Cambrian and Precambrian Rocks of the Groom District Nevada, Southern Great Basin

GEOLOGICAL SURVEY BULLETIN 1244-G

Prepared on behalf of the U.S. Atomic Energy Commission

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By HARLEY BARNES *and* ROBERT L. CHRISTIANSEN

CONTRIBUTIONS TO STRATIGRAPHY

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CAMBRIAN AND PRECAMBRIAN ROCKS OF THE GROOM DISTRICT, NEVADA, SOUTHERN GREAT BASIN

By HARLEY BARNES and ROBERT L. CHRISTIANSEN

ABSTRACT

More than 14,000 feet of conformable Cambrian and Precambrian rocks is exposed in the Groom district in southwestern Lincoln County, Nev. The lower half of this stratigraphic section is chiefly quartzite and siltstone, the upper half chiefly limestone and dolomite. Included are part of the Johnnie Formation (>300 ft) and the Stirling Quartzite (>2,930 ft) of Precambrian age; the Wood Canyon Formation (2,285 ft) of Cambrian and Precambrian age; and the Zabriskie Quartzite (220 ft), Carrara Formation (1,879 ft), Bonanza King Formation (4,355 ft), and Nopah Formation (2,035 ft) of Cambrian age.

The stratigraphic units exposed in the Groom Range can be recognized for more than 100 miles to the west and south, and the same formational names can be used throughout that region. The units can also be correlated with the Cambrian and Precambrian rocks of the Pioche district, but different stratigraphic nomenclature is preferred for the Pioche area.

INTRODUCTION

A nearly complete conformable section of Cambrian and upper Precambrian rocks is exposed in the Groom mining district, at the south end of the Groom Range in southwestern Lincoln County, Nev. (fig. 1). Although the section was described by Humphrey in 1945, redescription and reinterpretation seem worthwhile because considerably more is now known of regional stratigraphic relations in the southern Great Basin and because the revised interpretation of the Groom section affects the regional picture significantly. Also, on the basis of more complete data, this report revises an earlier outline of stratigraphic nomenclature for Cambrian rocks in the Nevada Test Site area (Barnes and Palmer, 1961).

Because it is on the Nellis Air Force Range, the Groom district is not readily accessible at present. Measurement of the stratigraphic section and preparation of the reconnaissance geologic map (fig. 2) were done with permission of the Air Force as part of geologic mapping at the Nevada Test Site of the U.S. Atomic Energy Commission.

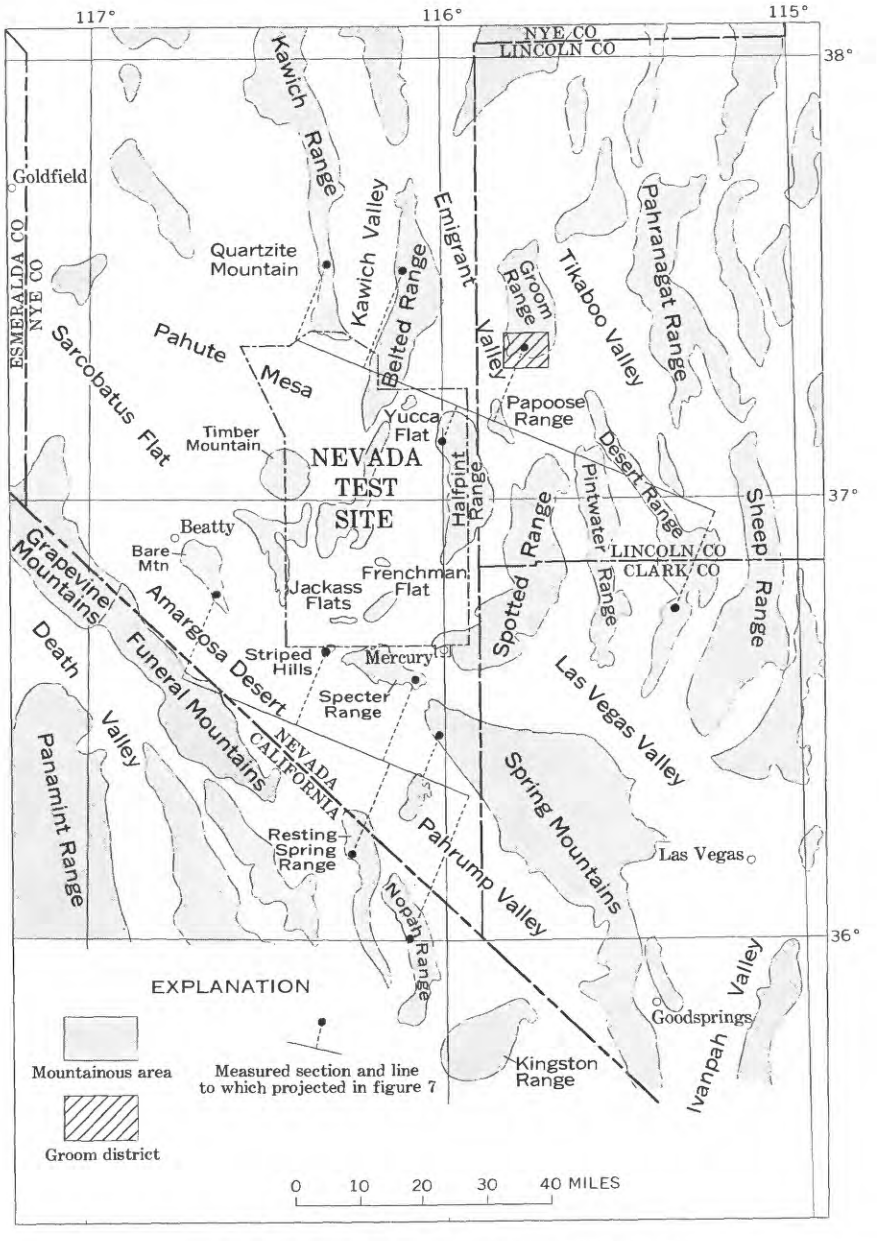

FIGURE 1.—Map of part of southern Great Basin.

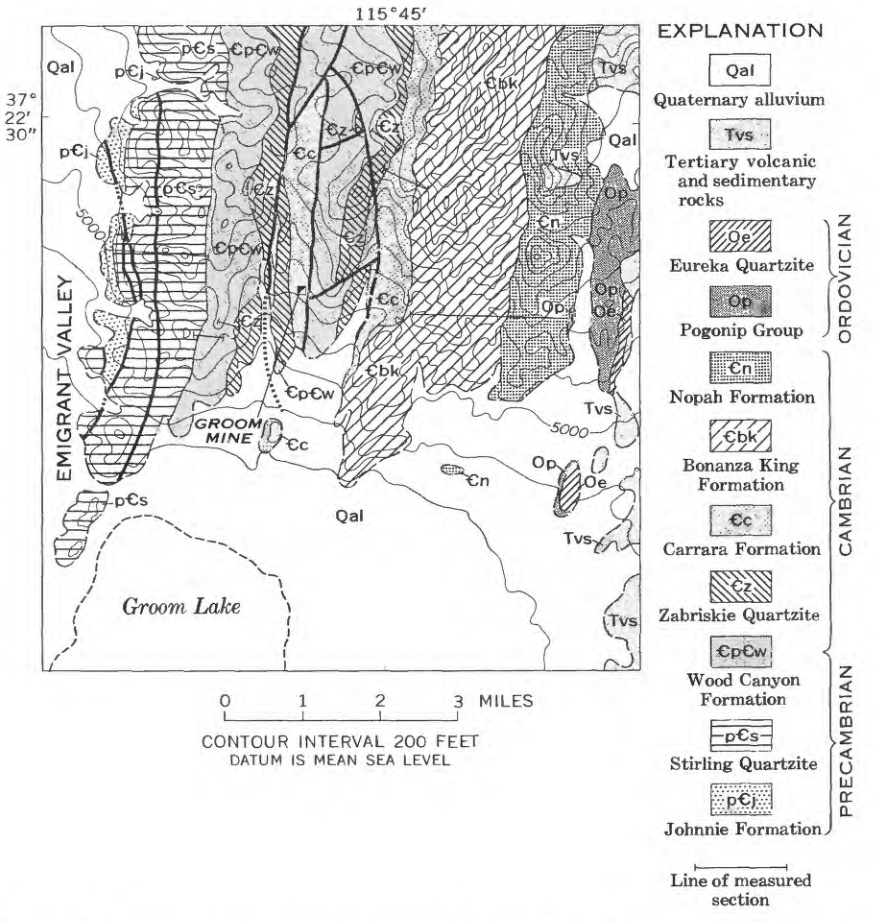

FIGURE 2.—Reconnaissance geologic map of Groom district, south end of Groom Range (in part after Tschanz and Pampeyan, 1961). Lines of measured sections are discussed in text.

Of the more than 14,000 feet of Cambrian and Precambrian rocks exposed at Groom, the lower half is chiefly quartzite and siltstone with minor limestone and dolomite and the upper half is chiefly limestone and dolomite with minor siltstone and shale. The dominantly clastic part of the section exposed at Groom includes the upper part of the Johnnie Formation, most of the Stirling Quartzite, and all the Wood Canyon Formation and Zabriskie Quartzite (figs. 3, 4). The dominantly carbonate part of the section consists of the Carrara, Bonanza King, and Nopah Formations (figs. 4, 5, 6).

Because the Groom section contains more than 5,200 feet of strata conformably below the lowest fossils of Early Cambrian age, the problem of defining the base of the Cambrian System is pertinent to

this discussion. The definition used here is one presently accepted by the U.S. Geological Survey and follows generally the proposal of Wheeler (1947) in placing the base of the Cambrian at the base of the strata containing the oldest Early Cambrian fossils and at the base of equivalent unfossiliferous strata. This usage has been found to be practical in the region considered here because the lowest Early Cambrian fossils known throughout a large region occur in the same stratigraphic unit, the upper part of the Wood Canyon Formation.

