UNITED STATES
DEPARTMENT OF THE INTERIOR
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PRELIMINARY GEOLOGIC SECTION FROM PAHUTE MESA, NEVADA TEST SITE, TO ENTERPRISE, UTAH

By

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Federal Center, Denver, Colorado 80225

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ABSTRACT

The 154-mile long geologic cross section trends nearly perpendicular to the structural grain of the Basin-Range province in Nevada, and in Utah extends eastward into the transition zone between the Basin-Range and Colorado Plateau provinces. The structure is characterized by complex thrust faults, involving uppermost Precambrian to lower Mesozoic sedimentary rocks, and normal faults which cut the thick sequence of Tertiary volcanic rocks as well as older rocks. Some of the normal faults are the result of caldera collapse. The principal normal faults trend northerly west of Delamar, Nev., and form north-trending basins and ranges. Farther east the principal faults trend northwesterly, and form a moderately rugged highland rather than distinct basins and ranges.

The uppermost Precambrian-Paleozoic strata thin markedly eastward across the region. The pre-Pennsylvanian sedimentary rocks vary from 32,500 feet in thickness at the Nevada Test Site (Harley Barnes, E. N. Hinrichs, F. A. McKeown and P. P. Orkild, written commun., 1963) to 4,500 feet in the Beaver Dam Mountains in western Utah (Cook, 1960). Thick Mesozoic deposits, similar to those of the Colorado Plateau, are present in western Utah, but are represented in eastern Nevada by only thin patches of Triassic rock.

INTRODUCTION

This preliminary cross section is one of a series that radiate from Pahute Mesa in the Nevada Test Site (figs. 1 and 2). These cross sections may be used to help relate geology to the measurements of seismic waves generated at the Nevada Test Site. This particular cross section was made as part of an effort to determine the degree of geologic complexity to be expected in the Basin and Range province around the Nevada Test Site. A knowledge of the complexity

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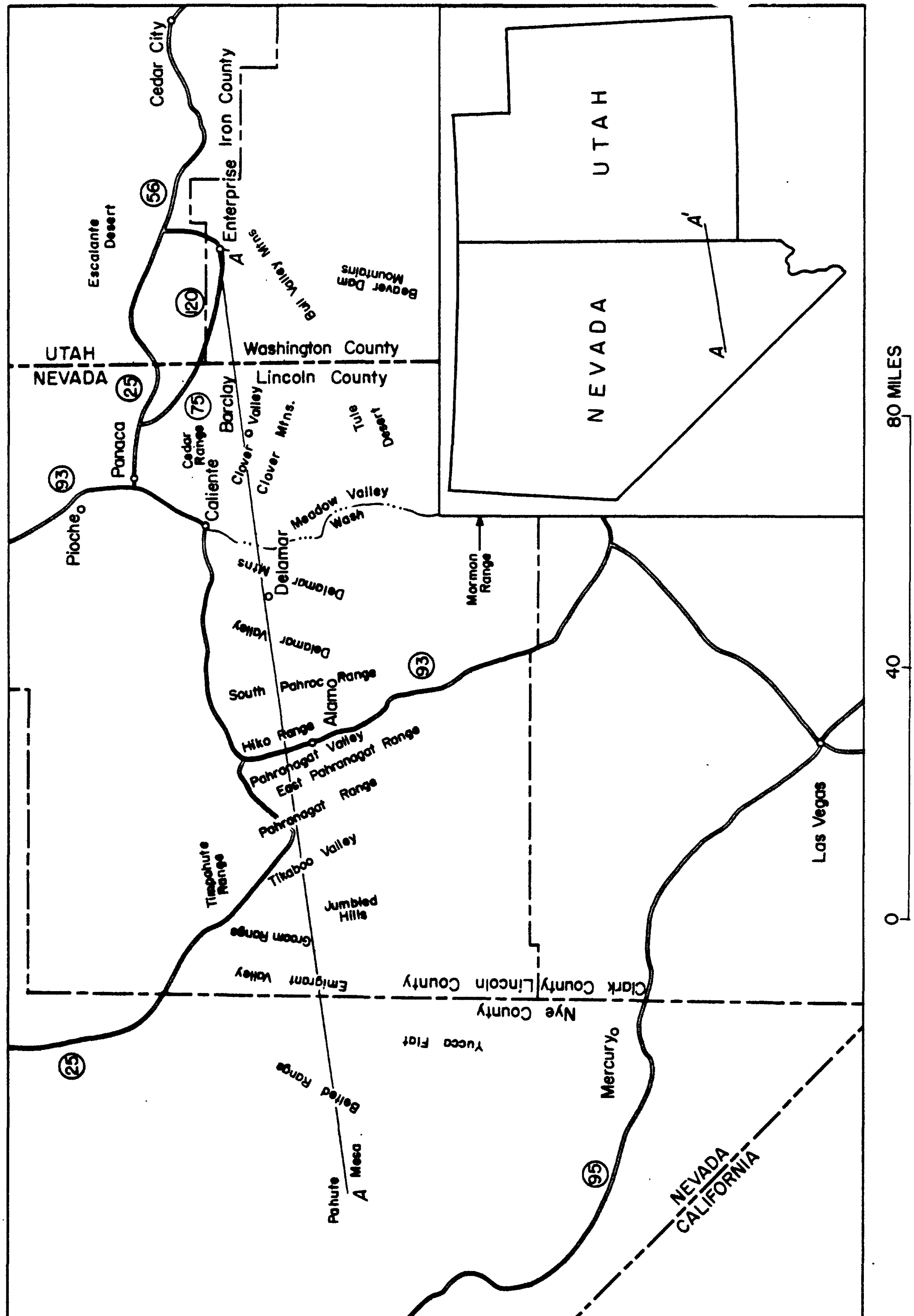

