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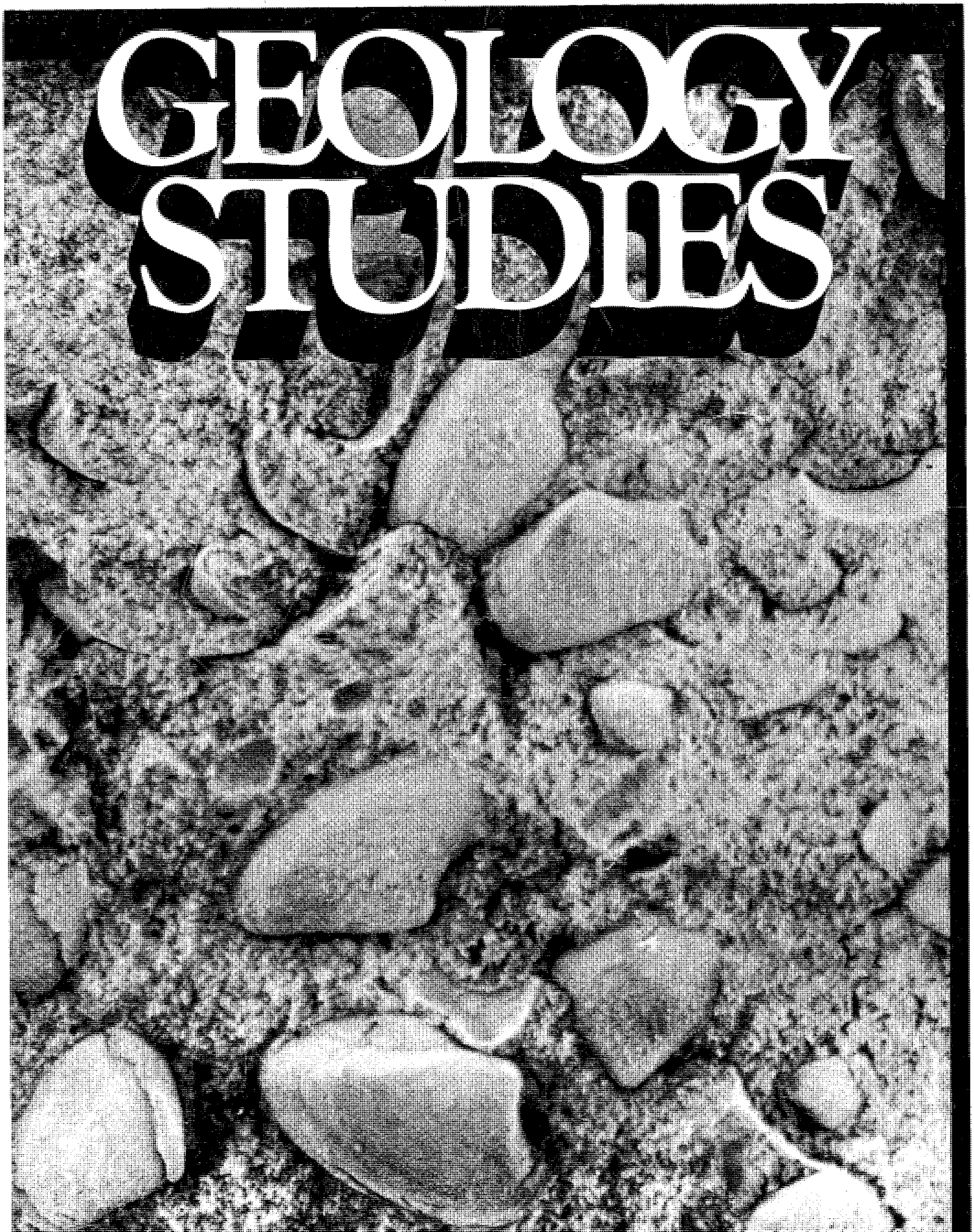

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CONTENTS

Cover: Slab of bivalves showing Myalina-Pleuroma *suite, from Torrey section, Sinbad Limestone Member, Moenkopi Formation in the Teasdale Dome Area, Wayne County, Utah. Photo courtesy James Scott Dean.*

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CONTENTS

Geology of the Longlick and White Mountain Area, Southern San Francisco Mountains, Beaver County, Utah*

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ABSTRACT.—The Longlick and White Mountain area is located near the eastern margin of the overthrust belt in the Basin and Range Province. The Paleozoic rocks are allochthonous in the lower plate of the Grampian thrust and probably in the upper plate of the Blue Mountain thrust. Inliers of Devonian, Mississippian, Pennsylvanian, and Permian units, which expose 1,920 m of strata, are surrounded by Tertiary volcanics. Upper Mississippian units here are similar to those in the Wah Wah Mountains, but this interval is absent in the adjacent Star Range. Oligocene and Miocene calc-alkalic and biomodal mafic-rhyolitic volcanism of the Needles Range Formation, the Isom Formation, and the Formation of Blawn Wash are similar to units in the adjacent Wah Wah Mountains. The presence of Miocene (?) flow-banded rhyolite flows suggests a local volcanic center.

A prominent east-west-trending fault-controlled lineament is strongly altered with early- to middle-Miocene alunitization and kaolinitization. Other altered areas exhibit disseminated pyrite in sulfide systems of 100 m^2. Occurrence of fumarolic native sulfur and localized uranium mineralization is typical of epithermal systems.

The abundance of locally derived volcanic rocks and alteration zones is indicative of a high-level mineralization. In surrounding mining districts, the level of erosion is deeper exposing skarns, replacement mantos, and veins carrying precious and base metals. The area studied holds potential for deep buried mineralization below the outcropping alteration.

INTRODUCTION

The complex, poorly exposed geology in the Longlick and White Mountain area of the southern San Francisco Mountains has received little study heretofore. However, recent interest in identifying thrust plates, the extent of bimodal mafic-rhyolite magmatism, and areas of hydrothermal alteration has generated academic and economic interest. Therefore, it was desirable to measure, describe, and correlate the Paleozoic strata; to identify and map the areal extent of volcanic units; and to provide an understanding of the structure and geologic history whereby the source and age of hydrothermal alteration could be more fully understood.

Paleozoic sections in the area and key sections outside the area were measured and staked with the use of a 60.9-m steel tape and a Brunton compass. Calculations were made for true thickness. All measured sections were marked at 60.9-m intervals with wooden stakes labeled with numbered brass tags. Rock samples were collected in fossiliferous zones for megafossils and conodonts. Volcanic units were identified on the basis of field examination and laboratory study of thin sections. Some thin sections were stained with sodium cobaltinitrite to reveal potassium feldspar. Geologic mapping was plotted on 1:20,000 scale black and white aerial photographs.

Location

The San Francisco Mountains are located in southwestern Utah in central Beaver County. Longlick and White Mountains lie near the southern end of the range (fig. 1). The area studied covers approximately 93 km² and is about 16 km southwest of the old Frisco townsite and 27 km southwest of Milford.

Physiographically the area possesses hogbacks and cuestas of subdued topography when compared with the adjacent northern San Francisco Mountains, Star Range, and Wah Wah Mountains and can be characterized as 6 percent Paleozoic inliers and 94 percent low-lying volcanic terrain.

Previous Work

Aside from the general geology of the area compiled by Hintze (1963) and preliminary maps of the Frisco and Milford Quadrangles by Lemmon and Morris (1979), only small areas have been mapped in any detail: Erickson and Dasch (1963), Stringham (1963), Brooke (1964), and Rowley (1978).

Stratigraphy, structure, and alteration have been studied in several of the surrounding areas: Butler (1913), East (1966), Miller (1959), Baer (1962), Stringham (1964, 1967), Whelan (1965), Abou-Zied and Whelan (1973), and Best and others (1973).

Acknowledgments

To all who supported this research appreciation is expressed. I am grateful to Kenneth C. Bullock, chairman, and Lehi F. Hintze and William Revell Phillips of my thesis committee for their time and helpful suggestions pertaining to the preparation of the thesis. Special thanks are expressed to John E. Welsh for assistance both in the field and during manuscript preparation.

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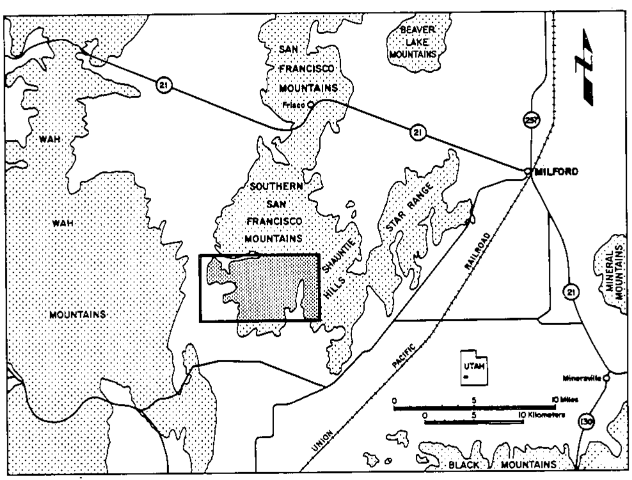

FIGURE 1.—Index map of the Longlick and White Mountain study area.

*A thesis presented to the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree Master of Science, August 1980. Thesis chairman: Kenneth C. Bullock.

Olson and Richard W. Copenhaver for drafting the illustrations and to YeVonne Loveridge and Jean Moore for typing the manuscript.

Finally, I extend appreciation to my wife Dale for her patience during my absence and for her continued encouragement.

STRATIGRAPHY

General Statement

The Longlick and White Mountain area contains sequences of Paleozoic carbonates and Tertiary volcanics (plate 1). The Paleozoic rocks are exposed as nine isolated inliers in a voluminous expanse of volcanics. Composite measured sections reveal Devonian, Mississippian, Pennsylvanian, and Permian limestones, dolomites, sandstones, and chert which possess an accumulative thickness of at least 1,920 m (fig. 2). Volcanic rocks,

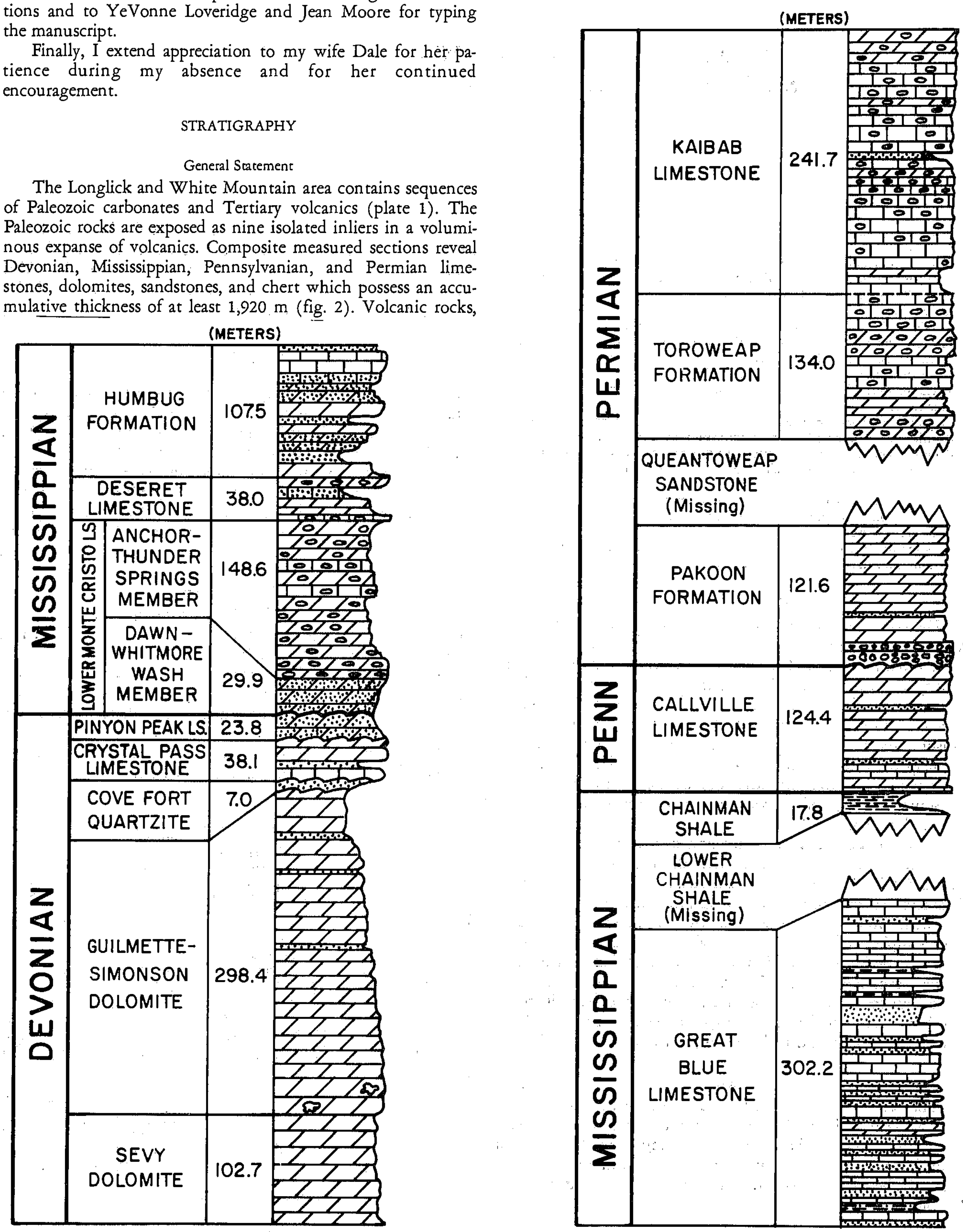

FIGURE 2.—Composite section of Paleozoic rocks measured in the southern San Francisco Mountains.

both mafic flows and ash flow tuffs, comprise 94 percent of areal outcrops and are as much as 500 m thick. All are commonly concealed by Quaternary colluvium and alluvium.

Devonian System

Outcropping Devonian strata are correlated with the Sevy Dolomite, Guilmette-Simonson Dolomite, Cove Fort Quartzite, Crystal Pass Limestone Member of the Sultan Limestone, and the Pinyon Peak Limestone.

Sevy Dolomite

The Sevy Dolomite occurs only in an incomplete section at the base of Longlick Mountain. Here it is light gray, fine crystalline, massive to medium bedded, dense and homogeneous, similar to the type Sevy described by Nolan (1930, 1935). The upper contact is gradational. The lower contact is not exposed. The 102.7 m measured correlate with 91.4 m of Sevy reported by Miller (1959) in the southern Wah Wah Mountains (fig. 3).

Guilmette-Simonson Dolomite

The thickest exposure of undivided Guilmette-Simonson Dolomite in both the San Francisco Mountains and Star Range is the 460.6 m of section measured on the west flank of Longlick Mountain. Here it is gray to medium gray, medium-crystalline dolomite, with massive to medium bedding. The upper third is sandy and contains five separate sandstone beds which are similar to sandstones in the upper Guilmette. Another outcrop of the upper Guilmette-Simonson is present 3.4 km north of Longlick Mountain.