STRATIGRAPHY

JOHNNIE FORMATION

Only 300–400 feet of the upper part of the Johnnie Formation is exposed locally at the western base of the Groom Range (fig. 2). This part of the Johnnie is composed of brownish, greenish, and reddish thin-bedded to laminated siltstones and calcareous siltstones (fig. 3). Humphrey (1945, p. 15) mentioned "a very flat-dipping, thin-bedded, red and white banded sandstone * * * exposed in gulches * * *" on the west flank of the Groom Range. In his reconnaissance, he considered these rocks as probably an erosional product of the Prospect Mountain Quartzite (this report, table 1) and, therefore, as much younger than the quartzite. Mapping has shown that these rocks are at the base of the stratigraphic section. Similarity to sections in the Halfpint and Papoose Ranges to the southwest and south (fig. 1) indicates that the strata are siltstones and calcareous siltstones of the Rainstorm Member of the Johnnie Formation.

Nolan (1929, p. 461–463) named the Johnnie Formation for Johnnie Wash in the northwest part of the Spring Mountains, about 60 miles south of the Groom district (fig. 1). The Rainstorm Member, named by Barnes, Christiansen, and Byers (1965), is the top 1,025 feet of the Johnnie in the Halfpint Range about 15 miles southwest of Groom. In the Groom Range and locally in the Halfpint Range, the uppermost part of the Rainstorm Member has been cut out by bedding-plane faults.

On the basis of its stratigraphic position, the Johnnie Formation is regarded as Precambrian in age.

STIRLING QUARTZITE

The Stirling Quartzite was named by Nolan (1929, p. 463) for exposures near Mount Stirling in the Spring Mountains. In the Groom district the Stirling is chiefly nonmicaceous quartzite with less abundant siltstone and micaceous quartzite, as well as a few thin beds of limestone. The formation is dominantly reddish in the lower part

and grayish pink in the upper part; it is more than 2,930 feet thick. On the basis of comparison with nearby areas, we estimate that before faulting the Stirling in the Groom district was 3,400–3,500 feet thick.

We have divided the Stirling at Groom into four members, the upper one comprising three lithologic units (fig. 3). The terminology of these members follows that of Stewart (1966). Member A, at the base, is composed of cliff-forming reddish to purplish medium-grained to pebbly-conglomeratic quartzite. Member B is a micaceous generally fine-grained quartzite with conspicuous planar lamellae. The total thickness of A and B could not be measured because of faults, but member A is more than 555 feet thick and member B is more than 755 feet. Mapping in nearby ranges convinces us that most of member B is present in the measured section but that about half of member A is missing. No other map units are present between members A and B in this region. Member C is 555 feet thick in the Groom Range and is composed of interbedded grayish-red very micaceous siltstone and nonmicaceous fine-grained thin-bedded quartzite. Micaceous siltstone is the dominant lithology at the slope-forming base of member C but becomes less abundant upward. The top 165 feet of the member forms a dark-colored ledgy cliff with conspicuous planar bedding. There is no member D in the Groom section. Member E consists of three units. The lowest, unit 1, is 235 feet of pinkish-gray cross-laminated quartzite that forms a light-colored cliff. The slope-forming unit 2, 440 feet thick, is yellowish-brown micaceous quartzite with interbedded light-gray nonmicaceous quartzite and a basal siltstone with a few thin beds of limestone. Unit 3 of member E is 390 feet of cliff-forming grayish-pink quartzite.

Wherever exposed in the Groom Range and in most places in the Papoose and Halfpint Ranges, the basal contact of the Stirling Quartzite is a bedding-plane fault. Comparison of lithologies at this contact in the three ranges, however, indicates that none of the basal Stirling Quartzite has been cut out by the faults and only locally is much of the Rainstorm Member of the Johnnie Formation missing. Sections are exposed at several places in the Papoose Range where the contact is apparently conformable.

No fossils have been found in the Stirling Quartzite, whose stratigraphic position indicates that it is of Precambrian age.

WOOD CANYON FORMATION

The Wood Canyon Formation was named by Nolan (1929, p. 463–464) for exposures in the northwestern part of the Spring Mountains. In the Groom district the Wood Canyon is 2,285 feet of siltstone and quartzite with minor sandy limestone; quartzite predominates in the

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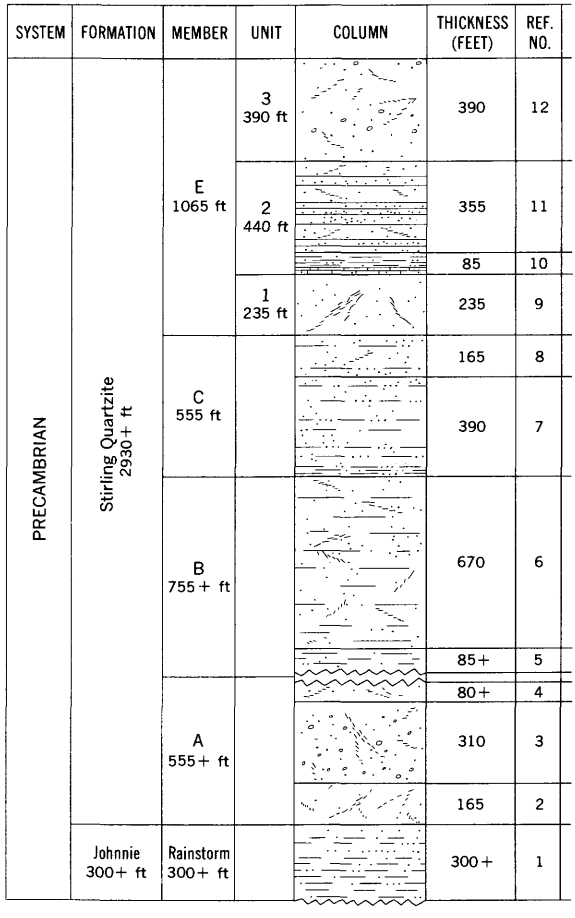


FIGURE 3.—Columnar section of incomplete Johnnie Formation and Stirling Quartzite in Groom district.

reddish ridge-forming middle part of the formation and siltstone in the lower and upper parts. The resulting threefold character of the Wood Canyon is similar to that in the type locality.

The Wood Canyon in the Groom Range is divided into three members (fig. 4). The lower member, 535 feet thick, is a slope-forming yellowish-gray micaceous siltstone and grayish-orange micaceous shale with interbeds of fine-grained quartzite and a few beds of sandy limestone. The middle member, 1,005 feet thick, is dominantly quartzite and can be divided into two units. The lower 785 feet is chiefly grayish-red medium- to coarse-grained quartzite that forms a ridge or rounded cliff. The upper 220 feet is light-gray fine-grained quartzite and interbedded dusky-yellow micaceous siltstone and fine-grained

REF. NO.	LITHOLOGY
12	Quartzite, grayish-pink to pale-red, medium-grained, well-sorted to moderately sorted; 1- to 5-ft beds with partings between, laminated and cross-laminated; forms cliff; basal 200 ft less well cemented than above; center part has a few pebbly beds; top bed is pebbly calcareous sandstone.
11	Quartzite, yellowish-brown, micaceous, fine-grained; thin beds 1–10 ft; thick interbeds of white medium-grained well-sorted laminated quartzite; sparse in basal part, more abundant upward and dominant at top. Unit forms steep slopes broken by a few ledges.
10	Siltstone, light-brown; little mica; ⅛- to ¼-in. partings; forms slope. Basal 25 ft has few thin beds of silty limestone that weathers moderate yellowish brown.
9	Quartzite, pinkish-gray, medium- to fine-grained, well-sorted; 3- to 5-ft beds, cross laminated, rare micaceous partings. Forms cliff.
8	Quartzite and siltstone; pale-red to grayish red cross-laminated quartzite, 1- to 3-ft beds; siltstone 1- to 2-in. beds; unit forms ledgy cliff.
7	Quartzite and siltstone; quartzite grayish red, fine to very fine grained, moderately sorted; 6- to 12-in. beds, discontinuous laminae. Siltstone micaceous, poorly sorted, 1- to 10-in. beds, shaly weathering; weathers yellowish gray; unit forms ledgy slope. Basal 40 ft, siltstone micaceous, grayish red, ¼-in. partings; unit forms slope.
6	Quartzite, grayish-red (dominant) to grayish-pink, fine- to medium-grained, well-sorted; 2- to 6-ft beds, conspicuously laminated, sporadically cross laminated; partings of very fine grained micaceous quartzite between beds; color bands 2–20 ft thick; forms ledgy slope.
5	Quartzite, grayish-red to grayish-red-purple, fine- to medium-grained, well-sorted (minor mica), well-laminated; partings ½- to 6-in.; forms slope.
	Fault
4	Quartzite (like unit 2 below).
3	Quartzite, red-purple to grayish-red-purple, medium-grained to pebbly conglomeratic, moderately sorted; 3- to 5-ft beds; no partings; cross-laminated but poorly stratified on larger scale; forms cliff.
2	Quartzite, pale red, medium- to coarse-grained, well-sorted; 2- to 3-ft beds, cross-laminated; forms cliff.
1	Siltstone, light-brown to yellowish-green in upper part, pale-red to orange-pink below, weakly to moderately calcareous, laminated; forms slope.

FIGURE 3.—Continued

quartzite that form a ledgy slope. The upper member of the Wood Canyon, 745 feet thick, forms a ledgy slope of dusky-yellow micaceous siltstone, shale, and fine-grained quartzite with interbeds of light-gray medium-grained quartzite. In the upper part are beds of calcareous sandstone and sandy limestone.

The basal contact of the Wood Canyon is a sharp but conformable contact between quartzite and siltstone.