Figure 1.--Index map showing location of cross section

is required to select intelligently a "seismic calibration line," which should contain the least complex geology. The cross section transects both regional structure and regional stratigraphic changes and represents the most geologically complex of the cross sections drawn to date. Lack of adequate details for many portions of the cross section, however, results in simplifications that may be misleading when comparing the relative complexities of the different cross sections.

The cross section extends 154 miles N. 82° E. from Pahute Mesa to Enterprise, Utah (figs. 1 and 2). It trends nearly perpendicular to the structural grain of the Basin-Range province and extends into the transition zone between the Basin-Range and Colorado Plateau provinces. Thus, the cross section is oriented to show the maximum structural complexity within this part of the Basin-Range province and the changes near its edge.

The interpretations along the line of section are based principally on published and unpublished geologic maps and subordinately on a photogeologic reconnaissance of the Hiko and East Pahranagat Ranges. In some areas almost all of the subsurface geology has been inferred due to cover or lack of detailed geologic maps or both. In areas where this is the case the geology shown on the cross section is meant to convey the general structural type rather than the actual structure and stratigraphy. Alternative interpretations may be made for most areas.

STRATIGRAPHY AND STRUCTURAL DEVELOPMENT

The stratigraphic column comprises five major parts: The Precambrian basement complex, the thick uppermost Precambrian-Paleozoic deposits of carbonate and minor clastic rocks resting on basal clastic deposits, the Mesozoic sandstones and shales, the Tertiary volcanic sequence, and the late Tertiary and Quaternary valley fills and mantling surficial deposits.

During the Precambrian various orogenic episodes produced a complex of metamorphic rocks, generally isoclinally folded with injections and small intrusions of igneous rocks. This complex was beveled by erosion in the late Precambrian and covered by carbonate and clastic deposits similar to the Paleozoic rocks. Deposition was followed by block faulting which has preserved some of these relatively undisturbed upper Precambrian rocks in downdropped blocks. Remnants of these downdropped rocks may be present at depth at places along the cross section.

The Precambrian was again planed by erosion and an eastward transgression, which started in the latest Precambrian, deposited a wedge of clastic rocks across the region by Middle Cambrian. These clastic rocks are about 10,000 feet thick at the Nevada Test Site (Harley Barnes, E. N. Hinrichs, F. A. McKeown and P. P. Orkild, written commun., 1963) and thin to 740 feet in the Beaver Dam Mountains (Reber, 1952b, p. 102) where all the sequence is probably Cambrian in age.

From Middle Cambrian to Late Devonian the region was part of a large slowly subsiding trough, a miogeosyncline, in which a thick sequence of carbonate rocks was deposited. In the Late Devonian central Nevada became tectonically active. During the latest Devonian and Mississippian eroded debris was, at times, shed southeastward interrupting the continuing carbonate deposition and forming the clastic deposits of the Pilot Shale, Eleana Formation and Chainman Shale. The tectonic unrest in central Nevada continued to some degree during the remainder of the Paleozoic. East of this active area the miogeosynclinal character was lost as the region became warped into separate sedimentary basins.

Middle Cambrian to Mississippian sedimentary rocks at the Nevada Test Site total about 22,400 feet in thickness (Harley Barnes, E. N. Hinrichs, F. A. McKeown and P. P. Orkild, written commun., 1963), but in the Beaver Dam Mountains the equivalent strata amount to only 3,300 feet (Reber, 1952b, p. 103). Pennsylvanian and Permian limestones and red sandstones and siltstones total as much as 8,500 feet in thickness in southeastern Lincoln County (Tschanz and Pampeyan, 1961) whereas rocks of this age are only about 4,400 feet thick in the northern Beaver Dam Mountains (Reber, 1952b, p. 104-105).

During the Permian abundant sands and silts, derived from the continental area to the east, formed the Coconino-Supai deposits, and during the Triassic and Jurassic terrigenous silts and sands continued to encroach from the east and interfinger with marine clastic rocks and limestone toward the west. Triassic and Jurassic rocks, which total about 6,700 feet in thickness in Washington County (Cook, 1960) probably covered the entire area of the cross section at one time.