Contact of the Guilmette-Simonson with the Cove Fort Quartzite is unconformable. Lithologies change abruptly from a light gray to tan gray, coarse-crystalline dolomite to a white to tan, coarse-grained, well-rounded sandstone. Stromatoporoids and *Amphipora* sp. occur in the lower Guilmette-Simonson Dolomite.

Cove Fort Quartzite

The Cove Fort Quartzite is limited to a small area on Longlick Mountain, where it is white to tan sandstone, clean and well cemented. It forms a prominent lithologic break in the section. The 7.0 m of Cove Fort correlate with similar units in the Wah Wah Mountains (fig. 3) south of Blawn Mountain (Miller 1959). Both occurrences correlate with the lower and middle units of Crosby's (1959) type section in the southern Pavant Range.

Crystal Pass Limestone

The Crystal Pass Limestone is an upper member of the Sultan Limestone described in Clark County, Nevada (Hewett 1931). On Longlick Mountain it consists of a basal lithographic, light gray to gray limestone and an upper alternating unit of white to tan, medium-grained, clean, well-rounded sandstone. This "porcelain-like" (Hewett 1931) lithographic limestone is distinctive and may be recognizable as a regional marker bed. Conformable with the underlying Cove Fort and disconformable with the overlying Pinyon Peak Limestone, the Crystal Pass is probably Upper Devonian in age (Hewett 1931). This 38.2-m outcrop of Crystal Pass can be correlated with the "dark gray and pinkish gray limestone" overlying Miller's (1959) basal quartzite member (fig. 3) and with the lower 45.7 m (Welsh 1973) of the Mowitza Formation (Baetcke 1969).

Pinyon Peak Limestone

Exposed solely on the western flank of Longlick Mountain, the Pinyon Peak Limestone consists of gray to tan, medium-grained, sandy dolomite. The Pinyon Peak was first mentioned by Lindgren and Loughlin (1919) and later described by Morris (1957). The contact with the Crystal Pass Limestone is disconformable, and the contact with the Monte Cristo is gradational.

The 23.8 m of Pinyon Peak which crop out on Longlick Mountain correlate with the "lower limestone member" of Miller's (1959) "Upper Devonian (?) Mississippian" and the upper 51.8 m (Welsh 1973) of the Mowitza Formation (Baetcke 1969) (fig. 3).

Mississippian System

Mississippian strata exposed in the Longlick and White Mountain area are partial representatives of the thick sequence of equivalent carbonates deposited farther north in the Oquirrh Basin. These strata fit existing regional nomenclature such as the Lower Monte Cristo Limestone, Deseret Limestone, Humbug Formation, Great Blue Limestone, and Chainman Shale. Depositionally, they can be grouped into the "lower depositional complex" (Monte Cristo and Deseret) and the "upper depositional complex" (Humbug, Great Blue, and Chainman) of Rose (1977). The lower depositional complex can further be divided into a lower platform sequence (Lower Monte Cristo) and an upper basinal sequence (Deseret) compared with the depositional sequences of adjacent ranges (Welsh 1979b).

Monte Cristo Limestone

The Monte Cristo Limestone was named by Hewett (1931) in Clark County, Nevada. Outcrops in the study area may also be correlated with the Thunder Springs and Whitmore Wash Members of the Redwall Limestone (McKee and Gutschick 1969). The Monte Cristo terminology is used in the Longlick and White Mountain area, rather than the Redwall, because these outcrops represent the prograded edge of the carbonate platform rather than the interior of the platform as does the Redwall (Welsh 1979b, Rose 1977).

In the study area 117.0 m of the Monte Cristo are exposed near the summit of Longlick Mountain. The lower two members, the Dawn and Anchor Limestones, are the only members present in these outcrops.

Dawn-Whitmore Wash Limestone Member. The Dawn-Whitmore Wash Limestone Member is exposed in a saddle immediately west of Longlick Peak. It consists of sandy dolomite, medium gray to dark gray, medium grained, 30 to 50 percent sand, containing sparse chert at the top and bottom. It contains *Lithostrotion* sp., *Syringopora* sp., *Triplophyllites* sp., all rugose coral. Contact with the underlying Crystal Pass is unconformable. The upper contact of the Dawn with the overlying Anchor-Thunder Springs Limestone Member is gradational from a sandy dolomite containing sparse chert nodules to a dolomite containing interbedded chert beds. The Dawn-Whitmore Wash is 53.6 m thick.

Anchor-Thunder Springs Limestone Member. The Anchor-Thunder Springs Limestone Member is observed at two locations, a 63.4-m section exposed on the upper summit of Longlick Mountain and a 148.6-m section exposed 3.7 km southeast of White Mountain (W ½, SW ¼, section 12, T. 29 S, R. 13 W) on a north-south-trending hogback. This member is composed of limestones and dolomites interbedded with 20 to 50 percent chert. Limestones are medium gray to gray, fine to medium grained, and they contain a moderate to large amount of

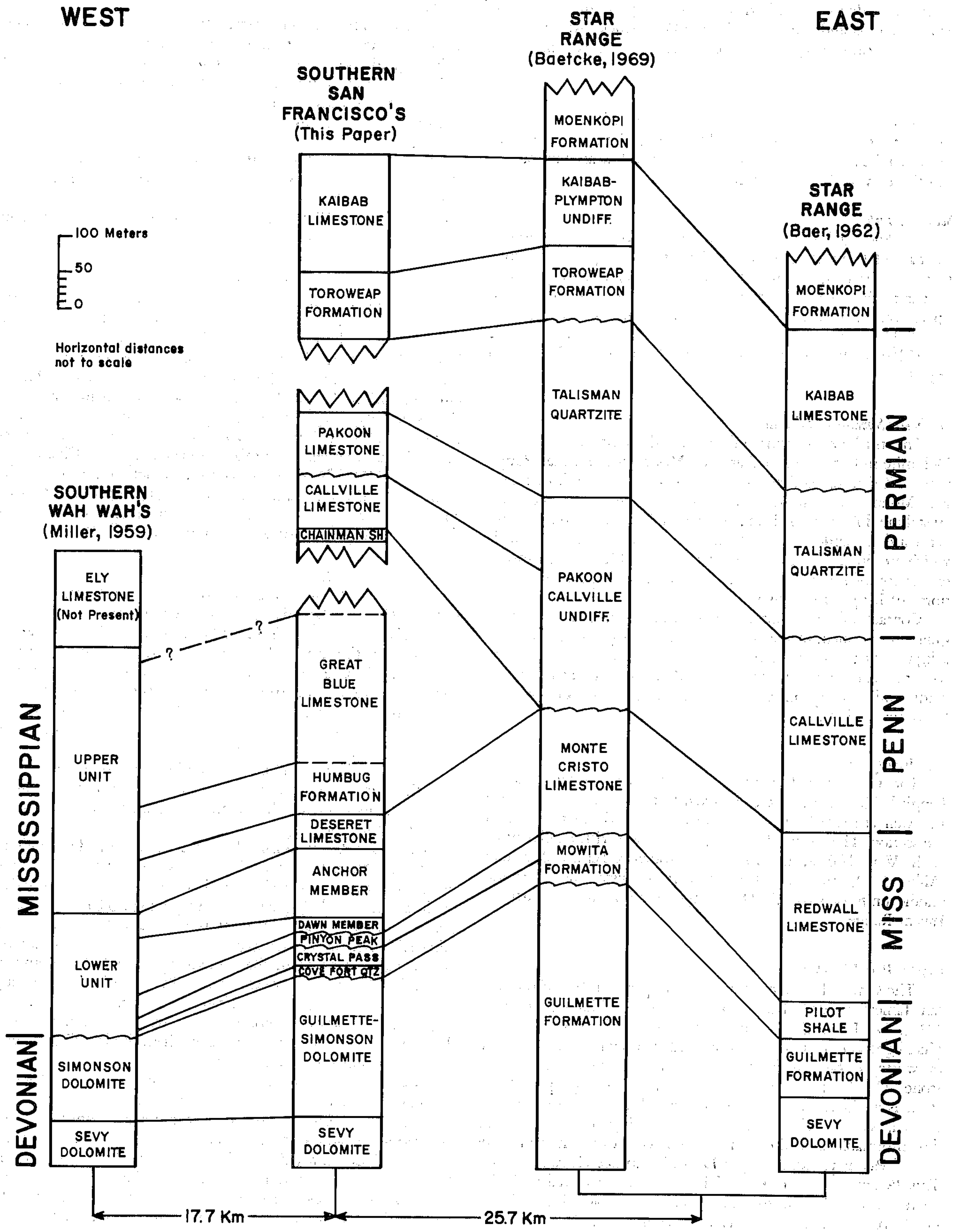

FIGURE 3.—Correlation of Paleozoic strata in the southern San Francisco Mountains with adjacent ranges.

crinoidal debris. Dolomites are medium gray to dark gray, generally medium grained. Chert is black to dark brown, usually bedded with some nodules in areas. Most units are abundant with fossils: *Lithostrotionella* sp., *Lithostrotion* sp., *Triplophyllites* sp., and *Syringopora* sp. Contact of the Anchor-Thunder Springs with the overlying Deseret Limestone is gradational.

Deseret Limestone

The Deseret Limestone is exposed on the north-south hogback 3.7 km southeast of White Mountain. It consists of medium gray to gray, medium- to coarse-grained, crinoidal limestone and dolomite interbedded with chert and sandy dolomite. Chert is black, usually bedded but sometimes nodular. Several units contain *Lithostrotion* sp. coral biostroms. The contact with the Anchor is gradational from a banded chert up to a limestone with interbedded chert. Regionally, the lowermost Deseret commonly has phosphatic shales. However, vigorous searching failed to identify them within the study area. These same lower Deseret beds in the southern Wah Wah Mountains have phosphatic shales (J. E. Welsh personal communication 1978). The contact with the Humbug Formation is conformable and gradational from massive chert beds and interbedded cherts to dolomite and silty dolomite. This 57.0 m of Deseret is correlated with similar outcrops described by Miller (1959) in the southern Wah Wah Mountains (fig. 3).

Humbug Formation

A partial section of the Humbug Formation is exposed atop the north-south-trending hogback located 3.7 km southeast of White Mountain. It is composed of sandstone, tan to light gray in color, interbedded dolomite, and sandy dolomite. The carbonates are pelletal calcarenites in the upper part of the section. Sandstone units are more siliceous in the upper part of the section.

The contact of the Humbug with the Deseret is gradational. The base is placed below the lowest sandstone. The contact with the Great Blue Limestone is not exposed in the area of study. The Humbug was first described by Gilluly (1932). Miller (1959) correlated it with measured sections in the Wah Wah Mountains (fig. 3), and now 107.5 m of Humbug are recognized in the Longlick and White Mountain area.

Great Blue Limestone

White Mountain is an isolated exposure of Great Blue Limestone (fig. 4). It consists of bioclastic limestone interbedded with sandstone and siltstone. Limestones are pelletal and contain some chert in the upper part of the section. The lower and upper contacts of the Great Blue are not exposed. At White Mountain, 302.2 meters of Great Blue is exposed. It is similar to the 365.8 m Miller (1959) measured in the southern Wah Wah Mountains (fig. 3).

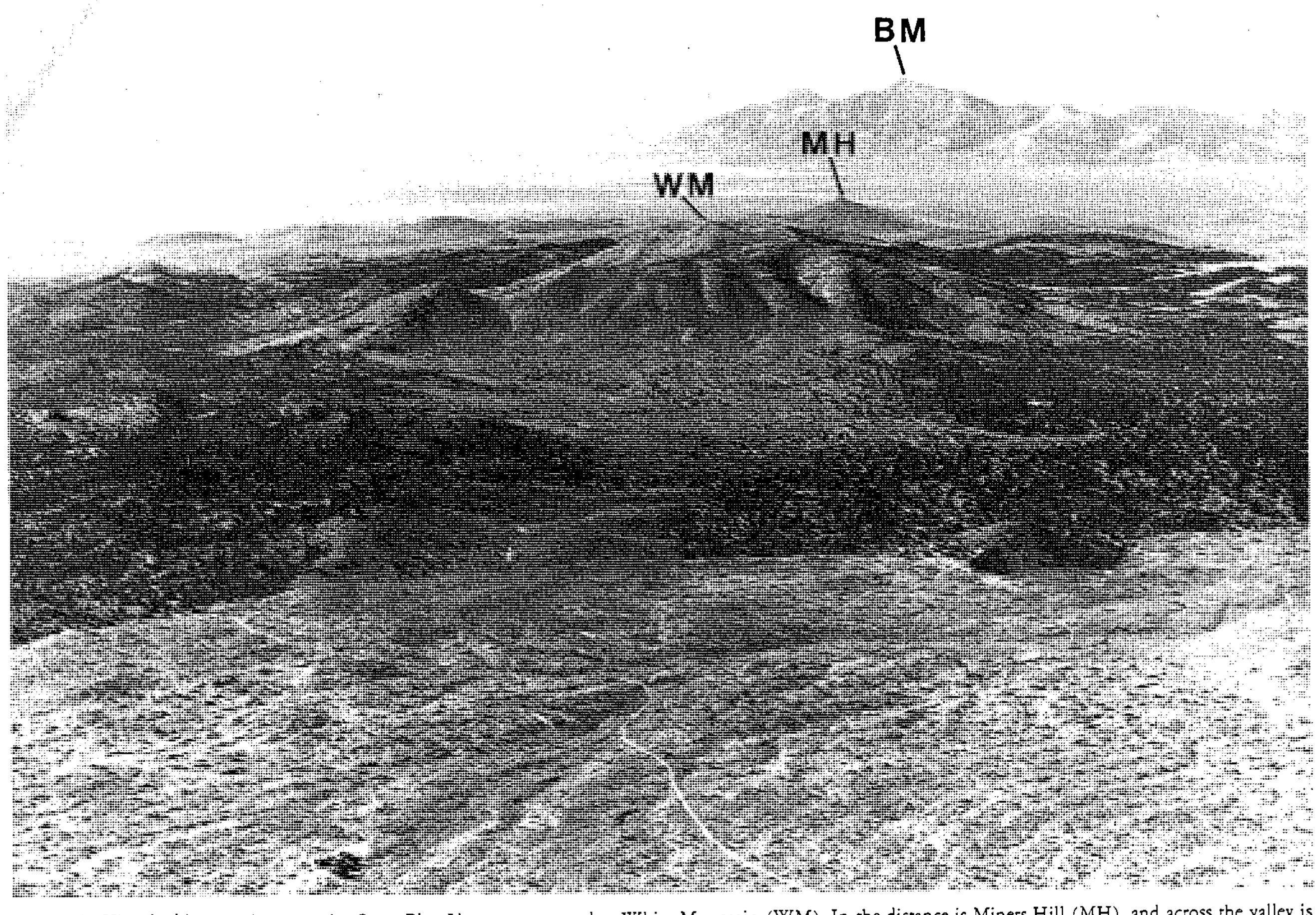

FIGURE 4.–View looking southwest at the Great Blue Limestone exposed at White Mountain (WM). In the distance is Miners Hill (MH), and across the valley is Blue Mountain (BM) of the southern Wah Wah Mountains.