The lowest stratigraphic position at which fossil organisms have been found in the Groom Range is about 325 feet below the top of the Wood Canyon Formation. Fragments of olenellid trilobites are preserved on the bedding surfaces of laminated quartzite. Trilobites, pelmatozoan debris, and *Scolithus* occur between this lowest fossil horizon and the top of the formation. The lowest stratigraphic posi-

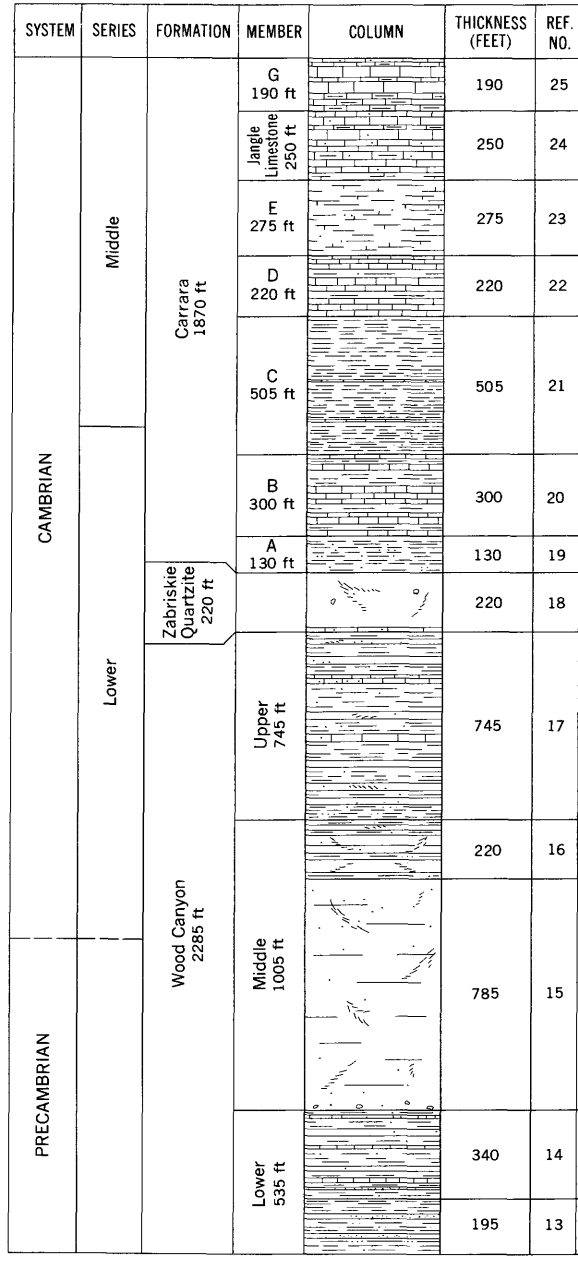


FIGURE 4.—Columnar section of Wood Canyon Formation, Zabriskie Quartzite, and Carrara Formation in Groom district.

REF. NO.	LITHOLOGY
25	Limestone, in part light-gray, massively outcropping, and in part medium-gray, thin-bedded, with discontinuous cuspate silty limestone laminae; forms benches. Silty limestone predominant in basal 70 ft.
24	Limestone, medium gray, thin-bedded, with irregular and discontinuous wavy to cuspate silty limestone interbeds that weather dark yellowish orange; scarce *Girvanella* near top; calcareous siltstone in basal 30 ft; forms cliff.
23	Siltstone, moderate-yellowish-brown, micaceous, generally calcareous; beds mostly ⅛–¾ in. thick, but 1–2 ft in upper 50 ft of unit; forms slope, but upper 50 ft forms bluff.
22	Limestone and siltstone; limestone medium dark gray, oolitic; abundant *Girvanella*; 4- to 24-in. beds, silty limestone partings; siltstone as dusky-yellow thin interbeds in limestone, especially in lower and upper parts; forms bluffs.
21	Shale, siltstone, and limestone; shale and siltstone greatly predominant, olive gray to yellowish brown; siltstone occurring as 1- to 2-in. interbeds in shale; limestone only in a 5-ft zone starting 120 ft above base and a 15-ft zone starting 260 ft above base, dark gray, 1- to 12-in. beds with silty limestone partings; unit forms slope.
20	Limestone, shale, and siltstone; limestone medium dark gray; 1- to 6-in. wavy beds in 5- to 25-ft zones with calcareous siltstone or shale partings; abundant trilobite fragments. Shale and siltstone dusky yellow to medium brown; siltstone calcareous; unit forms ledges.
19	Shale, siltstone, sandstone, and quartzite, brown-dusky-yellow, olive, dusky-red; sandstone fine grained; quartzite micaceous, poorly to moderately sorted, only in basal 30 ft; unit forms slope.
18	Quartzite, pale-red to pinkish-gray, medium- to fine-grained, well-sorted; ½- to 2-ft beds cross laminated, laminae more conspicuous in upper than lower part; abundant *Scolithus* in upper part; basal 45 ft has interbeds of calcareous sandstone and micaceous siltstone; sparse pebble lenses; unit forms cliff.
17	Siltstone, shale, quartzite, sandstone, and limestone; siltstone and shale dusky yellow to light brown, generally micaceous, 1- to 6-in. beds; quartzite and calcareous sandstone in part olive gray to yellowish gray, medium to coarse grained, moderately sorted, limonitic and glauconitic; quartzite in part light gray, fine to medium grained, well sorted; predominantly olive-gray limonitic-glauconitic quartzite in lower part; predominantly light gray well-sorted quartzite in upper part; 6–25 ft of siltstone and shale generally separated by 1–5 ft of quartzite or calcareous sandstone beds; sparse limestone moderate brown, laminated; unit forms ledgy slope.
16	Quartzite and siltstone; quartzite light gray, fine grained, moderately sorted; 1- to 1½-ft cross-laminated beds; siltstone dusky yellow, light olive, and grayish red, poorly sorted, micaceous, locally fissile; unit forms steep slope.
15	Quartzite, grayish-red, medium- to coarse-grained; locally pebbly in basal 25 ft; moderately sorted; ½- to 2-ft beds, micaceous quartzite partings, sweeping cross-lamination; finer grained toward top; upper 50 ft has sporadic micaceous siltstone beds as thick as 6 in.; unit forms ledgy cliff.
14	Siltstone, quartzite, and limestone; siltstone and quartzite as below, no fissile shale; siltstone predominant generally but zones as much as 75 ft thick have quartzite predominant. Two beds of light-olive-gray limestone weather moderate brown; 1-ft beds inconspicuously laminated, 65 and 190 ft above base. Unit forms slope.
13	Siltstone, shale, and quartzite; siltstone and shale yellowish gray to grayish orange, micaceous, 4- to 12-in. beds; quartzite pale brown, fine to medium grained, poorly sorted, micaceous; unit forms slope.

FIGURE 4.—Continued

tion at which fossils have been found in the surrounding region is also in the upper member of the Wood Canyon (Stewart, 1966, fig. 2). Somewhat older forms occur farther west in the Andrews Mountain Member of the Campito Formation, which Stewart (1966) has demonstrated to be approximately equivalent to the middle member of the Wood Canyon. As defined, therefore, the base of the Cambrian is near the middle of the Wood Canyon Formation.

ZABRISKIE QUARTZITE

The Zabriskie Quartzite was originally defined by Hazzard (1937, p. 309) in the Nopah-Resting Springs area as a member of his expanded Wood Canyon Formation. Wheeler (1948, p. 26) changed the rank of the Zabriskie to formation and reinstated Nolan's original definition (1929, p. 464) of the Wood Canyon. In the Groom district (fig. 4) the Zabriskie is 220 feet of ridge-forming well-sorted cross-laminated quartzite that weathers grayish orange pink. It is dominantly nonmicaceous.

The contacts of the formation are gradational. The basal 45 feet of the formation is slightly micaceous calcareous sandstone, which weathers pale yellowish orange, and grayish-red cross-laminated quartzite with a few interbeds of grayish-red micaceous siltstone. The upper contact is so drawn as to place 30 feet of poorly sorted micaceous quartzite, siltstone, and shale in the overlying Carrara Formation rather than in the Zabriskie.

No organic remains have been found in the Zabriskie Quartzite, but sand-filled burrows called *Scolithus* are abundant in the upper part. The Zabriskie is Early Cambrian in age because it is conformably underlain and overlain by rocks of known Early Cambrian age.

CARRARA FORMATION

The Carrara Formation is the name given by Cornwall and Kleinhampl (1961) to beds at Bare Mountain (fig. 1) that are transitional from the dominantly clastic rocks at the base of the Cambrian and Precambrian section into the overlying dominantly carbonate rocks. In the Groom Range the Carrara contains 1,870 feet of interbedded limestone, siltstone, shale, and quartzite. The formation is here divided into one formal and six informal members (fig. 4) which correspond to the seven members described in the Halfpint Range by Barnes, Christiansen, and Byers (1962).

The lower half of the formation is chiefly siltstone and shale with subordinate limestone and quartzite. This part of the formation forms ledgy slopes. The basal contact of the Carrara separates the well-sorted nonmicaceous Zabriskie Quartzite from the micaceous

clastics of the 130-foot member A of the Carrara Formation. The member is mainly shale and siltstone, but about 25 feet below the top is a 6-inch bed of medium-dark-gray limestone with abundant trilobite debris. Member B of the Carrara is 300 feet of thin-bedded medium-dark-gray limestone with abundant thin interbeds of dusky-yellow shale and silty shale. Member C is 505 feet of olive-gray to brown shale with interbedded siltstone and sparse limestone.

The upper half of the Carrara is composed of limestone with subordinate siltstone, weathering into a series of low bluffs and ridges. Member D, 220 feet thick, is chiefly medium-dark-gray limestone with abundant *Girvanella* and conspicuous thin oolitic beds. Member E, 275 feet thick, is mostly yellowish-brown micaceous calcareous siltstone. The next higher unit is the Jangle Limestone Member. The Jangle was originally defined as a formation by Johnson and Hibbard (1957, p. 339), who named it for Jangle Ridge in the Halfpint Range about 15 miles southwest of Groom, but later the Jangle was included as a member of the Carrara Formation by Barnes, Christiansen, and Byers (1962, p. D28). The Jangle Limestone Member, 250 feet thick in the Groom Range, consists of medium-gray limestone that has a characteristic mottling formed by discontinuous irregular wavy to cuspate laminae of dark-yellowish-orange silty limestone. Member G, the uppermost unit of the Carrara Formation, is about 190 feet thick and is composed of rocks transitional between the interbedded siltstone and limestone of the upper part of the Carrara and the relatively pure limestone and dolomite of the basal part of the Bonanza King Formation. In the Groom district member G consists of thick beds of light-gray limestone of a type common in the Bonanza King Formation interbedded with very thin bedded to laminated limestone, mottled silty limestone, and siltstone of types common in the Carrara Formation. The basal 70 feet of member G is especially silty.

The age of the Carrara Formation is Early and Middle Cambrian. The fauna is largely undescribed, but A. R. Palmer (written commun., 1964) is studying the trilobites collected from both the Groom district and the Jangle Ridge area of the nearby Halfpint Range. Palmer has identified Early Cambrian olenellids from members A, B, and C. Trilobites from the middle of member C and from the base of member D represent a pre-*Albertella* fauna of early Middle Cambrian age. Trilobites of the Middle Cambrian *Albertella* zone occur in the top of member D, in member E, and in the basal part of the Jangle Limestone Member. *Glossopleura*-zone trilobites, also Middle Cambrian, have been found near the base of member G.