During the Cretacous the entire region was engulfed in orogenic activity. A great deal of folding and thrusting took place; many of the thrust faults in the eastern Great Basin occur along horizons in the Mississippian Chainman Shale and in the uppermost Precambrian-Cambrian clastic sediments. Positive areas developed in Nevada, much of the Paleozoic and Mesozoic rocks were stripped off. The debris was spread eastward as part of a huge deltaic and marine deposit. The Iron Springs Formation, 1,500-3,900 feet thick (Blank, 1959; Cook, 1960), forms part of the west edge of this deposit. The tectonic episode was nearly over by the Eocene. The thick Eocene continental clastic material shed to the east, the Claron Formation and the basal Tertiary continental clastic deposits elsewhere in the region, are post-orogenic.

The Tertiary was characterized by normal faulting and volcanic activity which began at the start of the Oligocene and continued throughout most of the period (Armstrong, 1963). The volcanism was marked by occasional cataclysmic outpourings of ash-flow and ash-fall tuff from volcanic centers such as those near Pahute Mesa and Caliente and at Bull Valley. These eruptions, separated by space and time, were accompanied by normal faulting, some of which was associated with caldera collapse, in addition to warping and many periods of erosion. This volcanic complex conceals the older rocks along most of the cross section.

The volcanic rocks are intruded by quartz monzonite south and southeast of Enterprise, Utah, and may be intruded at depth by a granitic stock beneath the Silent Canyon caldera at the west side of Pahute Mesa. The relation between the volcanic rocks and the small dioritic intrusions in the vicinity of the Clover Mountains is not yet known.

The present topography had mainly taken shape by the end of the Tertiary. Volcanism ended with the Tertiary except for minor Pleistocene basalt flows near Enterprise. In the Pliocene and Pleistocene valleys were filled by alluvial and lakebed deposits that are now being dissected in the Meadow Valley Wash drainage area and in Washington County, Utah.

Physical properties of many of the stratigraphic units present along this line of section have been summarized by R. E. Anderson and W. D. Quinlivan (written commun., 1966), D. C. Hedlund (written commun., 1966), and D. C. Noble and E. J. McKay (written commun., 1964).

STRATIGRAPHY

PRECAMBRIAN

Metamorphic and igneous complex

The metamorphic and igneous basement complex that underlies the region crops out nearest the cross section in the Trappman Hills, Mormon Mountains and Beaver Dam Mountains. Gneissic quartz monzonite and biotite schist of probable early Precambrian age are exposed in the Trappman Hills, about 19 miles northwest of the west end of the cross section (Ekren and others, in prep.). The rocks are cut by a few thin aplite dikes and many quartz veins. In the Mormon Mountains granite, amphibolite, gneiss and biotite schist, which are cut by pegmatite dikes, crop out (Tschanz and Pampeyan, 1961).

Gneiss and schist, which are cut by small granitic pegmatite bodies and larger bodies of gray granite, are exposed in the Beaver Dam Mountains (Cook, 1960, p. 16; Reber, 1952a, p. 43; 1952b, p. 101).

In addition, downdropped blocks of late Precambrian quartzite, sericitic shale, limestone, and dolomite, similar to the Grand Canyon (Unkar Group) and Pahrump Series (Maxon, 1961; Hewett, 1956, p. 25-28) may be included locally within the basement complex.

Johnnie Formation

The Johnnie Formation consists of micaceous quartzite, siltstone and some cherty dolomite with interlaminated siltstone and silty limestone forming the upper part. The exposed thickness is greater than 2,900 feet east of northern Yucca Flat (Barnes and others, 1965). It is 4,500 feet thick near Johnnie, 18 miles southwest of Mercury (Nolan, 1929, p. 461), and could approach that thickness along the line of section.

Stirling Quartzite

The Stirling Quartzite is composed mainly of quartzite with minor amounts of micaceous quartzite, micaceous siltstone, conglomerate and carbonate. It is about 5,300 feet thick 12 miles north of Pahute Mesa (Ekren and others, in prep.), 2,850 feet thick near northern Yucca Flat (Barnes and others, 1965) and over 2,930 feet thick in the Groom Range (Barnes and Christiansen, 1967).

PRECAMBRIAN AND CAMBRIAN

Wood Canyon Formation

The Wood Canyon Formation is made up of quartzite and siltstone and minor amounts of conglomerate and carbonate rock. The formation is 3,750 feet thick in the northern Belted Range; at least the upper 635 feet is probably of Cambrian age (Ekren and others, in prep.). It is 2,350 feet thick near northern Yucca Flat (Barnes and others, 1965) and 2,285 feet thick in the Groom Range (Barnes and Christiansen, 1967).

Prospect Mountain Quartzite

East of the Groom Range the section between the basement complex and the Pioche Shale is generally undivided and mapped as the Prospect Mountain Quartzite as did Humphrey (1945). The formation thins southeastward. North of Caliente a section, with no base exposed, is estimated to be about 3,000 feet thick (C. M. Tschanz and E. H. Pampeyan, written commun.), in the Mormon Range the formation is 300-500 feet thick (Tschanz and Pampeyan, 1961); and in the Beaver Dam Mountains it is about 520 feet thick (Reber, 1952b, p. 102). The thinning is apparently from loss of strata at the base due to an onlap relationship and thus the probable Precambrian part of the formation pinches out to the east.

