differ in several respects from the Cambrian sections originally established to the south by Walcott (1908a, b) in the House Range, including subsequent nomenclature changes (Hintze and Robison, 1975; Hintze and Palmer, 1976), and by Nolan (1935) in the Deep Creek Mountains (fig. 1). The stepped appearance in eroded profile of alternating carbonate cliffs and mixed clastic and carbonate slope-forming

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[1]Geology Department, Eastern Washington Univ., Cheney, WA 99004

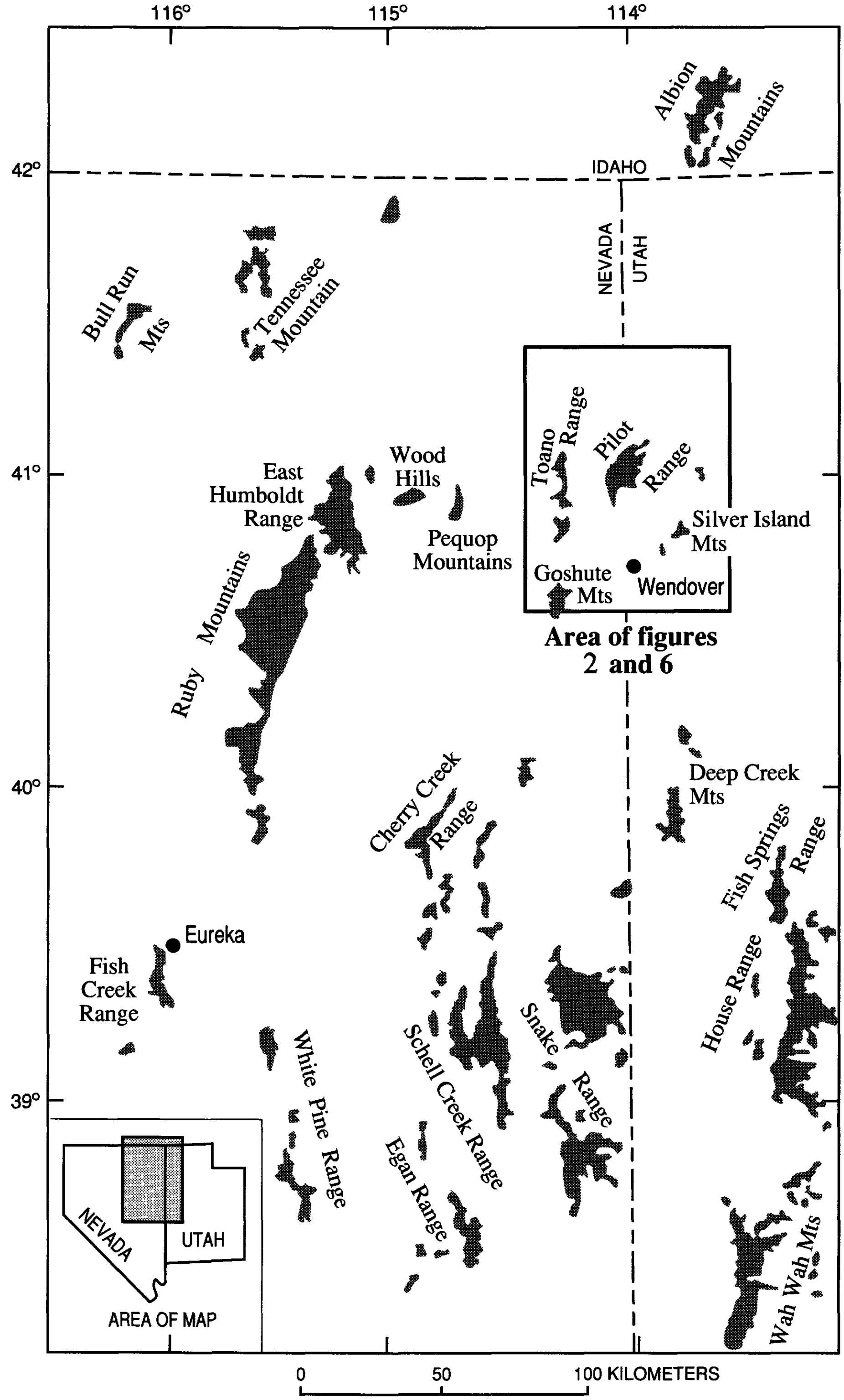


Figure 1. Index map of eastern Nevada and western Utah showing outcrops of Cambrian rocks (shaded).

units that is so typical of Middle Cambrian strata in those classic sections is absent in much of the Wendover region. Instead, sequences here are composed of slope-forming clastic and carbonate rocks. Only near plutons do the rocks form a more resistant topography, where they are highly recrystallized and metamorphosed. The sections of Upper Cambrian strata in the Wendover region form the more typical cliff-slope couplets and are recognizable within the context of established formations in the central Great Basin. However, as noted by Hintze and Palmer (1976, p. G4), regionally the lower half of the Upper Cambrian sequence is lithologically highly variable, is fossiliferous, and has been assigned a varied nomenclature.

In this paper we describe the Cambrian sections exposed in the Wendover area, name 10 formations, interpret depositional environments, and place these environments within a regional context. This report is an outgrowth of a regional study of the Cambrian outer-shelf environments in the Great Basin by McCollum and of recent detailed geologic mapping within the Pilot Range, northern Toano Range, and Silver Island Mountains by Miller and his associates.

Structural Setting

The Wendover region lies within a prominent eastward sigmoidal bend of Paleozoic facies and structural trends. This feature has been interpreted variously as (1) an irregularity on the Paleozoic continental margin (Stevens, 1981; Hurst and others,1985), (2) the result of right-lateral displacement of as much as 65 km during the Jurassic to Early Cretaceous along the hypothetical Wells fault (Thorman, 1968, 1970; Thorman and Ketner, 1979), and (3) the result of cumulative Mesozoic oroflexural bending of as

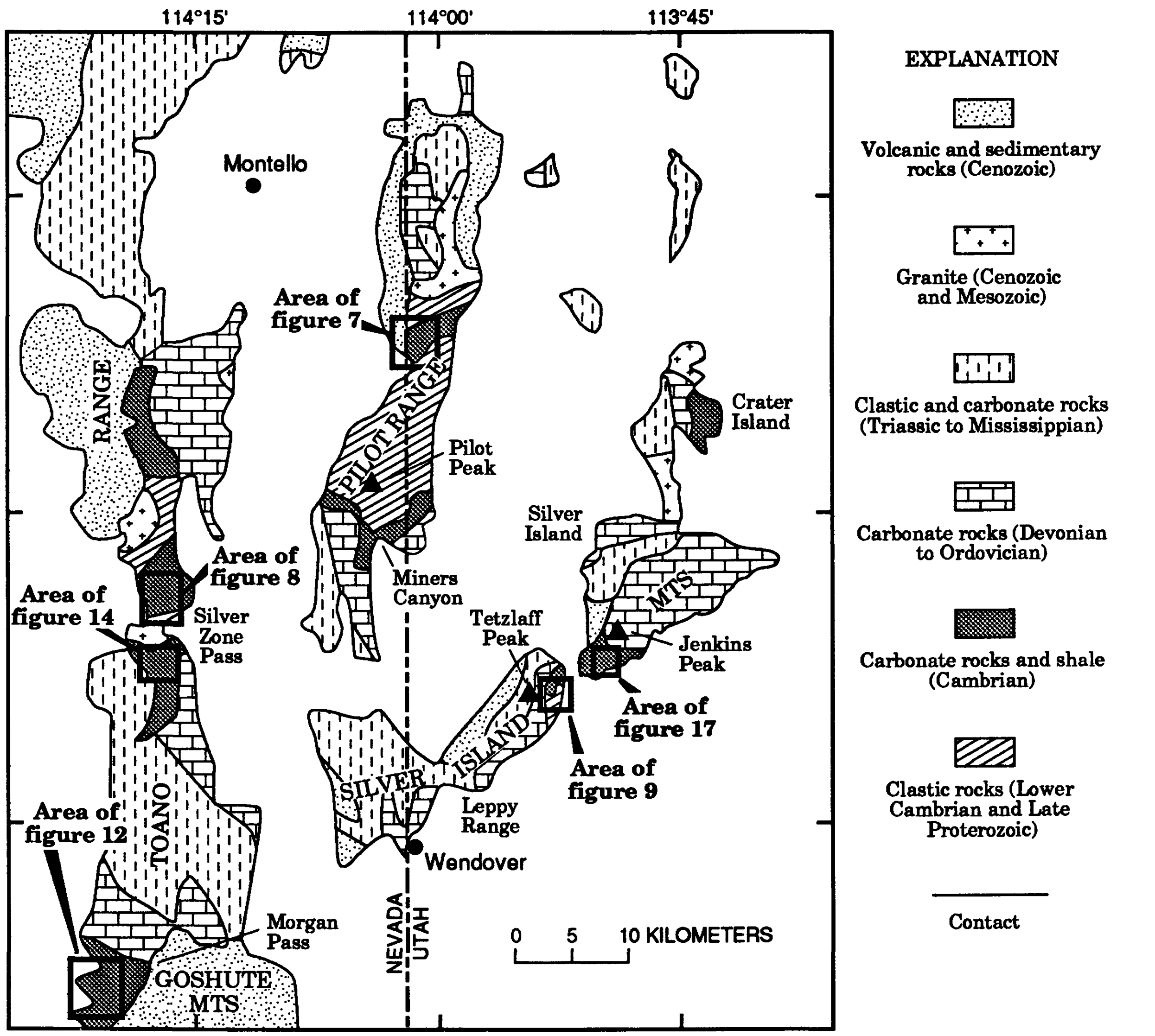


Figure 2. Simplified geologic map of Wendover region, northeastern Nevada and northwestern Utah. Modified from Miller (1984) and Day and others (1987). See figure 1 for location.

much as 120 km across the northern Great Basin (Stewart and Poole, 1974).

The most prominent structure in the study area is the Pilot Peak detachment, a major low-angle normal fault exposed in the Pilot Range (fig. 2). This fault separates a metamorphosed Late Proterozoic to Middle Cambrian sequence below from a slightly metamorphosed to unmetamorphosed Upper Cambrian to Lower Permian sequence above (Miller, 1983, 1984; Snoke and Miller, 1988). A similar detachment fault is present in the northern Toano Range, where it separates a lower plate, Late Proterozoic to Ordovician metamorphosed sequence from an unmetamorphosed Upper Cambrian to Permian sequence (Glick, 1987). At Tetzlaff Peak in the central Silver Island Mountains, a high- to low-angle fault separates a metamorphosed Cambrian section from relatively unmetamorphosed Ordovician and younger rocks (Schaeffer, 1960; D.M. Miller, 1988, unpubl. mapping).

Locally, all of the Cambrian facies vary over relatively short distances within and between ranges, probably as a result of rapidly shifting conditions of deposition at the seaward edge of a carbonate platform. It remains unclear to what extent telescoping by major Mesozoic structures and Tertiary extension have affected the original distribution of facies. Lower to Middle Cambrian facies of the metamorphosed sequence in the Wendover area differ markedly from the nearest temporally equivalent section just 60 km to the south, located near Gold Hill in the Deep Creek Mountains, Utah (McCollum and McCollum, 1984). Ultimately, an integration of Paleozoic facies patterns with Mesozoic and younger structures must be used to determine the most likely original paleogeographic configuration.

Acknowledgments

We greatly appreciate the efforts of several individuals who have added materially to the report. Michael B. McCollum aided us throughout the study. Richard A. Robison identified the Middle Cambrian fossils and made important collections in the Silver Island Mountains and Toano Range. Allison R. Palmer identified numerous Late Cambrian collections. Collections of Late Cambrian inarticulate brachiopods were identified by A.J. Rowell. John M. Repetski identified Late Cambrian conodont faunas. J. Keith Rigby examined sponge collections from the Pilot Range. Lehi F. Hintze visited the area and aided with regional Cambrian-Ordovician correlations. Mary L. Droser spent several days studying the ichnofabric patterns of the Cambrian and Ordovician carbonate section. Field observations of the Prospect Mountain Quartzite and the Killian Springs Formation in the Silver Island Mountains by Jeffrey F. Mount were very instructive. Linda L. Glick delimited the Cambrian stratigraphy in the northern Toano Range and guided us through these sections. Phyllis Camilleri recognized a Cambrian section in the Pequop Mountains and guided us through it. We are grateful to Keith B. Ketner and Michael E. Taylor for discussion of the Cambrian section of the Morgan Pass area in the northern Goshute Mountains. Able field assistance was rendered to McCollum by Mark W. Ansell and William M. Schneck.

OVERVIEW OF THE STRATIGRAPHIC NOMENCLATURE

The Paleozoic stratigraphy in the Wendover region was originally established as an outgrowth of geologic mapping by Anderson (1957, 1960) and Schaeffer (1960) in the Silver Island Mountains, by O'Neill (1968) in the Pilot Range, and by Pilger (1972) in the Toano Range. Strata in the Silver Island Mountains were included in a regional correlation of Upper Cambrian stratigraphy by Bentley (1958), and the faunas were studied by Robison (1960). Formational nomenclature for the Cambrian System used in these studies was largely adopted from that established to the south in the House Range by Walcott (1908a, b) and in the Deep Creek Mountains by Nolan (1935). However, these Cambrian correlations (fig. 3) were hampered by the remoteness from established sections, complex facies changes, poorly preserved and misidentified faunas, structural dislocations, plutonic disruptions, and low-grade metamorphism.

Anderson (1957, 1960) divided a highly faulted and incomplete Cambrian section at Crater Island in the northern Silver Island Mountains into six previously established formations and two undifferentiated or questionably assigned units. A more complete Cambrian section, exposed between Tetzlaff Peak and Jenkins Peak within the central Silver Island Mountains, was divided by Schaeffer (1960) into 13 previously established formations. Schaeffer's upper Middle Cambrian section was revised as Upper Cambrian by Robison and Palmer (1968), based on faunal reidentifications and additional collections. Palmer (1971, p. 50) later called for a complete reevaluation of the Cambrian stratigraphy near Wendover, and recent geologic mapping in the surrounding mountain ranges has confirmed this need (Miller and Lush, 1981; D.M. Miller and others, 1982; Glick, 1987).

A partial Cambrian section was identified by O'Neill (1968) in the highly faulted southern Pilot Range (fig. 2). O'Neill recognized that the Prospect Mountain Quartzite underlies Pilot Peak and assigned overlying black to purple phyllite to the Pioche Shale. He divided succeeding Cambrian silty limestones into four informal units and three previously designated formations: the Upper Cambrian Dunderberg Shale, Johns Wash "Formation," and Notch Peak Formation.

Cambrian rocks are extensively exposed within the northern half of the Toano Range. In the Silver Zone Pass area, Pilger (1972) mapped the Prospect Mountain Quartzite and assigned the overlying dark, argillaceous sedimentary rocks to the Pioche Shale. He divided the Cambrian carbonate section into informal units A and B, overlain by the Upper Cambrian Notch Peak Formation. To the north, Coats (1987) showed undifferentiated Cambrian rocks within much of the Toano Range. Glick (1987) adopted the Cambrian nomenclature proposed by McCollum and McCollum (1984) for the metamorphosed Cambrian section in the

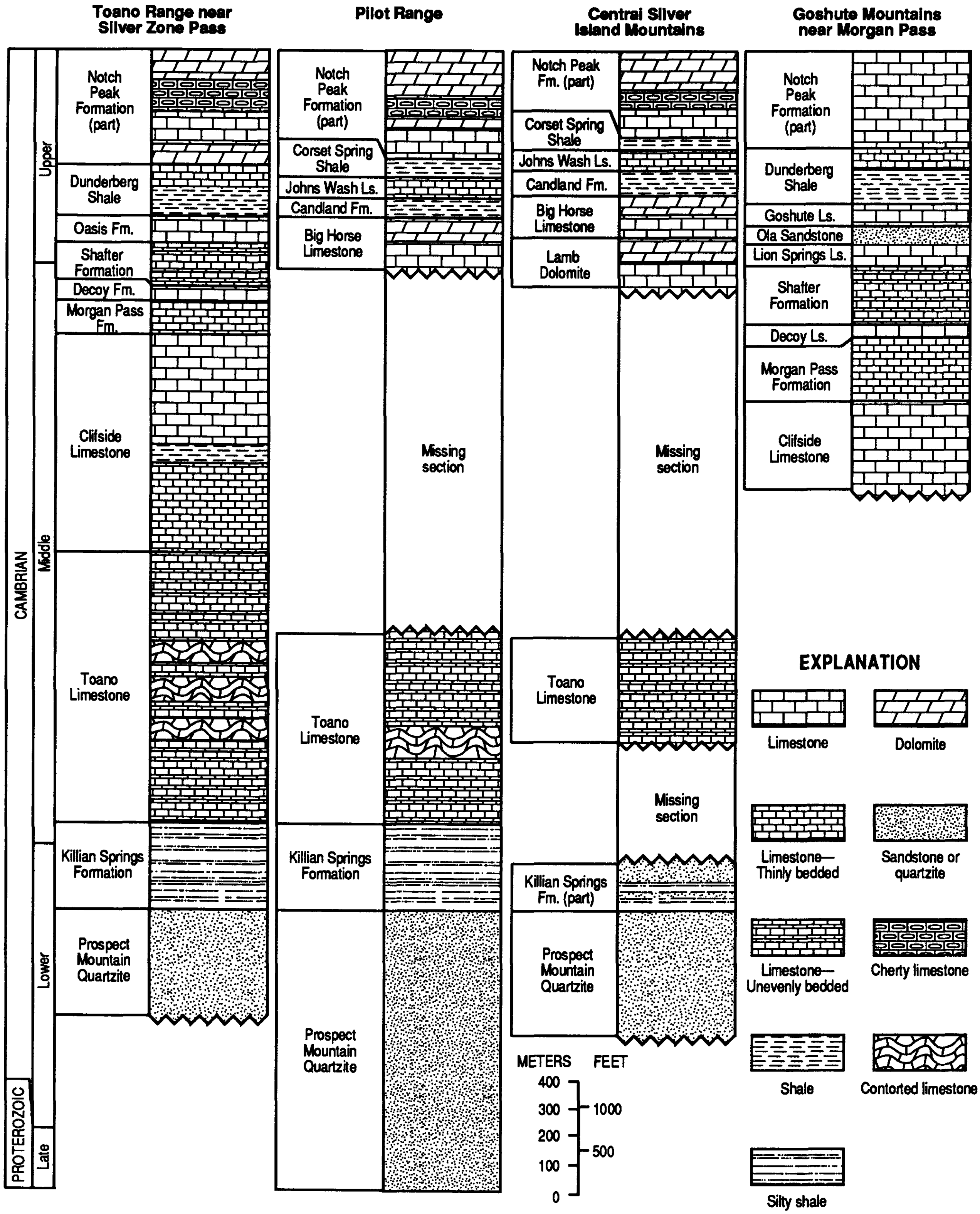


Figure 3. Columnar sections of Cambrian units in Wendover area. Thickness and lithology are portrayed; ages of units shown for Toano Range section only.

northern Toano Range, and she introduced the Orr Formation into the Toano Range for part of the unmetamorphosed, Middle and Upper Cambrian section.

The southern Toano Range and northern Goshute Mountains were recently mapped by Day and others (1987) in conjunction with studies of proposed wilderness areas (Ketner and others, 1987). The Middle and Upper Cambrian section below the Notch Peak Formation exposed at Morgan Pass at the junction of the two ranges was designated as informal units A through H, in descending order (Day and others, 1987). Taylor and others (1986), Taylor (1987), and Drumheller (1990) reported on the depositional environment and faunal content in part of that section below the Notch Peak Formation.

The formational scheme devised in this paper reflects complex facies changes within and between mountain ranges in the Wendover region. Cambrian sequences exposed in the Great Basin reflect a wide range of facies variation, and over 100 formational designations exist (Palmer, 1971). Historically, this nomenclature has grown as a result of the individual needs of local geologic mapping projects, with rather limited appreciation of regional facies similarities and differences. A special attempt is made in this paper to establish a formational nomenclature that accommodates both the local mapping needs, often affected by substantial facies variations, and the recognition of regionally extensive units that can be adopted locally.

The Cambrian section exposed in the Wendover region is estimated to be nearly 4,000 m thick, although no complete section extending from the base of the Prospect Mountain Quartzite to the top of the Notch Peak Formation is exposed at any single locality. The most complete Cambrian section is exposed near Silver Zone Pass in the Toano Range. Less complete Cambrian sections are present near Morgan Pass at the junction of the southern Toano Range and the northern Goshute Mountains, in the central Pilot Range, and in the central and northern Silver Island Mountains (fig. 2).

The Cambrian sequence exposed in these ranges is divided into 19 formations, 10 of which are new and are formally named and defined in this report. The new formations are the Killian Springs Formation, Toano Limestone, Clifside Limestone, Morgan Pass Formation, Decoy Limestone, Shafter Formation, Oasis Formation, Lion Spring Limestone, Ola Sandstone, and Goshute Limestone. Established formations that have either previously been used or are herein geographically extended into the Wendover region are the Prospect Mountain Quartzite, Trippe Limestone, Lamb Dolomite, Big Horse Limestone, Candland Formation, Johns Wash Limestone, Corset Spring Shale, Dunderberg Shale, and Notch Peak Formation (fig. 3).

Much of the Cambrian nomenclature previously used for the Wendover region was either inappropriate or inadequate, in many cases consisting of informal unit designations. We present previous formal unit designations and propose changes in the Silver Island Mountains (fig. 4) and also present regional correlations (fig. 5). The distribution in the Wendover region of the Cambrian units used in this report is depicted in figure 6. Further comments regarding nomenclature, age, and regional correlations can be found under the discussion of each formation below.

PROSPECT MOUNTAIN QUARTZITE

The cliff-forming Late Proterozoic and Lower Cambrian Prospect Mountain Quartzite has been recognized throughout the central Great Basin. The Prospect Mountain, originally named by Hague (1883), was redefined by Nolan and others (1956) for exposures near Eureka, Nevada, where the lower half of the formation is either covered or structurally removed. A complete reference section of the Prospect Mountain Quartzite was described by Misch and Hazzard (1962) in the Snake Range and later modified by Hose and Blake (1976).

Quartz arenite is the dominant lithology of the Prospect Mountain Quartzite, followed by subarkose, argillite to siltite, and quartzite-pebble conglomerate. The white to light-gray quartz arenite is generally fine to medium grained and crossbedded. Quartzite-pebble conglomerate is present as channel lags and in tabular sheets. Subarkose is common in several intervals, with microcline being the predominant feldspar.