BONANZA KING FORMATION

The Bonanza King Formation was named by Hazzard and Mason (1936, p. 234) for a mine in the Providence Mountains in southeastern California, about 155 miles south of the Groom Range. Hazzard's (1937, p. 316–318) original correlation of the Bonanza King in the Nopah Range was based on an incorrect age determination. A corrected correlation by Palmer and Hazzard (1956) has since been used extensively throughout the southern Great Basin. In the Groom district the Bonanza King is 4,355 feet of limestone and dolomite (fig. 5) with only minor siltstone and silty limestone; it forms ledgy cliffs and ridges. In the nearby Halfpint Range (fig. 1), Barnes and Palmer (1961, p. C102) divided the formation into the Papoose Lake Member and the overlying Banded Mountain Member, a division that is also recognized in the Groom district.

The Papoose Lake Member, about 2,075 feet thick at Groom, was divided informally into three units in the Halfpint Range (Barnes and others, 1962, p. D30). These same units can be recognized in the Groom district. Unit A of the Papoose Lake is 410 feet of massive-weathering dark-gray mottled limestone. The basal 170 feet is bleached to light gray and has indistinct bedding. Unit B of the member is 115 feet of distinctly laminated to thin-bedded light- to medium-gray limestone marked by laminae of pale-yellowish-orange calcareous siltstone and silty limestone. Unit C of the Papoose Lake Member is 1,550 feet of light- to dark-gray dolomite and limestone. The lower third of the unit is mostly limestone; the upper two-thirds is mostly dolomite, much of it laminated. Much of the upper two-thirds is bleached and recrystallized.

The Banded Mountain Member, about 2,280 feet thick at Groom, is here divided into four informal units. Unit A is 180 feet thick at Groom and is relatively silty like the middle unit of the Papoose Lake Member. Unit B of the Banded Mountain Member is a 1,600-foot section of interbedded limestone and dolomite characterized in outcrop by many light and dark color bands. Unit C is 310 feet of light-gray to yellowish-gray limestone that is conspicuous from a distance as a broad buff-colored band above the thin light and dark stripes of unit B. Unit D at the top of the Bonanza King is 190 feet of medium- to light-gray limestone and dolomite with moderately abundant brown-weathering silty limestone that increases in abundance upward. From a distance unit D appears as a gray band above the buff band formed by unit C.

The basal contact of the Bonanza King Formation is gradational but is arbitrarily placed to exclude silty limestone. All contacts between the units within the formation are also gradational, and some

of the units may vary considerably in thickness, even within the Groom Range.

The age of the Bonanza King Formation is Middle and Late Cambrian. In the Groom district A. R. Palmer (written commun., 1964) found Middle Cambrian fossils of the *Glossopleura* zone near the top of the underlying Carrara Formation and Late Cambrian fossils of the *Dunderbergia* zone in the overlying Dunderberg Shale Member. Humphrey (1945, p. 21) and Wheeler (1948, p. 38, 50) reported a Middle Cambrian trilobite, *Coelaspis*(?), from beds here assigned to unit B of the Papoose Lake Member of the Bonanza King. In the Bonanza King of the Halfpint Range, about 15 miles southwest of the Groom district, Palmer (written commun., 1960) found Late Cambrian fossils of the *Crepicephalus* zone 300 feet below the top of the formation in the base of the unit equivalent to unit D of the Banded Mountain Member at Groom. Another *Crepicephalus* zone fauna was collected 40 feet below the top of the formation in the Halfpint Range, 3 feet below a fossil collection representing the *Aphelaspis* zone (Palmer, 1965). Trilobites of the Late Cambrian *Dicanthopyge* zone were identified by Palmer (1965) from the top 10 feet of the Banded Mountain Member in the Halfpint Range.

NOPAH FORMATION

The nomenclature of rocks between the Bonanza King Formation and the Lower Ordovician Pogonip Group has not been entirely satisfactory in the southern Great Basin. To point out lithostratigraphic relations that had become apparent in regional studies since the earlier work at the Test Site and to correct misconceptions that might have arisen from the previous stratigraphic names, we have revised the nomenclature for this part of the section in the Nevada Test Site area (Christiansen and Barnes, 1966). This revised terminology is being used in the Groom district (table 1).

At the Nevada Test Site the rocks between the Bonanza King and the Pogonip can be readily divided into three lithologic units: at the base, 225 feet of shale with minor very thin bedded limestone; in the middle, 715 feet of flaggy-splitting very thin bedded limestone with silty laminae and common chert; and in the upper part, 1,070 feet of blocky- to massive-splitting dolomite and limestone with only sparse chert. The same three units are present in the Groom Range. Johnson and Hibbard (1957, p. 342–345), in preparing the first geologic map of the Test Site, recognized the basal shale as the Dunderberg Shale of the Eureka district but did not name the overlying limestone and dolomite. Barnes and Palmer (1961, p. C103) correlated the overlying rocks at the Test Site with the Windfall

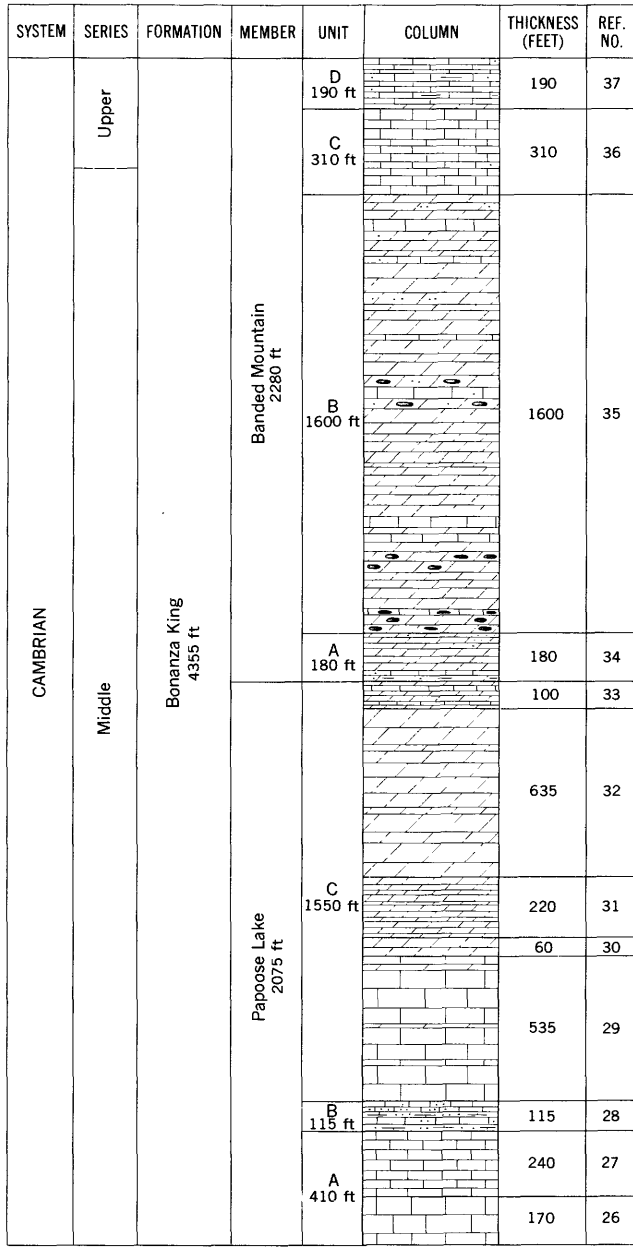


FIGURE 5.—Columnar section of Bonanza King Formation in Groom district.

REF. NO.	LITHOLOGY
37	Limestone and dolomite, light- to medium-gray thin bedded to laminated; silty limestone occurs as laminae and pockets and weathers medium to light brown, limestone more abundant upward; forms steep slope.
36	Limestone, light-yellowish-gray to light-gray; beds average about 5 ft thick; very rare silty limestone; forms bluff.
35	Dolomite and minor limestone; marked in outcrop by conspicuous light- to dark-gray stripes 2–10 ft wide; thin bedded to laminated, several zones of thin-bedded to lenticular black chert, scarce laminated silty dolomite; forms cliffs.
34	Dolomite, silty dolomite, silty limestone, and calcareous siltstone; silty rocks with minor chert predominant in top 55 ft and basal 35 ft; massive-weathering dark- to medium-gray mottled dolomite with some discontinuous cuspate silty laminae in central 90 ft.
33	Dolomite and limestone; dolomite light gray, laminated; limestone dark gray, laminated; forms saddle.
32	Dolomite, dominantly very pale orange to light-gray, thin- to thick-bedded; contains discontinuous beds and lenses of dark-gray dolomite.
31	Dolomite, light- to dark-gray, laminated to thin-bedded; forms ledgy slope.
30	Dolomite, dark-gray; discontinuous laminae and mottling; weathered surface deeply pitted; forms saddle.
29	Limestone and dolomite; (limestone predominant) light-gray with discontinuous 1- to 5-ft dark- to medium-gray beds; dominantly thick bedded; forms cliff.
28	Calcareous siltstone and silty limestone, pale-yellowish-orange, thin-bedded; forms slope.
27	Limestone, dark-gray; irregular discontinuous ½-in. beds give mottled appearance; small *Girvanella* in a few beds; forms cliff.
26	Limestone, medium-light gray; contains ¼- to ½-in. vermicular dolomite blebs parallel to bedding; bedding indistinct except for faint medium-gray discontinuous 1- to 5-ft bands.