CAMBRIAN

Zabriskie Quartzite

The Zabriskie Quartzite is composed of laminated quartzite and minor amounts of conglomerate, with some siltstone in the basal part.

It is 150 feet thick in the northern Belted Range (Ekren and others, in prep.), 175 feet thick in the Groom Range (Barnes and others, 1965) and in the Delamar Range it is probably equivalent to the laminated quartzite at the top of Prospect Mountain Quartzite, which is approximately 100 feet thick.

Carrara Formation

The lower part of the Carrara Formation consists mainly of shale and subordinate amounts of limestone and quartzite. The upper part is made up chiefly of limestone and minor amounts of shale and siltstone. The formation is 2,000 feet thick near northern Yucca Flat (Barnes and others, 1965) and 1,870 feet thick in the Groom Range (Harley Barnes and R. L. Christiansen,written commun.). In the Groom Range the Carrara is equivalent to the combined Pioche Shale, Lyndon Limestone, Chisholm Shale, and lower part of the undivided Highland Peak Formation (Peasley and Burrows Members) of Humphrey (1945) (Harley Barnes and R. L. Christiansen, written commun.).

Pioche Shale

The Pioche Shale consists of micaceous shale with some interbedded quartzite and limestone. The formation thins to the east. It is about 950 feet thick in the Groom Range (Humphrey, 1945, p. 16; Harley Barnes and R. L. Christiansen, written commun.), 888 feet thick at Delamar (Callaghan, 1937, p. 17-19), and approximately 220 feet thick in the Beaver Dam Mountains (Reber, 1952b, p. 102-103).

Lyndon Limestone

The Lyndon Limestone is composed of massive dark and light gray limestone. It is about 210 feet thick in the Groom Range (Humphrey, 1945, p. 17; Harley Barnes and R. L. Christiansen, written commun.) and 102 feet thick near Delamar (Callaghan, 1937, p. 17).

Chisholm Shale

The Chisholm Shale is composed of shale with thin limestone beds. It is about 300 feet thick in both the Groom and Delamar Ranges (Humphrey, 1945, p. 18; Harley Barnes and R. L. Christiansen, written commun.; and Callaghan, 1937, p. 17-19).

Bonanza King Formation

The Bonanza King Formation is composed of dolomite and very minor silty dolomite in the Nevada Test Site. In the Groom Range limestone forms a significant amount of the formation. It is about 4,600 feet thick near northern Yucca Flat (Barnes and others, 1965) and 4,355 feet thick in the Groom Range (Harley Barnes and R. L. Christiansen, written commun.).

Highland Peak Formation

The unrestricted Highland Peak Formation consists of dark and light gray limestone and dolomite. It is about 4,800 feet thick in the Groom Range, where it is equivalent to the Bonanza King and upper two members of the Carrara (Harley Barnes and R. L. Christiansen, written commun.) and it has an indicated thickness near Delamar of about 4,600 feet (C. M. Tschanz and E. H. Pampeyan, written commun.).

Nopah Formation

The Nopah (Windfall) Formation is divided into the Dunderberg Shale, Halfpint and Smoky Members (Barnes and Christiansen, 1967). The Dunderberg shale consists of gray shale and siltstone with thin interbeds of limestone. The Halfpint (Catlin) Member is composed of thin bedded cherty limestone and dolomite with some silty beds in the Nevada Test Site, but almost entirely of limestone in the Groom Range. The Smoky Member consists of thick bedded slightly cherty limestone and dolomite. In the northern Belted Range the Dunderberg Shale, Halfpint and Smoky Members are approximately 200, 1,900 and 900 feet thick, respectively (Ekren and others, in prep.), in northern Yucca Flat 225, 715 and 1,070 feet (Barnes, Houser, and Poole, 1963), and in the Groom Range 310, 1,055, and 670 feet thick respectively (Harley Barnes and R. L. Christiansen, written commun.).

Dunderberg Shale

East of the Groom Range the Dunderberg is separated as a formation. It is 340 feet thick on the west side of the Pahranagat Range (Reso, 1963, p. 904) and 344 feet thick in the southern Delamar Range (P. H. Heckel, written commun.).

Limestone and dolomite

The equivalent of the Halfpint and Smoky Members varies from 2,000-3,500 feet thick in Lincoln County, Nevada (Tschanz and Pampeyan, 1961). In the Pahranagat Range it is 2,200 feet thick and was referred to as the Desert Valley Formation by Reso (1963, p. 704-905). At the south end of the Delamar Range it is 2,228 feet thick (P. H. Heckel, written commun.).

ORDOVICIAN

Pogonip Group

The Pogonip Group is composed of limestone, dolomitic limestone and dolomite with some silty limestone and calcareous siltstone. The dolomite content decreases to the east. The Pogonip is about 3,000 feet thick in the northern Belted Range (Ekren and others, in prep.) over 2,775 feet thick at the east side of Yucca Flat (Byers and Barnes, 1964), 3,140 feet thick in the central part of the Pahranagat Range (Reso, 1963, p. 905-906) and 1,787 feet thick in the southern Delamar Range (P. H. Heckel, written commun.).