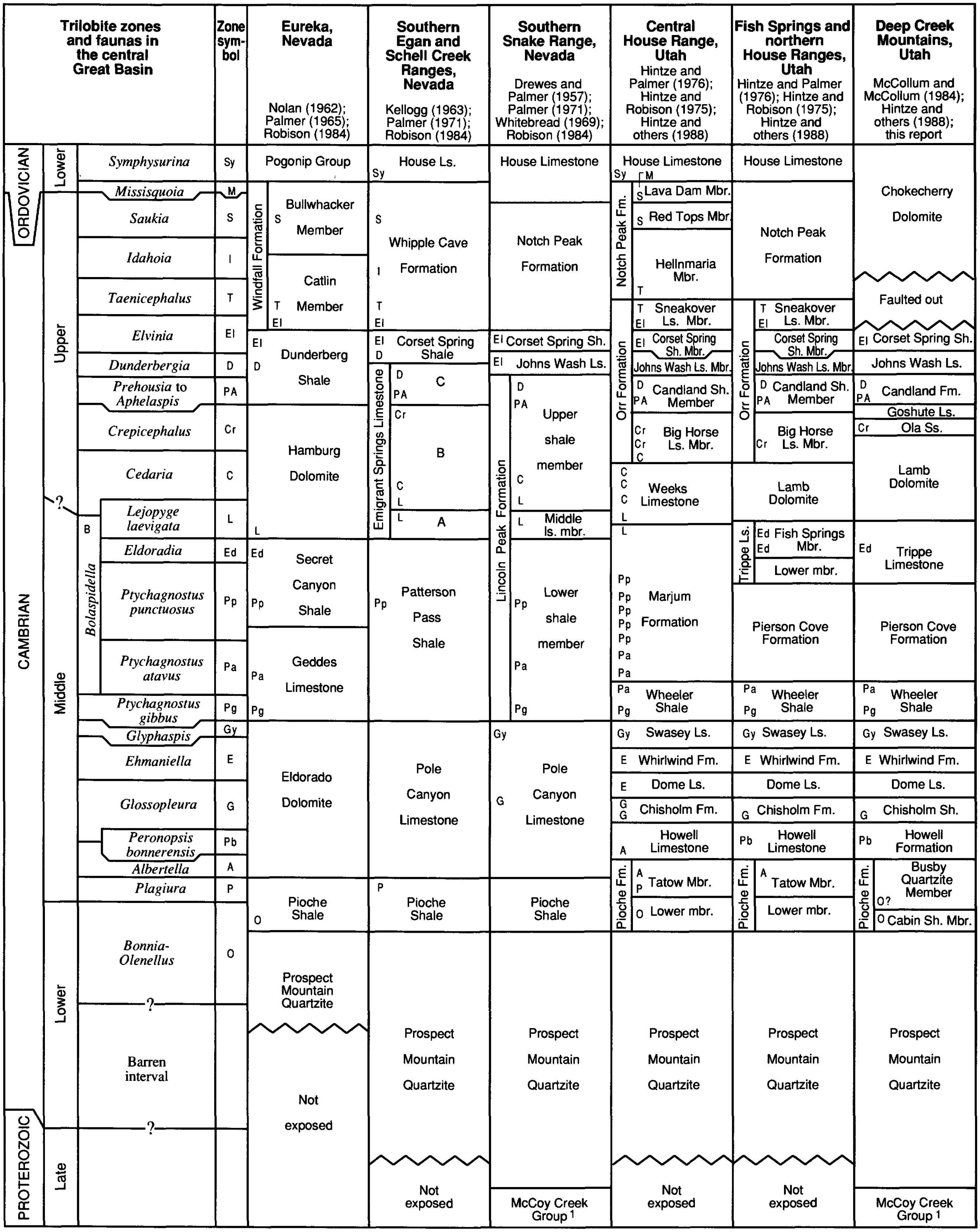
A complete section of the Prospect Mountain Quartzite, approximately 955 m thick, is exposed on Pilot Peak (Miller, 1983). The uppermost 430 m of the Prospect Mountain Quartzite are exposed near Tetzlaff Peak in the central Silver Island Mountains (Schaeffer, 1960). A faulted section, approximately 350 m thick, is present in the Toano Range north of Silver Zone Pass (Glick, 1987).

KILLIAN SPRINGS FORMATION (NEW)

The Killian Springs Formation is exposed on the flanks of Pilot Peak in the central Pilot Range (fig. 7), near Silver Zone Pass in the Toano Range (fig. 8), and on the north flank of Tetzlaff Peak in the Silver Island Mountains (fig. 9). It consists of strata previously assigned to the Pioche Shale by Schaeffer (1960) in the Silver Island Mountains, by O'Neill (1968) in the Pilot Range, and by Pilger (1972) in the Toano Range, and strata assigned to the Pioche Formation of Hintze and Robison (1975) by Miller and Lush (1981) in the Pilot Range. The Killian Springs Formation is here named for a 300-m-thick sequence of interbedded clastic and minor carbonate rocks exposed between Killian Springs and Cottonwood Springs on the west side of the Pilot Range in sec. 21, T. 5 N., R. 19 W., Patterson Pass 7½-minute quadrangle, Box Elder County, Utah (fig. 7); these rocks are designated as the type section of the

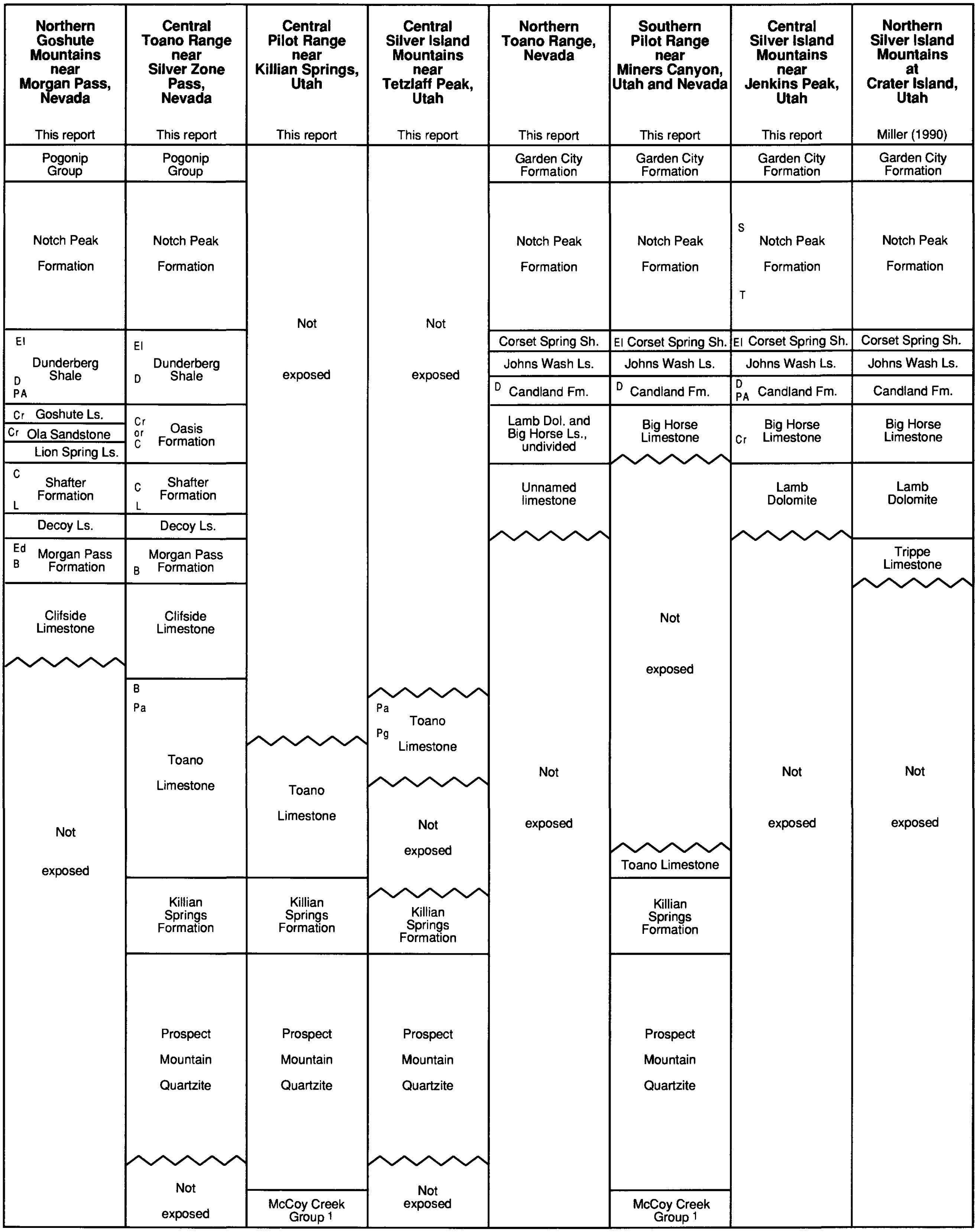
Central Silver Island Mountains		
Schaeffer (1960)	Robison and Palmer (1968)	This paper
Jenkins Peak section		
Notch Peak Formation 568 m 1864 ft	Notch Peak Formation	Notch Peak Formation 500 m 1640 ft
Weeks Formation 95 m 309 ft	Corset Spring Shale	16 m Corset Spring Shale 52 ft
Marjum Limestone 88 m 290 ft	Johns Wash Limestone	Johns Wash Limestone 80 m 262 ft
Wheeler Shale 85 m 279 ft	Dunderberg Shale	Candland Formation 85 m 279 ft
Restricted Swasey Limestone 94 m 307 ft	Lower Upper Cambrian, undifferentiated	Big Horse Limestone 175 m 574 ft
Condor Formation 81 m 265 ft		
Dome Formation? 108 m 355 ft		Lamb Dolomite 130 m 426 ft
Millard Ls.-Burrows Ls.?-Burnt Canyon Ls.?, undifferentiated		
Covered interval	Covered interval	Covered interval
Tetzlaff Peak section		
Covered interval	Not discussed	Covered interval
Millard Ls.-Burrows Ls.?-Burnt Canyon Ls.?, undifferentiated 542 m 1779 ft		Toano Limestone 375+ m 1230+ ft
Covered interval		Covered interval
Busby Quartzite 42+ m 142+ ft		Killian Springs Formation 166+ m 545+ ft
Pioche Shale 87 m 285 ft		
Prospect Mountain Quartzite 428+ m 1403+ ft		Prospect Mountain Quartzite

Figure 4. Comparison of published and proposed stratigraphic terminology for Cambrian section in central Silver Island Mountains, Utah.

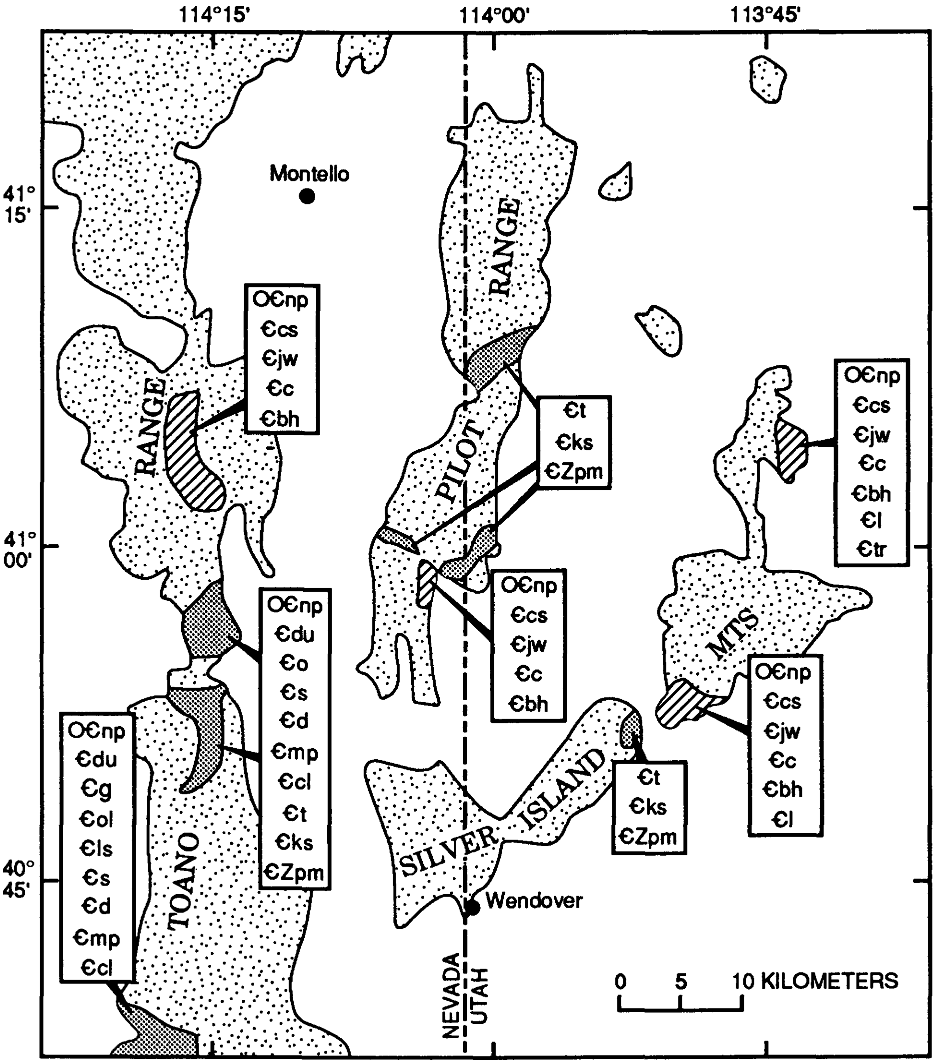


[1] Of Misch and Hazzard (1962) as modified by Hose and Blake (1976).

Figure 5. Correlation of Cambrian formations in northern and central Great Basin. Reported occurrences of fossil zones are shown schematically by lettered symbol. The Middle-Upper Cambrian boundary in North America has traditionally been placed between *Bolaspidella* and *Cedaria* zones (Lochman-Balk and Wilson, 1958; Robison, 1964). However, Daily and Jago (1975) noted that in reference to the standard of northwestern Europe, much of *Cedaria* zone of North America is Middle,



rather than Late, Cambrian in age. More recently, Robison (1984) has set Middle-Upper Cambrian boundary in western North America at top of *Lejopyge laevigata* zone, and thus includes much of *Cedaria* zone in Middle Cambrian. Pending formal subdivision of Cambrian System, boundary is shown as questionable in this report. Strata between the Chokecherry Dolomite and Ola Sandstone were formerly assigned to the Hicks Formation (abandoned) of Nolan (1935).



EXPLANATION

- Mountainous areas
- Upper plate rocks (Ordovician and Cambrian)
- Lower plate rocks (Ordovician, Cambrian, and Late Proterozoic)

OЄnp	Notch Peak Formation (Lower Ordovician and Upper Cambrian)
Єdu	Dunderberg Shale (Upper Cambrian)
Єo	Oasis Formation (Upper Cambrian)
Єg	Goshute Limestone (Upper Cambrian)
Єol	Ola Sandstone (Upper Cambrian)
Єls	Lion Spring Limestone (Upper Cambrian)
Єs	Shafter Formation (Upper and Middle Cambrian)
Єd	Decoy Limestone (Middle Cambrian)
Єmp	Morgan Pass Formation (Middle Cambrian)
Єcl	Clifside Limestone (Middle Cambrian)
Єt	Toano Limestone (Middle Cambrian)
Єks	Killian Springs Formation (Middle and Lower Cambrian)
ЄZpm	Prospect Mountain Quartzite (Lower Cambrian and Late Proterozoic)

upper plate:

Єcs	Corset Spring Shale (Upper Cambrian)
Єjw	Johns Wash Limestone (Upper Cambrian)
Єc	Candland Formation (Upper Cambrian)
Єbh	Big Horse Limestone (Upper Cambrian)
Єl	Lamb Dolomite (Upper Cambrian)
Єtr	Trippe Limestone (Middle Cambrian)

unit. The formational name is derived from Killian Springs, a natural spring located in the Patterson Pass 7½-minute quadrangle. This easily mappable unit, which was informally called the "phyllite of Killian Springs" by Miller (1983, p. 203), forms dark-colored, broad benches between the underlying Prospect Mountain Quartzite and overlying Toano Limestone.

The type section of the Killian Springs Formation in the Pilot Range is a fairly uniform sequence of very dark, impure, fine-grained clastic rocks that conformably overlie the Prospect Mountain Quartzite. The clastic rocks contain progressively increasing calcareous interstitial material toward the top of the section. The dominant lithology is grayish-black phyllite and phyllitic siltstone. Graphitic arenite and subgraywacke locally are interbedded with siltstone near the base of the formation, and argillaceous lime mudstone and calcareous phyllite are relatively common in the upper one-third of the formation. Impressions of siliceous sponge spicules and articulated sponges are sporadically distributed in the phyllite and argillaceous lime mudstone within the upper half of the formation. The soil that forms on the Killian Springs is generally carbon rich and dark compared with adjacent formations, making the unit easily distinguishable on aerial photographs.

Fault-bounded phyllite units 20 to 60 m thick present south of the type section of the Killian Springs Formation within the Pilot Range (rocks that are here assigned to the Killian Springs Formation) were originally assigned to the Pioche Shale by O'Neill (1968) and to the Pioche Formation of Hintze and Robison (1975) by Miller and Lush (1981), but later they were designated by Miller (1984) as the phyllite of Killian Springs. Amphibolite-facies equivalents in a fault slice east of Pilot Peak consist of a distinctive black graphitic schist resting on the Prospect Mountain Quartzite, which was correlated with the lower grade phyllite by Miller and Lush (1981) and assigned to the phyllite of Killian Springs by Miller (1983, 1984). Structurally overlying this schist is a thick unit of brown schistose marble, with local interbeds of metamorphosed calcareous quartz sandstone. Distinctive units in this section consist of black graphitic marble and pelitic schist. The schistose marble unit appears to be a facies variation of the upper, calcareous part of the type section of the Killian Springs Formation; it is overlain by marble assigned in this report to the Toano Limestone.

Strata originally assigned by Pilger (1972) to the Pioche Shale in the Toano Range were reassigned by McCollum and McCollum (1984) to the phyllite of Killian Springs of Miller (1983). Glick (1987) also adopted the phyllite of Killian Springs for her detailed geologic mapping in the northern Toano Range. The lithology and stratigraphic thickness of the Killian Springs Formation in the Toano Range are very similar to that of the type section of the unit in the Pilot Range.

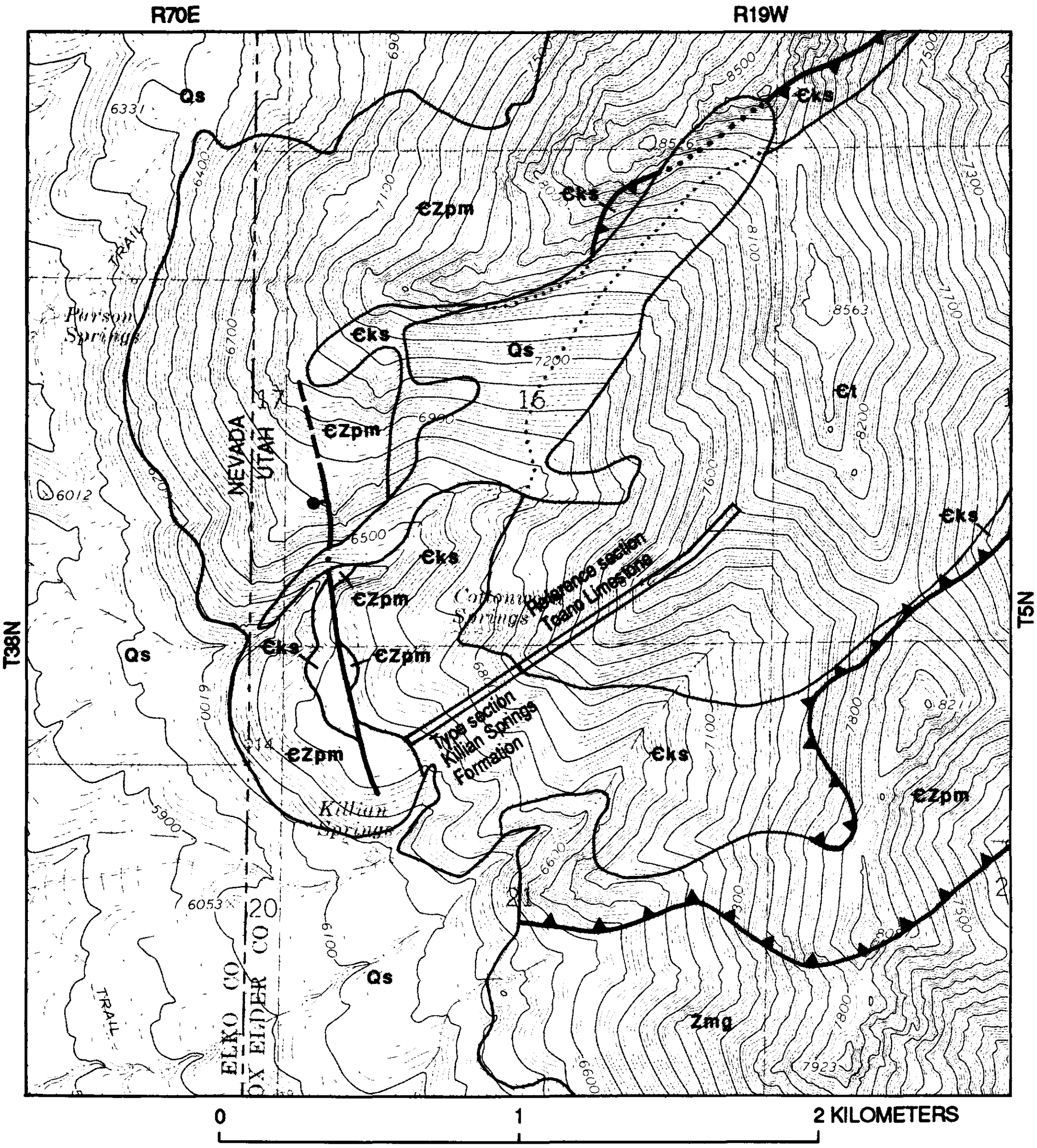
On the north flank of Tetzlaff Peak in the central Silver Island Mountains, strata formerly mapped by Schaeffer (1960) as the (uppermost part of the) Prospect Mountain Quartzite, Pioche Shale, and Busby Quartzite are here assigned to the Killian Springs Formation. At this location, facies changes from those at the type section of the unit, 35 km to the northwest, are evident, and approximately the upper one-third of the formation is not exposed locally. Three lithologically distinguishable, informally designated units comprise the Killian Springs here; they are, in ascending order, (1) a cliff-forming, 4-m-thick unit composed of interbedded quartzofeldspathic sandstone and dark phyllitic siltstone that weather into a stepped cliff profile; (2) a 90-m-thick, slope-forming unit composed of dark phyllitic siltstone and lime mudstone; and (3) a ridge-forming unit of friable, cavernous-weathering calcareous quartz sandstone with only its lowermost 35 m exposed. This upper unit may in part be correlative with the brown schistose marble unit of the Killian Springs occurring east of Pilot Peak.

Age.—The age of the Killian Springs is not well constrained. The formation overlies the Prospect Mountain Quartzite, which regionally contains a late Early Cambrian fauna near its top in Nevada (Stewart, 1976). Sponge spicules from the upper half of the Killian Springs Formation are suggestive of Middle Cambrian *Diagonella* and *Protospongia* forms, according to J. Keith Rigby (written commun., 1983). Thus, the Killian Springs Formation is here provisionally regarded as Early and Middle Cambrian in age.

Regional Correlations.—To the east and west of the Wendover region, the geographic distribution of dark, impure rocks has been masked either by the high degree of metamorphism and deformation or by inappropriate formational designations. Willden and Kistler (1979) used the name "Pioche Formation" for a 170-m-thick sequence of graphitic phyllite, hornfels, and marbleized limestone above the Prospect Mountain Quartzite at Rattlesnake Mountain in the central Ruby Mountains, Nevada (fig. 1). Black graphitic schist is present above prominent quartzite beds in the highly metamorphosed Cambrian section in the northern Ruby Mountains and adjacent East Humboldt Range in northern Nevada (Snoke and Lush, 1984), in the Pequop Mountains, and possibly also in the Albion Mountains of southern Idaho (Miller, 1983).