FIGURE 5.—Continued

TABLE 1.—*Comparison of stratigraphic units used by Humphrey in the Groom district, by Johnson and Hibbard and by Barnes and Palmer at the Nevada Test Site, and by this report in both areas*

<table>
<tr><th>Humphrey (1945)</th><th colspan="3">Johnson and Hibbard (1957)</th><th colspan="3">Barnes and Palmer (1961)</th><th colspan="3">This report</th></tr>
<tr><td rowspan="2">Not described</td><td rowspan="2">Upper Cambrian rocks</td><td rowspan="2">Units C and D
Unit B
Unit A</td><td></td><td rowspan="2">Windfall Formation</td><td>Smoky Member</td><td rowspan="2">Nopah Formation</td><td colspan="2">Smoky Member</td></tr>
<tr><td>Catlin Member</td><td colspan="2">Halfpint Member</td></tr>
<tr><td></td><td colspan="3">Dunderberg Shale</td><td colspan="2">Dunderberg Shale</td><td colspan="2">Dunderberg Shale Member</td></tr>
<tr><td rowspan="6">Highland Peak Formation</td><td rowspan="7">Yucca Flat Formation</td><td rowspan="6">Upper part</td><td>Unit D</td><td rowspan="6">Bonanza King Formation</td><td rowspan="3">Banded Mountain Member</td><td>Unit 3</td><td rowspan="6">Bonanza King Formation</td><td rowspan="4">Banded Mountain Member</td><td>Unit D</td></tr>
<tr><td>Unit C</td><td>Unit 2</td><td>Unit C</td></tr>
<tr><td rowspan="2">Unit B</td><td rowspan="2">Unit 1</td><td>Unit B</td></tr>
<tr><td>Unit A</td></tr>
<tr><td rowspan="2">Papoose Lake Member</td><td>Unit C</td></tr>
<tr><td>Unit A</td><td>Unit B</td></tr>
<tr><td>Burrows Dolomite</td><td>Lower part</td><td rowspan="2">Cadiz Formation</td><td>Jangle Limestone Member</td><td rowspan="5">Carrara Formation</td><td colspan="2">Member G</td></tr>
<tr><td>Peasley Limestone</td><td colspan="2">Jangle Limestone</td><td colspan="2">Jangle Limestone Member</td></tr>
<tr><td>Chisholm Shale</td><td colspan="2">Chisholm Shale</td><td colspan="2">Member E</td></tr>
<tr><td>Lyndon Limestone</td><td colspan="2">Lyndon Limestone</td><td colspan="2">Chambless Limestone</td><td colspan="2">Member D</td></tr>
<tr><td>Pioche Shale</td><td colspan="2">Pioche Shale</td><td colspan="2">Latham Shale</td><td colspan="2">Member C
Member B
Member A</td></tr>
</table>

Prospect Mountain Quartzite	Stirling Quartzite	Wood Canyon Formation	Zabriskie Quartzite		
			Wood Canyon Formation	Upper member	
				Middle member	
				Lower member	
			Stirling Quartzite	Member E	Unit 3
					Unit 2
					Unit 1
				Member C	
				Member B	
				Member A	
"...thin-bedded, red and white banded sandstone..." (p. 15)			Johnnie Formation	Rainstorm Member	

Formation of the Eureka district (Nolan and others, 1956, p. 19–22). Although not stated in the paper, their correlation was based on comparison of the Test Site rocks with those of the Nopah Range as well as the Eureka district. A marked similarity had been noted between the Dunderberg Shale and overlying flaggy-splitting silty and cherty limestone of the Test Site and similar strata at Eureka. These lower two lithologic types of the Test Site section are much less conspicuous in the Nopah Range, where they compose only 100 feet out of a total of 1,740 feet at the type locality of the Nopah Formation according to Hazzard (1937, fig. 3b). The upper lithology of the Test Site section was not found at Eureka but is conspicuous in the Nopah Range. Barnes and Palmer, in correlating the limestone and dolomite overlying the Dunderberg with the Windfall Formation, assigned the flaggy-splitting silty and cherty limestone to the Catlin Member of the Windfall as defined in the Eureka district; they designated the overlying blocky- to massive-splitting noncherty dolomite and limestone, a unit not present at Eureka, as the Smoky Member of the Windfall (Barnes and Palmer, 1961, p. C103; Barnes and Byers, 1961, p. C105).

Stratigraphic studies made during the past several years have done much to show where the three lithologic units of the Test Site area fit in the regional stratigraphy. The Dunderberg Shale is present in the area from the Eureka district to the southern Great Basin. The overlying flaggy-splitting silty and cherty limestone unit can be traced from the Groom district and the Test Site to the Nopah Range, although this unit and the Dunderberg thin notably southward. The stratigraphic continuity of the silty and cherty very thin bedded limestone between the Test Site and Eureka has not yet been demonstrated, but the unit resembles the lithology of the Windfall Formation at Eureka. The upper unit, the massively outcropping carbonate unit, thickens southward from the Test Site area to comprise most of the section in the Nopah Range but is not present at Eureka. Thus all three lithologic units are common to the Groom-Test Site region and the Nopah Range but not to the Eureka district.

We, therefore, assign the post-Bonanza King pre-Pogonip rocks in the Groom district to the Nopah Formation and divide the Nopah of this area into the Dunderberg Shale, Halfpint, and Smoky Members, as we have done at the Nevada Test Site (Christiansen and Barnes, 1966). The Halfpint Member of the Nopah Formation, as defined by Christiansen and Barnes (1966), is the equivalent of the Catlin Member of the Windfall Formation described at the Test Site by Barnes and Byers (1961, p. C104). The Smoky Member of the Nopah was a reassignment by Christiansen and Barnes (1966) from

the Smoky Member of the Windfall Formation (Barnes and Byers, 1961, p. C105).

Total thickness of the Nopah Formation in the Groom district (fig. 6) is about 2,035 feet. The Dunderberg Shale Member is about 310 feet thick, the Halfpint Member is 1,055 feet thick, and the Smoky Member is 670 feet thick.

The Dunderberg was named by Walcott (1908b, p. 184) as a replacement for Hamburg Shale because Hamburg was preempted. The Dunderberg Shale Member is composed of shale with very thin interbeds and concretions of limestone that are more abundant upward. The member is poorly exposed and forms a deep topographic saddle. Trilobite fragments are characteristically abundant in many of the limestones. The basal contact of the Dunderberg is sharp; the upper contact is gradational.

The Halfpint Member in the Groom Range is composed of 1,055 feet of cliff-forming very thin bedded flaggy-splitting medium-gray limestone with intercalated laminae of clayey and silty limestone and very thin beds of chert. Argillaceous and silty partings are especially conspicuous in the lower part, and bedded chert, in the upper part. The clayey and silty material weathers to pale red or reddish brown. Beds in the lower 60 feet of the member are wavy to nodular. The base of the Halfpint Member is gradational with the underlying Dunderberg Shale Member and is placed at the horizon where limestone becomes dominant over shale.

The Smoky Member at Groom is 670 feet thick and is composed chiefly of blocky- to massive-splitting medium- and light-gray limestone with little to no chert and silty limestone. It forms rounded dark cliffs or bluffs with light-colored bands. Stromatolites 1–2 feet wide and 2–4 feet high are common in the Smoky. One 50-foot unit of pale-red-weathering very thin bedded limestone and silty limestone is present about 200 feet above the base of the member in the Groom district. The Halfpint-Smoky contact is fairly sharp. It is marked by the change from abundant thin discontinuous beds and lenses of dusky-brown-weathering chert in the Halfpint to relatively few scattered nodules of chert in the Smoky. The contact of the Smoky with the overlying Goodwin Limestone of the Pogonip Group is gradational through about 50 feet. In general the base of the Goodwin is marked by abundant nodules and thin lenses of dusky-brown-weathering chert in yellowish-brown-weathering very thin bedded to thin-bedded limestone and silty limestone.

The Nopah is considered to be of Late Cambrian age. *Dunderbergia*-zone fossils of early Late Cambrian Dresbach age are found at several levels in the Dunderberg Shale Member at Groom

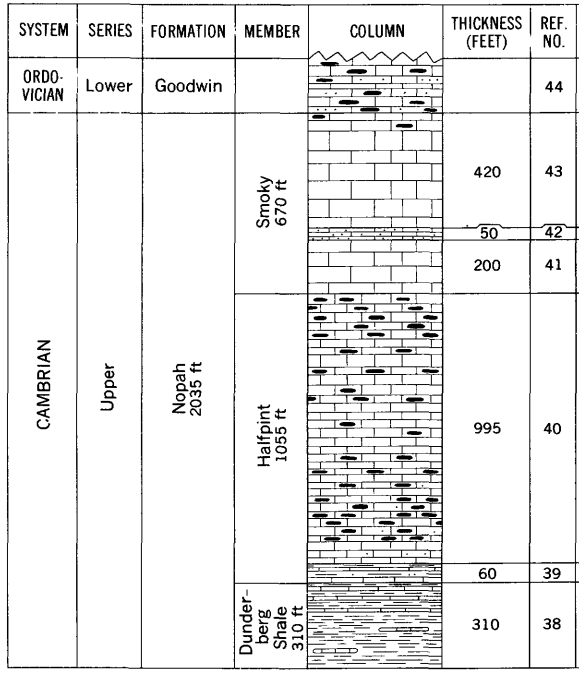


FIGURE 6.—Columnar section of Nopah Formation in Groom district.

and in the Halfpint Range (Palmer, 1965). Palmer (1965) also has identified trilobites from the basal part of the Halfpint Member as being from the *Elvinia* zone of Franconia age. Other trilobites from 150 to 350 feet above the base of the Halfpint are from the late Franconian *Ptychaspis-Prosaukia* zone (A. R. Palmer, written commun., 1960). Yet others from about 250 feet below the top of the Smoky Member in the Striped Hills (fig. 1) were identified by Palmer (written commun., 1964) as a typical Late Cambrian assemblage of Trempealeau age. R. J. Ross (Byers and others, 1961, p. C109) has identified Early Ordovician fossils from the Goodwin Limestone about 200 feet above the Nopah in the Halfpint Range.