Chainman Shale

The Chainman Shale is not exposed in the study area. However, a small poorly exposed outcrop exists approximately 700 m north of Grovers Wash (appendix D) (SW ¼, NW ¼, NW ¼, section 31, T. 28 S, R. 13 W). It consists of black to yellow tan shale with minor limestone and siltstone. The limestone beds are fossiliferous. Organic chemical analyses of the shale indicate 0.56 to 2.20 percent total organic carbon (TOC) with a Thermal Alteration Index (TAI) of 3- and a Kerogen Type (KT) of herbaceous to woody (J. E. Welsh personal communication 1979).

The lower contact of the Chainman is not exposed. However, the upper contact with the medium gray to gray Callville Limestone is abrupt. At this location the Chainman is 17.8 m thick. The nearest known exposure of the Chainman is west of the Wah Wah Mountains in the Needle Range (Sadlick 1965).

Pennsylvanian System

Pennsylvanian strata are not exposed in the study area. Noteworthy, however, are two exposures of Callville Limestone; one north of Grovers Wash (appendix D) and another west of Squaw Peak and south of Grampian Hill (fig. 5) in the Frisco Area (appendix E).

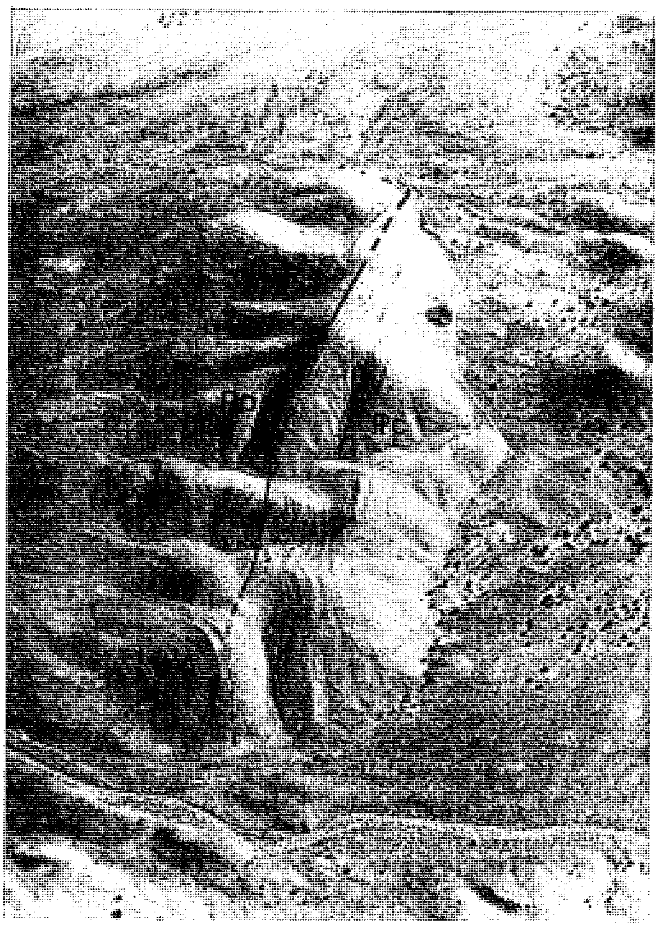

FIGURE 5.—View looking northeast at the northwest-dipping Permian Pakoon Formation (Pp) and the Pennsylvanian Callville Limestone (IPc) exposed in an overturned anticline 2.3 km northwest of Squaw Peak and 1.1 km south of Utah 21 south of Frisco.

Callville Limestone

A small exposure of Callville Limestone is located 700 m north of Grovers Wash (SW ¼, NW ¼, NW ¼, section 31, T. 28 S, R. 13 W). This 13.7 m of medium to light gray, fine-grained limestone is conformably overlying the Chainman Shale. A more representative section, 124.4 m, of Callville is exposed 2.2 km northwest of Squaw Peak (NE ¼, NW ¼, section 34, T. 27 S, R. 13 W) in an overturned section. Here the Callville consists of medium gray to gray cherty limestone interbedded with gray brown to brown sandstone. The upper 75 percent of the section is dolomitic, containing chert nodules, and only the upper 30 percent is fossiliferous. Lower contact of the Callville is not exposed west of Squaw Peak but is present north of Grovers Wash. The contact of the Callville with the overlying Pakoon Limestone is disconformable where exposed.

Permian System

The Permian System, as exposed in the southern San Francisco Mountains, is represented by four regional units: the Pakoon Limestone, Queantoweap Sandstone, Toroweap Formation, and Kaibab Limestone. These units account for 588.1 m of measured section.

Pakoon Limestone

Pakoon Limestone is exposed 2.2 km northwest of Squaw Peak (fig. 5) in an overturned anticline (East 1966) truncated by the Grampian Thrust. The Pakoon consists of three distinctive lithologies: gray to tan, fine-grained dolomite; gray brown to brown chert pebble conglomerate bound in a dolomitic matrix; and gray to light gray, poorly sorted, dolomitic sandstone. Chert pebble conglomerates diagnostically mark the base of the Lower Pakoon. The chert pebbles contain Pennsylvanian fusulinids and Mississippian corals (J. E. Welsh personal communication 1978). This disconformable contact of the Pakoon with the Callville is marked by a chert conglomerate-dolomite interface. The contact with the Queantoweap Sandstone (Talisman Quartzite) is not exposed in the southern San Francisco Mountains but is gradational in the Star Range.

Queantoweap Sandstone (Talisman Quartzite)

The Queantoweap Sandstone, as it is known regionally, or Talisman Quartzite, as it has been called locally in the Star Range (Butler 1913), may possibly be exposed in a structurally complex outcrop of quartzite 700 m north of Grovers Wash (NW ¼, NW ¼, section 31, T. 28 S, R. 13 W). This quartzite resembles that described by Baer (1962) and Baetcke (1969) in the Star Range. Trace fossil worm burrows in this quartzite favor its assignment to the Queantoweap rather than the alternative possibility that the small exposure represents an allochthonous remnant of Cambrian Prospect Mountain Quartzite.

Toroweap Formation

The Toroweap Formation is partially exposed on the northern half of Miners Hill (fig. 6). It can be characterized by three lithologies: cherty dolomite, dolomitic sandstone and sandy dolomite, and cherty-fossiliferous limestone. The lower third of the Toroweap is light gray to gray cherty dolomite and contains up to 10 percent sand. Chert varies from 10 to 50 percent in volume, weathers to brown or red brown colors, and is nodular to bedded. The cherty dolomite lithology changes to dolomitic sandstone which is medium gray to orange brown in color and is fine grained. Some units are very siliceous, and the weathering reveals low-angle cross-bedding. The upper two-thirds of the Toroweap is medium gray to light gray, cherty,

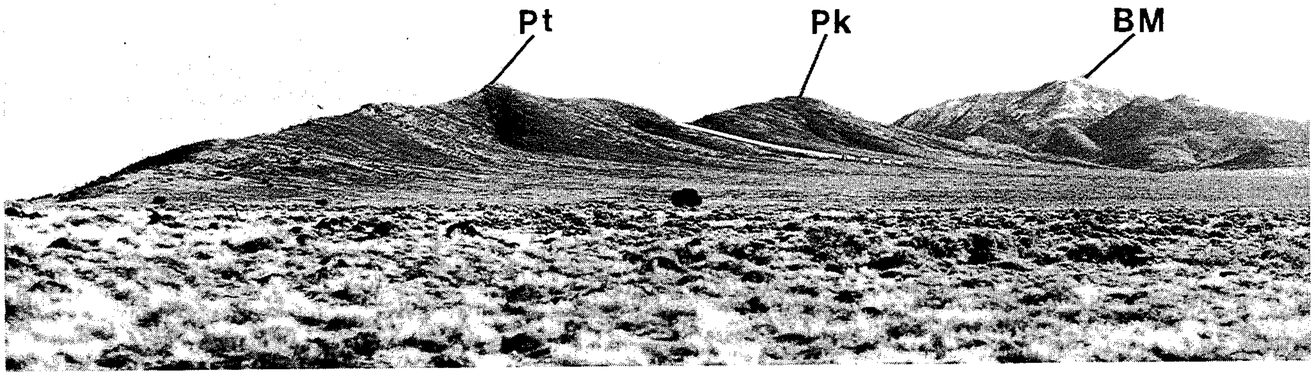

FIGURE 6.–View looking south at the southwest-dipping Permian Toroweap (Pt) and Kaibab Limestone (Pk) beds of Miners Hill. Blue Mountain (BM) is present in the background.

fossiliferous limestone. Chert weathers orange or orange brown and is nodular to bedded. Megafossils such as bryozoans, brachiopods, and crinoids are abundant in the upper limestone sequences. The contact with the Queantoweap (Talisman) is not exposed, and the upper Toroweap is faulted, making its relationship to the overlying Kaibab obscure. These 134.0 m of strata are correlated with the Toroweap of McKee (1938).

Kaibab Limestone

In the southern half of Miners Hill, the Kaibab Formation is partially exposed (fig. 6). These light gray to gray limestones contain abundant chert which is variable in character throughout the formation. Such variations are the color of chert which changes from gray to orange brown in the lower 40 percent of the formation and to a white to pastel pink in the upper 60 percent. Megafossils, such as bryozoans and crinoid columns, are common throughout the section. In general, the carbonates are more bioclastic in the upper portions of the section. Although the lower contact is obscured by faulting, it is probable that the prominent white to tan sandstone unit is near the basal contact. The upper Kaibab is concealed by colluvium, so that the overlying Plympton and Moenkopi Formations are not exposed. The strata correlate with McKee's (1938) Kaibab redesignation. The lower portion contains conodonts: *Ellisonia festiva, Hindeodus* n. sp., *Neostreptognathodus clinei behnken, Neostreptognathodus prayi behnken,* and *Neostreptognathodus* n. sp. (B. R. Wardlaw written communication to J. E. Welsh 1979). They indicate a middle-Late Permian age. Wardlaw says the presence of *Neostreptognathodus prayi* suggests the Toroweap probably near the Toroweap-Kaibab boundary. The conodont color alteration index (CAI) is 2.0. Kaibab exposed at Miners Hill is 256.6 m thick.

Jurassic System

The Jurassic System, which is regionally represented by the "Navajo" Sandstone, is not exposed in the Longlick and White Mountain area. It has, however, been identified to the east in the lower plate of the Star Range allochton and to the west in the lower plate of Blue Mountain autochton where it overlies the Triassic Chinle Formation (Weaver 1980). It may also crop out 8 km north of Longlick Mountain (V. L. Felt personal communication 1979).

Navajo Sandstone

The Navajo Sandstone mapped by Felt is a white, medium-grained, very well sorted, quartzose sandstone. It is discontinuously exposed (NE ¼, section 20, T. 28 S, R. 12 W) but resembles the Navajo in the Star Range.

Tertiary System

In the area mapped Tertiary rocks rest unconformably on Paleozoic strata. The Tertiary, which consists of Oligocene and Miocene lava flows, ash-flow tuffs, and volcaniclastic deposits, can be correlated with the Dacite of Shauntie Hills, the Needles Range Formation, the Isom Formation, the Formation of Blawn Wash, and local basalt flows of the Formation of Brimstone Reservoir. Although these units are locally altered and partly covered with colluvium, they are recognizable as mappable units.

Dacite of Shauntie Hills (Oligocene; Lemmon and Morris 1979)

This flow unit has widespread exposure throughout the southern portion of the area in outcrops on low-lying hills. It is aphanitic, dark reddish brown (10R 3/4) to brownish gray (5 YR 4/1) and commonly weathers to grayish red (10R 4/2) with moderate reddish brown (10R 4/6) liesegang bands. Plagioclase (An60) (10–15%) (>4mm), pyroxene (5–7%), and magnetite (5%) phenocrysts are readily apparent in thin section. This unit is similar to the mafic lava flow member of the Formation of Blawn Wash (M. G. Best personal communication 1979, Weaver 1980). It can be distinguished from the mafic flow member by its lower stratigraphic relationship to diagnostic units such as the overlying Needles Range Formation and the Isom Formation. The Dacite of Shauntie Hills is probably composed of more than one flow unit; however, for the purpose of this study, the others are not differentiated.

Needles Range Formation (Oligocene, 29 m.y.; Armstrong 1970, Fleck and others 1975)

The Needles Range Formation is a sequence of dacitic ash-flow tuffs. Its regional distribution in southwest Utah and eastern Nevada was first recognized by Mackin (1960). Internal stratigraphic relationships were later recognized and defined by Best and others (1973, 1979). As presently defined, the formation consists of four members: (1) the basal Cottonwood Wash Tuff Member, (2) the Wah Wah Springs Tuff Member, (3) the Lund Tuff Member, and (4) the Wallaces Peak Tuff Member. Only the upper three members are observed in the study area. Their exposure is discontinuous, and nowhere is the entire sequence exposed. Often they are weathered or hydrothermally altered making positive identification difficult.

Wah Wah Springs Tuff Member. Exposed in the southeast corner of the study area, the Wah Wah Springs Tuff Member is moderate red (5R 5/4) to grayish red (5R 4/2) and highly welded. Phenocrysts consist of quartz (trace), plagioclase (25–30%), biotite (3–5%), hornblende (7–10%), and opaque minerals (3–5%). Flattened pumice lapilli are often present. Conspicuous hornblende phenocrysts (3–5 mm) are abundant and diagnostic in the basal vitrophyre and lower part of the formation. When hornblende phenocrysts are sparse, as in the upper portion of the formation, the lack of abundant quartz phenocrysts can serve to differentiate it from the overlying Lund Tuff Formation. When altered, it is often bleached to lighter colors.

An exposure of basal vitrophyre is present 2.9 km southwest of Longlick Mountain east of the road in the eastern half of section 13 (T. 29 S, R. 13 W). At least 233 m of Wah Wah Springs Tuff Member rests on the Dacite of Shauntie Hills, which in turn rests unconformably on the Mississippian Humbug Formation.

Lund Tuff Member. The Lund Tuff Member accounts for 75 percent of the areal exposure of Needles Range Formation. It is pale red (5R G/2) to moderate red (5R 4/6) and highly welded. The conspicuous abundance of embayed quartz phenocrysts (5–10%) (up to 3 mm) in hand sample facilitates positive identification. Other phenocrysts consist of plagioclase (25–30%), biotite (5–6%), hornblende (3–4%), and opaque minerals (1–2%). Flattened pumice lapilli are common. Their preferred horizontal orientation facilitates measurement of foliation attitudes. The basal vitrophyre is exposed at several locations. An outcrop 1.9 km southeast of Mertons Spring in the southern half of section 14 (T. 29 S, R. 13 W) is the most extensive exposure. The basal vitrophyre's contact with the underlying Wah Wah Springs Formation is covered by colluvium. At least 85 m of Lund are observed. The Lund is hydrothermally altered in places. Though alteration may be intense, the pervasive embayed quartz phenocrysts make identification possible. The Lund has been age dated by Kistler (1968) as 29.2–29.3 m.y.