The metamorphic complex in the northern Ruby Mountains and adjacent East Humboldt Range contains a sillimanite zone (amphibolite-facies) Late Proterozoic to middle Paleozoic sequence. Howard (1971, p. 263) and Snoke (1980, p. 293) noted that a prominent graphitic calc-

◀ **Figure 6.** Distribution of Cambrian stratigraphic units in Wendover area, northeastern Nevada and northwestern Utah. Unit labeled Big Horse Limestone in the northern Toano Range is Lamb Dolomite and Big Horse Limestone, undivided (see text). See figure 1 for location.



EXPLANATION

Qs	Surficial deposits (Quaternary)
€t	Toano Limestone (Cambrian)
€ks	Killian Springs Formation (Cambrian)
€Zpm	Prospect Mountain Quartzite (Cambrian and Late Proterozoic)
Zmg	Unit G of McCoy Creek Group of Misch and Hazzard (1962) (Late Proterozoic)

Contact—Dotted where concealed

Faults—Dashed where approximate; dotted where concealed

Low-angle—Sawteeth on upper plate

High-angle—Bar and ball on downthrown side

Figure 7. Geologic map of part of Pilot Range, Utah and Nevada, showing location of type section of the Killian Springs Formation and reference section of the Toano Limestone. See figure 2 for location of map. Base from U.S. Geological Survey, 1:24,000-scale Patterson Pass 7½-minute quadrangle, 1967, Nevada and Utah. Contour interval 20 ft. Geology generalized from D.M. Miller and others (1982).

silicate facies overlies the metamorphosed Prospect Mountain Quartzite throughout much of the area. Based on the stratigraphic position and graphitic component of these rocks, they appear to be a high-grade metamorphic equivalent of the Killian Springs Formation.

In the Albion Mountains of southern Idaho, black, graphitic phyllite and black staurolite-garnet schist are present structurally below the overturned Harrison Summit Quartzite of Armstrong (1968). Miller (1983) tentatively correlated the Harrison Summit Quartzite with the Prospect Mountain Quartzite and the black phyllite and schist facies strata with the herein-named Killian Springs Formation [equivalent to the phyllite of Killian Springs of Miller (1983)]. However, metamorphism and structural complexities including bedding-plane faults, which may have structurally interleaved Mississippian with Cambrian(?) phyllite and schist units (Miller, 1983), preclude a confident formational assignment for these rocks at this time.

A partial lithologic and temporal equivalent of the Killian Springs Formation is the Edgemont Formation of Decker (1962) in the Bull Run Mountains, 200 km west of the Pilot Range (fig. 1). The Edgemont is a highly folded and pervasively cleaved sequence of light-olive-gray to brownish-gray phyllitic mudstone and thinly interbedded quartz arenite in its basal part and minor silty lime mudstone beds in its uppermost 50 m (Clark, 1984). The Edgemont conformably overlies the Prospect Mountain Quartzite and is itself overlain by a thick-bedded, fenestral dolomite interval originally included in the Porter Peak Limestone of Decker (1962). Clark (1984, p. 49) estimated the maximum thickness of the Edgemont as approximately 365 m but was unable to determine an internal stratigraphy for the unit owing to structural complications and poor exposures.

The uppermost 70 m of the Edgemont Formation in the Bull Run Mountains (fig. 1) contains a late Early Cambrian *Bonnia-Olenellus* Assemblage-zone fauna (Ehman, 1985). A.R. Palmer (written commun., 1981) has identified *Olenellus* cf. *O. puertoblancoensis* (Lochman), *Olenellus* cf. *O. howelli* ? (Meek), and *Zacanthopsis* sp. from a collection made by McCollum from the type section of the Edgemont in 1981. Palmer later identified *Olenellus nevadensis* (Walcott), *Olenellus* cf. *O. gilberti* Meek, and *Bonnia* sp. from an additional collection several kilometers to the south reported by Clark (1984). Palmer concluded that all of these faunas are characteristic of uppermost Lower Cambrian strata within the Great Basin.

The Killian Springs Formation is distinguished from the Edgemont Formation by its greater lithologic heterogeneity, including graphitic phyllites, and by a higher proportion of coarse clastic rocks. The Killian Springs is overlain by thin-bedded and laminated, silty lime mudstone, whereas the Edgemont Formation is overlain by thick-bedded to massive, fenestral dolomite. The Edgemont contains a fairly diverse Early Cambrian benthic fauna, whereas the Killian Springs is barren except for a few horizons containing likely Middle Cambrian sponge spicules.

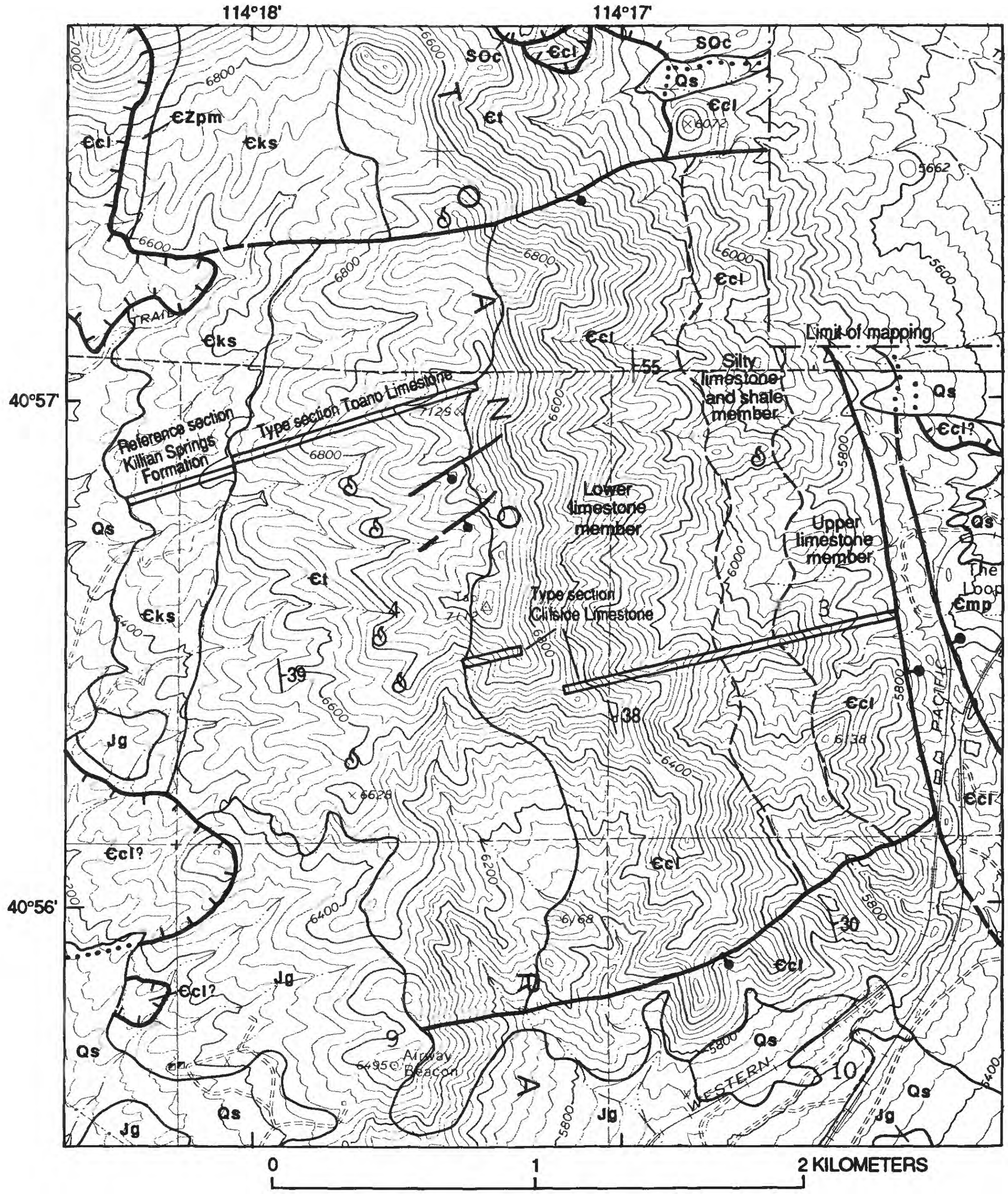
Three hundred kilometers to the east in the Bannock Range near Pocatello, Idaho, the lower part of the Gibson Jack Formation (Crittenden and others, 1971) has some striking lithologic and faunal similarities with the Killian Springs Formation exposed at Tetzlaff Peak. Laminated, carbon-rich, black shale and argillaceous siltstone containing numerous spicules of *Protospongia* dominate the lowermost 100 m of the Gibson Jack Formation. Above this is a friable, calcareous quartz sandstone approximately 35 m thick, which is overlain by at least 300 m of siliceous shale. These mappable subunits were labeled members A, B, and C, respectively, by Trimble (1976, p. 27–28). Members A and B possibly represent an eastern tongue of the Killian Springs Formation, whereas the siliceous shale of member C is lithologically similar to facies found within the Ophir Shale and the Pioche Shale in the eastern and central Great Basin, respectively.

The Lower and Middle Cambrian Pioche Shale, which lies upon the Prospect Mountain Quartzite throughout the central Great Basin, is stratigraphically correlative with the Killian Springs Formation but is easily distinguished from the Killian Springs lithologically. The Pioche consists primarily of light-green to tan, siliceous and fissile shale; interbedded quartz arenite; and oolitic or algal, light-gray limestone commonly composed of trilobite hash. Lithologies attributed to the Pioche Shale are not exposed north of the Cherry Creek, Schell Creek, and Snake Ranges (fig. 1), and there are no exposed transitional facies near the Wendover area.

TOANO LIMESTONE (NEW)

The Toano Limestone is here named for an 850-m-thick, slope-forming interval of silty lime mudstone and calcareous siltstone exposed about 4 km north of Silver Zone Pass in sec. 4, T. 35 N., R. 68 E., Silver Zone Pass 7½-minute quadrangle, on the west side of the Toano Range, Elko County, Nevada (fig. 8); these rocks are designated as the type section of the unit. The formational name is derived from the Toano Range, where the only complete section of this formation is known. The Toano is equivalent to unit A of Pilger (1972) and the limestone of Toano of McCollum and McCollum (1984). The contacts of the Toano Limestone are gradational, and the formation occupies a stratigraphic position intermediate between the clastic rocks of the Killian Springs Formation below and the lighter colored, less silty carbonate rocks of the Clifside Limestone above.

The predominant lithology is a uniform-appearing, thin- to medium-bedded, silty limestone. The bedding is parallel except where disrupted by soft-sediment deformation. The color contrast between the grayish-orange silty layers, which weather to relief, and the medium-dark-gray



EXPLANATION

Qs	Surficial deposits (Quaternary)
Jg	Granodiorite (Jurassic)
SOc	Carbonate rocks (Silurian and Ordovician)
€mp	Morgan Pass Formation (Cambrian)
€cl	Clifside Limestone (Cambrian)
€t	Toano Limestone (Cambrian)
€ks	Killian Springs Formation (Cambrian)
€mp	Prospect Mountain Quartzite (Cambrian and Late Proterozoic)

Contact—Contacts between members dashed

Faults—Dashed where approximate; dotted where concealed

High-angle—Bar and ball on downthrown side

Gravity-slide—Hachures on upper plate

30 Strike and dip of bedding

Fossil locality

lime mudstone presents the greatest variation within this formation.

The silty, laminated rocks of the Toano Limestone exhibit a large assortment of primary sedimentary features, owing in part to the lack of bioturbation. Although more than half of the formation is laminated, chaotic bedding and sedimentary folds due to slumping are common in the middle part of the unit (fig. 10). Imbricated clasts, truncation surfaces, and trough cross-stratification are also present (fig. 11).

In addition to its type section in the Toano Range, a complete section is present in the Pequop Mountains and incomplete sections of the Toano Limestone are exposed in the Pilot Range (fig. 7) and central Silver Island Mountains (fig. 9). Approximately the lower one-third of the Toano Limestone is exposed above the type section of the Killian Springs Formation in the core of a large syncline in the central Pilot Range (D.M. Miller and others, 1982; Miller, 1983). Several kilometers to the south in the Pilot Range, O'Neill (1968) mapped strata in Miners Canyon that we herein assign to the Toano Limestone. A light-colored schistose marble mapped by Miller and Lush (1981) east of Pilot Peak overlies metamorphosed strata of the Killian Springs Formation and is probably correlative with the Toano Limestone. The upper half of the Toano Limestone is the only unit exposed north of Tetzlaff Peak in the Silver Island Mountains, which Schaeffer (1960) tentatively mapped as a unit he called "Millard, Burrows?, and Burnt Canyon? Limestones, undifferentiated."

Age.—The Toano Limestone contains sparse and coarsely silicified, open-shelf, cosmopolitan Middle Cambrian fossils at its type section. The youngest fauna, taken from the uppermost 10 m of the type section, contains a

◀ **Figure 8.** Geologic map of Toano Range north of Silver Zone Pass, Nevada, showing locations of type sections of the Toano Limestone and Clifside Limestone and reference section of the Killian Springs Formation. See figure 2 for location of map. Base from U.S. Geological Survey, 1:24,000-scale Silver Zone Pass 7½-minute quadrangle, 1982, Nevada. Contour interval 40 ft. Geology generalized from Glick (1987).

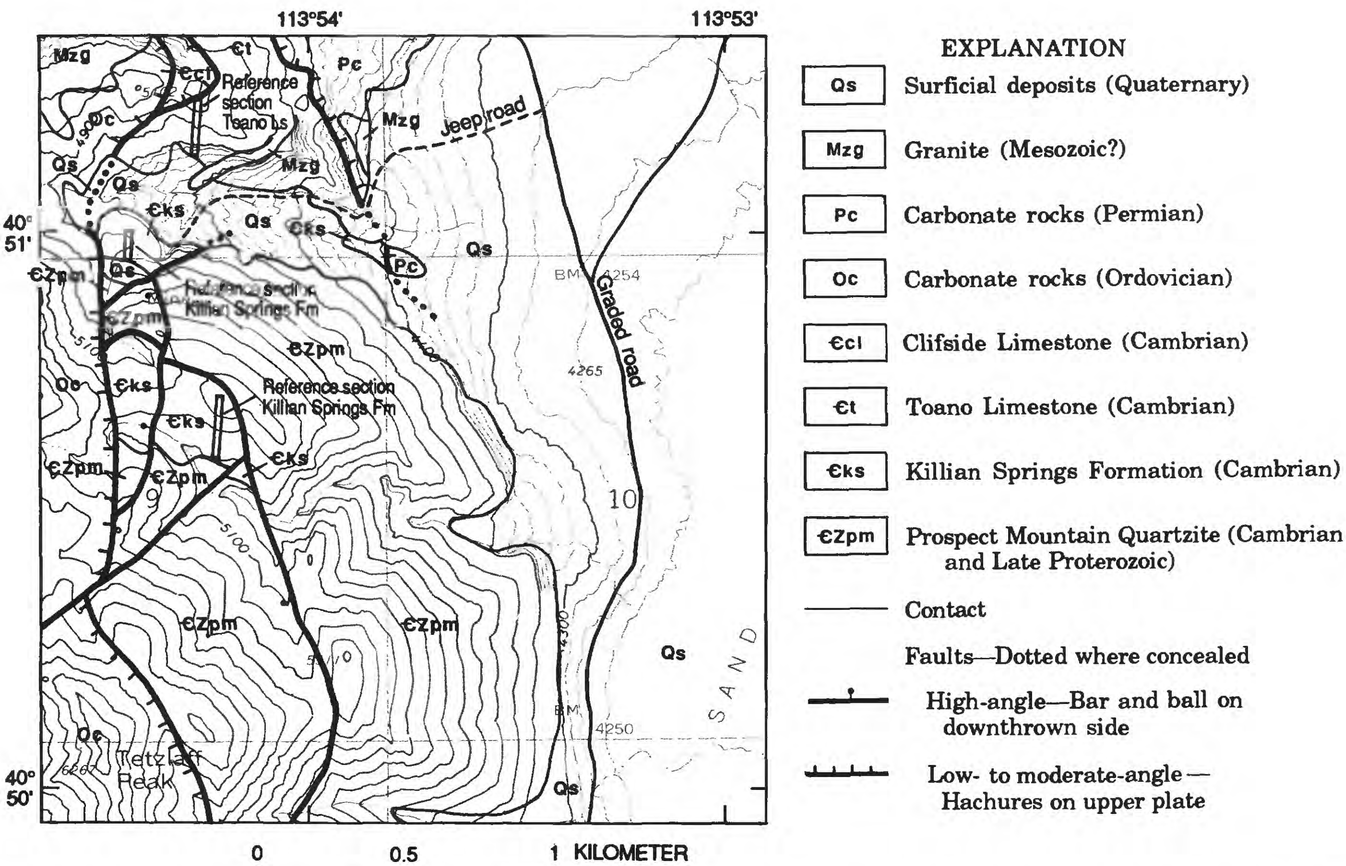
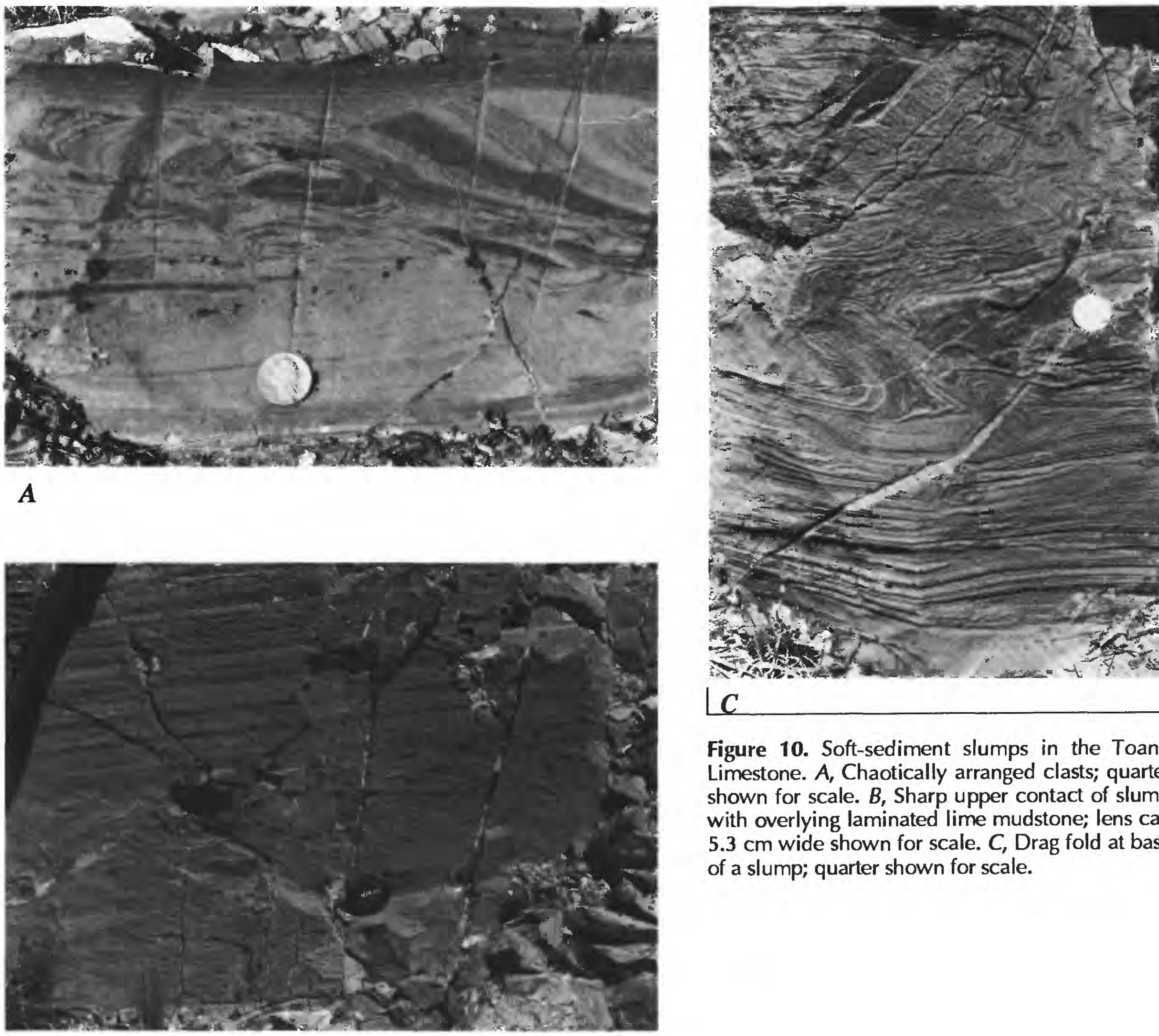


Figure 9. Geologic map of Tetzlaff Peak area, central Silver Island Mountains, Utah, showing location of reference sections of the Killian Springs Formation and Toano Limestone. See figure 2 for location of map. Base from U.S. Geological Survey, 1:24,000-scale Tetzlaff Peak 7½-minute quadrangle, 1971, Utah. Contour interval 20 ft. Geology modified from D.M. Miller (1988, unpublished).

species of *Bolaspidella*, identified by A.R. Palmer (written commun., 1983) and assigned to the late Middle Cambrian *Bolaspidella* Assemblage-zone of Robison (1976, p.102). R.A. Robison (written commun., 1982) identified numerous specimens of *Ptychagnostus atavus* (Tullberg) from 650 m above the base of the formation, both in the type section and in the Silver Island Mountains. He also collected *Tonkinella* and several questionable specimens of *Ptychagnostus* between 80 m and 90 m below the *P. atavus* fauna in the central Silver Island Mountains, indicating the presence of the *Ptychagnostus gibbus* Interval-zone of Robison (1984). A possible specimen of the trilobite *Elrathia* sp. identified by A.R. Palmer (written commun., 1983) was collected from a fault block of Toano Limestone on the east side of the Pilot Range. In addition, poorly preserved agnostoid and ptychopariid trilobites have been collected 300 m above the base of the type section of the Toano Limestone, and these could be as old as the early Middle Cambrian *Peronopsis bonnerensis* Assemblage-zone of Robison (1976, p. 103). The lower one-third of the Toano Limestone in the Toano Range appears to be barren. Based on the faunal evidence and the presumed Middle Cambrian age of the upper part of the underlying Killian Springs Formation, the Toano Limestone is considered to be Middle Cambrian in age.

Regional Correlations.—At present, the Toano Limestone is recognized outside of the Wendover area only in the Pequop Mountains. In the Tennessee Mountains (fig. 1), 160 km to the northwest, the Tennessee Mountain Formation of Bushnell (1967) overlies an unnamed phyllitic siltstone unit above the Prospect Mountain Quartzite. Although lithologically similar to the Toano Limestone, the



A

B

C

Figure 10. Soft-sediment slumps in the Toano Limestone. *A*, Chaotically arranged clasts; quarter shown for scale. *B*, Sharp upper contact of slump with overlying laminated lime mudstone; lens cap 5.3 cm wide shown for scale. *C*, Drag fold at base of a slump; quarter shown for scale.

Tennessee Mountain Formation may include rocks as young as Ordovician. In the Bull Run Mountains, a unit composed of thick-bedded to massive fenestral dolomite approximately 1,160 m thick (Clark, 1984) occupies the stratigraphic position of the Toano Limestone above the Edgemont Formation of Decker (1962). The Aura Formation of Decker (1962) and the Van Duzer Limestone of Decker (1962), which overlie the dolomite, are lithologically similar to the Toano but are Late Cambrian and Early Ordovician in their overall age, according to Ehman (1985). At Rattlesnake Peak in the central Ruby Mountains, Willden and Kistler (1979) recognized an unnamed, dark-gray silty limestone unit lithologically similar to the Toano Limestone above their Pioche Formation.