CORRELATION

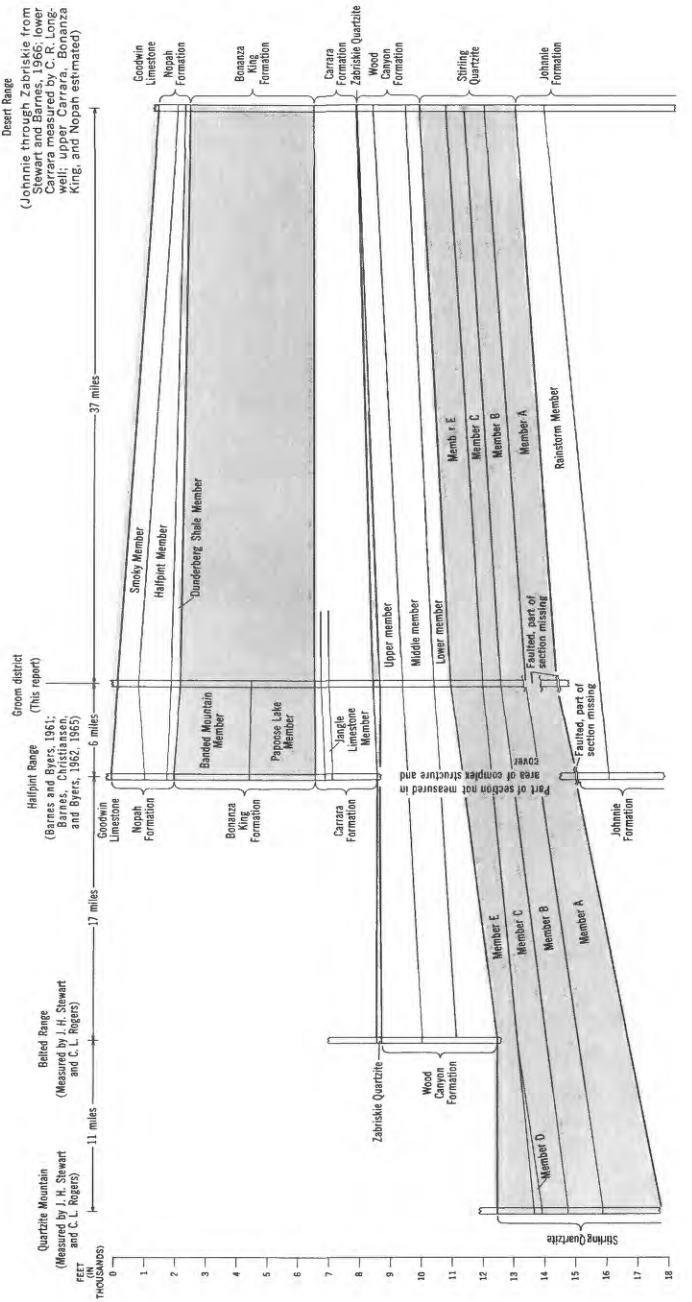
This section of the report compares the stratigraphic assignments, lithologies, thicknesses, and ages of Cambrian and Precambrian formations in the Groom district with those of units in the surrounding region and reviews associated problems of nomenclature. Figure 7 shows variations in thickness of major stratigraphic units in the region around the Nevada Test Site and the Groom Range. As an aid in

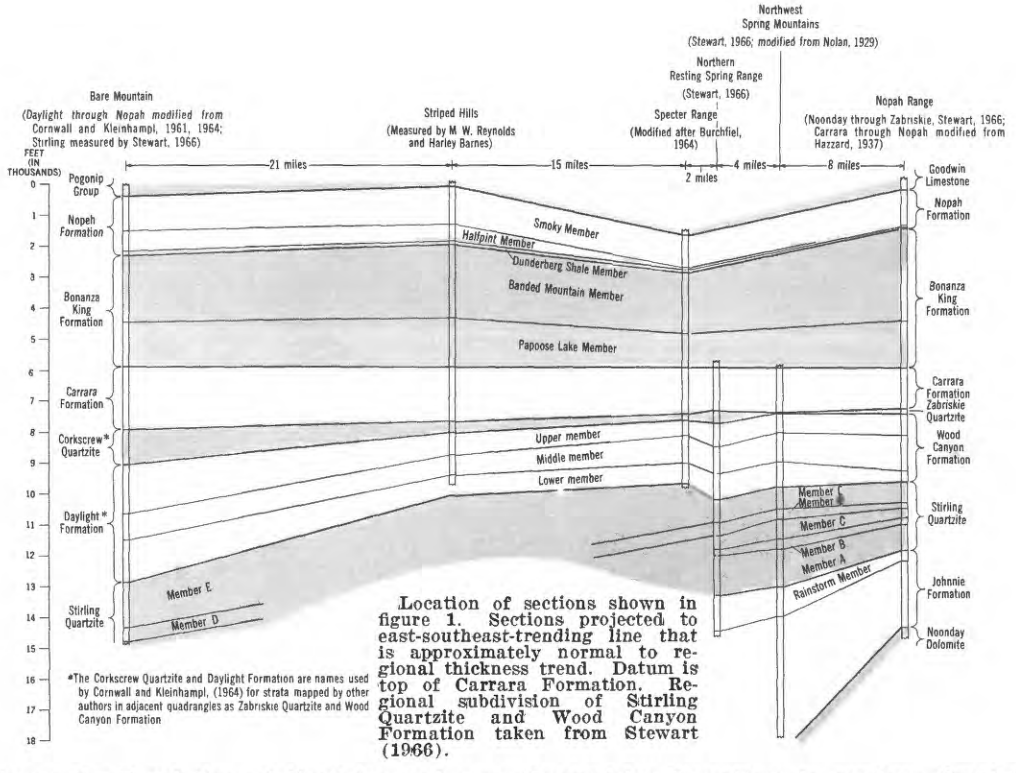
REF. NO.	LITHOLOGY
44	Limestone and silty limestone, pale-yellowish-gray to medium-light-gray; very thin bedded to thin-bedded chert nodules weathering dusky brown; basal beds form bench.
43	Limestone, dominantly medium- to dark-gray, thick-bedded, blocky- to massive-splitting; 20- to 50-ft light-gray bands; abundant stromatolites in upper 50 ft; some nodular chert in upper 25 ft; forms cliffs or steep slopes.
42	Limestone, silty, very thin bedded; weathers pale red; forms bench or saddle.
41	Limestone, dominantly medium-gray, thick-bedded, blocky- to massive-splitting; a few 20-ft light-gray bands; forms cliff.
40	Limestone, medium-gray; very thin bedded to thin-bedded with partings of pinkish-gray argillaceous limestone; thin-bedded irregular and discontinuous dark-gray chert abundant; unit forms cliff.
39	Limestone and siltstone; limestone medium gray; abundant trilobite debris; wavy 1- to 3-in. beds. Siltstone calcareous; weathers brown; irregular discontinuous very thin beds and partings between limestone beds. Unit forms bluff.
38	Shale and limestone; shale light olive gray to reddish brown, notably fissile; weathers to tiny flakes. Limestone medium gray; abundant trilobite fragments; in 1- to 3-in. nodular beds to flat lenticular concretions, increasing in abundance upward. Unit forms deep saddle.

FIGURE 6.—Continued

comparison of thickness changes, the measured sections are projected to two planes, whose traces trend east-southeast, approximately normal to regional thickness trends (fig. 1). The datum for figure 7 is the top of the Carrara Formation. This lithologic contact was selected as approximating a faunal horizon; the *Glossopleura* zone, wherever recognized in this region, includes the uppermost part of the Carrara Formation.

The four formations, Johnnie through Zabriskie, in the lower part of the Precambrian and Cambrian section are recognizable throughout a region that extends at least 100 miles south and west of the Groom district (fig. 1). Stewart (1966) correlated these formations and their distinctive members through the Spring Mountains–Death Valley region (including the Nopah Range, the Spring Mountains, and the Last Chance Range); he demonstrated that the units thicken, become progressively finer grained, and include higher proportions of carbonate strata northwestward across the region. They merge northwestward in the Inyo and White Mountains and surrounding parts of California and Nevada with formations that represent a northwestern facies characterized by siltstones, carbonates, and rela-


Quartzite Mountain
(Measured by J. H. Stewart and C. L. Rogers)
11 miles
Belted Range
(Measured by J. H. Stewart and C. L. Rogers)
17 miles
Hallpint Range
(Barnes and Byers, 1961; Barnes, Christiansen, and Byers, 1962, 1965)
6 miles
Groom district
(This report)
37 miles
Desert Range
(Johnnie through Zabriskie from Stewart and Barnes, 1966; lower Carrara measured by C. R. Longwell; upper Carrara, Bonanza King, and Nopah estimated)
FEET (IN THOUSANDS)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Goodwin Limestone
Nopah Formation
Bonanza King Formation
Carrara Formation
Zabriskie Quartzite
Wood Canyon Formation
Stirling Quartzite
Johnnie Formation
Smoky Member
Hallpint Member
Dunderberg Shale Member
Banded Mountain Member
Papoose Lake Member
Jangle Limestone Member
Upper member
Middle member
Lower member
Member E
Member C
Member B
Member A
Member D
Rainstorm Member
Faulted, part of section missing
Part of section not measured in area of complex structure and cover
Faulted, part of section missing
Stirling Quartzite



Location of sections shown in figure 1. Sections projected to east-southeast-trending line that is approximately normal to regional thickness trend. Datum is top of Carrara Formation. Regional subdivision of Stirling Quartzite and Wood Canyon Formation taken from Stewart (1966).

FIGURE 7.—Correlation of Cambrian and some Precambrian formations in southern Great Basin.

tively little quartzite and sandstone. Stewart and Barnes (1966) correlated units in the lower part of the Desert Range section with the units recognized by Stewart in the Spring Mountains–Death Valley region. The Groom district, in turn, can be correlated through the Desert Range section with the units to the southwest (fig. 7).

The Rainstorm Member at the top of the Johnnie Formation is present through much of the region (Barnes and others, 1965; Stewart, 1966). The fine-grained sandstones, siltstones, silty limestones, and thin oolitic dolomite beds of the Rainstorm contrast with the quartzite, phyllitic siltstone, and cherty dolomite of the main part of the formation below.

Members A, B, C, and E of the Stirling Quartzite in the Groom district are also recognizable for 100 miles to the south and west. They correlate with members A, B, C, and E of the Stirling in the Desert Range (Stewart and Barnes, 1966) and in the Spring Mountains–Death Valley region (Stewart, 1966). Stewart's member D of the Spring Mountains–Death Valley region is predominantly dolomite that tongues out southeastward into the overlying quartzite of member E. Stewart and Barnes indicate that member D does not extend as far eastward as the Desert Range, and there is no lithologic equivalent of this dolomite in the Groom District. Member E is virtually pure light-colored quartzite in the Nopah Range and Spring Mountains, but northward at Bare Mountain (Stewart, 1966, fig. 2) its lower part includes interbedded siltstone and minor limestone. The three lithologic subdivisions of member E at Groom correspond to three very similar subdivisions in the Desert Range: unit 1 of member E at Groom is equivalent to units 30 and 31 in the Desert Range (Stewart and Barnes, 1966), and units 2 and 3 of member E at Groom, are equivalent, respectively, to units 32 and 33 in the Desert Range. The total thickness of the Stirling Quartzite in the Groom district is uncertain, but regionally the formation thickens toward the northwest (fig. 7).