Eureka Quartzite

The Eureka Quartzite is made up of laminated quartzite with minor carbonate near the base or top in some parts of the region. The Eureka is 315 feet thick a few miles north of Yucca Flat (Ekren and others, in prep.), thins progressively southward from 552 to 386 feet along the west side of the Pahranagat Range (Reso, 1963, p. 906-907), 153 feet thick in the southern Delamar Range (P. H. Heckel, written commun., 1966) and is absent in the Mormon Range (C. M. Tschanz and E. H. Pampeyan, written commun.) and Beaver Dam Mountains (Reber, 1952b).

Ely Springs Dolomite

The Ely Springs Dolomite consists of dolomite with some limestone at the base and shale partings at the top in places. The formation is 340 feet thick a little north of Yucca Flat (Ekren and others, in prep.), varies from 276 to 527 feet thick in the Pahranagat Range (Reso, 1963, p. 907) and 414 feet thick in the southern Delamar Range (P. H. Heckel, written commun.).

SILURIAN

Laketown Dolomite

The Laketown Dolomite is composed of light to dark gray dolomite with cherty horizons. The Laketown is 736 to 938 feet thick in the Pahranagat Range (Reso, 1963, p. 907-908) and 970 feet thick in the southern Delamar Range (Heckel and Reso, 1962).

SILURIAN AND DEVONIAN

Undifferentiated dolomite

An undifferentiated cherty dolomite unit, 1,415 feet thick, overlying the Ely Springs and underlying the Nevada Formation, is present a few miles north of Yucca Flat. The lower third is probably Silurian, but the upper part may be Devonian (Ekren and others, in prep.). C. M. Tschanz and E. H. Pampeyan (written commun.) believe that 265 to 295 feet of this unit are equivalent to the Laketown Dolomite in Lincoln County.

DEVONIAN

Nevada Formation

The Nevada Formation consists of a basal unit of sandy dolomite overlain by dolomite and limestone with some sandy dolomite and siltstone. An incomplete section a few miles north of Yucca Flat is about 1,000 feet thick (Ekren and others, in prep.).

Undifferentiated limestone and dolomite

North of Yucca Flat the stratigraphic equivalent to the Devils Gate Limestone, the strata lying between the Nevada and the Eleana Formations, consists of limestone, limestone conglomerate, and silty limestone with the upper quarter formed of dolomite. The sequence is 1,285 feet thick a few miles north of Yucca Flat (Ekren and others, in prep.).

Sevy Dolomite

The Sevy Dolomite consists of light gray aphanitic dolomite with some chert near the contacts and a thin unit of calcareous sandstone at the top. The formation thins to the southeast. It is 1,341 to 1,578 feet thick in the Pahranagat Range (Reso, 1963, p. 908 and Plate 2) and 898 feet thick in the southern Delamar Range (P. H. Heckel, written commun.). The basal part of the Nevada Formation and the upper part of the undifferentiated dolomite in the Nevada Test Site are apparently equivalent to the Sevy (C. M. Tschanz and E. H. Pampeyan, written commun.).

Simonson Dolomite

The Simonson Dolomite is composed of alternating brown and gray dolomite. The sequence is about 1,200 feet thick in the Pahranagat Range and 737 feet thick southward in the Delamar Mountains (Reso, 1963, p. 909). The Simonson is considered equivalent to the Nevada Formation above the basal part in the Nevada Test Site (C. M. Tschanz and E. H. Pampeyan, written commun.).

Guilmette Formation

The Guilmette Formation is made up of limestone and dolomite with, in the Pahranagat Range, numerous sandstone units occurring in a 600-foot thick sequence at or near the top. The top limestone unit, 0 to 390 feet thick, was designated the West Range limestone by Reso (1963, p. 910). The Guilmette is 2,400 to 2,800 feet thick in the Pahranagat Range (Reso, 1963, p. 909-910) and about 1,300 or 1,400 feet thick in the southern Delamar Mountains (P. H. Heckel, written commun.). The equivalent but undifferentiated rocks in the southeast corner of Lincoln County may be only about 800 to 900 feet thick (C. M. Tschanz and E. H. Pampeyan, written commun.).

The Guilmette correlates with the Devils Gate Limestone (Reso, 1963, p. 910; Tschanz and Pampeyan, 1961).

CAMBRIAN, ORDOVICIAN?, AND DEVONIAN

Undifferentiated dolomite

A pre-Mississippian dolomite sequence nearly 2,200 feet thick is exposed in the Beaver Dam Mountains (Reber, 1952b, p. 103). The lower 1,100 feet is best assigned to the Cambrian on its gross lithologic similarities, the cherty dolomite from 1,100 to 1,300 feet above the base is suggestive of Upper Ordovician and Silurian dolomite elsewhere, and above 1,300 feet the section is mostly light gray dolomite, some sandy, which most closely resembles the Sevy (Hintze, 1963b, p. 27).