Cambrian and Ordovician carbonate rocks exposed in the folded, high-grade metamorphic complex of the northern Ruby Mountains and adjacent East Humboldt Range are difficult to subdivide into units correlative with less metamorphosed sections. However, the thin-bedded nature of the calc-silicate rocks and marble overlying the graphitic schist of the metamorphosed Killian Springs(?) Formation in this area is consistent with a protolith of organic silty lime mudstone typical of the Toano Limestone.

CLIFSIDE LIMESTONE (NEW)

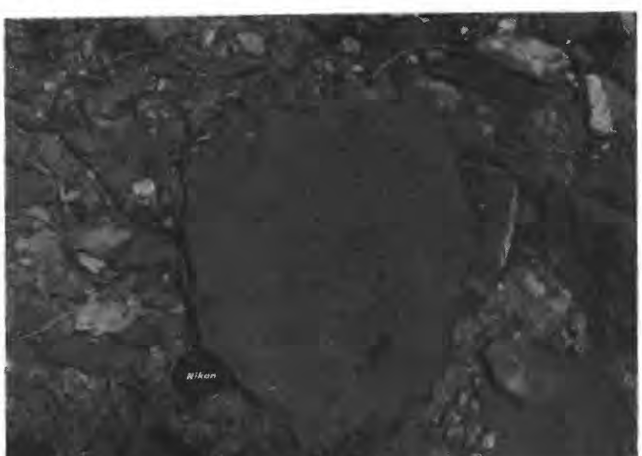
The Clifside Limestone is here named for an approximately 650-m-thick sequence of alternating gray limestone and brown silty limestone exposed on the crest and east slope of the Toano Range in sec. 3 and 4, T. 35 N., R. 68 E., Silver Zone Pass 7½-minute quadrangle, Nevada, about 2 km north of Clifside railroad siding in the Silver Zone Pass (1971) 7½-minute quadrangle; these rocks are designated as the type section of the unit (fig. 8). It consists of most of unit B of Pilger (1972), the limestone of Clifside of McCollum and McCollum (1984), and units A, B, and C of the limestone of Clifside of Glick (1987). The Clifside Limestone is exposed only within the Toano Range, Pequop Mountains, and northern Goshute Mountains. The stratigraphic interval that would be occupied by the Clifside Limestone is apparently not exposed in the Pilot Range or Silver Island Mountains.

The lower contact of the medium- to light-gray Clifside Limestone is placed at a prominent color and textural change above the darker gray, more laminated silty carbonate rocks of the Toano Limestone. The upper contact of the type section of the Clifside is a fault contact with the overlying Clifside Limestone and Morgan Pass Formation (fig. 8). However, a sharp depositional contact separates the Clifside from the overlying slope-forming, silty limestone and calcareous siltstone of the Morgan Pass Formation south of Silver Zone Pass and in the Morgan Pass section of the northern Goshute Mountains.

Glick (1987) divided her limestone of Clifside into five informal units, units A through E. Her units D and E are structurally separated from the remainder of the Clifside unit, and their strata are tentatively assigned herein variously to the Morgan Pass, Shafter, and Oasis Formations. Units A, B, and C of the limestone of Clifside of Glick (1987) represent a convenient tripartite division locally within the type section of the Clifside Limestone and are here recognized as the lower limestone, silty limestone and shale, and upper limestone members, respectively, of the Clifside Limestone.

The lower limestone member (equivalent to Glick's unit A) is characterized by alternating bands of light-gray oolitic limestone and light- to moderate-brown silty limestone. The repetitious occurrence of light-gray oolitic grainstone interbedded with medium-gray wackestone (zebra-striped pattern), alternating with layers of moderate-brown

A



B

Figure 11. Soft-sediment features of the Toano Limestone. *A*, Imbricated clasts near top of a slump. Note deformation of base of clast on left. *B*, Deformed trough cross-stratification.

siltstone with medium-gray wackestone interbeds (tiger-striped pattern), is the most distinguishing lithologic characteristic of this member. The member is 265 m thick in the type section of the Clifside Limestone.

The silty limestone and shale member (equivalent to Glick's unit B) is composed of basal black shale and oolitic and algal limestone, overlain by yellowish-orange silty limestone. The lower one-third of this member weathers recessively and forms a prominent saddle across ridges that developed on the dip slope of the type section of the Clifside Limestone. This member ranges in thickness from 155 to 175 m in the Clifside section north of Silver Zone Pass, to 205 m just south of the pass.

The upper limestone member [equivalent to Glick's unit C in the northern Toano Range and unit H of Day and others (1987) in the southern Toano and northern Goshute Mountains] is a medium-dark-gray limestone with thin, laminated to undulose silty layers. Fenestral fabric is present in the lower one-third of the Clifside type section, and cryptalgalaminites and oncolites are common throughout the member south of Silver Zone Pass. An incomplete section of 210 m is exposed in the type section of the Clifside Limestone but thins to only 100 m in a dolomitic section south of Silver Zone Pass.

The Clifside Limestone is locally dolomitized, extensively recrystallized, and bleached to a cream color near the Silver Zone Pass pluton. Tremolite and aligned white mica, accompanied by the loss of primary sedimentary features, are characteristic of the Clifside there. The upper limestone member of the Clifside forms the lowest exposures of the Cambrian section in Morgan Canyon.

Age.—The only fossils recovered from the Clifside Limestone are a few marjumid trilobites and numerous inarticulate linguloid brachiopods found within its silty limestone and shale member. However, *Bolaspidella* is present in the uppermost beds of the underlying Toano Limestone and also in the basal part of the overlying Morgan Pass Formation. Thus, the Clifside is entirely within the *Bolaspidella* Assemblage-zone in the upper Middle Cambrian. Therefore, the Clifside Limestone is considered to be Middle Cambrian in age.

Regional Correlations.—The Clifside Limestone appears to be partially age equivalent to the interbedded shale and silty limestone of the Marjum Formation in the west-central House Range; to the silty to pure limestone in the middle part of the Raiff Limestone of Young (1960) in the Cherry Creek, northern Egan, and northern Schell Creek Ranges; and to the thin- to medium-bedded limestone of the Pierson Cove Formation and the lower part of the overlying Trippe Limestone in the Deep Creek Mountains and Fish Springs Range, all far south of the Wendover region. To the west, the Clifside may be partially age equivalent to the hemipelagic carbonate rocks and interbedded phyllitic shales of the Tennessee Mountain Formation of Bushnell (1967) in the Tennessee Mountains and to the Aura Formation of Decker (1962), as described by Ehman (1985), in the Bull Run Mountains. The Rattlesnake Peak section of Willden and Kistler (1979) in the central Ruby Mountains contains an unnamed limestone unit that is approximately age equivalent (latest Middle Cambrian) to the (combined) Clifside Limestone and overlying Morgan Pass Formation. Whether or not these unit names can eventually be applied to these strata in the Ruby Mountains will have to await further investigation.

MORGAN PASS FORMATION (NEW)

The Morgan Pass Formation is here named for a 225-m-thick sequence of slope-forming shale and silty limestone exposed 1 km west of Morgan Pass in sec. 21, T. 32 N., R. 68 E., Morgan Pass 7½-minute quadrangle, at the northern terminus of the Goshute Mountains (figs. 12, 13). It consists of all the strata designated as units F and G by Day and others (1987). The formational name is derived from Morgan Pass. The basal contact of the unit is sharp and is placed at the base of the lowest shale or silty limestone above the massive, ridge-forming Clifside Limestone, whereas its upper contact is gradational and is placed at the top of the slope below the cliff-forming Decoy Limestone. The Morgan Pass Formation is present south of Silver Zone Pass in the central Toano Range (fig. 14) and in the Pequop Mountains but is not exposed to the east in the Pilot Range or Silver Island Mountains.

The Morgan Pass Formation is largely covered, except for two prominent limestone ledges between 40 and 65 m above its base. Small grayish-orange to yellowish-brown chips of calcareous siltstone, silty limestone, and shale float cover the steep slopes. Thin, parallel-bedded, grayish-orange calcareous siltstone, alternating with medium-dark-gray limestone, is present in limited and widely scattered exposures throughout the formation. The uppermost 19 m of the formation is well exposed in its type section, where oolitic grainstones, rip-up clasts, and stromatolitic layers (fig. 15) are present within the calcareous siltstone and limestone sequence.

South of Silver Zone Pass, oolitic and oncolitic limestone beds become more common throughout the Morgan Pass Formation as the silt content decreases. The formation also thins substantially to 125 m there.

Age.—Faunas within the Morgan Pass Formation are restricted to the upper half of the Middle Cambrian. A Middle Cambrian *Bolaspidella* Assemblage-zone fauna is present in the basal beds of the Morgan Pass Formation in the central Toano Range and in both of the prominent ledgy limestone layers between 40 and 65 m above the base of the unit's type section. An *Eldoradia* Assemblage-zone fauna is present in the uppermost 20 m in the type section. Thus, the age of the Morgan Pass Formation is considered to be Middle Cambrian.

Regional Correlations.—The Morgan Pass Formation, although lithologically quite different, appears to be correlative with the Fish Springs Member of the Trippe Limestone, exposed in several mountain ranges in west-central Utah. The Trippe Limestone was named by Nolan (1935) for exposures in the Deep Creek Mountains in Utah, just to the south of the study area, and consists of a thin-bedded limestone and dolomite sequence approximately 230 m thick. Hintze (1974) and Hintze and Robison (1975) reported an *Eldoradia* Assemblage-zone fauna from the upper half of the Trippe Limestone regionally.

DECOY LIMESTONE (NEW)

The Decoy Limestone is here named for a 60-m-thick, massive, light-gray limestone exposed 1 km west of Morgan Pass in sec. 21, T. 32 N., R. 68 E., Morgan Pass 7½-minute quadrangle, at the northern terminus of the Goshute Mountains (figs. 12, 13); these rocks are also designated as the type section of the unit. The Decoy is equivalent to unit E of Day and others (1987). The formational name is derived from Decoy, a site along the Northern Nevada Railroad, 17 km to the west [see Decoy 7½-minute (1971) quadrangle].

The Decoy Limestone is a very distinctive unit that generally forms a bold gray band of limestone, commonly recrystallized, between darker, well-bedded slope-forming formations. The lower contact of the Decoy Limestone is placed at the top of the thin-bedded calcareous siltstone and interbedded dark-gray limestone of the Morgan Pass Formation. The upper contact is placed at the top of the highest massive limestone below the recessive, thin-bedded Shafter Formation.

The Decoy Limestone is also present south of Silver Zone Pass in the central Toano Range (fig. 14) and in the

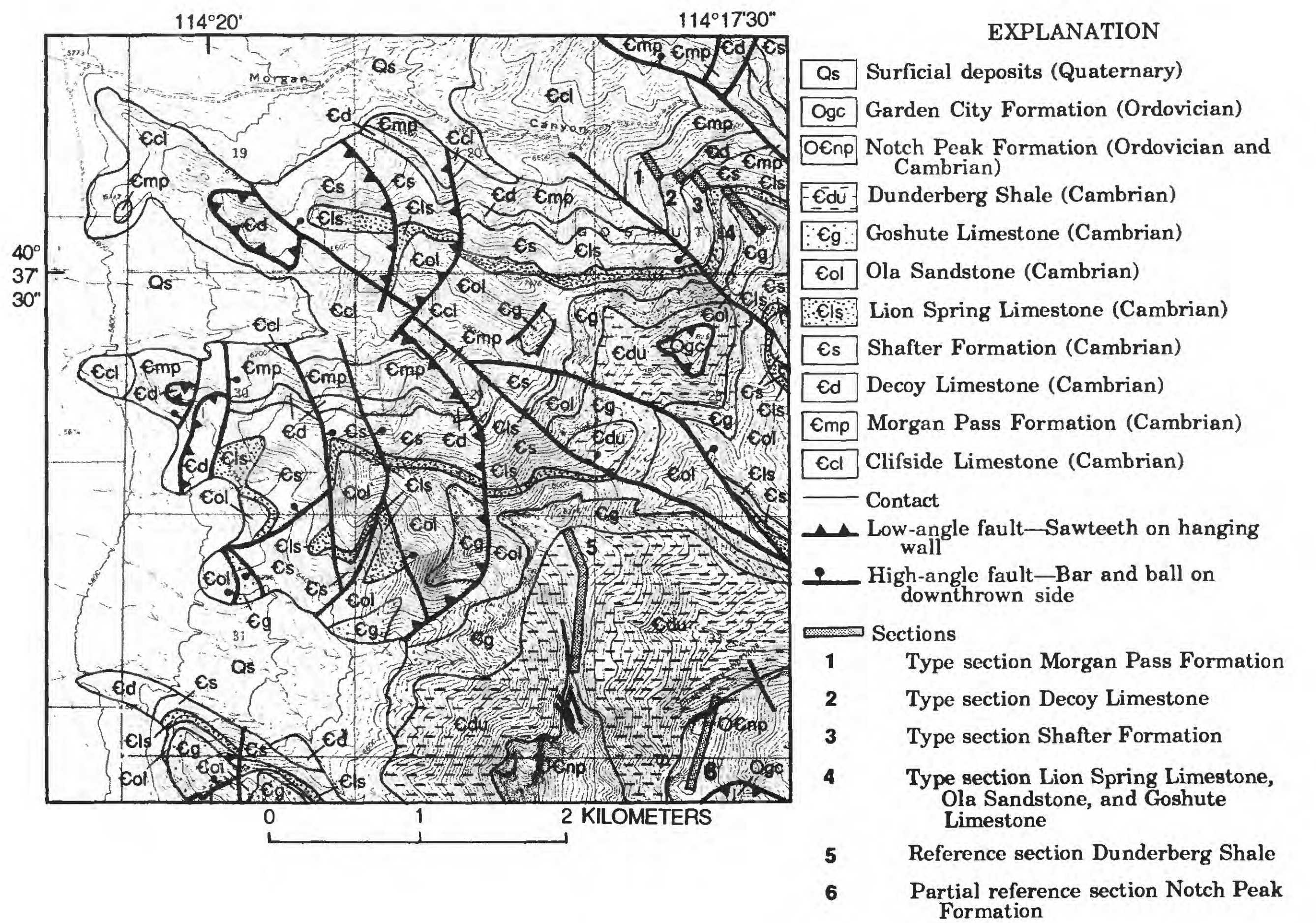


Figure 12. Geologic map of the Morgan Pass area, northern Goshute Mountains and southern Toano Range, Nevada, showing locations of type sections of the Morgan Pass Formation, Decoy Limestone, Shafter Formation, Goshute Limestone, Ola Sandstone, and Lion Spring Limestone, and reference sections for the Dunderberg Shale and Notch Peak Formation. See figure 2 for location of map. Base from U.S. Geological Survey, 1:24,000-scale Morgan Pass and Lion Spring 7½-minute quadrangles, 1972, Nevada. Contour interval 40 ft. Geologic contacts generalized from Day and others (1987).

Figure 13. Morgan Pass section, Goshute Mountains. Ridge on left contains type and reference sections for several formations. In sequence upward from base, Morgan Pass Formation underlies tree-covered slope, Decoy Limestone is lowest prominent white band of cliffs, Shafter Formation underlies next slope, Lion Spring Limestone is knob-forming limestone unit near skyline, and Ola Sandstone lies just below white, massive, upper cliffs of the Goshute Limestone. Dunderberg Shale underlies uppermost grassy slope on hill at right side of photograph, above cliffs of Goshute Limestone.

Pequop Mountains. The Decoy is highly recrystallized and dolomitic, but retains a thickness of 60 m, except where locally removed by faulting. The Decoy Limestone is not exposed in the Pilot Range or Silver Island Mountains to the east.

Age.—No faunas have been recovered from the Decoy Limestone in the study area. This may be due in part to extensive recrystallization and the massive texture of the unit. However, the Decoy Limestone is bracketed by late Middle Cambrian faunas in adjacent formations. Thus, the age of the Decoy Limestone is considered to be Middle Cambrian.

Regional Correlations.—The Decoy Limestone comprises the northern exposures of a prominent and widespread limestone facies in eastern Nevada. Regionally, the light- to medium-gray limestone forms a prominent ridge or small cliff between slope-forming, shalier facies. Its relatively pure carbonate strata range in thickness from 5 to 75 m regionally and are overlain by shaley strata containing trilobites of the *Lejopyge laevigata* Interval-zone of Robison (1984).

The Decoy Limestone is correlative with the (middle) limestone member of the Lincoln Peak Formation mapped by Drewes (1967) in the northern Schell Creek Range. The regional distribution of this limestone unit was depicted by Palmer (1971, p. 67), and it is present in the type section of the Lincoln Peak in the Snake Range (A.R. Palmer, written commun., 1989), in the Lincoln Peak Formation at the junction of the White Pine Mountains and Grant Range to the south (R.A. Robison, written commun., 1984), within the upper Marjum Formation in the House Range, and within an unnamed limestone unit of Willden and Kistler (1979, p. 229–230). The Decoy is also correlative with (basal) member A of the Emigrant Springs Limestone of Kellogg (1963) in the southern Schell Creek Range.

SHAFTER FORMATION (NEW)

The Shafter Formation is here named for a 200-m-thick, thin-bedded, dark-gray silty limestone exposed 1 km west of Morgan Pass in sec. 21, T. 32 N., R. 68 E., Morgan

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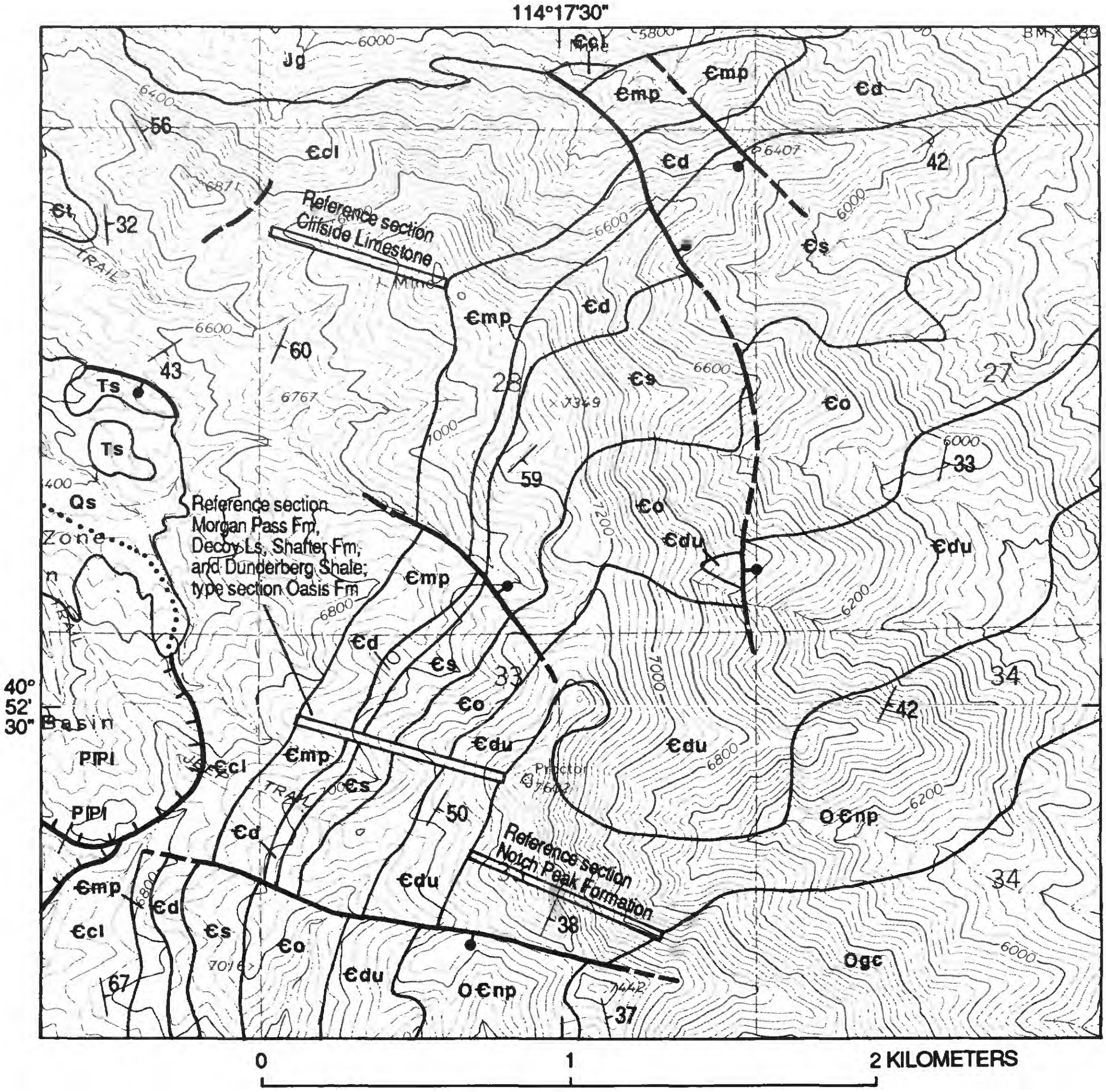
Figure 14. Geologic map of Toano Range south of ► Silver Zone Pass, Nevada, showing location of type section of the Oasis Formation and reference sections of the Clifside Limestone, Morgan Pass Formation, Decoy Limestone, Shafter Formation, Dunderberg Shale, and Notch Peak Formation. See figure 2 for location of map. Base from U.S. Geological Survey, 1:24,000-scale Silver Zone Pass 7½-minute quadrangle, 1982, and West Morris Basin 7½-minute quadrangle, 1971, Nevada. Contour interval 40 ft. Generalized geology from unpublished mapping by D.M. Miller.



EXPLANATION

Qs	Surficial deposits (Quaternary)
Ts	Sedimentary rocks (Tertiary)
Jg	Granodiorite (Jurassic)
PIPI	Limestone (Permian and Pennsylvanian)
Ogc	Garden City Formation (Ordovician)
O€np	Notch Peak Formation (Ordovician and Cambrian)
€du	Dunderberg Shale (Cambrian)
€o	Oasis Formation (Cambrian)
€s	Shafter Formation (Cambrian)
€d	Decoy Limestone (Cambrian)
€mp	Morgan Pass Formation (Cambrian)
€cl	Clifside Limestone (Cambrian)
€t	Toano Limestone (Cambrian)

Contact

Faults—Dashed where approximate; dotted where concealed

High-angle—Bar and ball on downthrown side

Gravity-slide—Hachures on upper plate

60 Strike and dip of bedding

Pass 7½-minute quadrangle, at the northern terminus of the Goshute Mountains (fig. 12); these rocks are also designated as the type section of the unit. The Shafter is equivalent to unit D of Day and others (1987). The formational name is derived from Shafter, a site along the Union Pacific Railroad, 25 km to the northwest [see Shafter 7½-minute (1971) quadrangle]. The Shafter Formation is also present south of Silver Zone Pass in the Toano Range (fig. 14) and in the Pequop Mountains, but the unit is not exposed in the Pilot Range or Silver Island Mountains.

The lower half of the Shafter Formation forms a prominent recessive and largely covered interval. The thin- to medium-bedded, dark-gray, aphanitic limestone erodes readily along parallel silty laminations, forming blocky limestone talus on south-facing slopes. A much deeper soil development is present in the higher elevations on north-facing slopes, including the type section, which supports dense stands of conifers and other vegetation.