Stewart (1966) divided the Wood Canyon in the Spring Mountains–Death Valley region into lower, middle, and upper members that correspond to the three parts of the formation noted in the description at the type locality (Nolan, 1929, p. 464). The same three members are present in the Desert Range, and in the Groom district. Figure 7 shows that the Wood Canyon thickens northwestward. As previously noted, the oldest trilobites found throughout the region occur in the upper half of the Wood Canyon Formation and equivalent units.

The Zabriskie Quartzite has been recognized in recent years to be a widespread unit in the region west and south of the Groom Range. Stewart correlates it throughout the Spring Mountains–Death Valley

region and shows that it thins southeastward. The corresponding strata are more than 1,000 feet thick at Bare Mountain and only about 20 feet thick in the Spring Mountains. Similarly, the formation thins from 220 feet in the Groom Range to only 6 feet in the Desert Range.

East of the Groom district, at Pioche, for example (Westgate and Knopf, 1932, p. 6–8; Wheeler and Lemmon, 1939, p. 33–34; Merriam, 1964, p. 9–13), the basal clastic part of the section is generally referred to the Cambrian Prospect Mountain Quartzite. Tschanz and Pampeyan (1961) mapped the Prospect Mountain Quartzite throughout Lincoln County, including the Groom Range, the Papoose Range, and the Desert Range, although they separated the Johnnie Formation from the Prospect Mountain at the base of the section in the Desert Range. The Prospect Mountain commonly has been regarded as equivalent to the Stirling Quartzite of the Spring Mountains–Death Valley region (Wheeler, 1948, p. 19; Longwell, 1952, p. 212); but the present study in the Groom district, mapping in the Halfpint and Papoose Ranges, and Stewart and Barnes' work in the Desert Range show that the Prospect Mountain as previously used in this area included at least parts of the Zabriskie, Wood Canyon, Stirling, and Johnnie as known in the region to the southwest. These four formations probably bear a corresponding relation to the Prospect Mountain Quartzite of the Pioche district (table 2). Upper beds of the Prospect Mountain at Pioche contain abundant *Scolithus* (Merriam, 1964, p. 11) and are probably correlative with the Zabriskie Quartzite. Lower Cambrian shale beds immediately above the Zabriskie Quartzite at Groom, characterized by the trilobite genus *Bristolia*, are definitely correlative with the basal part of the Pioche Shale in the Pioche district (A. R. Palmer, written commun., 1961).

In the Groom district Humphrey (1945, p. 15–16) placed virtually all the basal clastic rocks in the Prospect Mountain Quartzite (table 1), and measured a thickness of 7,855 feet for the formation. It is apparent, however, that the rocks can be correlated with well-established formations and their members throughout most of the southwestern Great Basin. Total thickness of this part of the section is greater than 5,735 feet, but almost certainly not much more than 6,300 feet.

In the Halfpint Range, Barnes, Christiansen, and Byers (1962, p. D27–D30) used the name Carrara Formation for the entire sequence of shale, siltstone, and limestone between the dominantly quartzite-siltstone sequence below and the dominantly limestone-dolomite sequence above in preference to the usage of the nomenclature of either Humphrey or Johnson and Hibbard. Humphrey (1945, p. 16–18) attempted to correlate the Groom Range strata with the classic section at Pioche, Nev., about 75 miles northeast of Groom; and Johnson and

TABLE 2.—*Comparison of stratigraphic units of Groom and Pioche districts*

<table>
<tr><th colspan="4">Groom district (this report)</th><th colspan="4">Pioche district (Merriam, 1964)</th></tr>
<tr><td colspan="4">Pogonip Group, Goodwin Limestone</td><td colspan="4" rowspan="2">Mendha Formation</td></tr>
<tr><td colspan="4">Nopah Formation</td></tr>
<tr><td rowspan="6">Bonanza King Formation</td><td rowspan="3">Banded Mountain Member</td><td>Unit D</td><td rowspan="2">Units B and C</td><td>Units 7 through 13</td><td>Upper part</td><td rowspan="6">Highland Peak Formation</td></tr>
<tr><td rowspan="4">Lower part</td><td>Meadow Valley Member</td></tr>
<tr><td>Unit A</td><td>Condor Member</td></tr>
<tr><td rowspan="3">Papoose Lake Member</td><td>Unit C</td><td>Step Ridge Member</td></tr>
<tr><td>Unit B</td><td>Burnt Canyon Member</td></tr>
<tr><td>Unit A</td><td>Burrows Member and Peasley Member</td></tr>
<tr><td rowspan="3">Carrara Formation</td><td colspan="3">Member G</td><td colspan="3">Chisholm Shale</td></tr>
<tr><td colspan="3">Jangle Limestone Member</td><td colspan="3">Lyndon Limestone</td></tr>
<tr><td colspan="3">Members A through E</td><td colspan="3">Pioche Shale</td></tr>
<tr><td colspan="4">Zabriskie Quartzite and older clastic formations</td><td colspan="4">Prospect Mountain Quartzite</td></tr>
</table>

Hibbard (1957, p. 337–339) applied Humphrey's correlations to the rocks of the Halfpint Range in the Nevada Test Site (table 1). In the Pioche area the section equivalent to the Carrara Formation is divided into three formations: in ascending order, the Pioche Shale (Walcott, 1908a, p. 11–12), the Lyndon Limestone (Westgate and Knopf, 1927, p. 820; 1932, p. 10), and the Chisholm Shale (Walcott, 1916, p. 409–410). Fossil evidence from the Groom district shows that the Lyndon Limestone of Humphrey, member D of the Carrara in this report, is older than the Lyndon in the Pioche district and correlates with beds in the upper part of the Pioche Shale (A. R. Palmer, written commun., 1961). Barnes and Palmer (1961) showed that the Lyndon Limestone of Johnson and Hibbard in the Halfpint Range also is correlative with the upper part of the Pioche Shale. Barnes and Palmer, in turn,

regarded the basal part of the Lyndon Limestone of Johnson and Hibbard as correlative with the Chambless Limestone, a Lower Cambrian formation recognized in the Providence Mountains of southeastern California. They accordingly divided the section in the Halfpint Range into the Providence Mountains units of Hazzard (1954, p. 30–32) : in ascending order, the Latham Shale, the Chambless Limestone, and the Cadiz Formation. After field examination of many sections in the southern Great Basin, Palmer (written commun., 1961) found that these correlations were also wrong. Until more data make certain the regional correlation of members within the Carrara, we prefer to limit our regional correlation to the more inclusive unit, the Carrara Formation.

The Jangle Limestone Member of the Carrara in the Groom-Halfpint area is correlative with the Lyndon Limestone in the Pioche district (table 2). The Jangle is lithologically much like the Lyndon and probably is the same unit. Humphrey (1945, p. 19) incorrectly correlated the Jangle in the Groom district with the Peasley Limestone of Wheeler (1940, p. 17–27) at Pioche, but the Peasley is younger and generally does not have the characteristic silty pink to brown mottling and discontinuous lamination of the Jangle and the Lyndon.

In the Belted Range, 25 miles northwest of Groom (fig. 1), a significant change of facies is apparent in strata equivalent to the upper part of the Carrara. J. H. Stewart and C. L. Rogers (written commun., 1964) measured 1,577 feet of siltstone and subordinate limestone there roughly comparable to members A through D of the Carrara in the Groom-Halfpint area, but above that they found very thin bedded limestone and siltstone in a faulted and partly covered section estimated to be at least 1,300 feet thick. The lithology of this upper 1,300 feet is unlike the upper part of the Carrara or basal part of the Bonanza King but is very similar to the limestone sequence in the upper part of the Emigrant Formation of Esmeralda County, Nev., and the surrounding region (Albers and Stewart, 1962, p. D27).

Division of the Bonanza King Formation into two members in the Groom and Halfpint Ranges follows the practice of other workers in the southern Great Basin. Palmer and Hazzard (1956) clarified the relations between these members in the Providence Mountains of southeastern California, in the Nopah Range, and in the Goodsprings district; they showed that the Bonanza King can be divided in all three areas into upper and lower parts separated by a sandy or argillaceous unit. This sandy-argillaceous zone at the base of the upper member was shown by Palmer (1956, p. 672–674), to have a widespread distribution in the southern Great Basin. Little detailed stratigraphic work beyond recognition of lower and upper members

has been published for the Bonanza King Formation in the region southwest of the Groom and Halfpint Ranges. Our own regional studies now in progress suggest that several units within the Bonanza King are wide ranging across the region.

Strata largely equivalent to the Bonanza King Formation in areas east of the Groom district are placed in the Highland Peak Formation as defined and mapped in the Bristol and Highland Ranges and the Pioche district (Westgate and Knopf, 1927, 1932). The Highland Peak Formation has been divided into members and described in several papers on the stratigraphy of the region around Pioche (Wheeler and Lemmon, 1939, p. 37–42; Wheeler, 1940, p. 17–33; 1948, p. 33–43; Merriam, 1964, p. 33–50). Humphrey (1945, p. 19–22) correlated rocks in the Groom district above the shaly part of the Carrara Formation with the Highland Peak and related units (table 1).

As the name Highland Peak has priority over the name Bonanza King, the question of which name is preferable for the strata in the Groom area should be answered. We have used the name Bonanza King because the Bonanza King Formation as used widely in the southern Great Basin is correlative with all the strata at Groom between the top of the Carrara Formation and the base of the Dunderberg Shale Member, but the Highland Peak Formation in the Pioche district is not. Palmer (1956, p. 673) indicated that the fossiliferous basal part of the Mendha Formation, which overlies the Highland Peak in its type locality, is not correlative with the Dunderberg, which overlies the Bonanza King at Groom. Instead, the basal beds of the Mendha form an older stratigraphic unit not conspicuously represented farther southwest. A shaly zone faunally and lithologically equivalent to the Dunderberg occurs in the Pioche area some distance above the base of the Mendha (Merriam, 1964, p. 52). Thus the Bonanza King Formation includes strata correlative with the entire Highland Peak plus the lower part of the Mendha. It seems preferable to use the Highland Peak terminology only in the region where the formational contacts generally accepted for the unit are clearly recognizable, and to regard the equivalent rocks in the Groom district as belonging to the Bonanza King.