Wallaces Peak Tuff Member. The Wallaces Peak Tuff is observed on low-lying flats north of the Brimstone Lineament. When fresh, it is brownish gray (5 YR 4/1) to grayish red (10R 4/2) and highly welded. Phenocrysts are composed of quartz (1–2%), plagioclase (20–25%), biotite (3–5%), hornblende (4–5%) and opaque minerals (1–2%). Commonly it possesses lithic clasts of the Lund Tuff or mafic rock. There are localized areas where it has been bleached by hydrothermal alteration. The best exposures of the Wallaces Peak Tuff are present 2.3 km north of the area and west of Antelope Peak.

Isom Formation (Late Oligocene or Early Miocene; 25 m.y.; Armstrong 1970; Fleck and others 1975)

The Isom Formation is composed of the Baldhills Tuff Member, the Hole-in-the Wall Tuff Member (Mackin 1960), and the Blue Meadows Tuff Member (Rowley and others 1975). In the study area only the Hole-in-the-Wall Tuff Member is present.

Hole-in-the-Wall Tuff Member. A discontinuously exposed, resistant, densely welded, crystal-poor, ash-flow tuff, the Hole-in-the-Wall Tuff Member is grayish red (10R 4/2) to dusky red (5R 3/4) and contains numerous tiny vesicles and thin light gray lenticules. Phenocrysts of plagioclase (1–2%), magnetite (1%), and quartz (trace) are visible in unaltered hand samples. When weathered, it becomes crumbly and breaks easily into popcornlike fragments. Numerous small outcrops are exposed throughout the study area. Throughout the region it serves as a diagnostic stratigraphic marker. The basal vitrophyre is exposed 2.7 km southwest of White Mountain (NE ¼, section 17, T. 29 S, R. 13 W). The Isom is estimated to be at least 7 m thick.

Formation of Blawn Wash (Miocene)

The Formation of Blawn Wash is composed of rhyolitic ash-flow tuffs, rhyolite flows, and mafic lava flows. They have been informally designated (M. G. Best personal communication 1979) as (1) the basal garnetiferous tuff member, (2) mafic flow member, (3) the upper tuff member, and (4) the rhyolite flow member. In addition, two older units are proposed: (1) The Tuff of Sevey's Well Member, and (2) the Quartz Latite of Squaw Peak (V. L. Felt personal communication 1979). All of these members are present in the study area.

Tuff of Sevey's Well Member. The Tuff of Sevey's Well Member has variable texture and composition. It is moderate orange pink (10R 7/4) to very pale orange (10 TR 8/2), a pumaceous tuff, with crystal and lithic fragments. Crystal fragments consist of quartz (1 to 4 mm), plagioclase, biotite, and hornblende (trace). Pumice lapilli are near white and variable in size up to several centimeters. Lithic fragments are from the Needles Range Group and mafic material. The porous nature of the ash matrix has made it highly susceptible to hydrothermal alteration. A large altered exposure of the Sevey is located 900 m northeast of Longlick Mountain. The estimated thickness of exposure in the study area is approximately 100 m.

Quartz Latite of Squaw Peak Member. Thin and discontinuous, the Quartz Latite of Squaw Peak Member is pale red purple (5RP 6/2) to grayish purple (5P 4/2) and contains abundant zoned, andesine phenocrysts (up to 7 mm), embayed quartz, augite, biotite (trace), and opaque minerals. North of the study area around Antelope Peak, the Quartz Latite of Squaw Peak commonly rests upon the Tuff of Sevey's Well (V. L. Felt personal communication 1980). Within the study area, it rests on units as old as the Isom Formation. Its estimated thickness is 73 m.

Lower Tuff Member. The lower tuff member is present only north of the Brimstone fault zone which truncates Longlick and White Mountains. It is very pale orange (10YR 8/2) to pale red (10R 6/2) and densely welded. Phenocrysts of plagioclase and biotite form a minor part of the rock. Their percentage is greatly variable as is that of lithic fragments (3–5 mm). Since no garnet is present in thin section, its equivalence to the basal garnetiferous tuff of Best is in question. When broken, it displays conchoidal fractures.

Although the tuff is densely welded, it is susceptible to hydrothermal alteration and may be highly colored, displaying liesegang banding. The estimated thickness is at least 49 m.

Mafic Flow Member. The mafic flow member is discontinuous throughout the area. It is dark reddish brown (10R 3/4) to brownish gray (5YT 4/1) and, when weathered, displays liesegang bands. It contains phenocrysts of pyroxene and plagioclase. This unit is similar to the Dacite of Shauntie Hills, but is distinguishable by its relatively higher stratigraphic position. Commonly, it rests on the upper tuff member but is also observed to rest on units as low as the Needles.

Upper Tuff Member. When unaltered, the tuff is grayish pink (5R 8/2) to moderate orange pink (10R 7/4). Representative exposures of this unit are located on the north side of the Brimstone fault zone—but several altered exposures exist on the southern side of the fault. Phenocrysts form a minor constituent. Their amounts consist of wide variations of quartz, sanidine, plagioclase, and biotite. The upper tuff member is very pumaceous, containing lapilli as large as 1 cm, and is poorly welded. Lithic fragments are common, varying in size from a few millimeters to approximately 2 cm. They consist of unidentified mafic rocks and fragments of the Lund Tuff.

Because of its inherent high porosity and permeability, the tuff has been subject to alteration by migrating hydrothermal fluids. These altered outcrops are light red (5R 6/6) to moderate red (5R 4/6) because of hematization. Pumice lapilli and feldspars may appear only as casts. Quartz phenocrysts are pervasive, and in severe cases of alteration, such as the Brimstone mound, only a silicified spongelike skeletal texture remains.

The areal extent and thickness of the upper tuff are greater than those of the lower tuff.

Rhyolite Flow Member. The rhyolite flow member is found in one poorly exposed outcrop in the extreme northwest corner of the area. It is grayish red (10R 4/2) to pale brown (5TY 5/2) and rests on the upper tuff member. The basal perlite is a pale brown (5YR 5/2) to pale olive (10Y 6/2) and grades upward into a darker, silicified rhyolite which displays prominent flow banding. The uppermost part contains numerous small (1 mm or less) phenocrysts of plagioclase, biotite, and occasional quartz. This member has a very localized origin which is clearly related to the domed vent area (V. L. Felt personal communication 1980) less than 1 km to the northwest.

Formation of Brimstone Reservoir (Pliocene?; Lemmon and Morris 1979)

The Formation of Brimstone Reservoir is discontinuous throughout the area. It consists of black, dense, basalt flows. The base is vesicular, becoming less so upward in the unit. On the south edge of the area the basalt rests on the Dacite of Shauntie Hills. It also rests on the Isom and the upper tuff member of Blawn Wash. The best exposure is located on a small cuesta 900 meters north of Brimstone mound. Although these flows have not been dated radiometrically, Lemmon and Morris (1979) believe they are Pliocene or early Pleistocene. Topographic expression suggests correlation with flows on the west side of the Wah Wah Valley which have been dated at 13 m.y. (M. G. Best personal communication 1979).

ALLUVIAL COVER

Much of the study area is covered by unconsolidated valley fill, colluvium, and alluvial gravels, none of which have been differentiated on the map.

STRUCTURE

General Statement

The San Francisco Mountains lie within the eastern margin of the overthrust belt of the Basin and Range Province. Allochthonous Paleozoic rocks occur in all surrounding ranges. Longlick and White Mountain adjoin a major east-west lineament (fig. 6) which is enhanced by lightly colored hydrothermal alteration. Other faults are present but less apparent. Paleozoic inliers contain structures crucial to understanding the subsurface structure. Faults and lineaments may be categorized into four directional trends: (1) east-west, (2) north-south, (3) northeast-southwest, and (4) northwest-southeast.

Thrust Faults

The southern San Francisco Mountains are surrounded by various thrust allochthons (Miller 1959, East 1966, Baer 1973, Welsh 1979a, and Weaver 1980). Baer (1973) interprets Paleozoics of the Star Range to be resting on Jurassic strata. Welsh (1979a) interprets the Grampian Thrust in the northern San Francisco Mountains as Cambrian and Ordovician resting on overturned Pennsylvanian and Permian strata. In the Wah Wah Mountains, Welsh (1979a) interprets the Wah Wah Thrust as Precambrian resting on Upper Mississippian. Miller (1959) and Weaver (1980) interpret the Blue Mountain Thrust as Cambrian resting on Jurassic strata.

In the Longlick and White Mountain area, there is no exposed thrust faulting. However, it is evident from the geology of surrounding areas that thrust faults must be present. Good correlation exists in Devonian through Upper Mississippian of the Longlick and White Mountain area and that of the upper plate of the Blue Mountain thrust. Conversely, these strata incompletely correlate with stratigraphy of similar age in the Star Range. The Upper Mississippian Humbug Formation and Great Blue Limestone are not present there (fig. 3). While the edge of an erosional wedge of Upper Mississippian Humbug and Great Blue Formation did exist, the close proximity of these two different Mississippian sequences imply juxtaposition by thrust faulting. Moreover, recognition of probable Jurassic Navajo Sandstone (V. L. Felt personal communication 1979) 8 km north of Longlick Mountain and 2.7 km northeast of exposed Simonson Dolomite further strengthens the argument in favor of a thrust fault. It suggests that either tremendous vertical displacement has taken place or that Paleozoics have been thrust over the Navajo in the southern San Francisco Mountains.

East-West-Trending Faults

The major east-west-trending lineament which terminates the northern extent of Longlick and White Mountains (fig. 7) is herein named the Brimstone Lineament for the native sulfur prospect at its western limit. Nowhere along its extent is the fault exposed. Mapping reveals that tuffs conceal its trace. On the basis of the estimated thickness of the volcanics, it is postulated that its vertical displacement is at least 600 m. Fault reactivation and ascension of accession of hydrothermal fluids have, to varying degrees, altered the overlying tuffs and indirectly enhanced the fault's trace.

At the northern foot of Longlick and White Mountain are examples of the covered lineament. Only colored linear trends of hydrothermal alteration mark the base of these topographic discontinuities. Other faults mark topographic lineaments which parallel the Brimstone lineament. Alteration is a remnant of thermal spring activity.

Lateral extent of the Brimstone fault is unknown. It is probably downdropped on the west by the Wah Wah Valley graben. It may continue east through Longlick Canyon and connect with a fault which terminates the Navajo Sandstone north of the Moscow Reservoir (Lemmon and Morris 1979).

The age of east-west faulting seems to be pre-Needles. The inundating volume of the lower Needles members apparently covered all but the highest of topographic points. Fault reactivation during post-Needles time apparently contributed to increased topography, thus later restricting the areal deposition of the Formation of Blawn Wash.

North-South-Trending Faults

Several north-south-trending faults are mapped throughout the area. They are divided into an older pre-Oligocene (post-thrusting pre-Isom) series and a younger, post-Miocene (post-basaltic volcanism) series which may be of basin-and-range origin.

The older series of faults does not appear to displace the Isom or the Dacite of Shauntie Hills. They have, however, downdropped the Paleozoics in a roughly en echelon manner and caused progressive displacement from east to west. The observed result is that older Paleozoic sequences are exposed in the east, and younger Paleozoic sequences are exposed in the west. Hence, a composite of sections measured parallel to this trend reveals Devonian Sevy through Permian Kaibab strata (see fig. 2) in normal stratigraphic succession.

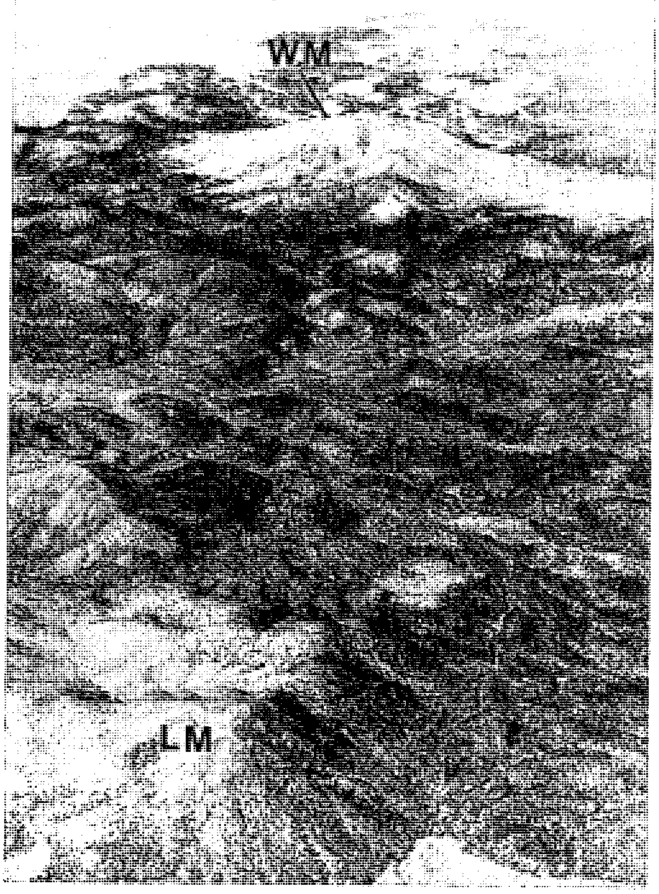

FIGURE 7.–View looking west at the Brimstone Lineament and its northern termination of Longlick Mountain (LM) and White Mountain (WM).

The younger faults express themselves as north-south drainages and topographic lineaments. Displacement is slight, and they are observed in only a few locations, such as basalt-capped exposures north of the Brimstone sinter mound. The displacement of the basalts suggests they are related to basin-and-range extension.

Northeast-Southwest-Trending Faults

Northeast-southwest-trending faults have a subtle expression although they seem to be well defined to the west (Best and others in press), southwest (Weaver 1980), and east (Abou-Zied and Whelan 1973). These faults may be genetically related to the older north-south faults of pre-Oligiocene age. Both have displaced the Paleozoics in an en echelon manner. It is postulated that Longlick Mountain and the Simonson exposure 2.7 km to the north may have been structural highs prior to faulting as it is in the Longlick fault block that the Sevy, the lowest exposed Paleozoic unit, is present. Measured sections and field mapping suggest that the Paleozoics are in the correct relative stratigraphic sequence from east to west and that prior to normal faulting these strata were nearly horizontal to slightly domed as is noted in the general southern dip of all fault blocks. Faulting may have been initiated on the west in the vicinity of Miners Hill where the eastern side of the faults acted as footwalls. Such en echelon migration from west to east may explain why the Permian ultimately experienced the greatest displacement.