The upper half of the Shafter Formation is composed of medium-gray limestone and grayish-orange silty limestone to calcareous siltstone. In appearance, this lithology closely resembles that of the Morgan Pass Formation, but the Shafter can be distinguished from the Morgan Pass by the former's more undulose bedding and more irregular weathering pattern. The upper half of the Shafter forms steeper slopes and is better exposed than the lower half of the unit. In the Morgan Pass area, the upper contact of the Shafter Formation is relatively sharp and is placed at the boundary separating the formation's thin, interbedded limestones and calcareous siltstones below from the massive, cliff-forming beds of the Lion Spring Limestone above.

Age.—The lower half of the Shafter Formation contains polymeroid trilobites and inarticulate brachiopods of the upper *Bolaspidella* and *Cedaria* Assemblage-zones. *Baltagnostus* and *Clavagnostus*, elements of the uppermost Middle Cambrian *Lejopyge laevigata* Interval-zone of Robison (1984), are also present in the Shafter Formation. Robison (1984, p. 8) reassigned much of the North American *Cedaria* Assemblage-zone to the Middle Cambrian. Thus, the Shafter Formation is mostly, if not entirely, Middle Cambrian in age.

Regional Correlations.—The Lamb Dolomite, named by Nolan (1935) for exposures in the Deep Creek Mountains of Utah, is a partial temporal equivalent of the Shafter Formation. The Lamb Dolomite is a widespread unit, present not only in the study area, but also in several mountain ranges to the south. Throughout its geographic extent, the Lamb Dolomite consists of massive, light-gray, oolitic and oncolitic dolomite, which contrasts sharply with the thin-bedded limestones and calcareous siltstones of the Shafter Formation.

The approximately 400-m-thick Weeks Limestone, exposed only in the west-central House Range (Hintze and Robison, 1975), is lithologically similar to and temporally equivalent with the Shafter Formation. The lower half of both formations is composed of thin, parallel-bedded, micritic limestone. However, the upper Weeks contains bio-

Figure 15. Stromatolitic limestone interval near the base of Morgan Pass Formation in Morgan Pass, northern Goshute Mountains.

clastic and oolitic limestones, which are not present in the Shafter. The Weeks Limestone was deposited in a localized depocenter within the House Range embayment (Rees, 1986), which may account for it being twice the thickness of the Shafter. In addition, the Shafter and Weeks are separated geographically from one another by the largely temporally equivalent Lamb Dolomite, exposed in the intervening mountain ranges, such as the Fish Springs Range, Deep Creek Mountains, and Silver Island Mountains.

In eastern Nevada, the lower part of the "upper shale member" (see Drewes, 1967, p. 12) of the Lincoln Peak Formation is correlative with the Shafter Formation. In the southern Schell Creek Range, the lower half of member B of the Emigrant Springs Limestone of Kellogg (1963) also appears to correlate with the Shafter. The "unnamed hornfels formation" of Willden and Kistler (1979) in the central Ruby Mountains is roughly correlative with the Shafter, although an exact correlation is hampered by lack of faunal control in this and other Cambrian sections to the west of the Wendover region.

LION SPRING LIMESTONE (NEW)

The Lion Spring Limestone is here named for an 85-m-thick limestone to silty limestone sequence that forms the basal unit of a tripartite cliff-forming section exposed 1 km west of Morgan Pass in sec. 21, T. 32 N., R. 68 E., Morgan Pass 7½-minute quadrangle, at the junction of the Toano Range and Goshute Mountains (figs. 12, 13); these rocks are designated as the type section of the unit. The formation is equivalent to unit C of Day and others (1987), a mappable unit exposed over several square kilometers and believed to underlie a much greater area. The Lion Spring Limestone is a cliff former that has not been observed elsewhere in the northern Great Basin. The formational name is derived from Lion Spring, located approximately 6 km south of the type section in the Lion Spring 7½-minute quadrangle in the northern Goshute Mountains. The basal contact of the formation is relatively sharp and is placed at the base of a relatively pure cliff-forming limestone interval above the calcareous siltstones and silty limestones of the underlying Shafter Formation. The upper contact is somewhat gradational and is placed at the base of a distinct color and lithologic change of the overlying yellowish-orange to brick-red Ola Sandstone.

Texturally, the Lion Spring Limestone is generally massive and forms a bold, light- to medium-gray cliff. The medium- to thick-bedded carbonate unit contains some thin silty interbeds, silty mottles, and fenestral fabric. Oncolitic and oolitic interbeds are also present.

Age.—Trilobite hash from the middle part of the Lion Spring Limestone contains a *Crepicephalus* Assemblage-zone fauna. The underlying Shafter Formation contains a *Cedaria* Assemblage-zone fauna in its upper beds, and thus the Lion Spring Limestone is considered to be early Late Cambrian in age.

OLA SANDSTONE (NEW)

The Ola Sandstone is here named for a 60-m-thick sequence of ridge- to cliff-forming quartz sandstone, calcareous siltstone, and silty limestone exposed 1 km west of Morgan Pass in sec. 21, T. 32 N., R. 68 E., Morgan Pass 7A-minute quadrangle; these rocks are designated as the type section of the unit. The Ola is equivalent to unit B of Day and others (1987) exposed in the Goshute Mountains (figs. 12, 13). The formational name is derived from Ola, a site along the Western Pacific Railroad, 15 km to the northeast [see Ola 7½-minute (1972) quadrangle]. In the Deep Creek Mountains, the uppermost 50 m of the Lamb Dolomite, which consists of a very distinctive sandstone lithology, is here reassigned to the Ola Sandstone.

The Ola Sandstone consists of reddish-orange medium-bedded sandstone, calcareous siltstone, and silty to oolitic limestone that is sandwiched between two massive cliff-forming carbonate units. It represents an important but rather limited lithofacies in which coarse- to fine-grained quartz sand and silt were deposited. Its yellowish-orange to brick-red color and quartz sand make it one of the most distinctive Upper Cambrian formations in the Great Basin.

Age.—Tricrepicephalus is abundant in trilobite packstone near the top of the type section for the Ola Sandstone in the Morgan Pass section in the Goshute Mountains. In the Deep Creek Mountains, Bick (1966, p. 35) reported a *Crepicephalus* Assemblage-zone fauna from the uppermost part of the Lamb Dolomite, which is reassigned to the Ola Sandstone in this report. In the northern Goshute Mountains, the underlying Lion Spring Limestone and the overlying Goshute Limestone both contain *Crepicephalus* Assemblage-zone faunas. Thus, the Ola Sandstone is considered to be entirely Late Cambrian in age.

GOSHUTE LIMESTONE (NEW)

The Goshute Limestone is here named for a 65-m-thick, cliff-forming, light- to medium-gray limestone sequence exposed 1 km west of Morgan Pass in sec. 21, T. 32 N., R. 68 E., Morgan Pass 7½-minute quadrangle; these rocks are designated as the type section of the unit (figs. 12, 13). The formational name is derived from the Goshute Mountains, where the unit is exposed. The Goshute is equivalent to unit A of Day and others (1987); its thickness is as great as 200 m.

Texturally, the Goshute Limestone is medium-bedded to massive, and it forms inaccessible cliffs throughout much of its outcrop area. Its relatively pure limestone is recrystallized, giving a uniform light- to medium-gray color. Thin silty layers, silty mottles, and several oncolitic beds are present. Basal and upper contacts of the formation are relatively sharp. The lower contact is placed at the top of the calcareous siltstone in the underlying Ola Sandstone; the upper contact is placed at the base of the overlying recessive, thin-bedded Dunderberg Shale in the northern Goshute Mountains and at the base of the Candland Formation in the Deep Creek Mountains.

Age.—A *Crepicephalus* Assemblage-zone fauna is present 10 m below the top of the Goshute Limestone. Therefore, the Goshute Limestone is considered to be entirely early Late Cambrian in age.

Regional Correlations for the Lion Spring Limestone, Ola Sandstone, and Goshute Limestone.—The Lion Spring Limestone, Ola Sandstone, and Goshute Limestone are temporally equivalent to the Oasis Formation and the Big Horse Limestone in the study area. They are also temporally equivalent to the upper part of the Raiff Limestone of Young (1960) in the Cherry Creek, northern Egan, and northern Schell Creek Ranges in eastern Nevada. In the Deep Creek Mountains of western Utah, the upper part of the Lamb Dolomite (as stratigraphically restricted in this report) is the age equivalent of the Lion Spring Limestone mapped elsewhere. The Ola Sandstone is present in the Deep Creek Mountains and Dugway Range above the Lamb Dolomite (emended). In the Deep Creek Mountains, the Goshute Limestone is equivalent to an unnamed dolomite in the lower part of the herein-abandoned Hicks Formation.

OASIS FORMATION (NEW)

The Oasis Formation is here named for a 145-m-thick sequence of light-gray recrystallized limestone, bluish-gray dolomite, and calcareous siltstone exposed in the central Toano Range. The type section is located southeast of Silver Zone Pass in sec. 33, T. 35 N., R. 68 E., West Morris Basin 7½-minute quadrangle (fig. 14). The formational name is derived from a small village on Interstate 80 [see Cobre 7½-minute (1967) quadrangle], approximately 30 km to the northwest of the type section. Although the Oasis Formation has a limited outcrop area, it is a very distinctive unit because of its uniform light-gray color, coarsely crystalline texture, and slope-forming outcrop pattern. The Oasis Formation crops out in the Pequop Mountians and Wood Hills but is not described elsewhere in Utah and Nevada.

The basal and upper contacts of the formation are relatively sharp and are placed at the top of the calcareous siltstone in the underlying Shafter Formation and the base of the overlying recessive, thin-bedded Dunderberg Shale, respectively. Much of the Oasis Formation is composed of mottled lime mudstone, trilobite packstone, oolitic grainstone, cryptalgalaminites, and fenestral lime mudstone. A 10-m-thick, light-brown calcareous siltstone is present 60 m below the top, and thin, light-gray dolomitic silty layers are common throughout.

Age.—Early Late Cambrian faunas assigned to the upper *Cedaria* or lower *Crepicephalus* Assemblage-zones are

Figure 16. Upper Cambrian section, central Silver Island Mountains, Utah, near Jenkins Peak. Prominent white band is the Johns Wash Limestone.

present between 7 and 10 m above the base of the Oasis Formation at its type section in the Toano Range. The basal beds of the overlying Dunderberg Shale contains a *Dicanthopyge* Assemblage-zone fauna. Thus, the Oasis Formation is considered to be early Late Cambrian in age.

Regional Correlations.—The Oasis Formation is temporally equivalent to the Big Horse Limestone Member and lower beds (pre-*Aphelaspis* Assemblage-zone) of the Candland Shale Member of the Orr Formation in west-central Utah. To the north in the Deep Creek Mountains, the Oasis is equivalent to the upper part of the Lamb Dolomite (restricted), the overlying Ola Sandstone, and the unnamed dolomite that was previously included as the base of the herein-abandoned Hicks Formation. In eastern Nevada, the middle part of the "upper shale member" (see Drewes, 1967, p. 12) of the Lincoln Peak Formation contains a *Crepicephalus* Assemblage-zone fauna (Drewes and Palmer, 1957). The lack of faunal control and formational descriptions precludes any regional correlations west of the Wendover region.

DUNDERBERG SHALE

The Dunderberg Shale, named by Walcott (1908b) in the Eureka district, Nevada, and revised there by Nolan and others (1956), crops out widely in east-central Nevada. As indicated in fig. 5, the Dunderberg Shale includes five faunal zones, ranging from the upper *Aphelaspis* Assemblage-zone into the *Elvinia* Assemblage-zone (Palmer, 1960, 1965). The Dunderberg ranges in thickness from 81 m in its type section to 190 m in the Cherry Creek Range (Palmer, 1965).

The Dunderberg Shale is present south of Silver Zone Pass in the Toano Range, in the Pequop Mountains, in the Wood Hills, and in the Morgan Pass section in the northern Goshute Mountains (figs. 12–14). Regionally, it is about 150 m thick and has thin-bedded, dark-gray to black shale and argillaceous limestone in its lower half and pale-olive to tan shale and medium-bedded crinoidal limestone in its upper half. Faunas collected during this study and identified by A.R. Palmer (written commun., 1984, 1986, 1987)

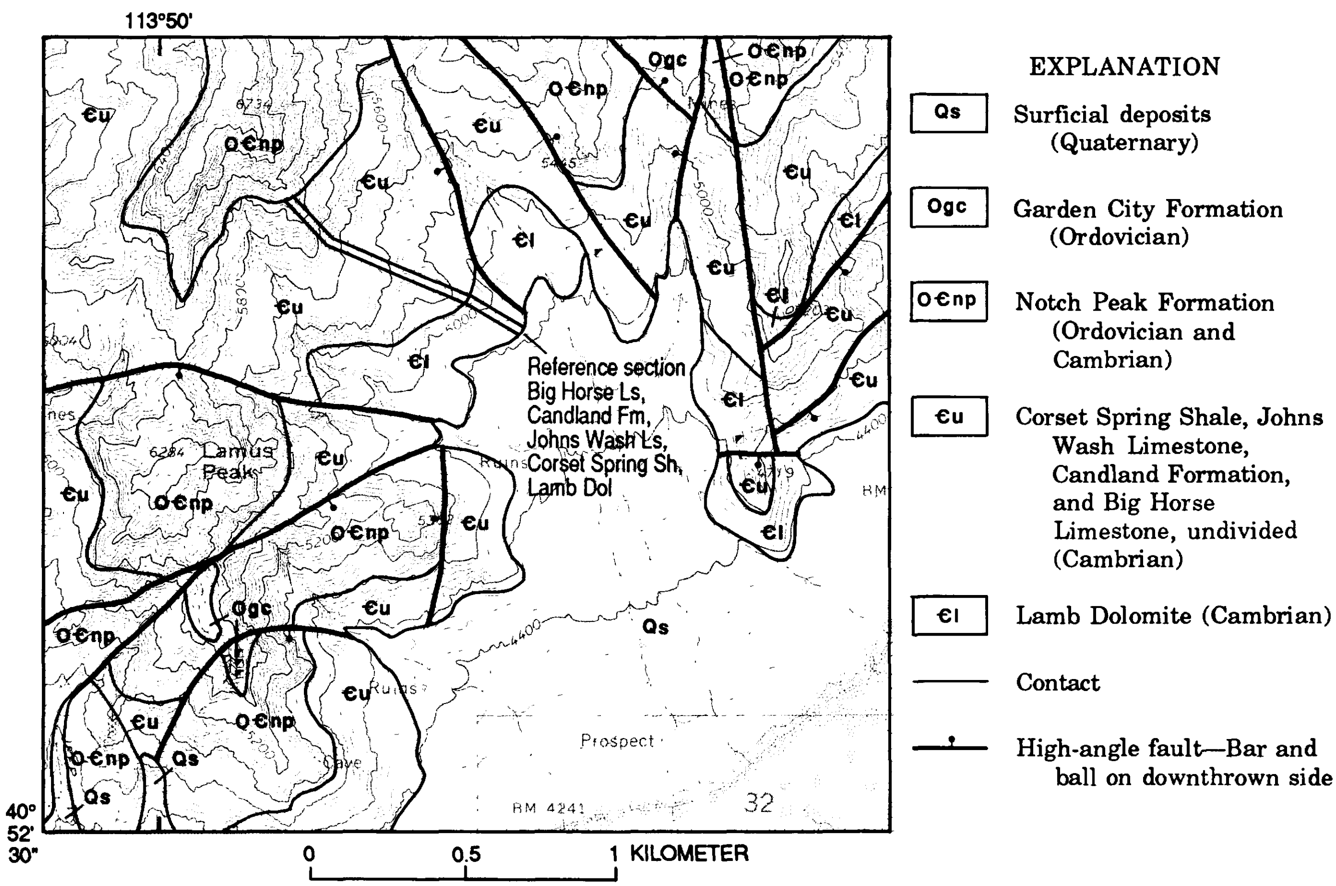


Figure 17. Geologic map of Jenkins Peak area, central Silver Island Mountains, Utah, showing location of reference sections of the Big Horse Limestone, Candland Formation, Johns Wash Limestone, and Corset Spring Shale. See figure 2 for location of map. Base from U.S. Geological Survey, 1:24,000-scale Graham Peak 7½-minute quadrangle, 1971, Utah. Contour interval 40 ft. Geology modified from Schaeffer (1960); because Schaeffer did not break these units out, central part of section is undivided.

from the Dunderberg Shale in the Silver Zone Pass and Morgan Pass sections represent the *Dicanthopyge* to *Elvinia* Assemblage-zones.

The Dunderberg Shale in the Toano Range south of Silver Zone Pass (fig. 14) is temporally equivalent to the (combined) Candland Formation, Johns Wash Limestone, and Corset Spring Shale in the Silver Island Mountains, the southern Pilot Range, and the northern Toano Range. This represents the most striking facies change between the Upper Cambrian sections exposed below and above the Pilot Peak detachment. Absent in the lower-plate section is the prominent "white band" lithology (equivalent to recrystallized white limestone) mentioned by Schaeffer (1960, p. 32) in the central Silver Island Mountains (fig. 16), which was later called the Johns Wash Limestone by Robison and Palmer (1968). The thin Corset Spring Shale probably correlates with the much thicker olive to tan shale and silty crinoidal limestone unit present in the uppermost part of the Dunderberg Shale in the Toano Range, which is exposed south of Silver Zone Pass.

UPPER-PLATE CAMBRIAN SECTION

A separate Middle and Upper Cambrian stratigraphic nomenclature, primarily developed outside of the Wendover region, is applied to a largely carbonate section exposed above the Pilot Peak detachment. Miller (1983, p. 199), in his discussion of the Pilot Range, was the first to note dissimilarities between the unmetamorphosed Upper Cambrian section exposed immediately above the Pilot Peak detachment and the metamorphosed section below it. Similar structure and facies are present in the Silver Island Mountains and at the northern end of the Toano Range.

The stratigraphic sequence of Middle and Upper Cambrian rocks above the Pilot Peak detachment is fairly similar to temporally equivalent sequences in west-central Utah and adjacent Nevada. Some previously established nomenclature has already been applied in the Wendover region, such as the Johns Wash Limestone, Corset Spring Shale, and Notch Peak Formation (see Whitebread, 1969). Recent geologic mapping by Glick (1987) in the northern Toano Range and by D.M. Miller (unpub. data) in the Pilot Range and Silver Island Mountains has shown that the Trippe, Lamb, Big Horse, and Candland units are also present regionally. A brief description of each of these previously established units within the Wendover region is given here to facilitate comparison with both the lower-plate rocks of the Wendover region and similar facies outside the study region.

Glick (1987) used the Orr Formation in her discussion of Upper Cambrian upper-plate rocks in the northern Toano Range. The Orr Formation was divided into five formal members by Hintze and Palmer (1976); the lower four of these members appear to be readily mappable at a scale of 1:24,000 in the Wendover region. The Orr Formation is raised to group status, with the Big Horse Limestone and Candland Shale Members (of the Orr Formation) raised to formational rank. The overlying Johns Wash Limestone and Corset Spring Shale already are of formational rank in east-central Nevada (see Drewes and Palmer, 1957). Strata correlative with the Sneakover Limestone Member, the uppermost member of the Orr Formation in Utah, were assigned to the Notch Peak Formation by Whitebread (1969) in Nevada. That usage is followed here.

TRIPPE LIMESTONE

The Trippe Limestone was named by Nolan (1935) for a 230-m-thick section of medium-gray silty limestone and light-gray to white, laminated dolomite in the Deep Creek Mountains, Utah. Hintze and Robison (1975) recognized the Trippe Limestone as a widespread unit in east-central Utah. In addition, they divided the type section of the Trippe into an informal lower limestone member and an upper Fish Springs Member.

Miller (1990) has identified the Trippe Limestone in the northern Silver Island Mountains at Crater Island, where it is the lowest exposed Cambrian unit. Only about 150 m of the upper Trippe Limestone is exposed below the Lamb Dolomite, and this sequence consists of medium-dark-gray limestone and silty limestone. The Trippe Limestone is extended northward into the Silver Island Mountains based on stratigraphic position and on such lithologic similarities to the Fish Springs Member of the Trippe at its type section as silty, oolitic, and oncolitic limestone, and intraformational conglomerate. The Trippe in the Silver Island Mountains differs from the Trippe at the type section by lacking shale and light-colored, laminated dolomite (cryptalgalaminite), except locally as clasts in silty limestone within its upper part.

Age.—No fossils were found in the Trippe Limestone at Crater Island, possibly owing to the extensive recrystallization of the Cambrian section, which is adjacent to a Jurassic intrusion (Miller and others, 1990). Hintze (1974) and Hintze and Robison (1975) reported a late Middle Cambrian *Eldoradia* fauna from the Fish Springs Member of the Trippe Limestone elsewhere.

LAMB DOLOMITE (EMENDED)

The Lamb Dolomite was named by Nolan (1935) for a 320-m-thick sequence of light-gray dolomite, much of which is highly recrystallized, in the Deep Creek Mountains, Utah. Nolan (1935, p. 13) informally subdivided the type section of the Lamb into three distinct lithologies: a lower, 150-m-thick, crossbedded, oolitic and oncolitic dolomite; a middle, 120-m-thick, mottled and highly recrystallized dolomite; and an upper, 50-m-thick, thin-bedded dolomite with yellowish-orange to red sandstone, siltstone, and shale. We herein restrict the type section of the Lamb Dolomite to include only the purer dolomitic rocks of the two lower facies of Nolan (1935) and reassign the upper 50 m of sandy dolomite to the Ola Sandstone of this report.

The Lamb Dolomite is present in several mountain ranges southeast of the type area (Hintze and Robison, 1975) and also in the Wendover area. Miller (1990) assigned approximately 75 m of light-gray to white, crystalline dolomite and dolomitic limestone of the unit between the underlying Trippe Limestone and the overlying Big Horse Limestone to the Lamb Dolomite in the northern Silver Island Mountains at Crater Island. In the Jenkins Peak section at Silver Island (fig. 17) in the Silver Island Mountains, Schaeffer (1960, p. 23–24) mapped a 108-m-thick dolomite interval as the Dome(?) Formation; these rocks are herein assigned to the Lamb Dolomite.

Age.—The Lamb Dolomite is largely unfossiliferous, and its age is constrained by faunas in the underlying and overlying formations. A late Middle Cambrian *Eldoradia* Assemblage-zone fauna is present near the top of the underlying Trippe Limestone in central Utah, and the overlying Big Horse Limestone Member of the Orr Formation in western Utah contains trilobites of the *Cedaria* Assemblage-zone. Bick (1966, p. 35) reported *Crepicephalus* Assemblage-zone trilobites from the upper beds of the Lamb Dolomite in the type area in the Deep Creek Mountains, in strata that are now assigned to the Ola Sandstone. Robison and Palmer (1968) also collected a species of *Crepicephalus* from rocks herein assigned to the Lamb Dolomite in the central Silver Island Mountains. The upper contact of the Lamb Dolomite is therefore diachronous and becomes younger in a northward direction.

The base of the *Cedaria* Assemblage-zone has traditionally been used as the base of the Upper Cambrian in North America (Lochman-Balk and Wilson, 1958; Robison, 1964), which would place the Lamb Dolomite in the Upper Cambrian. However, recently Robison (1984), following a suggestion by Daily and Jago (1975), included much of the *Cedaria* zone within the Middle Cambrian. By this revision the Lamb Dolomite could include Middle Cambrian beds; we at present adopt this age reassignment of the *Cedaria* zone and consider the Lamb to be Middle and Late Cambrian in age.