DEVONIAN AND MISSISSIPPIAN

Eleana Formation

The Eleana Formation is composed of argillite, quartzite and conglomerate with some limestone at the base and top. It has a probable minimum thickness of 7,700 feet west of Yucca Flat (Poole and others, 1961, p. D104).

Pilot Shale

The Pilot Shale consists of calcareous shale, shaly limestone, and some sandstone and siltstone. It thickens southward to a maximum of 460 feet in the East Pahranagat Range, but is only about 250 feet thick in the Pahranagat Range (Reso, 1963, p. 910). In the Meadow Valley Mountains, south of the Delamar Mountains, the Pilot is about 100 feet thick and on Lime Mountain, in the northeastern Tule Desert, questionably equivalent beds are perhaps several hundred feet in thickness (C. M. Tschanz and E. H. Pampeyan, written commun.). The Pilot is apparently equivalent to the basal Eleana Formation.

MISSISSIPPIAN

Joana Limestone

The Joana Limestone consists of limestone with some shale partings and minor to abundant chert. The Joana is 1,000 feet thick inthe Pahranagat Range (Reso, 1963, p. 911), 850 feet thick in the east Pahranagat Range near Alamo (Langenheim, 1963, p. 34), and an estimated 1,500 feet thick in the Meadow Valley Mountains, south of the Delamar Mountains (C. M. Tschanz and E. H. Pampeyan, written commun.).

Redwall Limestone

The Redwall Limestone is equivalent to the Joana Limestone. In the Beaver Dam Mountains it is about 964 feet thick (Langenheim, 1963, p. 31) to 1,100 feet thick (Reber, 1952b, p. 103).

Chainman Shale

The Chainman Shale is made up of shale with interbedded calcareous siltstone, silty limestone, and sandstone. The Chainman is about 1,050 feet thick in the Pahranagat Range (including the Peers Spring and Scotty Wash Formations of Reso, 1963, p. 11-12), 1,040 feet thick in southern Kane Springs Wash, just south of the Delamar Mountains, and is absent in the northern Mormon Mountains (Langenheim, 1963, p. 34). The Chainman is a finer grained equivalent of much of the Eleana Formation.

PENNSYLVANIAN AND PERMIAN

Callville Limestone

The Callville Limestone in the Beaver Dam Mountains consists of limestone with intercalated quartzite and calcareous sandstone in the lower and upper parts and a 500-foot thick dolomite unit near the middle of the formation. It is about 1,560 feet thick (Reber, 1952b, p. 104). The upper part is [redacted] Permian in age [redacted].

[redacted]

Undifferentiated limestone

In southern Lincoln County the undifferentiated Pennsylvanian and Permian strata consist of gray cherty limestone and silty limestone with some calcareous siltstone. The sequence thins to the southeast. It is 4,300 feet thick in the Meadow Valley Range, south of the Delamar Mountains, and about 1,500 feet thick in the southern Mormon Mountains (Tschanz and Pampeyan, 1961, and written commun., 1966). This unit is partly equivalent to the Callville to the east.

PERMIAN

Undifferentiated red beds

Overlying the undifferentiated limestone unit south of the Clover Mountains is a sequence of red beds composed of sandstone, siltstone, gypsiferous shale, and some thin beds of limestone. It is about 3,200 feet thick along Meadow Valley Wash, near the Mormon

Range, and decreases eastward to 1,100 feet (Tschanz and Pampeyan, 1961).

Supai-Coconino

The undivided Supai-Coconino sequence (Queantoweap sandstone of McNair, 1952) in the Beaver Dam Mountains consists of massive crossbedded sandstone about 1,800 feet thick (Reber, 1952b, p. 104). This unit is equivalent to the undifferentiated red bed sequence in southeastern Lincoln County (C. M. Tschanz and E. H. Pampeyan, written commun.).

Kaibab Limestone-Toroweap Formation

The Kaibab-Toroweap sequence consists of two massive gray cherty limestone units separated by a thin unit of gypsum or gypsiferous limestone. The sequence is 800 to 1,050 feet thick in the Beaver Dam Mountains (Reber, 1952b, p. 105; Cook, 1960, p. 21) and thins westward and pinches out in Lincoln County (Tschanz and Pampeyan, 1961).

TRIASSIC

Moenkopi Formation

In Washington County, Utah, the Moenkopi Formation is composed of shale, sandstone, and mudstone with minor limestone and some gypsum. Farther west the limestone content increases (Cook, 1960, p. 21-22) and west of Vigo, in Meadow Valley Wash, limestone forms the entire formation (Tschanz and Pampeyan, 1961, and written commun., 1966). The Moenkopi is 1,800 to 2,100 feet thick at the north end of the Beaver Dam Mountains (Reber, 1952b, p. 105; McCarthy, 1959, p. 33-36) and has an estimated thickness of 2,500 to 3,500 feet in southeastern Lincoln County (Tschanz and Pampeyan, 1961).