Northwest-Southeast-Trending Faults

Northwest-southeast-trending faults are not well exposed here but are present in the southern Wah Wahs (Best personal communication 1979, Weaver 1980) and the Star Range (Abou-Zied and Whelan 1973).

On the southwest flank of Longlick Mountain, there is a sequence of Mississippian Anchor, Deseret, and Humbug which has been downfaulted. In the Deseret Limestone 2.0 km southwest of Longlick Peak are two examples of this type of faulting. It is possible that additional northwest-southeast-trending faults exist in the poorly exposed volcanic rocks.

Folds

No major folds are apparent in the study area. Paleozoic strata in Longlick and White Mountain display only minor monoclines which dip to the south (fig. 8).

ALTERATION

The prominent east-west zone of hydrothermal alteration which exists on either side of White Mountain (fig. 7) has been described by Stringham (1963) and Brooke (1964). It is represented largely by light colored alteration products and contains alunite, hematite, kaolinite, manganese oxide, pyrite, limonite, and quartz. Alunite and kaolinite are more abundant.

Alteration selectively occurs in the lower and upper tuff members of the Formation of Blawn Wash and, to a less obvious extent, in the Needles Range Formation. The pumiceous nature of the lower and upper tuffs and the moderately welded nature of the Needles Range Formation have provided ample porosity and permeability to host the influx of migrating hydrothermal fluids. The lack of these same physical conditions in the Tertiary extrusives and in the Isom Formation has limited their alteration. The basalt flows seem to have been deposited after hydrothermal alteration ceased. Thus, alteration is older than the basalts (middle Miocene?) and younger than the up-

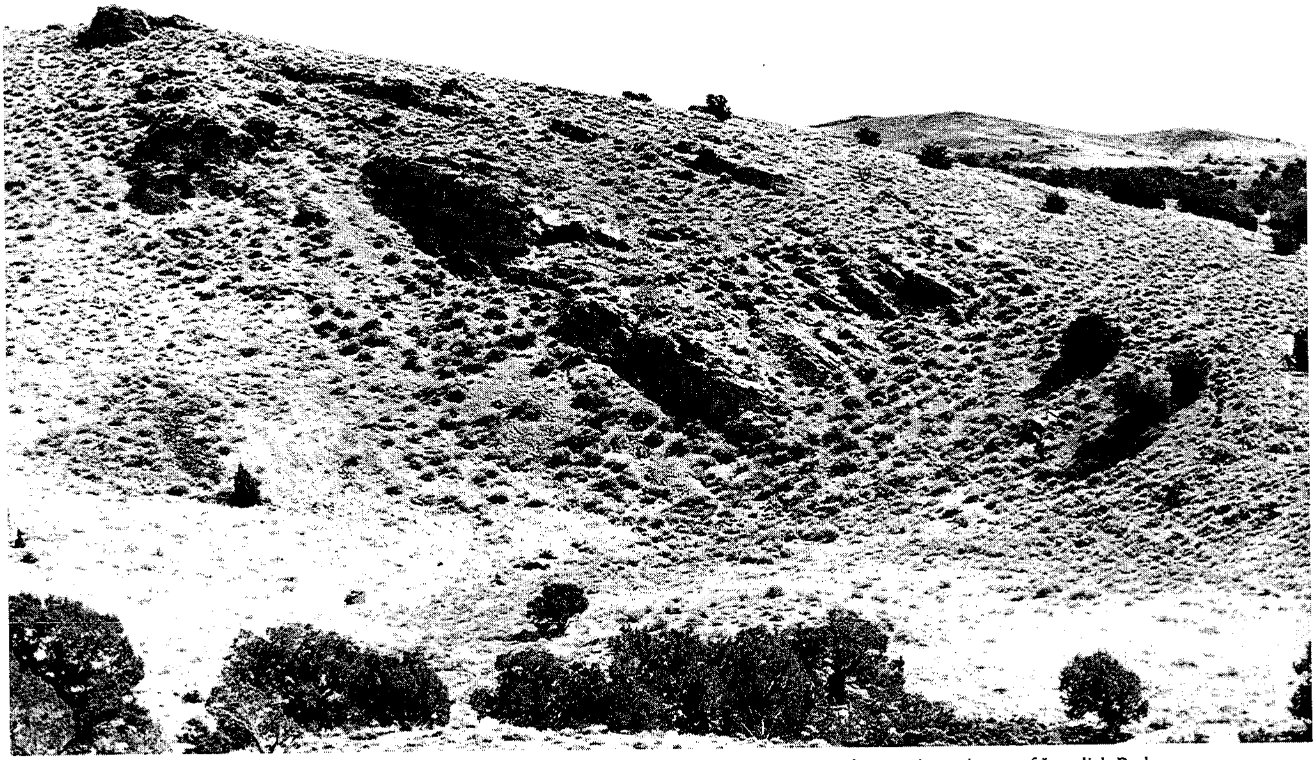

FIGURE 8.—View looking east at a slight monocline in the Mississippian Humbug Formation location 3.0 km south-southwest of Longlick Peak.

per tuff member of the Formation of Blawn Wash (late Oligocene?).

Stringham (1963) and Brooke (1964) confined their work to the more distinct alteration along the east-west-trending Brimstone lineament. But other small areas exist which are worthy of note. Such an example is a 100-m² area directly north of White Mountain (W ½, section 3, E ½ section 4, and section 6). The area is covered with the Wallaces Peak Tuff. It has acted as an "ink blotter" (fig. 9) in soaking up hydrothermal fluids. These areas, several square meters in dimension, display alunitic and kaolinitic alteration and limonitic oxidation of pyrite. All these are zoned and grade into unaltered Needles. Limonitization often appears as liesegang banding. When areas have experienced silicification, they appear only stained with rust brown limonite. Detailed examination of freshly broken rock surfaces reveals intense silicification which is light gray (N7) to light bluish gray (5B 7/1). In some instances, remnant crystal textures are present but commonly they are obliterated. Careful inspection reveals abundant finely disseminated pyrite. No detailed mapping was done of these hydrothermal areas because of their obscure character and a lack of detailed aerial photography. Alteration appears to be associated with underlying fracture and joint (fig. 9) systems which have leaked hydrothermal fluids. These limited evidences suggest a sulphide system. Further, the general lack of alteration south of the Brimstone Lineament suggests that the main part of the system lies north of the fault.

MINERALIZATION

The area around the Brimstone Lineament contains disappointingly little mineralization. Of these sparse occurrences, two are deserving of note.

At the west end of the Brimstone Lineament is a mound of siliceous sinter and silicified volcanics (fig. 10) known as the Brimstone or Sulphur mound (fig. 11). The mound is what remains of a hot-spring deposit like those presently active at Yellowstone, Wyoming; Mount Lassen, California; and Roosevelt Hot Springs, Utah. First described by Nackowski and Levi (1959), the native sulphur at Brimstone mound was deposited along with siliceous sinter. Of particular interest are the paleofumaroles lined with native sulphur (fig. 12). The sulphur was deposited as vapor condensate.

Another example of mineralization is found east of White Mountain, on the northern side of the Brimstone Lineament (section 11, T. 29 S, R. 13 W). There two faulted blocks of Mississippian carbonates are strongly silicified and inundated by the Needles Range Formation which has been moderately chloritized. Associated with the volcanics are localized deposits of autinite and carnotite (Stringham 1963). No additional uranium mineralization is evident anywhere else in the study area.

These types of alteration and infrequent mineralization are suggestive of the upper limits of an epithermal hydrothermal system. Economic mineralization may or may not lie at depth.

GEOLOGIC HISTORY

Sevy and Guilmette-Simonson record an interior continental carbonate shelf environment which bordered western Utah during the Silurian and Devonian (Poole and others 1977). The upper sandy portions of the Devonian strata, such as the Cove Fort Quartzite and the Pinyon Peak Limestone, signify instability that preceded the Antler Orogeny and its developing island arc in central Nevada. Lower Mississippian strata are a complex of transgressive-regressive carbonates, constructional

FIGURE 9.—Hydrothermal bleaching along one of the joint selvages in the Wal-

skeletal shelf-margin carbonates, and starved-basin sediments (Rose 1977) while the upper Mississippian is characterized as a carbonate shelf (Rose 1977, Welsh 1979b). The Chainman Shale represents the progradation of fine-grained detrital flysch sediments derived primarily from the Antler orogenic belt of Nevada (Hintze 1973, Welsh 1979b). Pennsylvanian limestones and sandy dolomites, with various degrees of chert, are typical of carbonates deposited on the Callville Platform (Welsh 1979b). The erosion of the Pennsylvanian on the Emery uplift of eastern Nevada and western Utah is represented by chert pebble conglomerates which regionally mark the basal Pakoon. The Wolfcampian Lower Pakoon Formation was deposited in a restricted interior platform environment (Welsh 1972).

Queantoweap deltaic clastics which prograded over the Callville-Pakoon platform were derived from the Uncompahgre and other contemporary Permian uplifts. The repeated transgression and regression of open and restricted shallow-marine Toroweap and Kaibab environments marked the close of the Paleozoic era.

Erosion of Upper Permian rocks—such as the Plympton Formation—represent an early Triassic regional unconformity. The early Triassic marked a major change from tidal-flat marine to clastic-dominated nonmarine depositional environments evident in the Moenkopi Formation, Shinarump Conglomerate, and the Chinle Formation of the Blue Mountain lower thrust plate (Weaver 1980). Navajo Sandstone is a record of widespread aeolian environment mainly east of the area studied.

During the late Mesozoic Sevier orogeny southeastern thrusting placed allochthonous Paleozoic sequences over Paleo-

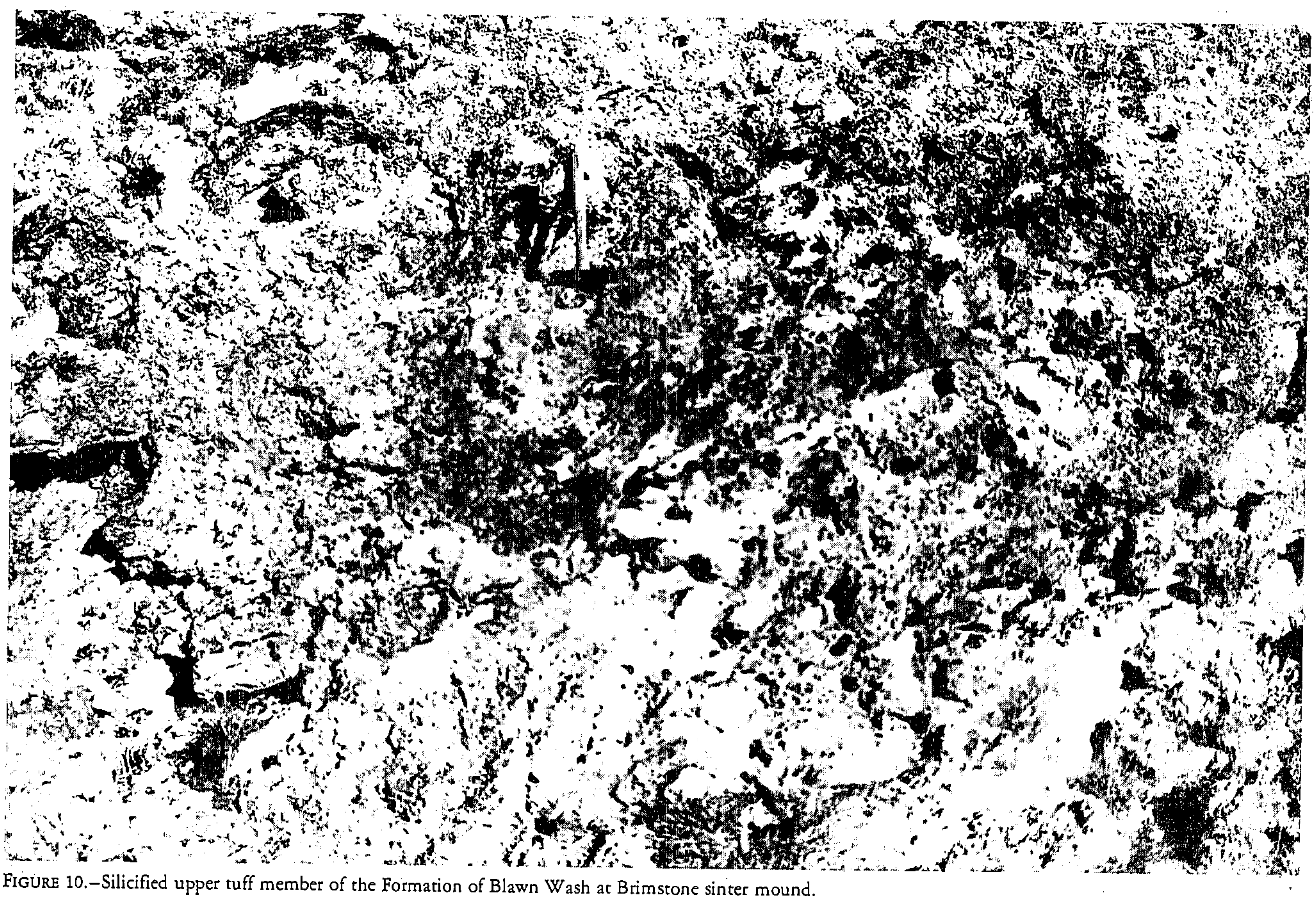

FIGURE 10.—Silicified upper tuff member of the Formation of Blawn Wash at Brimstone sinter mound.

zoic–Mesozoic autochthonous sequences. The allochthonous nature of the Longlick and White Mountain Paleozoic rocks is evidenced by the excellent correlation with like strata in the upper plate of the Blue Mountain thrust. During compressional thrusting, shear was active between the thrust plates. Within the plates, shear couplets and imbricate reverse faults disrupted the Paleozoic rocks between the Wah Wah-Frisco and Blue Mountain thrusts.

Initiation of late Eocene volcanism (M. G. Best personal communication 1979) is recorded in the southern San Francisco Mountains by accumulations of pre-Needles stratovolcanic flows and pyroclasts. Middle Oligocene deposition of the Needles Range Formation included the local caldera venting, from some unknown locality, of ash flows units such as the Wallaces Peak Tuff. By late Oligocene (Fleck and others 1975) deposition of the calcalkalic magmatism had produced subdued topo-

FIGURE 11.–View looking north at the Brimstone sinter mound and associated prospect pits.