BIG HORSE LIMESTONE

The Big Horse Limestone Member of the Orr Formation was named by Hintze and Palmer (1976) for a limestone and dolomite sequence ranging from 135 to 270 m in thickness in the House Range of west-central Utah. They reported that it generally forms bold cliffs of limestone, silty limestone, and dolomite. Such features as oolites, oncolites, and stromatolites are present in the Big Horse Limestone Member.

The unit is here raised to formational rank within the Wendover region as the Big Horse Limestone. In the northern Silver Island Mountains, Miller (1990) has mapped a much faulted section of the Big Horse Limestone at Crater Island, where the unit is approximately 180 m thick. A 175-m-thick sequence of light- to medium-gray limestone and minor dolomite in the Jenkins Peak section at Silver Island in the Silver Island Mountains (fig. 17), which Schaeffer (1960, p. 25–27) mapped as the Condor Formation and restricted Swasey Limestone, is here reassigned to the Big Horse Limestone. In Miners Canyon on the southeast flank of Pilot Peak in the Pilot Range, much faulted, light-gray dolomite and recrystallized limestone below the Candland Formation and above the Pilot Peak detachment are here reassigned to the Big Horse Limestone. In the northern Toano Range, Glick (1987) mapped a 270-m-thick dolomite and limestone unit below the Candland Shale Member (of the Orr Formation) as the Big Horse Limestone Member (of the Orr Formation). These rocks are here reassigned to the Lamb Dolomite and Big Horse Limestone, undifferentiated.

Age.—Robison and Palmer (1968) reported a *Crepicephalus* Assemblage-zone fauna from about 45 m above the base of an undifferentiated lower Upper Cambrian unit in the Jenkins Peak section in the central Silver Island Mountains, which is here assigned to the Big Horse Limestone. Additional fossils were not found in the unit during this study. Hintze and Palmer (1976) noted that, regionally, faunas from the Big Horse Limestone Member of the Orr Formation range from the upper part of the *Cedaria* to near the top of the *Crepicephalus* Assemblage-zones of the Upper Cambrian. Thus, the Big Horse Limestone is considered to be Late Cambrian in age.

CANDLAND FORMATION

The Candland Shale Member of the Orr Formation was named by Hintze and Palmer (1976) for a shale and silty limestone sequence approximately 125 m thick in the House Range of west-central Utah. They noted that the unusually fossiliferous Candland Shale Member is an easily mappable unit that forms broad benches and slopes between the underlying cliff-forming Big Horse Limestone and overlying Johns Wash Limestone Members (of the Orr Formation).

The unit is here raised to formational rank in the Wendover region as the Candland Formation. In the Jenkins Peak section at Silver Island in the Silver Island Mountains (fig. 17), the Candland Formation consists of 85 m of strata that were mapped as the Wheeler Shale by Schaeffer (1960, p. 27–29) and later referred to as the Dunderberg

Shale by Robison and Palmer (1968). Miller (1990) has mapped an approximately 60-m-thick section of the Candland Formation at Crater Island in the northern Silver Island Mountains. In the southern Pilot Range, it consists of strata previously assigned to the Dunderberg Shale by O'Neill (1968) and Miller (1984) above the Pilot Peak detachment. In the northern Toano Range, strata mapped as the Candland Shale Member of the Orr Formation by Glick (1987) are here assigned to the Candland Formation.

The lower contact of the Candland Formation is placed at the base of the thin- to medium-bedded, recessive silty limestone above the cliff-forming Big Horse Limestone. The upper contact is gradational and is placed at the top of the thin- to medium-bedded silty limestone below the massive, recrystallized and locally dolomitic, cliff-forming Johns Wash Limestone. The Candland Formation thins westward from 85 m in the Jenkins Peak section of the Silver Island Mountains to approximately 60 m in the northern Toano Range. Thickness measurements in the Pilot Range were precluded by faulting.

An irregular or undulose weathering, thin- to medium-bedded, medium-gray limestone unit, locally containing numerous inarticulate brachiopods, is present in the basal few meters of the Candland Formation. Slope-forming, laminated to thinly bedded black shale, which weathers light olive gray to grayish orange pink, and nodular to thin-bedded argillaceous limestone compose the remainder of the formation. Black shale is the main lithology in the lower half of the formation, and in the upper half it is subequal with argillaceous limestone.

Age.—Robison and Palmer (1968) reported trilobites of the lower *Dicanthopyge* Assemblage-zone from strata in the central Silver Island Mountains, which they called the Dunderberg Shale and are here reassigned to the Candland Formation. An *Aphelaspis* Assemblage-zone fauna was recovered during this study from the basal beds of the Candland Formation in the same section. Additional fossils collected in the Pilot Range south of Pilot Peak represent the *Dicanthopyge* to *Dunderbergia* Assemblage-zones (A. R. Palmer, written commun., 1983). Regionally, the Candland Shale Member of the Orr Formation ranges from the uppermost *Crepicephalus* Assemblage-zone to the middle of the *Dunderbergia* Assemblage-zone (Hintze and Palmer, 1976). Thus, the Candland Formation is considered to be entirely Late Cambrian in age.

JOHNS WASH LIMESTONE

The Johns Wash Limestone was named by Drewes and Palmer (1957) for a 76-m-thick, cliff-forming, light- to dark-gray, recrystallized oolitic limestone interval exposed in the Snake Range in eastern Nevada. Robison and Palmer (1968) identified the Johns Wash Limestone in the Wendover region by applying the name to a prominent 80-m-thick, cliff-forming unit of medium-gray limestone that is overlain by light-gray to white, recrystallized limestone and dolomite in the Jenkins Peak section at Silver Island in the Silver Island Mountains (figs. 16, 17); we agree with that extension and further extend it to Crater Island (Miller, 1990). A similar limestone and dolomite unit was assigned to the Johns Wash Limestone by O'Neill (1968) and Miller (1984) in the southern Pilot Range and was mapped as the Johns Wash Limestone Member of the Orr Formation by Glick (1987) in the northern Toano Range. That unit is here assigned to the Johns Wash Limestone.

Age.—Drewes and Palmer (1957) reported a Late Cambrian *Elvinia* Assemblage-zone fauna from the upper beds of the type section of the Johns Wash Limestone in eastern Nevada. The Johns Wash Limestone in the Wendover region appears to be unfossiliferous, possibly owing to recrystallization and dolomitization. However, the Johns Wash Limestone is considered to be Late Cambrian in age because it lies between well-dated Upper Cambrian units locally and regionally.

CORSET SPRING SHALE

The Corset Spring Shale was named by Drewes and Palmer (1957) for a 20-m-thick unit of olive-gray shale and interbedded medium-gray, crystalline limestone in the Snake Range of eastern Nevada. Robison and Palmer (1968) designated a 16-m-thick, recessive weathering, silty limestone and shale unit in the Jenkins Peak section at Silver Island in the central Silver Island Mountains as the Corset Spring Shale (fig. 17); we here agree with that assignment. Miller (1990) has mapped the Corset Spring Shale at Crater Island in the northern Silver Island Mountains. A unit of yellowish-green shale and silty limestone in the northern Toano Range was mapped as the Corset Spring Shale Member of the Orr Formation by Glick (1987); these rocks are here assigned to the Corset Spring Shale.

Age.—Drewes and Palmer (1957) reported trilobites of the Late Cambrian *Elvinia* Assemblage-zone fauna from the type section of the Corset Spring Shale in the Snake Range. Robison and Palmer (1968) also reported an *Elvinia* fauna from the Corset Spring Shale at Silver Island in the Silver Island Mountains. An *Elvinia* fauna is also present in green shales of the uppermost Dunderberg Shale south of Silver Zone Pass in the Toano Range. Thus, the Corset Spring Shale is considered to be Late Cambrian in age.

NOTCH PEAK FORMATION

The Notch Peak Formation was named by Walcott (1908b) for exposures in the House Range; it has been redefined and subdivided into three formal members by Hintze and others (1988). The Notch Peak, which is one of the most widespread units in the central Great Basin, caps all of the Cambrian sequences in the Wendover region. However, lithology and outcrops of the formation vary locally.

Schaeffer (1960) was the first to identify the Notch Peak Formation in the Jenkins Peak section at Silver Island in the central Silver Island Mountains, and Miller (1990) has mapped the formation at Crater Island to the north. O'Neill (1968) and Miller (1984) mapped the Notch Peak Formation near Miners Canyon in the Pilot Range. Pilger (1972) and Glick (1987) also mapped the formation in the northern Toano Range. We here agree with these assignments in each of these areas. It is also present in the northern Goshute Mountains (Day and others, 1987). In all of these areas, the Notch Peak forms steep, massive cliffs consisting of both limestone and dolomite. Just south of Silver Zone Pass in the Toano Range (fig. 14), the Notch Peak is siltier and forms steep slopes and ridges above the Dunderberg Shale. It also is less stromatolitic than in surrounding sections.

Age.—Robison and Palmer (1968) reported a fauna from the basal part of the Notch Peak Formation in the Jenkins Peak section at Silver Island in the central Silver Island Mountains that represents the *Taenicephalus* Assemblage-zone of the Upper Cambrian. Schaeffer (1960) reported fossils assignable to the overlying *Saratogia* and *Saukia* Assemblage-zones from the middle part of the Notch Peak Formation in the same area. Late Cambrian euconodonts collected from the Notch Peak in the Toano Range just south of Silver Zone Pass were questionably assigned to *Proconodontus* and given a color alteration index of 6 by J. M. Repetski (written commun., 1984). Miller (1969), J.F. Miller and others (1982), and Hintze and others (1988) noted that the Cambrian-Ordovician boundary is near the top of the Notch Peak near its type locality in the southern House Range. Therefore, the Notch Peak Formation is considered to be Late Cambrian and Early Ordovician in age.

DEPOSITIONAL ENVIRONMENTS

Perhaps the greatest diversity of Cambrian depositional environments in the Great Basin is present in the Wendover region. Although a detailed sedimentological study of these rocks by McCollum (1987; McCollum and others, 1988) is still ongoing, a summary of the depositional environments is given here to facilitate an understanding of the facies distributions and formational designations applied in this report. It is still unclear as to what extent Mesozoic and younger structure modified the original geographic distribution.

The lithofacies patterns and environmental interpretation of the Cambrian sequence in the Wendover region are consistent with a paleogeographic setting in an outer shelf on a passive margin. Late Proterozoic rifting and cratonal emergence produced an immense braid-plain to shallow-marine clastic wedge along the Cordilleran margin (Stewart, 1976), which persisted until a carbonate platform developed and gradually moved cratonward during the Cambrian. The heterogeneity of facies developed within the Cambrian of the Great Basin reflects the diversity of depositional environments present on a passive margin at low latitudes.

The Late Proterozoic McCoy Creek Group and the overlying Late Proterozoic and Early Cambrian Prospect Mountain Quartzite span the time interval during which continental rifting gave way to development of a passive continental margin in the northern Great Basin. The Prospect Mountain Quartzite in the Wendover area is composed entirely of siliciclastic sedimentary rocks characterized by planar and shallow trough crossbeds and horizontal stratification. Distinct channels of quartzite-pebble conglomerate, in places accompanied by thin, dark argillite at their margins, are interpreted as representing braided-stream and overbank deposits. Bimodal low-angle crossbedding, indicative of a shallow marine or estuarine environment, is present regionally in the upper part of the Prospect Mountain Quartzite (Schneck and McCollum, 1985; Schneck, 1986). Thus, facies development within the Prospect Mountain Quartzite in the Wendover area is consistent with the regionally extensive braid-plain to shallow-marine paleoenvironmental interpretation.

In the central Great Basin, a transitional facies of mixed siliciclastics and carbonates, assignable to the Lower and Middle Cambrian Pioche Formation, exists between the quartz arenites of the Prospect Mountain Quartzite and the overlying carbonate platform. The Pioche Formation is generally fossiliferous and was deposited under shallow-marine conditions. A shallow subtidal *Cruziana* ichnofauna is present along bedding surfaces in the clastic facies, whereas algal structures are present in the bioclastic carbonates. In addition, a fairly abundant and diverse benthic shelly fauna, ranging from the *Bonnia-Olenellus* to *Albertella* Assemblage zones, has been reported from the Pioche Formation regionally (Hintze and Robison, 1975, fig. 3).

Deep-water deposits of the Killian Springs Formation overlie the Prospect Mountain Quartzite in the Wendover area. These deposits consist of dark-gray to black, laminated, graphitic siltstone; impure limestone; quartz-granule conglomerate; and minor silty limestone that contains only siliceous sponge spicules. The dark, virtually unfossiliferous facies of the Killian Springs Formation are in sharp contrast to the lighter colored, more fossiliferous rocks of the Pioche Formation, as exposed from the Deep Creek Mountains southward.

The onset of deep-water deposition appears to be due to rapid subsidence, resulting from downfaulting along the outer shelf in the northern Great Basin. The area where this structural downwarping occurred is not exposed, but the presence of a coarser, more proximal facies in the Killian Springs Formation at Tetzlaff Peak, north of Wendover, suggests that the flexure exists along the southeast margin of the study area. Once established, this deep outer-shelf environment persisted from late in the Early Cambrian to well into the Middle Cambrian, a duration of at least 15 m.y.

Although it is difficult to gauge depth, sediments within the Killian Springs Formation and the Toano Limestone appear to have been deposited in an anoxic environment below storm-wave base. There is no indication of biotic or abiotic reworking of the sediment. The absence of tempestites and both shelly and ichnofossils from these laminated sediments suggests depths greater than storm-wave base.

A shallow-water carbonate platform developed southeast of the Wendover area during the early Middle Cambrian *Albertella* Assemblage-zone. Terrigenous clastics that bypassed the platform, combined with carbonate muds generated from it, settled out as laminated, hemipelagic sediments of the Toano Limestone. Graded bedding is apparent in some of the silty limestone and may be the result of distal turbidity currents.

Although much of the Toano Limestone is laminated, trough crossbedding is present at two horizons low in the type section. Soft-sediment deformation is found throughout the Toano but is most common in the middle one-third of the formation. Semicoherent to incoherent flows as thick as 1.5 m are common (McCollum and McCollum, 1984). The direction of transport, based on axes of soft-sediment folds, was to the northwest.

The Toano Limestone was deposited under unrestricted open-marine conditions, as evidenced by a medial Middle Cambrian cosmopolitan, pelagic, agnostoid and polymeroid trilobite fauna. The absence of a benthic fauna may be attributed to substrate instability and high fluidity within the sediments. Although carbonate muds of the Toano Limestone must have been generated from a nearby carbonate platform, the lack of redeposited oolites or algal debris, coupled with the slope needed to generate debris flows, suggests deposition in the lower part of a northwest-facing, distally steepened carbonate ramp (McCollum and McCollum, 1984).

The Clifside Limestone records a shallowing-upward sequence in response to an oceanward progradation of the carbonate platform across the Wendover area. Storm-generated oolitic grain flows, some of which include algal mat rip-up clasts, flowed downslope and are interbedded with the hemipelagic ramp sediments of the lower limestone member of the Clifside.

The first appearance in the Wendover area of a shallow subtidal to peritidal environment occurs near the middle of the Clifside Limestone, deposited during the middle *Bolaspidella* Biochron. A relatively thin, laminated dark shale, overlain by rip-up clasts, at the base of the (middle) silty limestone and shale member of the Clifside may have been deposited as a flood sheet. A shoaling-upward sequence developed above this, beginning with bioturbated lime muds and crossbedded oolitic sands, overlain by intertidal domal stromatolites and supratidal fenestral lime muds and dolomitic algal mats. The sequence is overlain by a silty, laminated limestone virtually devoid of benthic forms except linguloid brachiopods, which can tolerate conditions found in a restricted intrabasin or lagoonal environment. The upper limestone member of the Clifside represents a gradual shallowing, as a sequence of shallow subtidal, bioturbated, silty lime muds, and supratidal fenestral lime muds, covered by dolomitic algal mats, prograded across the lagoonal deposits.

The Morgan Pass Formation and Trippe Limestone in the Wendover area are largely time equivalent but differ sedimentologically. Strata of the Morgan Pass Formation are mainly terrigenous silts and muds, whereas the Trippe Limestone is almost exclusively burrowed and algal carbonate. Despite the differences in lithology, both formations apparently were deposited under shallow-water conditions adjacent to one another in the study area.

The influx of terrigenous mud and silt of the Morgan Pass Formation smothered the outer part of the carbonate platform. Shallow-water conditions persisted, however, despite the decrease in carbonate production caused by the dampening effect of this clastic blanket. Except for the presence of inarticulate brachiopods on some bedding surfaces, the muds are devoid of benthic fauna, suggesting a restrictive environment. The rhythmic nature of the thin- to medium-bedded calcareous siltstones and the presence of low-amplitude hummocky layering suggest flood deposits that were tidally reworked.

Occasionally storm tracks cut across the outer platform, breaching the oolitic shoal barrier and spreading coarse carbonate debris (rip-up clasts) and oolitic shoal sands across the normally placid muddy lagoonal environment. These storms probably improved marine circulation in the lagoons and certainly provided a firmer substrate, allowing formation of microbial bioherms. Some of the columnar stromatolites and thrombolites grew to 1 m in height before being smothered by the next substantial influx of terrigenous mud.

The Trippe Limestone was deposited in the area of the carbonate platform not blanketed by terrigenous clastics of the Morgan Pass Formation but under similar environmental conditions. Lime muds continued to accumulate in a shallow subtidal environment where storms periodically covered these burrowed muds with rip-up clasts and redeposited oolitic sands. Microbial mats commonly colonized the surface of these redeposited sediments, although biohermal builders are absent. Fenestral fabric also developed in the lime muds under peritidal conditions.

The Decoy Limestone preserves a deepening-upward or retrogressive carbonate sequence. The basal deposits of the Decoy record the cratonward migration of the oolitic and oncolitic shoal environment. This is succeeded by burrowed peloidal lime muds deposited under deepening subtidal conditions.

Increasing water depth brought about the first drowning of the carbonate platform since its establishment in the Wendover area. This transgression brought open-marine conditions across the outer edge of the carbonate platform during the *Lejopyge laevigata* Biochron. These deeper water deposits and those formed during the subsequent shallowing event are recorded within the strata of the Shafter Formation.

Strata in the lower half of the Shafter Formation were deposited as laminated calcareous mud and silt. Unrestricted marine conditions must have been present to account for the cosmopolitan, pelagic agnostoids. However, the absence of a benthic fauna and of tempestite beds, in a low-latitude region obviously affected by storms, suggests that the sediments may have been deposited under anoxic conditions below storm-wave base. In the upper half of the Shafter Formation, terrigenous silts increased and the bedding became distinctly hummocky as a result of wave action. Shallowing into the zone of wave mixing may also account for the addition of endemic, benthic, polymeroid trilobites to the cosmopolitan agnostoid fauna.

A continuous sequence of shallow subtidal to peritidal carbonates of the Lamb Dolomite were being deposited inboard of the transgression that brought about the outer-shelf drowning recorded in the Shafter Formation. Shallow subtidal, burrowed lime muds; migrating oolitic and oncolitic shoals; and peritidal, fenestral lime muds and dolomitic algal mats dominated the carbonate platform. The lack of terrigenous silt may have contributed to the extensive synsedimentary dolomitization.

The carbonate platform again prograded completely across the Wendover area during the early Late Cambrian. Facies patterns began to have a more regional extent, and several formational designations from the central Great Basin can be applied to the Wendover area. Some of the Late Cambrian paleoenvironments present within the Wendover area have also been studied in detail to the south in west-central Utah (see Robison and Rowell, 1976; Taylor, 1989).

Shallow subtidal to peritidal conditions existed in the Wendover area during the *Crepicephalus* Biochron. Initial deposits consist of shallow subtidal, burrowed lime muds and peritidal fenestral muds and algal mats, overlain by oolitic shoal deposits in the Lion Spring Limestone, the lower half of the Oasis Formation, and the uppermost Lamb Dolomite. Carbonate production was then locally interrupted by an influx of terrigenous clastics across the southern part of the Wendover area.

The Ola Sandstone represents a tidally influenced, mixed clastic and carbonate environment. Broad channels and sheets of quartz sand and silt, interbedded with oolitic sands, formed along the outer-platform margin from the northern Goshute Mountains southward to the Deep Creek Mountains and eastward to the Dugway Range. Several channeled quartz-sand beds in the lower strata of the Big Horse Limestone in the Silver Island Mountains may represent the northern extent of this coarse terrigenous influx. A prominent interval of calcareous siltstone in the middle of the Oasis Formation may also represent distal clastics that were locally impounded behind an oolitic shoal barrier along the outer shelf.

With the cessation of clastic input, a retrogressive carbonate sequence was deposited across the area. Oolitic shoals migrated cratonward and were replaced by subtidal, burrowed lime muds of the Goshute Limestone, the upper Oasis Formation, and most of the Big Horse Limestone. These muds are overlain by laminated lime muds and shales in what was the last and most widespread of the Cambrian marine transgressions in the Great Basin.

Platform drowning across the Wendover area had been accomplished by the beginning of the *Dicanthopyge* Biochron. This terrigenous event is recorded in strata of the Dunderberg Shale and Candland Formation. These formations are composed largely of laminated clastics and interbedded carbonate debris flows and tempestites.

Paleoenvironmental conditions were initially similar for both the Dunderberg Shale and Candland Formation, although the drowned environment represented by the latter was of shorter duration and in a more cratonward position. Barren, black, laminated muds, deposited under anoxic conditions, are interbedded with thin bioclastic limestones. These carbonates are sometimes graded and contain shell lags of disarticulated polymeroid trilobites, and they probably represent both debris flows and tempestites.

The carbonate platform (Johns Wash Limestone) prograded across the open-shelf sediments of the Candland Formation during the middle *Dunderbergia* Biochron. The Johns Wash preserves a shallowing-upward sequence of bioturbated lime mud, overlain by oolitic shoal deposits. Cratonally derived mud and silt of the Corset Spring Shale covered the carbonate platform during the *Elvinia* Biochron.

This newly established shallow carbonate platform did not extend completely across the Wendover area. Deeper water, open-shelf conditions continued into the *Elvinia* Biochron in the Dunderberg Shale. By the end of the *Elvinia* Biochron, the prograding carbonate platform (Notch Peak Formation) had completely covered the Wendover area, and shallow subtidal to peritidal deposits continued into the Early Ordovician.

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MEASURED SECTIONS

All sections were measured by McCollum with a 1.5-m Jacob staff. The carbonate classification by Dunham (1962) was used. The degree of bioturbation was based on the ichnofabric index of Droser and Bottjer (1986). Fossil identifications were made by A.R. Palmer, R.A. Robison, and A.J. Rowell.

Section 1

Type section of the Killian Springs Formation and partial reference section of the Toano Limestone, Pilot Range. Section located in NW ¼ NW ¼ sec. 21 and S ½ SE ¼ sec. 16, T. 5 N., R. 19 W., along a northeast-trending ridge starting at 6,500 ft and ending at 7,700 ft, Patterson Pass 7½-minute quadrangle, Nevada-Utah (fig. 7). Measured in June 1984.

Toano Limestone (Middle Cambrian) (incomplete):	*Meters*
3. Lime mudstone, dark-gray (N3) to medium-light-gray (N6); dark-yellowish-orange (10 YR 6/6) to light-brown (5 YR 5/6) silty laminations; measurement terminated in synclinal axis	260
Incomplete thickness of Toano Limestone	260

Gradational contact.

Killian Springs Formation (Lower and Middle Cambrian):	*Meters*
2. Siltstone, phyllitic, grayish black (N2); and medium-gray (N5), platy lime mudstone, containing sponge spicules	175
1. Siltstone, fine-grained sandstone, and phyllite, grayish-black (N2) to medium-gray (N5), hackly to fissile; dark-yellowish-orange (10 YR 6/6) to light-brown (5 YR 5/6) iron staining common; moderately to highly cleaved locally	125
Total thickness of Killian Springs Formation	300

Sharp conformable contact.