Chinle Formation, Shinarump Member

The Shinarump Member consists of sandstone and some conglomerate. It is about 170 feet thick at the north end of the Beaver Dam Mountains (Reber, 1952b, p. 105; McCarthy, 1959, p. 36-37) and 50 to 200 feet thick in Lincoln County (Tschanz and Pampeyan, 1961).

Chinle Formation, upper part

The upper part of the Chinle Formation typically consists of shale and is about 385 feet thick in Washington County (Cook, 1960, p. 23-24). The upper part of the Chinle is described as composing about 1,030 feet of strata in the Beaver Dam Mountains (Reber, 1952b, p. 105) and an estimated 1,500 to 3,000 feet in Lincoln County (Tschanz and Pampeyan, 1961), but apparently this sequence also includes the Moenave and Kayenta Formations.

Moenave Formation

The Moenave is made up of sandstone, siltstone, and mudstone and is as much as 475 feet in thickness in Washington County, Utah (Cook, 1960, p. 23-24).

Kayenta Formation

The Kayenta Formation consists mainly of siltstone and sandstone and ranges in thickness from 640 to 740 feet in Washington County (Cook, 1960, p. 24).

TRIASSIC AND JURASSIC

Navajo Sandstone

The Navajo Sandstone is composed of massive crossbedded sandstone. In Washington County, the Navajo ranges in thickness from 1,800 to 2,200 feet (Cook, 1960, p. 24) and is 2,200 feet thick in the Beaver Dam Mountains (Reber, 1952b, p. 105-106). It has not been recognized in Lincoln County (Tschanz and Pampeyan, 1961).

JURASSIC

Carmel Formation

The Carmel Formation is composed of sandstones, gypsiferous shales, and gypsum in the lower third and predominantly limestone, above. It ranges in thickness from 480 to 675 feet in Washington County (Cook, 1960, p. 25). The predominantly limestone interval is over 545 feet thick in the Bull Valley district (Blank, 1959).

Entrada Formation

In the Bull Valley district the Entrada Formation, described by Blank (1959), consists of 50 to 130 feet of maroon to olive-green shale. This sequence may possibly be part of the Carmel Formation.

CRETACEOUS

Iron Springs Formation

The Iron Springs Formation is composed of a sequence of variegated sandstones and siltstones and gray shales with some conglomerate at the base and near the top. In the Bull Valley district it is about 1,500 to 2,000 feet thick (Blank, 1959) and to the southeast of there about 3,850 feet thick (Cook, 1960, p. 28).

TERTIARY

Pahute Mesa

Pre-Belted Range volcanic rocks

A sequence of rocks, totaling several thousand feet in thickness, lies between the Paleozoic rocks and Belted Range Tuff. It is composed of rhyolitic lavas, various types of tuffs and minor sedimentary rocks (Ekren and others, in prep.; P. P. Orkild, written commun., 1966).

Belted Range Tuff

The Belted Range Tuff is composed of compound cooling units of ash-flow tuff with some intercalated rhyolite flows (Sargent and others, 1964; Ekren and others, in prep.). Its thickness varies from 0 to over 2,000 feet (P. P. Orkild, written commun., 1966).

Post-Belted Range rocks of Silent Canyon volcanic center

Overlying the Belted Range Tuff and underlying either the Paintbrush Tuff or tuffs and rhyolites of Area 20 in the eastern part of Pahute Mesa is a unit composed of rhyolite, rhyolite breccia, tuff breccia, and zeolitized tuff. This unit forms a caldera fill around the edge of the Silent Canyon caldera and pinches out towards the center of the caldera (P. P. Orkild, oral commun.). The maximum thickness is about 6,000 feet (P. P. Orkild, written commun., 1966).

Tuffs and rhyolites of Area 20

A sequence of rhyolite lavas and ash-flow and bedded tuffs overlies either the Belted Range Tuff or post-Belted Range rocks of Silent Canyon volcanic center and underlies the Paintbrush Tuff and, in the central part of Pahute Mesa, forms part of a caldera fill (P. P. Orkild, written commun., 1966, and Ekren and others, in prep.). The sequence is about 5,300 feet thick at the west end of the cross section and pinches out eastward partly by interfingering with the post-Belted Range rocks of the Silent Canyon volcanic center (P. P. Orkild, written and oral commun., 1966).

Paintbrush Tuff

The Paintbrush Tuff consists of ash-flow, ash-fall, and reworked tuff (Ekren and others, in prep.). The thickness varies from 40 to 812 feet near the line of section (P. P. Orkild, written commun., 1966).

Timber Mountain Tuff

The Timber Mountain Tuff is composed of a sequence of silicic ash-flow tuffs and some bedded tuffs (Ekren and others, in prep., p. 185-186). The thickness, where complete, varies from 931 to 2,562 feet near the line of section.

Thirsty Canyon Tuff

The Thirsty Canyon Tuff consists of a series of ash-flow tuffs generally with associated ash-fall tuffs at the base (Ekren and others, in prep.). Incomplete sections of Thirsty Canyon along the line of section are as much as 348 feet thick (P. P. Orkild, written commun., 1966).