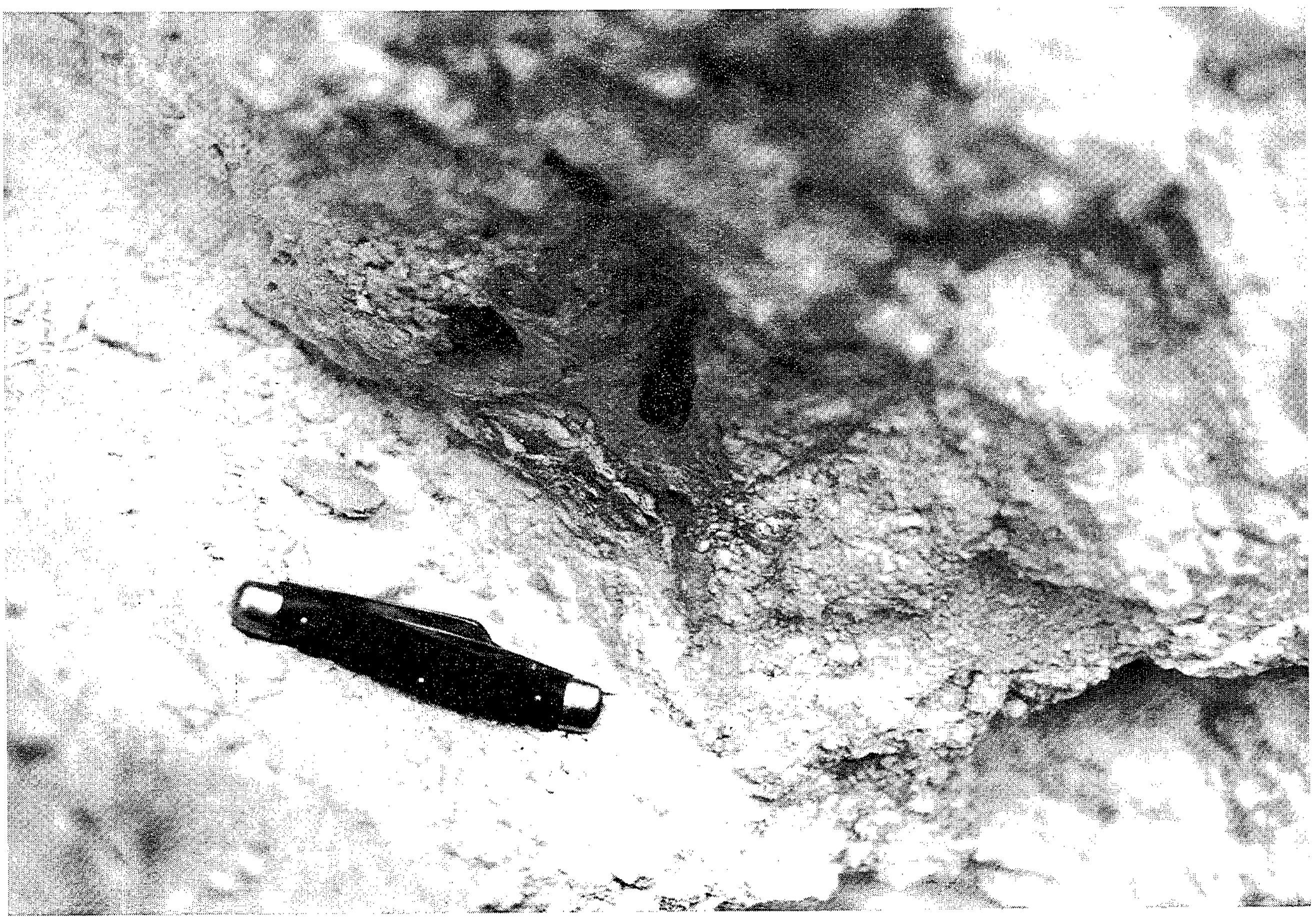

FIGURE 12.–A fumarole lined with native sulfur (dark gray) in the bleached upper tuff member (light gray) of the Formation of Blawn Wash which comprises the siliceous Brimstone sinter mound.

graphy, which contributed to the widespread regional distribution of the Isom Formation. Near the end of the Oligocene local caldera-type volcanism yielded the Formation of Blawn Wash, a sequence of bimodel mafic-rhyolitic units (M. G. Best personal communication 1979). Hydrothermal alteration of these and older units started no later than the early Miocene and ceased by middle-Miocene before the venting of mafic lavas which presently cover a large portion of the area.

The early Miocene marked the advent of basin-and-range extensional faulting. Many previous faults were transformed into gravitationally driven normal faults. Extension in the Basin and Range is responsible for major north-south normal faulting which overprints the area.

ECONOMIC POTENTIAL

The southern San Francisco Mountains are located within the Wah Wah-Tushar mineral belt (Hilpert and Roberts 1974) and the connecting Pioche mineral belt (Roberts 1974, Shawe and Stewart 1976). Both are believed "to be related to the same type and age of volcanism along an east-west structural trend" as the Goldfield and Tonopah deposits (Stewart and others 1977). Roberts (1966) designated the Wah Wah-Tushar end of the belt as a metallogenic province characterized by base-metal deposits rather than precious metal deposits. Moreover, the southern San Francisco Mountains are surrounded by several historically productive mining districts as well as areas of current exploration and development. Districts such as the San Francisco, Preuss, North Star, and South Star have produced silver, lead, zinc, copper, gold, and tungsten. Uranium and fluorite have been produced, in small quantities, from the Staats Mine and Blawn Mountain areas of the central Wah Wah Mountains. Current interest is focused on the recent molybdenum-tungsten discovery in the Wah Wah Mountains which is hosted by the Pine Grove porphyry (Keith 1979). This intrusive is thought to be the surface correlative of the lower, garnet-bearing tuff member of the Formation of Blawn Wash (M. G. Best personal communication 1979).

Local volcanic centers exist adjacent to the Longlick and White Mountain area (V. L. Felt personal communication 1979, Rowley and others 1978). Hydrothermal alteration is extensive, and there is evidence for a sulfide system. The area is structurally complex, lying along the Blue Ribbon Lineament (Rowley and others 1978). Beneath the volcanics, Mesozoic and Paleozoic carbonates possess potential as hosts for mineralization. Such combined geologic conditions suggest possibilities for "blind" economic targets and merit further investigation.

Hydrothermal alteration probably represents self-sealing of a geothermal system. But heat flow measurements observed around the fringe of the area which range from 75 ± 2 mWm^{-2} to 160 ± 28 mWm^{-2} (Chapman and others 1979) indicate low commercial steam potential. Because the area is associated with extensive volcanism and high heat flow, there is little potential for oil and gas.

Appendix A
LONGLICK MOUNTAIN SECTION

Section measured: T. 29 S, R. 12 W, section 6, S ½, SW ½; T. 29 S, R. 13 W, section 1, S ½, NE ¼, SE ¼.

Lower Monte Cristo Limestone

Anchor-Thunder Springs Limestone Member

Unit		Meters
11	Silty limestone, gray, fine grained thinly bedded.	2.4
10	Chert, black, interbedded with limestone, 60 percent chert, 40 percent thinly bedded limestone, chert weathers yellow brown.	2.7
9	Limestone, medium gray, fine grained, massive, interbedded with thin beds of chert; chert, black, weathers yellow brown.	2.7
8	Silty, dolomite, gray, thinly interbedded with black chert, forms slope.	2.4
7	Chert, black, thinly interbedded with yellow brown silty dolomite.	3.7
6	Cherty dolomite, gray to dark gray, 30-cm-thick beds of black chert interbedded with fine-grained dolomite.	2.4
5	Cherty limestone, gray to medium gray, thin beds of black chert, interbedded with thin beds of limestone.	4.0
4	Dolomite, gray to medium gray, medium grained, massive, forms cliff.	4.9
3	Dolomite, gray to medium gray, interbedded with black chert, forms slope.	7.9
2	Limestone, gray to medium gray, fine grained, interbedded with light to black brown chert, 50 percent chert, covered slope, contains some corals.	15.5
1	Dolomite, dark gray to black, medium grained, interbedded with black chert beds 15 cm to 30 cm thick.	14.3
	Total thickness of Anchor-Thunder Springs Limestone Member	62.9

Dawn-Whitmore Wash Limestone Member

4	Sandy dolomite, medium gray to dark gray, medium grained, 40 percent sand, some very low-amplitude cross-beds, sparse chert nodules, contains *Lithostrotion* sp.	4.0
3	Sandy dolomite, medium gray to dark gray, medium grained, 40 percent sand, contains rugose coral, *Lithostrotion* sp., *Syringopora* sp., and *Triplophyllites* sp.	11.6
2	Bedded chert, black.	0.3
1	Sandy dolomite, medium gray to dark gray, medium grained, 40 percent sand, contains rugose coral, *Lithostrotion* sp., *Syringopora* sp., and *Triplophyllites* sp.	14.0
	Total thickness of Dawn-Whitmore Wash Limestone Member	29.9

Fault in Saddle

Pinyon Peak Limestone

4	Sandy dolomite, gray to tan, medium grained, 50 percent sand, medium beds.	4.6
3	Sandy dolomite, gray to tan, medium grained, 30 percent sand, medium beds.	5.5
2	Sandy dolomite, gray to tan, medium grained, 50 percent sand, medium beds.	7.3
1	Sandy dolomite, gray to tan, medium grained, interbedded with chert nodules in upper portion of unit, some soft sediment deformation.	6.4
	Total thickness Pinyon Peak Limestone	23.8

Unconformity?

Crystal Pass Limestone

10	Sandstone, white to light brown, clean, well-rounded and well-sorted grains, forms cliff.	1.2
9	Crystalline dolomite, gray to medium gray, medium grained, forms slope.	3.0
8	Sandstone, white to light tan, clean, well-rounded and well-sorted grains, cross-bedded, forms cliff.	1.5
7	Silty dolomite, medium gray to dark gray, 20 percent silt, medium beds, forms cliff.	7.0
6	Silty dolomite, medium gray to dark gray, 20 percent silt, medium beds, forms cliff.	2.7
5	Sandstone, white, coarse grained, well rounded, forms cliff.	0.3
4	Silty dolomite, gray to medium gray, fine grained, 20 percent silt, forms ledge.	3.0

Fault

3	Sandstone, tan gray to tan, medium grained, clean, well rounded, some small-scale cross-bedding, forms cliff.	6.4
2	Lithographic limestone, light gray to gray, fine grained, medium beds, forms ledge.	6.4

1	Lithographic limestone, light gray to gray, fine grained, medium beds, forms ledge.	6.7
Total thickness Crystal Pass Limestone		38.2

Cove Fort Quartzite

2	Sandstone, white to tan, coarse, well-rounded grains, 5 percent dolomitic cement, forms cliffs.	2.4
1	Sandstone, white to tan, coarse, well-rounded grains, dolomitic cement, forms cliffs.	4.6
Total thickness Cove Fort Quartzite		7.0

Unconformity

Guilmette-Simonson Dolomite

22	Crystalline dolomite, light gray to tan gray, coarse grained, sandy weathered appearance, forms ledge.	2.7
21	Sandy dolomite, light gray to medium gray, fine grained, 20 percent sand, some very small sand lenses.	7.0
20	Dolomitic sandstone, light gray to tan, medium grained, 60 percent sand, forms ledge.	9.8
19	Sandy dolomite, gray to medium gray, medium grained, crystalline, forms slope.	4.0
18	Sandstone, white, coarse, well-rounded grains, well sorted, very clean, low-angle cross-beds, dolomitic cement.	2.4
17	Dolomite, gray to dark gray, fine grained, 20 percent silt, hackled weathering, forms ledge.	15.8
16	Sandstone, white to tan, coarse, well-rounded grains, well sorted, forms prominent ledge.	4.3
15	Dolomite, gray to medium gray, medium beds, sparse chert nodules throughout, bedded chert at base of unit, forms ledge.	28.0
14	Sandstone, white to tan, coarse, well-rounded grains, well sorted, forms cliff.	2.1
13	Dolomite, black, rich in algal structures, badly recrystallized, some chert nodules and sand in upper portion of unit.	0.6
12	Dolomite, gray to medium gray, medium grained, sugary texture, medium beds, forms ledge.	8.8
11	Dolomite, gray to medium gray, fine to medium grained, massive to medium beds, forms ledge.	44.5
10	Dolomite, gray to medium gray, medium grained.	11.6
9	Sandstone, white to tan, coarse, well-rounded grains, well sorted, forms ledge.	1.8
8	Dolomite, medium gray to black, medium grained, medium beds, forms covered slope.	25.3
7	Dolomite, black, medium grained, recrystallized, medium beds, small, forms ledges.	34.7
6	Dolomite, black, medium grained, massive to medium beds.	5.2
5	Stromotoporoid and *Amphipora* sp. bed, partially recrystallized.	0.3
4	Dolomite, dark gray to black, medium grained, low-angle cross-bedding, partial recrystallization, contains Stromatoporoids, and *Amphipora* sp., forms slope.	31.1
3	Dolomite, dark gray to black, medium grained, brecciated and recemented, poorly exposed.	10.7
2	Dolomite, gray to medium gray, fine grained, forms slope.	14.9
1	Dolomite, dark gray to black, fine grained, massive to medium beds, some areas brecciated and recemented.	33.2
Total thickness Guilmette-Simonson Dolomite		298.8

Sevy Dolomite

8	Dolomite, light gray, fine grained, forms slope.	13.7
7	Dolomite, medium gray to dark gray, medium grained, forms slope.	3.0
6	Dolomite, light gray, fine grained, massive to medium beds, forms slope.	5.2
5	Dolomite, light gray, fine grained, massive to medium beds, forms ledge.	4.0
4	Dolomite, medium gray to dark gray, fine grained, forms small beds.	0.3
3	Dolomite, light gray, fine grained, massive to medium beds, forms ledges.	17.4
2	Dolomite, light gray, fine grained, massive to medium beds, some areas mottled, forms ledges.	36.6
1	Dolomite, light gray, fine grained, massive to medium beds, some areas mottled, forms ledges.	36.6
Total thickness Sevy Dolomite		116.8

Appendix B
EAST WHITE MOUNTAIN SECTION

Section measured: T. 29 S, R. 13 W, section 12, W ½, SW ¼.