Prospect Mountain Quartzite (Late Proterozoic and Lower Cambrian) (not measured)

Section 2

Type section of the Toano Limestone and reference section of the Killian Springs Formation, Toano Range. Section measured across the northern half of sec. 4, T. 35 N., R. 68 E., on a prominent east-trending ridge at 6,600-ft contour and ending at Hill 7129, Silver Zone Pass 7½-minute quadrangle, Nevada (fig. 8). Measured in July 1983.

Clifside Limestone (Middle Cambrian) (not measured)

Conformable contact.

Toano Limestone (Middle Cambrian):	*Meters*
8. Silty lime mudstone, medium-gray (N5) to dark-gray (N3), with very pale orange (10 YR 8/2) to grayish-brown (5 YR 3/2) silty laminated beds. Occasional megaslumps, including one in which several lithified, imbricated, silty lime mudstone clasts align at a 60° angle with a southeastward dip, indicate movement to the northwest; silicified agnostoids, including *Ptychagnostus atavus*, 20 m above base, and silicified polymeroid trilobites, including *Bolaspidella*, in upper 30 m	225
7. Silty lime mudstone, medium-dark-gray (N4), with light-olive-gray (5 Y 6/1) silty laminations. Interval is characterized by soft-sediment megaslumps as thick as several meters, separated by horizontally laminated beds. Megaslumps range from semicoherent to incoherent, some with prominent Z-folds	315
6. Silty lime mudstone, medium-gray (N5) to dark-gray (N3), with very pale orange (10 YR 8/2) to grayish-brown (5 YR 3/2) silty laminated beds; occasional megaslumps and black phyllitic siltstone beds; poorly preserved Middle Cambrian silicified ptychopariids and agnostoids 10 m below top	140
5. Silty lime mudstone, medium-dark-gray (N4), with light-olive-gray (5 Y 6/1) silty laminations. Interval is characterized by soft-sediment megaslumps, as thick as several meters, separated by horizontally laminated beds.	

Toano Limestone (Middle Cambrian):—Continued — Meters

Megaslumps range from semicoherent to incoherent, some with prominent Z-folds 50

4. Silty lime mudstone to calcareous siltstone, medium-gray (N5) to dark-gray (N3); silt laminae grayish brown (5 YR 3/2) to very pale orange (10 YR 8/2); annealed microfaults and minor soft-sediment deformation present throughout; bidirectional trough cross-stratification to the northwest and southeast; minor rotational slumps present 110
3. Argillaceous lime mudstone, dark-gray (N3) to black (N1), with thin phyllitic shale interbeds. Finely disseminated white mica gives a reflective sheen; distinct soil color change at the formational contact from medium gray (N5) below to pale brown (5 YR 5/2) above; forms slopes 10

Total thickness of Toano Limestone 850

Gradational contact.

Killian Springs Formation (Lower and Middle Cambrian) (incomplete):

2. Calcareous siltstone to lime mudstone, medium-dark-gray (N4) to dark-gray (N3), with occasional thin interbeds of laminated fine-grained sandstone; clays altered to white micas, floating, generally not oriented; forms slopes and low-lying hills 95
1. Siltstone, phyllitic to micaceous, medium-dark-gray (N4) to dark-gray (N3), thin to platy, occasionally blocky, microlaminated; thin (15-cm) interbeds of fine-grained, dark-gray (N3) sandstone and occasional argillaceous limestone beds. Siltstone and fine-grained sandstone weather to blocky slopes 155

Incomplete thickness of Killian Springs Formation 250

Base of section covered.

Section 3

Type section of Clifside Limestone, Toano Range. Section located in SE ¼ sec. 4 and SW ¼ sec. 3, T. 35 N., R. 68 E., Silver Zone Pass 7½ -minute quadrangle, Nevada (fig. 8). Measured in July 1984. The type Clifside Limestone contains medium- to thin-bedded lithologic units that have a distinctly striped appearance. In the descriptions below, brown, silty beds alternating with gray limestone are referred to as "tiger-striped," and light-gray, oolitic grainstone beds alternating with gray limestone are referred to as "zebra-striped."

Top of section faulted against Clifside Limestone and Morgan Pass Formation. — Meters

Clifside Limestone (Middle Cambrian) (incomplete):

Upper limestone member:

14. Lime mudstone to wackestone, medium-gray (N5) to medium-dark-gray (N4), laminated to undulose, with yellowish-gray (5 Y 7/2) silt; fenestral fabric in lower 60 m; massive texture 210

Incomplete thickness of upper limestone member 210

Silty limestone and shale member:

13. Lime mudstone to packstone, medium-gray (N5); interbedded with calcareous siltstone, light-brown (5 YR 5/6) to moderate-brown (5 YR 4/4), undulose to laminar; "tiger-stripe" facies 20
12. Lime mudstone to wackestone, medium-dark-gray (N4) to dark-gray (N3), with prominent grayish-orange (10 YR 7/4) silty laminations; contains inarticulate linguloid brachiopods and marjumid trilobites in upper 6 m 70
11. Lime mudstone to wackestone, medium-light-gray (N6) to medium-dark-gray (N4); stromatolitic, diffuse silty laminae, with fenestral fabric; oncolitic beds 20 m above base and in uppermost meter; oolitic grainstone and flat pebble limestone conglomerate (tempestites) present 75
10. Phyllitic siltstone and shale, black (N1); interbedded with thin to nodular lime mudstone, dark-gray (N3); forms saddles on dip-slope ridges 10

Total thickness of silty limestone and shale member 175

Lower limestone member:

9. Lime mudstone to grainstone, medium-gray (N5) to medium-light-gray (N6); oolite beds at 32–36 m, 9–14 m, and 0–5 m; fenestral fabric at 14–32 m; silty beds at 5–9 m; "zebra-stripe" facies 38
8. Lime mudstone to packstone, medium-gray (N5); interbedded with calcareous siltstone, light-brown (5 YR 5/6) to moderate-brown (5 YR 4/4); fenestral fabric at 15–19 m; "tiger-stripe" facies 24
7. Lime mudstone to grainstone, medium-gray (N5) to medium-light-gray (N6); oolite beds at 43–44 m and 0–13 m; fenestral fabric at 13–43 m; "zebra-stripe" facies 44

Section offset 400 m southward along ridge crest. Measurement resumed along a prominent eastward spur.

6. Lime mudstone to packstone, medium-gray (N5); interbedded with calcareous siltstone, light-brown (5 YR 5/6) to moderate-brown (5 YR 4/4), undulose to laminar; "tiger-stripe" facies 12
5. Lime mudstone to grainstone, medium-gray (N5) to medium-light-gray (N6); thin, dark-yellowish-orange (10 YR 6/6) to grayish-orange (10 YR 7/4), undulose silty layers. Oolitic grainstones in tabular beds or discrete shallow troughs that have sharp parallel contacts with adjacent laminated layers; stromatolitic layer near top; "zebra-stripe" facies 22
4. Wackestone to packstone, medium-gray (N5); layers of silt and fine sand, light-brown (5 YR

Lower limestone member: —Continued	Meters
5/6) to moderate-brown (5 YR 4/4), undulose to laminar; top 7 m largely covered; at 30 m and 31.5 m above base, rip-up clasts (storm deposits) 10 and 15 cm thick; "tiger-stripe" facies	49
3. Lime mudstone to grainstone, medium-gray (N5) to medium-light-gray (N6); thin, dark-yellowish-orange (10 YR 6/6), undulose silty layers. Oolitic grainstones are tabular and present in discrete shallow troughs; at 9 m above base, rip-up clasts (storm deposit) 10 cm thick; "zebra-stripe" facies	18
2. Wackestone to packstone, medium-gray (N5); layers of silt and fine sand, light-brown (5 YR 5/6) to moderate-brown (5 YR 4/4), undulose to laminar; "tiger-stripe" facies	18
1. Lime mudstone to grainstone, medium-gray (N5) to medium-light-gray (N6); thin, dark-yellowish-orange (10 YR 6/6), undulose silty layers. Oolitic grainstones are tabular and present in discrete shallow troughs; oolite beds at 39.2–39.3 m, 37.5–37.56 m, 36.25–36.35 m (planar bottom), 35.4–35.6 m, 33.85–33.9 m, 33.5–33.65 m (channeled at top), 31.85–32.05 m, 30.85–31.1 m, 30–30.15 m, 27.4–27.6 m, 12.2–12.4 m, 9.2–9.3 m, and 6.4–6.5 m; "zebra-stripe" facies	40
Total thickness of lower limestone member	265
Incomplete thickness of Clifside Limestone	650

Gradational contact.
Toano Limestone (not measured)

Section 4

Type section of the Morgan Pass Formation, Decoy Limestone, Shafter Formation, Lion Spring Limestone, Ola Sandstone, and Goshute Limestone, and partial reference section of the Dunderberg Shale just west of Morgan Pass, Goshute Mountains. Section located in S ½ sec. 21, T. 32 N., R. 68 E., along northern flank of Hill 8018 in Morgan Pass 7½-minute quadrangle, Nevada (fig. 12). Measured in July 1985.

Pogonip Group (Lower Ordovician) (incomplete):	Meters
25. Lime mudstone to packstone, medium-dark-gray (N4); weathers medium-light-gray (N6); chert layers 5 cm thick, some discontinuous chert nodules; highly folded and crumpled at base, probably owing to Tertiary detachment faulting	15
Incomplete thickness of Pogonip Group	15

Faulted contact.

Dunderberg Shale (Upper Cambrian):	Meters
24. Largely covered interval; float composed of dark-gray (N3), platy limestone and black shale; forms slopes; limestone float highly fossiliferous; trilobites include *Homagnostus, Pseudagnostus, Prehousia*?, and *Tumicephalus*	100
Incomplete thickness of Dunderberg Shale	100

Conformable contact.

Goshute Limestone (Upper Cambrian):	Meters
23. Wackestone to packstone, medium-gray (N5); some silty mottled (ichnofabric 3) intervals. Oncolites and a *Crepicephalus* Assemblage-zone fauna, including *Tricrepicephalus, Angulotreta* cf. *A. postapicalis* Palmer, *Kingstonia*, and *Opisthotreta*, present in upper 10 m; forms the highest gray massive cliff	65
Total thickness of Goshute Limestone	65

Conformable contact.

Ola Sandstone (Upper Cambrian):	Meters
22. Calcareous siltstone, quartz sandstone, and silty limestone, dark-yellowish-orange (10 YR 6/6) to light-brown (5 YR 5/6) and grayish-red (10 R 4/2). Oolitic packstone to grainstone at 57–57.5 m, 44–44.5 m, 37–37.5 m, and 33–34.5 m; trilobite packstone at 56 m contains numerous specimens of *Tricrepicephalus*; forms a prominent reddish-orange cliff	60
Total thickness of Ola Sandstone	60

Conformable contact.

Lion Spring Limestone (Upper Cambrian):	Meters
21. Wackestone to grainstone, medium-gray (N5), oolitic; indistinct silty mottling (ichnofabric 3 and 4) and thin siltstone beds; weathers moderate reddish orange (10 R 6/6) and grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6); forms small, cliffy ledges	45
20. Silty wackestone to packstone, dark-gray (N3); weathers medium dark gray (N4). Silt content decreases upwards; fenestral fabric intermixed with silty mottles (ichnofabric 3 to 4); oncolites; trilobite hash near top. Upper half forms a bluish-gray cliff	40
Total thickness of Lion Spring Limestone	85

Conformable contact.

Shafter Formation (Middle and Upper Cambrian):	Meters
19. Lime mudstone, medium-gray (N5); and calcareous siltstone, grayish-orange (10 YR 7/4) to dark-yellowish-orange (10 YR 6/6); thin to medium bedded, with horizontal burrows (ichnofabric 2) on some bedding planes; forms low cliffs. Unit contains a sparse fauna, including *Clavagnostus* and an unidentified cedariid trilobite	63
18. Covered interval; platy silty limestone float	6
17. Lime mudstone to wackestone, medium-dark-gray (N4); becomes more mottled, less laminated upward. Basal 13 m form ledgy cliffs,	

Shafter Formation (Middle and Upper Cambrian):—
Continued *Meters*

13–22 m form slopes, and uppermost 8 m form ledgy cliffs 30

16. Covered interval 9
15. Lime mudstone to wackestone, medium-dark-gray (N4); silty layers grayish orange (10 YR 7/4); occasional burrows. *Cedaria* Assemblage-zone fauna includes *Cedaria prolifica*?, *Lonchocephalus* sp., *Modocia* sp., *Clavagnostus* sp., *Proagnostus bulbus*?, *Oedorhachis* sp., *Anabolotreta* sp., *Angulotreta* sp., and *Micromitra* sp.; intermittent exposures in a recessive slope; partially covered. Unit forms small ledges 77
14. Lime mudstone to packstone, medium-dark-gray (N4); weathers medium gray (N5); medium-bedded silty layers, moderate-yellowish-brown (10 YR 5/4). *Bolaspidella* Assemblage-zone fauna at 6 m above base includes marjumid trilobites and a diverse inarticulate brachiopod fauna, including *Acrothele*, *Dictyonina*, *Linnarssonia*, *Picnotreta*, *Prototreta*, linguloids, and several species of acrotretids .. 15

Total thickness of Shafter Formation 200

Conformable contact.

Decoy Limestone (Middle Cambrian):

13. Lime mudstone to packstone, recrystallized, medium-gray (N5); weathers medium light gray (N6); silt grayish orange (10 YR 7/4); distinct, slightly undulatory bedding less than 3.5 cm thick; horizontal burrows (ichnofabric 2). Lower 7 m contain abundant oncolites; becomes less silty and progressively recrystallized and dolomitized toward the top; forms massive gray cliff........ 60

Total thickness of Decoy Limestone 60

Conformable contact.

Morgan Pass Formation (Middle Cambrian):

12. Calcareous siltstone, silty lime mudstone, and wackestone, with interbeds of algal packstone and oolitic grainstone, medium-dark-gray (N4) to medium-light-gray (N6); rip-up beds (tempestites); clasts at high angle to bedding in basal 0.5 m; highly bioturbated (ichnofabric 3 to 4) silty wackestone at 0.5–1 m; rip-up bed (tempestite), flat-lying algal clasts at 1–1.25 m; oolitic grainstone at 1.25–1.6 m; mottled (ichnofabric 3) and semicoherent laminae with stromatolites, 25 cm diameter, near the top at 1.6–2.5 m; oolitic grainstone infilling between stromatolites; surface relief on stromatolite heads as much as 10 cm; light-brown (5 YR 5/6) siltstone with thin to discontinuous, light-olive-gray (5 Y 6/1) silty lime mudstone at 2.5-16 m; bedding thickness generally 3 cm or less; thin (10-cm-thick) beds of rip-up clasts at 5.5 m and 6 m; oolitic grainstone at 12–13

Morgan Pass Formation (Middle Cambrian):—
Continued *Meters*

m; layers of domal stromatolites, 25 cm diameter, which overlie several beds of rip-up clasts at 16–19 m. Fauna includes *Eldoradia* and *Lingulella*; small horizontal burrows (ichnofabric 2) on some bedding planes throughout unit 19

11. Covered interval; silty and platy limestone float; occasional small discontinuous outcrops 30
10. Silty lime mudstone, medium-dark-gray (N4); weathers light gray (N7); thicker bedded and less silty than unit 7; horizontal burrows (ichnofabric 2) present 27
9. Covered interval; silty lime chips and platy limestone in float 20
8. Silty lime mudstone, medium-dark-gray (N4), which weathers light gray (N7); grayish-orange (10 YR 7/4) calcareous siltstone; and pale-olive (10 Y 6/2) shale; thinly bedded, with parallel laminations. Carbonate interbeds are 3 cm or less in thickness; rip-up clasts (tempestites), 10 cm thick, at 2 m, 9 m, and 18 m above base; siliceous shale 26–30 m above base....... 35
7. Covered interval; silty limestone, calcareous siltstone, and shale float; slope surface hummocky, appears to be a recent rotational slide 30
6. Silty lime mudstone, medium-dark-gray (N4); weathers light gray (N7); mottled (ichnofabric 3) to thinly bedded 6.5
5. Calcareous siltstone, oolitic grainstone, and trilobite packstone of the *Bolaspidella* Assemblage-zone; largely covered 9
4. Calcareous siltstone and shale, grayish-orange (10 YR 7/4) to dark-yellowish-orange (10 YR 6/6); and oncolitic wackestone to oolitic grainstone, medium-dark-gray (N4) to medium-light-gray (N6); basal meter calcareous siltstone and shale, overlain by 0.5 m of oolitic grainstone, followed by 1 m of silty mottled limestone. Above this is 1.5 m of oncolitic packstone, topped by a 25-cm-thick domal stromatolite bed in which the heads weather in relief........ 4.25
3. Silty lime mudstone to oolitic grainstone, medium-light-gray (N6) to medium-dark-gray (N4). Silty layers and mottles are dark yellowish orange (10 YR 6/6). Basal 0.5 m is wackestone to packstone with silty mottles (ichnofabric 3 to 4), overlain by 1 m of oolitic grainstone and 0.5 m of oncolitic wackestone to packstone. Above this is a 1-m-thick unit of domal stromatolites, with individuals as wide as 0.5 m, and silty limestone between individual heads. A meter of oncolitic limestone overlies the stromatolites and is overlain by a 25-cm-thick domal stromatolite layer in which the heads weather in relief. Unit forms a prominent ridge 4.25
2. Shale, calcareous siltstone, and silty lime mud-

Morgan Pass Formation (Middle Cambrian):—
Continued — *Meters*

stone; silt beds pale yellowish orange (10 YR 8/6); weather moderate reddish brown (10 R 4/6) to dark yellowish orange (10 YR 6/6); at 9 m above base, outcrop of oncolitic packstone, medium-dark-gray (N4) to medium-gray (N5); small silty lime chips, 1 cm average, in float; mostly covered 40

Total thickness of Morgan Pass Formation 225

Conformable contact.

Clifside Limestone (Middle Cambrian) (incomplete):

1. Lime mudstone to packstone, silty, medium-dark-gray (N4); weathers to light gray (N7); light-gray (N7) silty mottles (ichnofabric 4 and 5); fenestral fabric, yellowish-gray (5 Y 8/1), thin silty layers; bedding medium to indistinct and massive; bed of oncolites at 16 m and oolitic sandstone, 0.5 m thick, 21 m below top of unit; silty laminae and fenestral fabric present in upper 8 m 60

Incomplete thickness of Clifside Limestone 60

Section 5

Reference section of the Dunderberg Shale and partial section of the Notch Peak Formation, northern Goshute Mountains. Section located along the crest of the mountain range in E ½ sec. 32, T. 32 N., R. 68 E., Lion Spring 7½-minute quadrangle, Nevada (fig. 12). Measured in August 1989.

Notch Peak Formation (Upper Cambrian and Lower Ordovician) (incomplete): — *Meters*

16. Lime mudstone, medium-gray (N5), with minor dusky yellow (5 Y 6/4) silty mottles (ichnofabric 3); bedding 40 cm thick or less; top of major vertical cliff 150
15. Lime mudstone to packstone, medium-gray (N5), with dusky yellow (5 Y 6/4) silty mottles (ichnofabric 3); platy and thin bedded, 5–10 cm thick in most of section; bedding planes are separated by silty layers; contains sparse trilobites and inarticulate brachiopods; basal meter contains *Taenicephalus*?, *Billingsella*? sp., *Angulotreta*? sp. (*Taenicephalus* Assemblage-zone) 90
14. Covered interval 11
13. Lime mudstone, medium-gray (N5), with dusky yellow (5 Y 6/4) silty mottles (ichnofabric 3); bedded, 5–8 cm thick 2
12. Covered interval 24
11. Lime mudstone to packstone, light-gray (N7), completely recrystallized; silty mottles moderate red (5 R 5/4) and dusky yellow (5 Y 6/4) (ichnofabric 2); mottled layers 0.5–2 cm apart; beds 70 cm thick, separated by 20 cm of medium-dark-gray (N4) thin-bedded lime mudstone, some of which is recrystallized into calcite (white-band appearance); cliff-former 21
10. Covered interval 27

Notch Peak Formation (Upper Cambrian and Lower Ordovician) (incomplete):—Continued — *Meters*

9. Lime mudstone to packstone, medium-gray (N5), with dark-yellowish-orange (10 YR 6/6) and yellowish-gray (5 Y 8/1) silty mottles (ichnofabric 3); bedding 15–30 cm thick; forms a low cliff 6

Incomplete thickness of Notch Peak Formation 331

Conformable contact.

Dunderberg Shale (Upper Cambrian):

8. Shale, light-olive-gray (5 Y 6/1); fissile, siliceous, with a few 10-cm-thick limestone layers; forms slopes, mostly covered 15
7. Wackestone to packstone, medium-gray (N5) to light-gray (N7); interbedded with calcareous siltstone, yellowish-gray (5 Y 8/1); forms small cliffs on ridge crest 18
6. Silty limestone, medium-gray (N5); and thinly interbedded calcareous siltstone, dark-yellowish-orange (10 YR 6/6) 6
5. Lime mudstone to packstone, medium-gray (N5); thin- to medium-bedded, nodular; dark-yellowish-orange (5 YR 6/6) silty mottles (ichnofabric 3); trilobite packstone in basal meter contains *Irvingella angustilimbata* Kobayashi, *Housia* cf. *H. varro* (Walcott), *Sigmocheilus flabellifer* (Hall and Whitfield), *Homagnostus tumidosus* (Hall and Whitfield), *Pseudagnostus* sp., and *Kinbladia* sp. (lower *Elvinia* Assemblage-zone) 6
4. Shale, light-olive-gray (5 Y 6/1) to dark-gray (N3); fissile, siliceous; interbedded with medium-gray (N5) lime mudstone beds as thick as 1 m; yellowish-gray (5 Y 8/1) silty mottles (ichnofabric 2) present in limestone beds 27
3. Lime mudstone, medium-gray (N5), with grayish-orange (10 YR 7/4) silty mottles (ichnofabric 2); bedding 10–20 cm thick; shale float near top; poorly exposed; slope former 35
2. Silty limestone, medium-dark-gray (N4); silts moderate yellowish brown (10 YR 5/4) and dark yellowish orange (10 YR 6/6); beds undulose to nodular; siltstone; thin bedded; bedding 1–6 cm thick; trilobites include *Dunderbergia nitida* (Hall and Whitfield), *Aphelotoxon punctata* Palmer, *Homagnostus tumidosus* (Hall and Whitfield), and *Pseudagnostus* sp. (*Dunderbergia* Assemblage-zone); forms small cliffs and benches along ridge crest 30
1. Covered interval; float composed of medium-dark-gray (N4) platy silty limestone and dark-gray (N3) to black (N1) shale; silty beds moderate yellowish brown (10 YR 5/4) and dark yellowish orange (10 YR 6/6); trilobite packstone in basal meter contains *Prehousia indenta* Palmer and *Pseudagnostus* sp. (*Prehousia* Assemblage-zone); collection 12 m above base

Dunderberg Shale (Upper Cambrian): —Continued *Meters*

contains *Dicanthopyge quadrata* Palmer, *Olenaspella regularis* Palmer, *Listroa*? sp., *Pseudagnostus* sp., undetermined small olenid, *Angulotreta* sp. (*Dicanthopyge* Assemblage-zone) 38

Total thickness of Dunderberg Shale 175

Conformable contact.