The basal parts of the Bonanza King and Highland Peak Formations, corresponding to unit A of the Papoose Lake Member in the Groom section, are notably similar throughout the region (for example, see Hazzard and Mason, 1936, p. 235; Hazzard, 1937, p. 277; Burchfiel, 1964, p. 48; Merriam, 1964, p. 35–36). These parts are generally composed of dark- to medium-gray limestone or dolomite that forms massive cliffs but has a somewhat inconspicuous thin bedding of discontinuous laminae or alined nodes that give a mottled

appearance to the rock. The mottling is generally somewhat lighter gray and more coarse grained than the bulk of the rock. This lithologic type makes up most of unit A of the Papoose Lake Member of the Bonanza King in the Groom and Halfpint Ranges and most of Hazzard's (1937, p. 277) unit 6A of the Bonanza King in the Nopah Range; it is characteristic of the Peasley Member of the Highland Peak Formation in the Pioche district (Merriam, 1964, p. 35–36).

In the Halfpint and Groom Ranges, in the Nopah Range (Hazzard, 1937, p. 316), and elsewhere in the region one or more conspicuous light-colored zones occur within unit A and equivalent rocks, commonly near the top. Thickness, continuity, and detailed features of these light-colored zones vary, but faint to conspicuous remnants of darker and finer grained strata within them indicate that the zones were formed by alteration of the darker material. This light-colored rock type is similar in some respects to the Burrows Member, which occupies a similar stratigraphic position in the Highland Peak Formation of the Pioche district (Merriam, 1964, p. 36–41). Merriam notes that the thickness of the Burrows and the character of its boundaries are highly variable in the Pioche region; this variability is also displayed by the light-colored zones in unit A of the Papoose Lake Member of the Bonanza Kng Formation. The total thickness of unit A is comparable over a large region, but the individual thicknesses of the Peasley and Burrows type lithologies are not. Unit A, therefore, is probably the stratigraphic equivalent of both the Peasley and Burrows at Pioche (table 2).

Siliceous clastic material like that characteristic of unit B of the Papoose Lake Member at Groom appears to be somewhat more common regionally in the lower than in the upper part of the Bonanza King. Hazzard's Nopah Range section (following Palmer and Hazzard, 1956) has several siliceous detrital zones in the lower part of the Bonanza King, as do many other sections in the region southwest of the Nevada Test Site. In the Halfpint and Groom Range sections, however, unit B is the only zone of comparable type in the lower part of the Bonanza King. Stratigraphic relations indicate (table 2) that unit B is approximately equivalent to the Burnt Canyon Member of the Highland Peak Formation in the Pioche district (Merriam, 1964, p. 41–43). In both areas this part of the section is characteristically thin-bedded to laminated limestone with nodes and partings of red-, yellow-, or brown-weathering argillaceous and silty limestone, occurring generally 400–600 feet above the base of the formation. In the Pioche district the Burnt Canyon Member is fossiliferous, containing several undescribed trilobite species of Middle Cambrian age (Merriam, 1964, p. 43). The only fossil reported from unit B in the Groom

or Halfpint Ranges is the "*Coelaspis*(?)" reported by Humphrey (1945, p. 21) and by Wheeler (1948, p. 38, 50). Wheeler (1948, p. 38, 51) also reported "*Coelaspis* sp." from the Burnt Canyon Member in the Pioche district.

Unit C of the Papoose Lake Member, bracketed by the only significant silty or argillaceous units in the Bonanza King of the Groom Range, is correlative (table 2) with the Step Ridge Member of the Highland Peak Formation near Pioche (Merriam, 1964, p. 43–45), and the lithologies of the corresponding intervals in the two areas are similar. Because a single siliceous detrital unit is not distinguishable in the lower part of the Bonanza King farther southwest, similarly direct correspondence to sections in the southwest is less obvious.

The silty or sandy zone at the base of the Banded Mountain Member of the Bonanza King Formation is present regionally (Palmer, 1956, p. 672–674). Palmer showed that unit F of the Highland Peak Formation as described in the Pioche region by Wheeler and Lemmon (1939, p. 47), the Condor Member of Merriam (1964, p. 45–46), is equivalent to the regional clastic zone at the base of the Banded Mountain Member of the Bonanza King (table 2). In the Groom section this clastic zone is represented by unit A of the Banded Mountain Member although the upper contacts of our unit A and Merriam's Condor Member differ slightly.

Not enough detail is known about units B, C, and D of the Banded Mountain Member in the Groom district to correlate them with the equivalent rocks in the Pioche region. Unit B at Groom has not been subdivided on a scale comparable to the remainder of the formation. This entire unit, 1,600 feet thick, is characterized by its conspicuously striped appearance when viewed from a distance. This striped appearance has also been described in equivalent strata of the Nopah Range (Hazzard, 1937, p. 319) and at Bare Mountain (Cornwall and Kleinhampl, 1961). In contrast, units C and D of the Banded Mountain Member form wider color bands at the top of the Bonanza King. Similar bands were noted by Hazzard and by Cornwall and Kleinhampl in other parts of the region. In the region southwest of the Test Site, a dark-gray unit generally lies between units similar to the striped unit B and the buff unit C of the Groom and Halfpint Ranges. At Pioche the Highland Peak Formation above the Condor Member is divided into 8 (Merriam, 1964, p. 46–50) or 11 (Wheeler and Lemmon, 1939, p. 45–47) units. We do not yet know enough about the equivalent rocks in the Groom Range to correlate them individually with the divisions in the Pioche district (table 2). Units B and C of the Banded Mountain Member at Groom appear to correlate with the Highland Peak Formation of Reso (1963, p. 904, pl. 2) in the Pahranagat Range (fig. 1). Unit D appears to be the lithologic

equivalent of the lower member of the Dunderberg Formation of Reso (1963, p. 904, pl. 2).

The Racetrack Dolomite (McAllister, 1952, p. 8–9) of the northern Panamint Range is probably correlative with the uppermost part of the Papoose Lake Member and the entire Banded Mountain Member of the Bonanza King Formation.

Reasons for changing previous nomenclature for the Upper Cambrian rocks above the Bonanza King Formation in the Nevada Test Site region (Christiansen and Barnes, 1966) have already been given. The Nopah Formation, as used in this paper for the Groom district and Nevada Test Site, is directly correlative with the Nopah as generally mapped in areas southwest of Groom (McAllister, 1952; Cornwall and Kleinhampl, 1961; Yochelson and others, 1965, p. B75). Christiansen and Barnes (1966) have noted, however, that the top of the Nopah Formation as generally mapped in the region varies slightly from the description of the Nopah at the type section. Hazzard (1937, p. 276) tentatively placed the top of the Nopah at the base of a "sandy and clayey, locally cross-bedded dolomite" (unit 9A) that he referred to as the basal "Pogonip(?) dolomite." Subsequent detailed mapping and regional work by McAllister (1952, p. 10–11), by R. J. Ross (written commun., 1965), and by us has shown that this sandy and clayey dolomite is correlative with a widespread silty unit in the Goodwin Limestone some distance above the base of the Pogonip Group. Regionally the base of the Pogonip corresponds to an upward change from massive-splitting relatively chert-free beds in the Smoky Member of the Nopah Formation to thin-bedded partly silty beds with abundant chert in the basal Goodwin Limestone. There is generally also a change in weathered color from medium gray below to lighter, more yellowish gray above this contact. Rocks above and below the contact may be either limestone or dolomite. One of us (Barnes) remeasured the type section of the Nopah and found that the base of the Pogonip, as recognized regionally, is about 500 feet lower than the tentative boundary proposed by Hazzard; the Nopah Formation in the Nopah Range is, therefore, about 1,270 feet thick rather than 1,740 feet.

The Nopah Formation of the Groom Range is correlative with only the middle part of the Mendha Formation of the Pioche region. The Mendha is not yet well known stratigraphically, but its base is correlative with rocks in unit D of the Bonanza King Formation and its top is correlative with part of the Lower Ordovician Goodwin Limestone (Merriam, 1964, p. 52). In the Pahranagat Range, 20 miles east of Groom, the upper member of the Dunderberg Formation and members A, B, and C of the Desert Valley Formation (Reso, 1963, p. 904–905, pl. 2) are probably correlative with the Nopah of the Groom Range.

The most striking changes in the Nopah Formation in the region shown on figure 7 are the simultaneous northward thickening of the Dunderberg Shale and Halfpint Members and the northward thinning of the Smoky Member. The Smoky Member, which composes the bulk of the Nopah at its type section, thins from about 1,135 feet in the Nopah Range to 670 feet at Groom. The Dunderberg Shale Member thickens from 40 feet in the Nopah Range to 310 feet in the Groom Range. The Halfpint Member thickens from 95 feet in the northern Nopah Range to 1,055 feet at Groom. Both the Dunderberg and Halfpint Members of the Nopah are represented in Hazzard's (1937, p. 276) unit 8A of the type locality but are more fully exposed on the next ridge to the north, where their total thickness is 135 feet instead of 100 feet (Christiansen and Barnes, 1966). Burchfiel (1964, p. 45) included both members in the 200 feet of his Dunderberg Shale in the Specter Range. The Lead Gulch Formation of the Inyo Mountains likewise is equivalent to the combined Dunderberg and Halfpint (Ross, 1963, p. B74–B77). The overlying Tamarack Canyon Dolomite is at least largely correlative with the Smoky Member of the Nopah Formation (Ross, 1963, p. B77–B78).

Although rocks now assigned to the Halfpint and Smoky Members of the Nopah were formerly included in the Windfall Formation at the Nevada Test Site (Barnes and Byers, 1961), only the Halfpint is lithologically similar to the Windfall of the Eureka district and surrounding areas. Until more is known about the Nopah and Windfall Formations between the Groom and Eureka districts, the following is presented only as a hypothesis for consideration in future work: It seems likely that the Halfpint Member of the Nopah Formation thickens northward to become the Windfall Formation of central Nevada. This lithology may, therefore, be a facies of the Nopah Formation; the principal facies in the southern Great Basin is the Smoky Member.

In summary, the stratigraphic nomenclature of the Spring Mountains and Nopah Range fits the Precambrian and Cambrian rocks of the Groom Range, but the nomenclature of the Pioche district is less applicable. Among the reasons for this better fit are a greater number of well-studied sections, and less marked facies changes between Groom and the Nopah Range than between Groom and the Pioche district.

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