Humbug Formation

Unit		Meters
50	Sandstone, brown, fine grained, siliceous, ledge former.	2.1
49	Pelleral limestone, medium gray to gray, fine grained.	0.3
48	Sandstone, brown, fine grained, siliceous.	2.1
47	Pelletal limestone, medium gray to gray, fine grained.	2.4
46	Pelletal limestone, medium gray to gray, fine grained, laminated, medium bedding.	8.2
45	Sandstone, brown, medium grained.	1.8
44	Pelletal limestone, medium gray to gray, fine grained, laminated, medium bedding.	0.9
43	Limestone, medium gray to gray, fine grained, ledge former.	12.5
42	Sandstone, brown to brown red, medium grained, forms resistant ledges.	3.0
41	Pelletal limestone, medium gray to gray, fine grained, poorly exposed.	1.2
40	Pelletal limestone, medium gray to gray, fine grained, forms ledges.	2.1
39	Sandstone, brown to gray, medium grained, fractured.	3.7
38	Pelletal limestone, gray to light gray, fine grained, forms ledges.	0.6
37	Sandy dolomite, gray to tan, fine to medium grained.	1.8
36	Dolomite, gray to light gray, fine grained.	1.5
35	Sandstone, brown, medium grained.	0.9
34	Dolomite, gray to light gray, fine grained, forms ledges.	0.6
33	Dolomitic sandstone, gray to brown red, medium grained, forms cliff.	1.8
32	Limestone, light gray, medium grained, becomes more dolomitic upward in unit.	3.7
31	Dolomite, dark gray, medium grained, interbedded with siliceous sandstone.	1.5
30	Limestone, dark gray, medium grained.	0.3
29	Dolomite, dark gray, medium grained, weathers orange brown, contains singular coral.	0.6
28	Dolomite, medium gray, medium grained, recrystallized.	0.3
27	Limestone, dark gray to medium gray, coarse grained, forms ledges.	0.9
26	Dolomite, medium gray, medium grained, forms ledges.	4.6
25	Dolomite, medium gray, medium grained, some floating sand grains and areas of undolomitized limestone.	2.7
24	Dolomite, medium gray, medium grained, forms ledges.	0.6
23	Pelletal limestone, dark gray, fine grained, small beds, forms ledges.	0.6
22	Limestone, medium grained, fine grained, dolomitized areas.	0.6
21	Dolomite, light gray, fine grained, some iron stains, forms slopes.	1.5
20	Sandstone, gray to brown, medium grained, interbedded with limestone medium gray to gray, forms ledges.	1.2
19	Pelletal limestone, gray to light gray, fine grained, thin bedding.	0.3
18	Dolomite, medium gray to brown gray, some chert.	1.5
17	Sandstone, gray to brown, coarse grained, well centered, forms massive ledges.	7.0
16	Dolomite, tan to orange brown, medium grained, thinly bedded, forms slopes.	4.3
15	Limestone, medium gray to gray, fine grained, crinoidal debris, some very large elliptical chert nodules.	0.9
14	Sandstone, gray to brown, medium to fine grained, some iron staining, sand is silicified.	2.7

13	Silty dolomite, tan to brown, 40 percent silt, forms slopes.	1.8
12	Sandy dolomite, gray to tan gray, coarse grained, 40 percent sand, forms slopes.	4.3
11	Dolomite, gray to tan, coarse grained, to 25 percent silt, forms slopes.	3.0
10	Sandstone, tan to light gray, coarse grained, well sotted and well rounded, forms ledges.	0.6
9	Dolomite, gray, medium grained, forms slopes.	3.0
8	Sandstone, tan to light gray, coarse grained, well sorted and rounded; forms slopes.	1.2
7	Dolomite, tan to gray, medium grained, some sand grains, limy at the top of unit.	2.4
6	Dolomitic sandstone, tan to gray, medium to fine grained, some skeletal debris, 30 percent dolomite, forms slopes.	5.5
5	Siliceous sandstone, tan to brown, medium grained, forms prominent ledges.	0.9
4	Sandstone, tan to brown, coarse grained, well rounded and well sorted, cemented with dolomite, forms slopes.	1.5
3	Dolomite, gray to tan; fine to medium grained; some bedded chert; forms slopes.	3.7
2	Dolomite, gray to medium gray; fine grained; less than 20 percent massive gray chert; forms ledges.	1.2
1	Dolomite: tan to gray; fine grained; some iron staining; forms ledges.	8.8
Total thickness Humbug Formation		120.6

Deseret Limestone

10	Chert, black, interbedded with dolomite, 70 percent chert, dolomite weathers orange brown, forms ledges.	2.1
9	Chert, black, interbedded with dolomite, 70 percent chert, dolomite weathers orange brown, forms ledges.	2.1
8	Crinoidal limestone, gray to medium gray, some chert nodules in unit, coral biostromes at base of unit, forms ledges.	0.9
7	Dolomite, medium gray to gray, coarse grained, forms ledges.	5.2
6	Sandy limestone, medium gray to gray, coarse grained, forms ledges.	11.3
5	Crinoidal dolomite, medium gray to gray, coarse grained, contains *Lithostrotion* sp., forms ledges.	2.7
4	Chert: black; bedded.	2.1
3	Crinoidal dolomite: medium gray to gray; coarse grained; contains *Lithostrotion* sp.; forms ledges.	9.4
2	Crinoidal limestone: gray to medium gray; medium grained, interbedded with chert; 40 to 60 percent thinning upward in unit; forms cliffs.	17.7
1	Limestone: medium gray to gray; medium grained; forms ledges.	1.5
Total thickness Desert Limestone		55.0

Anchor-Thunder Springs Limestone Member

15	Banded chert, black to dark brown, less than 10 percent dolomite, interbedded, forms cliffs.	1.8
14	Cherty dolomite, black to dark brown, 50 percent banded chert, dolomite, medium to coarse grained, forms ledges.	4.3
13	Limestone, gray to light gray, coarse grained, dolomitized in areas, forms ledges.	4.6
12	Dolomite, dark gray to gray, 30 percent banded chert, forms cliffs.	7.9
11	Limestone, gray to light gray, fine to medium grained, interbedded with chert, 50 percent chert, some areas dolomitized, forms slopes.	6.4
10	Limestone, gray to light gray, fine to medium grained, crinoidal debris, some chert nodules, forms ledges.	3.0
9	Dolomite, medium gray to gray, medium grained, interbedded with chert, 20 percent chert, forms ledges.	11.9
8	Dolomite, medium gray to gray, fine to medium grained.	1.5
7	Limestone, medium gray to gray, fine to medium grained, interbedded with chert, 30 percent chert, becomes dolomitic toward top of unit, contains *Lithostrotion* sp. and *Triplophyllites* sp.	6.7
6	Limestone biostrome, medium gray to gray, contains *Lithostrotion* sp. and *Triplophylites* sp. and *Syringopora* sp.	1.2
5	Dolomite, medium gray, medium grained, 10 percent silt, contains some poorly preserved thin-bedded corals.	8.2
4	Crinoidal limestone, medium gray to gray, medium to fine grained, coral limestone at base of unit, becomes dolomitic toward the top, contains *Lithostrotion* sp. and *Lithostrotionella* sp.	7.9
Fault?		
3	Cherty dolomite, medium gray to dark gray, fine grained, 20 percent chert in thick black bands, forms ledges.	15.8
Fault		
2	Cherty crinoidal dolomite, medium gray to dark gray, fine grained, 20 percent chert, forms slopes and ledges.	44.5
1	Cherty dolomite, medium gray to dark gray, fine grained, dolomite, silty, 40 percent chert, dolomite is thinly interbedded with chert beds, chert is black, forms slopes and ledges.	22.9
Total thickness Anchor-Thunder Springs Limestone Member		148.6

Appendix C

WHITE MOUNTAIN SECTION

Section measured: T. 29 S, R. 13 W, section 9, E ½, NE ¼.

Great Blue Limestone

Unit		Meters
104	Pelletal limestone, medium gray, fine grained.	1.5
103	Silty limestone, light gray to gray, 20 percent calcareous matrix.	0.3
102	Sandy limestone, gray to tan, 20 percent dolomitic matrix, bedding structure.	3.0
101	Sandstone, yellow tan to tan, 10 percent dolomite matrix.	4.3
100	Sandy limestone, light gray to gray, 60 percent sand, chert nodules.	0.9
99	Pelletal limestone, gray to medium gray, medium grained, forms ledges.	1.5
98	Sandy limestone, medium gray, forms slope.	0.6
97	Bioclastic limestone, medium gray, medium grained, brown orange chert nodules, forms ledge.	5.8
96	Sandstone, light gray, 10 percent calcareous matrix, forms slopes.	5.2
95	Sandstone, gray, 10 percent dolomitic matrix.	3.4
94	Pelletal limestone, gray, medium grained, forms ledge.	7.6
93	Pebblestone conglomerate, brown, dark brown matrix.	0.3
92	Fossiliferous limestone, medium gray, white chert nodules.	6.4
91	Pelletal limestone, medium gray, some chert, contains sparse fossil fragments.	0.6
90	Bedded chert, white, some sedimentary structures.	1.2
89	Limestone, medium gray, fine grained, forms slope.	1.2
88	Sandstone, light tan to gray, 10 percent calcareous matrix.	1.2
87	Cherty limestone, light gray, fine grained, interbedded chert, forms ridge.	1.5
86	Pelletal limestone, medium gray, forms slope.	1.2
85	Calcareous sandstone, red to brown, 80 percent sand, forms slope.	0.6
84	Fossiliferous limestone, medium gray, fine grained, horizons of fossil hash, forms ridge.	1.8
83	Fossiliferous limestone, medium gray, contains bryozoans, *Composita* sp.	2.7
82	Bedded chert, light gray to gray.	0.6
81	Bioclastic limestone, medium gray, fine grained, forms ridge.	3.7
80	Chert, white to tan, interbedded with bioclastic limestone, contains large massive bryozoans.	0.6
79	Bioclastic limestone, medium gray, fine-grained, zones of fossil hash, forms ledge.	3.7
78	Pelletal limestone, medium gray, forms ledge.	3.4
77	Pelletal-bioclastic limestone, medium gray, forms ledge.	2.7
76	Bedded chert, white to tan.	0.6
75	Bioclastic limestone, medium gray, fine grained, contains some fossil fragments.	4.9

74	Calcareous shale, medium gray, covered interval.	3.7
73	Pelletal limestone, medium gray, crystalline, forms slope.	4.0
72	Bioclastic limestone, light gray, fine grained, white chert nodules.	0.6
71	Siltstone, gray to tan, bedding structure, forms slope.	0.6
70	Bioclastic limestone, gray to medium gray, medium grained, some chert beds.	2.1
69	Crystalline limestone, gray to medium gray, interbedded with shaly limestone, contains orange brown siltstone which shows bedding structure.	4.0
68	Limestone, light gray to tan, interbedded with chert, chert is light orange in color.	4.6
67	Bioclastic limestone, light gray, crystalline, forms slight ridge, contains brachiopods.	1.8
66	Shale, tan to brown, covered interval.	3.3
65	Crystalline limestone, light gray, medium grained.	0.9
64	Fossiliferous limestone, gray, thick dark bedded chert, contains spirifer, brachiopods.	3.0
63	Bioclastic limestone, gray to tan, medium grained, contains *Punctospirifer transversus, Composita* sp., and *Spirifer* sp.	2.4
62	Crystalline limestone, medium gray, interbedded with chocolate brown chert, forms slope.	1.2
61	Siltstone, yellow to tan, very fine grained, calcareous, dark rounded pebblelike chert nodules.	2.4
60	Calcareous siltstone, gray to dark gray, 80 percent silt, interbedded with small lenses of tan yellow siltstone, siltstone tends to cover slopes, forms slope.	10.7
59	Sandstone, light gray to yellow tan, 10 percent lime matrix, some chert nodules, forms slope.	6.4
58	Sandy limestone, light gray to gray, fine grained, sparse pellets, 40 percent sand, some limestone beds, forms gentle ledge.	8.8
57	Sandstone, brown to red brown, covered interval.	2.1
56	Sandstone, brown to red brown, rusty colored in places, fine grained, forms slopes.	4.3
55	Pelletal limestone, light gray to gray, slightly recrystallized, forms ledge.	3.7
54	Sandstone, tan to brown, liesegang banding.	5.5
53	Silty limestone, light gray, fine grained, 60 percent lime matrix.	6.7
52	Limestone, dark gray, some bioclastic material, contains coral fragments.	1.2
51	Sandstone, tan to brown, fine grained, covered interval.	1.5
50	Pelletal limestone, gray to medium gray, fine grained, forms slight ledge.	4.9
49	Limestone, gray to dark gray, slightly micritic, some pellets, forms slope.	5.5
48	Sandstone, tan to brown, fine grained, grades into a platy siltstone.	5.2
47	Pelletal limestone, light gray to tan, 20 percent silt, forms slope.	3.4
46	Sandstone, red brown to brown, 5 to 10 percent matrix, forms slope.	4.6
45	Lithographic limestone, gray, forms slope.	1.5
44	Sandstone, tan to light brown, forms slope.	1.5
43	Limestone, gray, fine grained.	0.3
42	Micritic limestone, medium gray, very fine grained, forms ledge.	1.8
41	Siltstone, yellow brown to brown, fine grained.	1.8
40	Dolomite, light gray, fine grained.	1.5
39	Sandstone, light gray to gray, 10 to 20 percent lime matrix.	0.6
38	Sandstone, light tan to brown, coarse grained, frosted, well rounded.	2.4
37	Pelletal limestone, gray, contains sandy unit with algal balls.	1.2
36	Micritic limestone, dark gray, contains small lenses of sandstone and siltstone, some mudcracks?	1.8
35	Silty dolomite, light gray to gray tan, medium grained.	2.4
34	Bioclastic limestone, gray to medium gray, contains horn corals.	1.5
33	Sandstone, light gray to gray, medium grained.	1.2
32	Sandstone, tan to brown, coarse grained, 20 percent carbonate matrix.	1.5
31	Dolomitic limestone, light gray to gray, very fine grained, 20 to 30 percent silt, sparse geothite stains, jointed.	7.3
30	Sandstone, light brown to brown, coarse grained to fine grained, slightly calcareous.	0.6
29	Calcareous dolomite, light gray to gray, 20 percent silt, jointed.	2.7
28	Limestone, gray to dark gray, contains algal balls with carbonaceous rims.	0.3
27	Sandy limestone, light gray, 60 percent carbonate, covered slope.	2.7
26	Sandstone, light brown to medium brown, some gray organic coloration, 20 percent carbonate.	4.3
25	Sandstone, light gray to light brown, fine-grained carbonate matrix, 70 percent sand, covered interval.	2.7
24	Limestone, gray, fine grained, forms ledge.	2.4
23	Pelletal limestone, medium gray, forms cliff, contains *Ekvasophyllum* sp., *Triplophyllites* sp., and *Lithostrotion* cf. *whitney*.	2.4
22	Sandstone, tan to brown, forms slope.	4.6
21	Sandy limestone, medium gray, forms ledge, contains solitary coral.	3.4
20	Pelletal limestone, gray to medium gray, fine grained, forms cliff.	1.8
19	Sandstone, tan, coarse grained, forms ledge.	8.5
18	Sandy limestone, gray to tan, forms slope.	4.6
17	Fossiliferous limestone, gray, fine grained, forms ledge, contains *Ekvasophyllum* sp.	0.6
16	Limestone, gray, fine grained, forms slope.	2.4
15	Sandstone, tan to tan gray, coarse grained, forms slope.	3.0
14	Limestone, gray to medium gray, forms cliff.	0.6
13	Limestone, gray to tan, fine grained, forms slope.	5.5
12	Sandy limestone, light gray to gray, forms cliff.	1.2
11	Sandstone, brown to dark gray, medium grained, 10 percent carbonate matrix.	1.2
10	Silty limestone, gray to tan, medium grained, 20 percent silt.	3.7
9	Dolomite, light gray, fine grained, forms ledge.	0.9
8	Bioclastic limestone, medium gray to gray, fine grained, forms ledge.	1.5
7	Limestone, gray to medium gray, fine grained, forms slope.	1.5
6	Siltstone, light gray, medium grained, 20 percent carbonate matrix.	4.6
5	Limestone, medium gray, fine grained, some dark brown chert nodules, contains *Lithostrotion* sp., forms ledge.	0.6
4	Calcareous siltstone, light gray to gray, grades upward into a bioclastic limestone capped with a biostrome at the top, contains *Lithostrotionella* sp., forms ledge.	7.0
3	Limestone, medium gray, some chert nodules, contains horn coral, *Lithostrotion* sp., and *Syringopora* sp.	4.0
2	Limestone, medium gray, forms ledge.	0.9
1	Sandstone, medium gray to brownish gray, 10 percent carbonate matrix, massive, forms ledge.	8.8
	Total thickness Great Blue Limestone	302.2

Appendix D

GROVERS WASH SECTION

Section measured SW ¼, NW ¼, NW ¼, section 31, T. 28 S, R. 13 W.