Goshute Limestone (Upper Cambrian) (not measured)

Section 6

Type section of the Oasis Formation and reference sections of the Morgan Pass Formation, Decoy Limestone, Shafter Formation, and Dunderberg Shale, Toano Range. Section located in NW ¼ sec. 33, T. 35 N., R. 68 E., on ridge between Silver Zone Basin and "Proctor" Peak (7,602 ft), West Morris Basin 7½-minute quadrangle, Nevada (fig. 14). Measured in June 1985.

Notch Peak Formation (Upper Cambrian and Lower Ordovician) (not measured)

Conformable contact. *Meters*

Dunderberg Shale (Upper Cambrian):

22. Lime mudstone to wackestone, medium-gray (N5), platy to nodular, thin bedded, with almost 50 percent silt in a variety of colors, including pale red (5 R 6/2), light brown (5 YR 6/4), and yellowish gray (5 Y 8/1); inarticulate brachiopods common on some bedding planes; *Housia*, *Homagnostus*, *Pseudagnostus*, and *Elvinia*? in nodular carbonate 24
21. Shale, pale-olive (10 Y 6/2), fissile, siliceous, with rare trilobites including *Housia*; mostly covered; forms slopes 20
20. Wackestone to packstone, medium-gray (N5) to light-gray (N7); interbedded with dusky yellow (5 Y 6/4) siltstone; crinoid columnals common, recrystallized 10
19. Shale and siltstone, greenish-gray (5 G 6/1); weathers pale olive (10 Y 6/2); finely laminated to medium bedded 15
18. Lime mudstone to wackestone, medium-gray (N5), thin-bedded to nodular; grayish-orange (10 YR 7/4) silty mottles (ichnofabric 3); pale-brown (5 YR 5/2) to light-olive-gray (5 Y 5/2) shaly interbeds 10
17. Shale, dark-gray (N3) to black (N1); weathers light gray (N7); interbedded with medium-dark-gray (N4) lime mudstone beds as thick as 1 m; partly covered 35
16. Lime mudstone to wackestone, medium-gray (N5), with grayish-orange (10 YR 7/4) silty laminae; trilobite hash on bedding surfaces, including *Dunderbergia* sp 12
15. Shale, dark-gray (N3) to black (N1); weathers light gray (N7); interbedded with medium-dark-gray (N4) lime mudstone 15
14. Wackestone to grainstone, medium-dark-gray (N4); weathers brownish gray (5 YR 4/1); indistinct, undulose bedding surfaces occasionally covered with inarticulate brachiopods 9

Total thickness of Dunderberg Shale 150

Conformable contact.

Oasis Formation (Upper Cambrian):

13. Lime mudstone to wackestone, medium-light-gray (N6); and light-gray (N7) dolomite, with yellowish-gray (5 Y 8/1) silty mottles (ichnofabric 2 and 3); partially recrystallized; weathers blocky and forms a moderate cliff ... 60
12. Calcareous siltstone to silty wackestone, light-brown (5 YR 5/5) to moderate-brown (5 YR 4/4); beds 1–10 cm thick; weathers platy and forms slope 10
11. Wackestone to grainstone, medium-light-gray (N6); and light-gray (N7) dolomite; fenestral and cryptalgalaminite facies; minor silty mottles (ichnofabric 4 and 5) and oolitic grainstone, partially recrystallized 65
10. Packstone, light-gray (N7), bioclastic with light-brown (5 YR 5/6) silty partings; fauna of the upper *Cedaria* or lower *Crepicephalus* Assemblage-zones, including *Meteoraspis* cf. *M. metra* 3
9. Wackestone to grainstone, medium-light-gray (N6) to light-gray (N7); fenestral, stromatolitic, and cryptalgalaminite facies. Minor silty mottles (ichnofabric 4 and 5) and oolitic grainstone, partially recrystallized 7

Total thickness of Oasis Formation 145

Conformable contact.

Shafter Formation (Middle and Upper Cambrian):

8. Lime mudstone to wackestone, medium-dark-gray (N4); moderate-yellowish-brown (10 YR 5/4) silty layers decreasing upward; poorly exposed 13
7. Lime mudstone, dark-gray (N4); and grayish-orange (10 YR 7/4), thin-to medium-bedded calcareous siltstone; bedding undulose to laminated; horizontal traces (ichnofabric 2) in thicker bedded unit at 19 m above base 57
6. Covered interval; platy silty limestone float 20
5. Lime mudstone to wackestone, medium-dark-gray (N4), with grayish-orange (10 YR 7/4) to dark-yellowish-orange (10 YR 6/6) silty laminae; weathers platy; trilobites and brachiopods common on some bedding surfaces, including *Bolaspidella*?, *Cedaria*?, *Baltagnostus*, and *Acmarhachis*?; partly covered; forms slopes .. 50
4. Lime mudstone to wackestone, medium-dark-gray (N4) to medium-gray (N5); moderate-brown (5 YR 4/4) silty laminae with discrete mottles (ichnofabric 2); forms low, fairly continuous outcrop 10

Total thickness of Shafter Formation 150

Conformable contact.

Decoy Limestone (Middle Cambrian): *Meters*

3. Dolomite and dolomitic limestone, medium-gray (N5) to very light gray (N8); very pale orange (10 YR 8/2) silty layers; forms a prominent light-gray cliff between slope-forming units ... 60

Total thickness of Decoy Formation 60

Conformable contact.

Morgan Pass Formation (Middle Cambrian):

2. Wackestone to grainstone, medium-dark-gray (N4) to medium-light-gray (N6), with grayish-orange (10 YR 7/4) silty layers and mottles (ichnofabric 2 and 3); greenish-gray (5 GY 6/1) to pale-olive (10 Y 6/2), fissile shale interbeds; flat-pebble conglomerates and oolitic layers containing oncolites and stromatolites present; largely covered; forms slopes 120
1. Lime mudstone to wackestone, medium-dark-gray (N4) to medium-light-gray (N6), with prominent grayish-orange (10 YR 7/4) silty partings. Weathering along silty partings 1–10 cm in thickness; *Bolaspidella* cf. *B. wellsvillensis* (*Bolaspidella* Assemblage-zone) 5

Total thickness of Morgan Pass Formation 125

Conformable contact.

Clifside Limestone (not measured):

Packstone to oolitic grainstone, medium-gray (N5) to medium-light-gray (N6), with thin, light-gray (N7) silty partings and mottles (ichnofabric 2 and 3); fenestral lime mudstone to wackestone, medium-dark-gray (N4) to medium-gray (N5), with beds of oncolites and cryptalgalaminites; massive texture; forms ridges.

Section 7

Reference section for the middle and upper parts of the Clifside Limestone, Toano Range. Section located in NW ¼ sec. 28, T. 35 N., R. 68 E., Silver Zone Pass 7½-minute quadrangle, Nevada (fig. 14). Measured in June 1988.

Morgan Pass Formation (Middle Cambrian) (not measured)

Conformable contact. *Meters*

Clifside Limestone (Middle Cambrian):

Upper limestone member:

7. Dolomite, white (N9) to very light gray (N8); highly altered, primary sedimentary features obliterated; upper 20 m less altered; undulose silty lime mudstone alternating with very light gray (N8) cryptalgalaminites; upper member less altered to the south and composed entirely of alternating medium-gray (N5) lime mudstone, silty lime mudstone, and cryptalgalaminites 100

Total thickness of upper limestone member 100

Silty limestone and shale member: *Meters*

6. Lime mudstone to wackestone, medium-light-gray (N6) to light-gray (N7); thin grayish-orange (10 YR 7/4), silty undulose layers alternating with silty mottled (ichnofabric 2) limestone 25
5. Lime mudstone to wackestone, medium-light-gray (N6) to light-gray (N7), with grayish-orange (10 YR 7/4) silty layers as thick as 5 cm. Bedding is generally parallel to laminated, although nodular lime mudstone is present within the thicker silty beds. Unit weathers platy and rubbly; contains numerous inarticulate linguloid brachiopods and a few silicified marjumid trilobites. Unit has numerous calcite-filled fractures and a prominent calcite bed about 21 m above the base, although no faulting or offset is apparent 30
4. Lime mudstone to wackestone, medium-light-gray (N6) to light-gray (N7), with grayish-orange (10 YR 7/4) thin silty layers and mottles (ichnofabric 2) 40
3. Dolomite, white (N9) to very light gray (N8); highly altered and bleached. Primary sedimentary features are largely obliterated; highly fractured throughout 35
2. Lime mudstone to oolitic grainstone, medium-light-gray (N6) to light-gray (N7), with grayish-orange (10 YR 7/4) to dark-yellowish-orange (10 YR 6/6) silty layers; parallel bedded to undulose, thin to medium bedded. At 9–9.5 m, silt locally weathers light red (5 R 6/6) to moderate red (5 R 5/4); at 22–35 m, silty limestone becomes thinner bedded and platier, with small horizontal burrows on bedding surfaces; at 34–34.5 m, light-gray (N7) to medium-light-gray (N6) oolitic grainstone overlain by oncolitic wackestone to packstone; at 45 m, 25-cm-thick oolitic grainstone; at 46.5–47.5 m, oolitic grainstone; at 56–57 m, silt becomes mottled (ichnofabric 3). Above 57 m, thin silty layers become light gray (N7) 70
1. Calcareous siltstone, silty limestone, and shale, light brown (5 YR 5/6), micaceous sheen; forms rubbly slopes; poorly exposed 5

Total thickness of silty limestone and shale member 205

Lower limestone member (not measured):

Lime mudstone to oolitic grainstone, medium-gray (N5) to medium-light-gray (N6); light-gray (N7), undulose, dolomitic, and silty laminae. Yellowish-gray (5 Y 8/1) dolomitic cryptalgalaminites, fenestral lime mudstone, oncolitic packstone, and oolitic grainstone beds are present. Clifside is recrystallized, and pure limestones are hydrothermally altered to coarsely crystalline dolomite owing to proximity of Silver Zone Pass pluton.

Section 8

Reference section of the Notch Peak Formation, Toano Range. Section located in NW ¼ sec. 33, T. 34 N., R. 68 E.,West Morris Basin 7½-minute quadrangle, Nevada (fig. 14). Measured in June 1986.

Pogonip Group (Lower Ordovician) (not measured)

Conformable contact. *Meters*

Notch Peak Formation (Upper Cambrian and Lower Ordovician):

5. Lime mudstone to wackestone, medium-gray (N5) to medium-dark-gray (N4); laminated, grayish-orange (10 YR 7/4) silty partings and black (N1) nodular chert; medium bedded, with some recrystallized very light gray (N8) dolomitic layers. A 20-cm-thick bed containing soft-sediment folding, with an east-west axis, crops out 5 m above the base. Vertical silty burrows (ichnofabric 3) are present 3.5–4 m above the base; forms ridges 20
4. Limestone, light-gray (N7), recrystallized, containing black (N1) nodular chert in upper 5 m. Occasional 1-m-high thrombolites are present; forms rubbly slope; largely covered 45
3. Lime mudstone to wackestone, medium-gray (N5) to medium-dark-gray (N4), with thin, diffuse, grayish-orange (10 YR 7/4) silty laminae. Upper 3 m contain black (N1) nodular chert as thick as 5 cm. Yellowish-gray (5 Y 8/1), mottled silty layers and burrows, 1 cm in diameter (ichnofabric 2), present near middle; largely cliff forming 50
2. Lime mudstone to wackestone, medium-gray (N5) to medium-dark-gray (N4); largely recrystallized, dolomitic, prominent silty layers present; layers of black (N1) nodular chert throughout; forms slopes, with extensive covered intervals. Locally faulted 250
1. Lime mudstone to wackestone, medium-gray (N5) to medium-dark-gray (N4); grayish-orange (10 YR 7/4) silty laminae; locally mottled, with horizontal burrows (ichnofabric 2); occasional beds of medium-dark-gray (N4) to black (N1) nodular chert as thick as 3 cm. Several light-gray (N7) recrystallized beds as thick as 25 cm give this unit a faintly banded appearance 85

Total thickness of Notch Peak Formation 450

Conformable contact.

Dunderberg Shale (not measured)

Section 9

Incomplete reference section of Toano Limestone and Killian Springs Formation, central Silver Island Mountains. Section located in SW ¼ NE ¼ sec. 9, and SW ¼ SE ¼ sec. 4, T. 1 N., R. 18 W., Tetzlaff Peak 7½-minute quadrangle, Utah (fig. 9). Measured in July 1983.

Clifside Limestone (Middle Cambrian)(not measured)

Conformable contact.

Toano Limestone (Middle Cambrian) (incomplete): *Meters*

18. Lime mudstone, medium-gray (N5) to dark-gray (N3), silty, laminated. Silicified agnostoids, including *Ptychagnostus atavus*, present 80 m below top. Silicified trilobites, including *Ptychagnostus*, *Tonkinella*, and *Zacanthoides*, present 80 m above base 253
17. Covered interval 7
16. Lime mudstone, medium-gray (N5) to dark-gray (N3), laminated 13
15. Covered interval 5
14. Lime mudstone, medium-gray (N5) to dark-gray (N3), with finely laminated, dark-yellowish-orange (10 YR 6/6), calcareous phyllitic siltstone 37
13. Covered interval 11
12. Lime mudstone, medium-gray (N5) to dark-gray (N3), laminated 4
11. Covered interval 31
10. Phyllitic siltstone, calcareous; and laminated to thin-bedded lime mudstone; dark gray (N3); weathers medium light gray (N6), with dark-yellowish-orange (10 YR 6/6) iron staining; pyrite throughout 14

Incomplete thickness of Toano Limestone 375

A prominent alluvial strike valley separates the upper siliciclastic facies of the Killian Springs Formation from the Toano Limestone, making accurate thickness measurements impossible. Approximately 450 m of the Toano Limestone covered.

Killian Springs Formation (Lower and Middle Cambrian) (incomplete):

Light-brown quartz sandstone unit:

9. Quartz sandstone, calcareous, very light gray (N8) to light-gray (N7), with light-brown (5 YR 5/6) to grayish-brown (5 YR 3/2) iron staining and Liesegang banding. Calcareous sandstone has rudimentary bedding averaging 10–15 cm thick and is characterized by a uniform grain size and lack of primary bedding features; cavernous weathering; small pyrite cubes present, becoming abundant near siltier layers. Top is faulted against the Prospect Mountain Quartzite, which is riddled by numerous milky white quartz veins 35

Incomplete thickness of light-brown quartz sandstone unit 35

Phyllitic siltstone and argillaceous limestone unit:

8. Graphitic siltstone and phyllite, medium-dark-gray (N5), finely laminated. Contact with overlying sandstone is sharp; interbeds of very pale orange (10 YR 8/2) to light-brown (5 YR 5/6) sandstone in the lowermost 8 m; occasional sponge spicules throughout; cubic pyrite as wide as 2 cm throughout; locally covered; best exposed on small ridge along southern border of section 4 11

Phyllitic siltstone and argillaceous limestone unit:—
Continued *Meters*

7. Argillaceous limestone, medium-gray (N5) to dark-gray (N3); and finely laminated siltstone and silty mudstone; black (N1) to dark-gray (N3) phyllitic siltstone interbeds; sponge spicules present in uppermost 5 m; only intermittently exposed in channel washes on talus slopes 20
6. Covered interval 17
5. Siltstone and silty mudstone, dark-gray (N3) to light-gray (N7), noncalcareous and fissile to calcareous and nonfissile, grading into thin-bedded lime mudstone at top; pyrite throughout 15
4. Covered interval 12
3. Siltstone, phyllitic, medium-dark-gray (N4), noncalcareous fissile to calcareous and nonfissile; occasional sponge spicules and rare, round granules of phosphate present; thin (10–30 cm), dark-gray (N3) granule sandstone interbeds; has a metalliferous sheen, probably due to mica and pyrite 15

Total thickness of phyllitic siltstone and argillaceous limestone unit 90

Quartzofeldspathic granule sandstone and phyllitic siltstone unit:

2. Quartz sandstone, yellowish-gray (5 Y 8/1) with dusky brown (5 YR 2/2) staining, moderately to poorly sorted, medium- to coarse-grained, locally conglomeratic, weakly parallel-laminated; massive weathering; forms layers 5–7 m thick; sharp tabular to channeled contact at base; ledge former. Grayish-black (N2), light-gray (N7) to white (N9) weathering phyllitic shale and siltstone form intervals 1.5–9 m thick between sandstone layers; sooty appearance on weathered surfaces; recessive; mostly covered 34
1. Phyllitic shale and siltstone, grayish-black (N2); weathers light gray (N7) to white (N9); highly stained, moderate red (5 R 4/6) to blackish red (5 R 2/2); sooty appearance on weathered surfaces; beds 7–60 cm thick; discontinuous beds of quartz-granule conglomerate, 5–10 cm thick, with load casts at base; small pyrite cubes throughout; recessive weathering 6

Total thickness of quartzofeldspathic sandstone and phyllitic siltstone unit.. 40

Incomplete thickness of Killian Springs Formation 165

Sharp conformable contact.

Prospect Mountain Quartzite (not measured):

Quartzite, white (N9) to very light gray (N8), with a dusky yellowish-brown (10 YR 2/2) appearance due to iron staining; medium- to coarse-grained, conglomeratic channel deposits present; medium to

Prospect Mountain Quartzite (not measured):—
Continued *Meters*

thick crossbeds present in tabular sets; occasional thin silty beds containing ubiquitous pyrite cubes; forms prominent cliffs.

Section 10

Reference section of the Big Horse Limestone, Candland Formation, Johns Wash Limestone, Corset Spring Shale, and Notch Peak Formation, central Silver Island Mountains. Section located in NW ¼ unsurveyed sec. 29, SW ¼ unsurveyed sec. 20, NE ¼ unsurveyed sec. 19, T. 2 N., R. 17 W., Graham Peak 7½-minute quadrangle, Utah (fig. 17). Measured in May 1986.

Garden City Formation (Lower Ordovician) (not measured)

Conformable contact. *Meters*

Notch Peak Formation (Upper Cambrian and Lower Ordovician):

11. Limestone, medium-dark-gray (N4) to dark-gray (N3), and medium-gray (N5) to medium-bluish-gray (5 B 5/1) dolomite, with dark-yellowish-brown (10 YR 4/2) to brownish-black (5 YR 2/1) chert nodules common in lower half; indistinctly bedded, possibly owing to bioturbation and lack of silt; a 15-cm-thick, light-bluish-gray (5 B 7/1) quartz sandstone bed, weathering moderate brown (5 YR 4/4), present 60 m above base; stromatolitic and oolitic beds near middle; forms inaccessible vertical cliffs; thickness estimated 400
10. Lime mudstone to wackestone, medium-gray (N5), with moderate-brown (5 YR 4/4) silty mottles (ichnofabric 2 and 3); occasional chert nodules near top of unit; abundant inarticulate brachiopods on some bedding planes; has an alternating light- and dark-gray banded appearance owing to white (N9) to very light gray (N8) marker layers present at 66.5–68 m, 62.5–65.5 m, 48–48.5 m, 40–40.5 m, 36.5-37 m, 18–18.3 m, 16.5–17 m, 14.5–15 m, and 0.6–1 m above base; forms ledges and cliffs .. 75
9. Lime mudstone to wackestone, medium-dark-gray (N4), with moderate-brown (5 YR 4/4) to light-brown (5 YR 6/4), undulose silty beds about 2 cm thick (ichnofabric 3); inarticulate brachiopods on some silty surfaces. Robison and Palmer (1968) reported a *Taenicephalus* Assemblage-zone fauna (5984-CO); forms ledges 25

Estimated thickness of Notch Peak Formation 500

Conformable contact.

Corset Spring Shale (Upper Cambrian):

8. Limestone, recrystallized, pinkish-gray (5 YR 8/1), stylolitic; alternating layers, 0.3–0.5 m thick, of pale-brown (5 YR 5/2) to moderate-brown (5 YR 4/4) wackestone and dusky brown

Corset Spring Shale (Upper Cambrian):—Continued *Meters*

(5 YR 2/2) siltstone, 15–25 cm thick; occasional medium-dark-gray (N4), less recrystallized limestone beds; calcareous, moderate-brown (5 YR 4/4) shale and siltstone, and thin-bedded (10 cm), light-olive-gray (5 Y 6/1) silty limestone in basal meter. Robison and Palmer (1968) reported an *Elvinia* Assemblage-zone fauna (5985-CO); forms prominent ledges 16

Total thickness of Corset Spring Shale ... 16

Conformable contact.

Johns Wash Limestone (Upper Cambrian):

7. Dolomite and limestone, coarsely recrystallized, light-gray (N7) to yellowish-gray (5 Y 8/1). Uppermost 8 m are medium-gray (N5) to pinkish-gray (5 YR 8/1) limestone, somewhat less altered; cliff-forming white band at 25–57 m. Slope-forming, very light gray (N8) to white (N9) dolomitic limestone, with occasional pockets of dark-gray (N3) limestone at 10–25 m above the base; moderate-brown (5 YR 4/4) siltstone concentrated in stylolites; light-bluish-gray (5 B 7/1) dolomite in lowermost 10 m; forms cliffs 65
6. Silty lime mudstone to wackestone, medium-dark-gray (N4), with moderate-brown (5 YR 4/4) to dark-yellowish-brown (10 YR 4/2) siltstone containing discrete mottles (ichnofabric 2 and 3) in beds about 5 cm apart. Upper half contains several oncolite and thin limestone rip-up beds; forms ledges in lower half and cliffs in upper half 15

Total thickness of Johns Wash Limestone 80

Conformable contact.

Candland Formation (Upper Cambrian):

5. Shale, black (N1); weathers light olive gray (5 Y 6/1) and grayish orange pink (10 R 8/2); laminated; contains nodular limestone; thin interbeds of medium-dark-gray (N4) argillaceous limestone throughout; forms slopes ... 82

Candland Formation (Upper Cambrian):—Continued *Meters*

4. Wackestone to packstone, medium-dark-gray (N4); and wispy light-brown (5 YR 5/6) to moderate-yellowish-brown (5 YR 5/4) siltstone; lowest beds covered with inarticulate brachiopods. Robison and Palmer (1968) reported a *Dicanthopyge* Assemblage-zone fauna (5986-CO); forms slopes 3

Total thickness of Candland Formation .. 85

Conformable contact.

Big Horse Limestone (Upper Cambrian):

3. Lime mudstone to wackestone, medium-dark-gray (N4) to medium-gray (N5), generally recrystallized and dolomitic above 60 m; recrystallized beds light gray (N7) to bluish-white (5 B 9/1); silty mottles (ichnofabric 3 and 4) and domal stromatolites common in basal 30 m; moderate-red (5 R 4/6) quartz sandstone beds 35 m above base. Robison and Palmer (1968) reported a *Crepicephalus* Assemblage-zone fauna (5987-CO); forms upper two-thirds of a light-gray cliff 175

Total thickness of Big Horse Limestone . 175

Conformable contact.

Lamb Dolomite (Upper Cambrian):

2. Dolomite, recrystallized; uppermost 50 m pinkish-gray (5 YR 8/1); lowermost 60 m medium gray (N5) to medium bluish gray (5 B 5/1); discrete silty mottling (ichnofabric 2) and faint low-angle crossbedding; forms lower one-third of a light-gray cliff 110
1. Wackestone to packstone, medium-dark-gray (N4), fresh; weathers medium light gray (N6); mottled dark-yellowish-orange (10 YR 6/6) to light-brown (5 YR 5/6) dolomitic silt (ichnofabric 4 and 5). Robison and Palmer (1968) reported a *Cedaria* or *Crepicephalus* Assemblage-zone fauna (5988-CO); base of section in alluvium 20

Incomplete thickness of Lamb Dolomite 130

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