Callville Limestone

Unit		Meters
5	Limestone, gray to medium gray, fine grained, medium bedding.	5.2
4	Silty limestone, gray to orange brown, fine grained, forms slopes.	1.2
3	Limestone, medium gray to gray, fine grained, massive, forms slopes.	1.8
2	Limestone, gray to light gray, fine grained, medium bedding, forms slopes.	2.4
1	Limestone, medium gray to gray, fine grained, forms slopes.	3.0
	Total thickness Callville Limestone	13.7

Chainman Shale

9	Shale: yellow tan, more calcareous and resistant than unit 8.	1.5
8	Shale, yellow tan, 12-cm beds, contains brachiopods.	1.8
7	Shale, black, thinly bedded, slope former.	0.9
6	Siltstone, brown yellow, calcareous, 12-cm beds.	0.6
5	Shale, black, thinly bedded, slope-former.	1.5
4	Siltstone, yellow brown, poorly exposed.	1.8
3	Limestone, medium gray to dark gray, silty, fossiliferous, contains *Orthotetes (Orthotetes)* sp.; *Spirifer cf. curvilateralis.*	2.1
2	Fossiliferous limestone, brown, contains bryozoans, crinoids *Rhombopora, Fenestrellina, Fistulipora,* silty horizons.	2.4
1	Shale, black, covered.	5.2
Total thickness of Chainman Shale		17.8

Appendix E

WEST SQUAW PEAK SECTION

(Overturned Section)

Section measured T. 27 S, R. 13 W, section 34, NE ¼, NW ¼.

Pakoon Formation

Unit		Meters
15	Dolomite, gray to tan, fine grained, some chert nodules, *Triticites,* and *Pseudoschwagerina* silicified in chert nodules which are in place rather than reworked.	20.4
14	Dolomite, gray to tan, fine grained, interbedded with 5-cm beds of chert.	6.1
13	Dolomite, tan to white, fine grained, sparse nodular chert.	18.0
12	Dolomite, gray to light gray, fine grained, sparse chert.	35.4
11	Sandstone, gray to tan, poorly sorted, laminar bedding, dolomitic.	4.0
10	Dolomite, gray to light gray, fine grained, very little chert.	11.9
9	Dolomite, gray to light gray, fine grained.	13.1
8	Chert pebble conglomerate, gray to dark tan, 50 percent angular chert pebbles, 50 percent dolomitic matrix.	0.3
7	Dolomitic sandstone, gray to light gray, poorly sorted.	0.9
6	Chert pebble conglomerate, 50 percent angular chert, dolomitic matrix.	0.9
5	Dolomitic sandstone, gray to light gray, poorly sorted.	2.7
4	Chert pebble conglomerate, 25 to 50 percent angular chert, grades upward into sandier unit, chert becoming larger at top of unit, dolomitic matrix.	1.5
3	Sandstone, gray to tan, coarse grained, low-angle cross-bedding, very dolomitic.	2.7
2	Chert conglomerate, gray to white, 50 percent angular chert, some carbonate clasts, carbonate matrix.	3.7
1	Chert conglomerate, becomes sandier and less cherty in upper part of unit, sparse horn coral fragments, very angular clasts, looks reworked, contains Mississippian coral, *Faberophyllum, Chaetetes, Cainia,* also bryozoans and crinoids found in reworked clasts.	9.4
Total thickness of Pakoon Formation		132.6

Callville Limestone

19	Dolomite, gray to light gray, fine grained, covered.	5.5
18	Dolomite, medium gray to gray, fine grained, some chert nodules.	19.5
17	Fossiliferous dolomite, medium gray to gray, some large white fossiliferous chert beds, contains *Composita* and *Spirifer occidus.*	4.3
16	Sandstone, tan to white, coarse grained, well rounded and well sorted, low-angle cross-bedding.	6.4
15	Dolomite, gray to light gray, fine grained, some chert nodules.	11.3
14	Sandy dolomite, gray to lighr gray, medium grained, some white chert, low-angle cross-bedding, sandier at top of unit.	1.5
13	Dolomite, gray to light gray, medium grained.	0.9
12	Sandy dolomite, gray to tan, medium grained, sandier at top of unit.	7.0
11	Sandy dolomite, tan to brown, fine grained, low-angle cross-bedding, some chert nodules.	4.0
10	Sandy dolomite, gray to light gray, medium grained, low-angle cross-bedding.	10.1
9	Sandy dolomite, gray to light gray, medium grained, low-angle cross-bedding.	1.5
8	Limestone, medium gray to gray, micritic, some pellets and algal structures.	0.6
7	Calcareous sandstone, brown to dark brown, medium grained.	3.7
6	Sandy limestone, gray to medium gray, fine grained.	6.4
5	Sandstone, gray to dark brown, medium grained, dirty, poorly sorted.	1.5
4	Dolomite, gray to light gray, medium grained.	1.8
3	Limestone, medium gray to gray, medium grained.	3.0
2	Dolomite, gray to light gray, medium grained, pelletal, calcareous in some areas, some chert.	10.4
1	Limestone, medium gray to gray, coarse grained, slope former.	5.8
Total thickness of Callville Limestone		115.0

Appendix F

MINERS HILL LOWER SECTION

Section measured T. 29 S, R. 14 W, section 24, NE ¼, SW ¼, NW ¼.

Toroweap Formation

Fault

Unit		Meters
21	Fossiliferous limestone, medium gray to gray, bryozoans, crinoids.	7.6
20	Fossiliferous limestone, medium gray to gray, medium grained, 25 percent nodular chert.	1.5
19	Crinoidal limestone, gray to medium gray, coarse grained, 10 percent chert nodules, forms ledges.	10.1
18	Crinoidal limestone, light gray to medium gray, very fossiliferous, 50 percent nodular chert.	10.7
17	Dolomite, light gray, fine grained, some chert nodules, contains brachiopods, forms slopes.	22.2
16	Fossiliferous dolomite, medium gray to gray, recrystallized, forms cliffs.	7.0
15	Fossiliferous limestone, medium gray to light gray, coarse grained, fossil hash, some chert nodules, forms ledges.	2.4
14	Cherty limestone, medium gray, 50 percent chert, chert orange to orange brown, limestone and chert in alternating beds.	1.5
13	Cherty limestone, medium gray, fine grained, lenses of siltstone, chert orange to orange brown, limestone and chert in alternating beds.	4.3
12	Crinoidal limestone, medium gray, fine grained, 25 percent chert, nodular chert beds alternate with crinoidal limestone.	15.2
11	Sandy dolomite, medium gray to light gray, fine grained, 20 to 30 percent sand, forms slopes.	9.8
10	Dolomitic sandstone, gray to orange brown, medium grained, 90 percent sand, forms ledges.	1.8
9	Dolomitic sandstone, medium gray, fine grained, forms slopes.	2.1
8	Dolomitic sandstone, medium gray to orange brown, 90 to 95 percent sand, low-angle cross-bedding, seems to be in no particular direction, very siliceous, the top of the unit is more siliceous and massive, cliff former.	2.7
7	Cherty dolomite, light gray, cherr is orange to orange brown, dolomite is fine grained, 5 percent nodular chert beds.	1.2
6	Dolomite, light gray, 10 percent chert nodules, 10 percent sand, forms slopes.	3.4
5	Dolomitic sandstone, red to red brown, sand is cross-bedded and very siliceous.	2.7
4	Cherty dolomite, light gray to gray, 50 percent chert, 50 percent dolomite.	12.5
3	Chert, light gray, 20 percent dolomite, crystalline dolomite.	0.9
2	Covered interval.	6.1
1	Cherty dolomite: lighr gray, 10 percent sand in dolomite, chert is brown to red brown in color.	9.4
Total thickness of Toroweap Formation		134.0

Appendix G
MINERS HILL UPPER SECTION

Section measured T. 29 S, R. 14 W, section 23, E ½, SE ¼, and section 24, NW ¼, SW ¼.

Kaibab Limestone

Unit		Meters
63	Dolomite, light gray, fine grained, areas of bioclastic material.	5.8
62	Limestone, gray, medium grained, areas of bioclastic material.	1.2
61	Limestone, medium gray to gray, medium to fine grained, some bioclastic areas, interbedded with chert.	0.3
60	Dolomite, light gray, interbedded with limestone and chert.	5.2
59	Dolomite and limestone, light gray, interbedded with chert, less dolomitic and less chert than unit 81.	2.7
58	Bedded chert, tan to dark brown, massive.	0.9
57	Limestone, medium gray, coarse grained, carbonate clasts, 25 percent chert nodules, massive, contains bryozoans and crinoids.	0.9
56	Limestone, medium gray, coarse-grained carbonate clasts, 25 percent chert nodules, massive, contains bryozoans and crinoids.	17.4
55	Limestone, medium gray, coarse-grained carbonate clasts, 20 percent nodular chert beds, contains bryozoans and crinoids.	12.2
54	Dolomite, gray to light gray, fine grained, some limestone horizons at top of unit, 50 percent bedded chert.	5.5
53	Chert, pink, massive.	3.4
52	Bioclastic limestone, gray to medium gray, coarse grained, 40 to 50 percent pink chert.	7.6
51	Bioclastic limestone, gray to medium gray, coarse grained, 30 percent pink chert.	3.1
50	Bioclastic limestone, gray to medium gray, coarse grained, 20 to 30 percent pink chert.	16.5
49	Limestone, gray to medium gray, coarse grained, contains crinoid fragments, nodular chert, white to pastel pink.	7.3
48	Limestone, light gray, coarse-grained crinoidal fragments, 40 to 50 percent white to pastel pink nodular.	2.4
47	Limestone, light gray, coarse grained, contains abundant crinoidal fragments, 20 percent white to pastel pink nodular chert.	1.2
46	Limestone, light gray, coarse grained, 10 percent nodular chert beds, contains abundant crinoidal fragments.	2.7
45	Siltstone, gray, medium grained.	1.5
44	Crinoidal limestone, gray to medium gray, coarse grained.	0.3
43	Sandstone, white to light gray, medium grained.	0.3
42	Calcareous siltstone, tan to brown, medium grained.	3.7
41	Limestone, medium gray, fine grained, 10 percent chert nodules.	3.7
40	Micritic limestone, medium gray, fractured, some dolomitic horizons.	0.9
39	Sandstone, light gray to gray, medium grained.	1.5
38	Micritic limestone, medium gray, some chert nodules.	0.6
37	Sandstone, light gray, medium grained, well-rounded grains, calcareous cement.	1.5
36	Micritic limestone, medium gray.	0.9
35	Calcareous sandstone, brown to tan, fine grained, covered.	2.1
34	Dolomite, dark gray to medium gray, fine grained, some limestone horizons, 10 percent chert beds.	0.6
33	Dolomite, dark gray to medium gray, fine grained, limy in places, less than 10 percent chert beds.	2.1
32	Limestone, dark gray, fine grained, less than 10 percent medium gray chert nodules, contains *Dictyoclostus.*	4.6
31	Limestone, dark gray, fine grained, less than 10 percent medium gray chert nodules, contains *Dictyoclostus.*	2.4
30	Dolomite, light gray to medium gray, laminated with chert.	
29	Dolomite, light gray to medium gray, laminated with chert, less chert than unit 49.	0.6
28	Dolomite, light gray to medium gray, laminated with chert.	1.2
27	Limestone, medium gray, interbedded with dolomite, sparse nodular chert.	0.3
26	Dolomite, light gray, medium to fine grained, laminated, becoming more limy towards top of unit, sparse nodular chert.	0.3
25	Dolomite, light gray to gray, fine to medium grained, limy in places, 30 percent interbedded with chert.	0.9
24	Bioclastic limestone, medium gray to gray, fine to medium grained, 20 percent tubular chert.	14.0
23	Limestone, medium gray, 30 percent bedded chert, contains some crinoidal fragments.	3.0
22	Limestone, medium gray, fine grained, 20 percent dolomitic, some silt-sized quartz grains where limestone and dolomite are laminated, sparse bedded chert.	0.9
21	Cherty limestone, medium gray, fine grained, 20 percent bedded chert is gray to orange brown in color, 20 percent dolomitized limestone.	6.4
20	Lithographic to sublithographic limestone, gray to medium gray, chert beds at top of unit.	2.1
19	Bioclastic limestone, medium gray, 50 percent tubular chert that looks as if it has replaced worm burrows, contains bryozoans, crinoids.	5.5
18	Bioclastic limestone, medium gray to gray, contains some large bryozoans, massive unit.	5.5
17	Bioclastic limestone, medium gray, medium grained, sparse chert, contains bryozoans.	14.6
16	Limestone, gray, fine to medium grained, 10 percent chert nodules, contains crinoidal fragments.	3.7
15	Bedded chert, brown to tan.	1.8
14	Limestone, medium gray to gray, 30 percent nodular and bedded chert, some horizons consist of crinoidal limestones with bryozoans.	4.6
13	Limestone, medium gray to gray, 70 percent limestone, 30 percent chert, chert is black with white centers; it is irregularly shaped and becomes more abundant in upper part of the unit, contains large crinoidal columns and large bryozoans.	0.9
12	Limestone, gray, medium grained, some chert.	1.8
11	Limestone, gray to medium gray, fine grained.	1.5
10	Limestone, gray to medium gray, fine grained, 25 percent nodular chert.	0.6
9	Cherty limestone, light gray to medium gray, fine grained.	5.5
8	Crinoidal limestone, medium gray, medium to coarse grained, contains *Ellisonia festiva, Hindeodus* n. sp., *Neostreptognathodus clinei behnken, Neostreptognathodus prayi behnken,* and *Neostreptognathodus* n. sp.	0.9
7	Dolomite, medium gray, medium grained.	0.9
6	Dolomitic sandstone, gray to light gray, 50 percent sand.	1.5
5	Dolomite, light gray, 25 percent bedded chert nodules, chert is orange brown.	0.9
4	Dolomite, light gray, fine grained.	4.6
3	Limestone and siltstone, covered interval.	3.7
2	Limestone, light gray to gray, fine grained, poorly exposed.	8.5
1	Sandstone, white to tan, medium grained, clean, well sorted.	3.7
Total thickness of Kaibab Limestone		256.6

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