Central Lincoln County

Pre-Hiko rocks

Beneath the Hiko Tuff in the Pahranagat area is a sequence 0 to 1,000 feet thick, consisting of a basal boulder conglomerate, ash-flow tuffs, rhyolite flows and a top unit of water-lain tuffs, tuffaceous sandstones and fresh-water limestones (Reso, 1963, p. 913 and Plate 2). It includes parts of the Pahroc sequence and Quichapa Formation (Cook, 1965, p. 19-26).

Hiko Tuff

The Hiko Tuff consists of dacite ash-flow tuff. It is 450 to 1,000 feet thick in the Pahranagat area (Reso, 1963, p. 913) and 1,135 feet thick in the south Pahroc Range (Cook, 1965, p. 27-28).

Kane Wash Tuff

The Kane Wash Tuff consists of a mainly ash-flow tuff. It is over 375 feet thick in the South Pahroc Range and 660 feet in Meadow Valley Wash east of Delamar (Cook, 1965, p. 29-31).

Muddy Creek and Panaca Formations

The Muddy Creek and Panaca Formations are composed of loosely consolidated clays, silts, fine-grained sands, and marly limestone representing basin fills. Their thickness is as much as 1,200 feet (Tschanz and Pampeyan, 1961).

Northwest Washington County

Claron (Wasatch) Formation

The Claron Formation consists of fresh-water limestone, calcareous sandstone, limestone pebble conglomerate, and shale above a basal sandstone and quartzite pebble conglomerate (Cook, 1960, p. 32). A 0 to 55-foot thick ash-flow tuff, the Needles Range Formation, is interbedded in the upper part of the formation (Blank, 1959, p. 27; Mackin, 1963, p. 71). Westward there is an increase in the percentage of clastic material and thickness. West of Gunlock, south of the Bull Valley Mountains, the formation ends against a thrust sheet from which, in that locality, it has obviously been derived (Cook, 1960, p. 36). At the northwest margin of the thrust fault it is well over 1,000 feet thick, in the Pine Valley Mountains, about 20 miles east, it is about 475 feet thick (Cook, 1960, p. 36) and in the eastern Bull Valley Mountains, it is 0 to 630 feet thick (Blank, 1959).

Isom Formation

The Isom Formation consists of chiefly ash-flow tuff and lava flows with intercalations of sedimentary rocks. It is at most only about 500 feet thick in southwest Utah (Mackin, 1960, p. 98-99) and varies from 0 to 150 feet in thickness in the Bull Valley district (Blank, 1959, p. 38-42). It correlates with part of the Pahroc sequence in Nevada (Cook, 1965, p. 19).

Quichapa Formation

The Quichapa Formation is made up of a series of ash-flow tuffs. It is thickest, about 1,600 feet, in the vicinity of Caliente, over 1,000 feet thick in northwestern Washington County, and pinches out westward near the Pahranagat range and eastward at the edge of the

Colorado Plateau (P. L. Williams, written commun.).

Rencher Formation

The Rencher Formation consists predominantly of ash-flow tuff with lesser amounts of tuff breccia, mud-flow breccia, flows and flow breccia. It was erupted from a volcanic center in the Bull Valley district and the thickness varies from 0 to 1,000 feet in the district (Blank, 1959, p. 51-53).

Shoal Creek Breccia

The Shoal Creek Breccia consists of andesite(?) breccia with a maximum thickness of 200 feet in the Bull Valley district, but thicker sections northwest of Enterprise (Blank, 1959, p. 108-110).

Maple Ridge Porphyry

The Maple Ridge Porphyry consists of andesite(?) lava with a thickness of 0 to 300 feet in the Bull Valley district (Blank, 1959, p. 110-111).

Cove Mountain Formation

The Cove Mountain Formation consists mainly of an ash-flow unit with top and bottom units of volcanic sediments and ash-fall tuffs of limited distribution and a unit of flow basalt (Blank, 1959, p. 112-120). The ash-flow unit (the Racer Canyon Tuff or Kane Point Tuff) is as much as 1,500 feet thick in the Bull Valley district (Blank, 1959, p. 112-120) and has the same stratigraphic position as the Hiko Tuff (Cook, 1965, p. 28). The upper part of the formation correlates with the lower part of the Kane Wash Tuff (Cook, 1965, p. 31).

Ox Valley Tuff

The Ox Valley Tuff is composed of an ash-flow tuff having a maximum thickness of about 400 feet in the Bull Valley district (Blank, 1959, p. 120-123). It correlates with the upper part of Kane Wash Tuff (Cook, 1965, p. 31).

Resevoir Formation

The Resevoir Formation is made up of tuff, agglomerate, fine-grained tuffaceous sediments and volcanic conglomerate with a maximum thickness of about 1,400 feet (Blank, 1959, p. 28-30). The formation extends westward into Nevada.

Flattop Mountain Suite

The Flattop Mountain Suite consists of a series of silicious rhyolite to rhyodacite flows and small intrusives, generally intercalated with and intruding the Resevoir Formation southwest of Enterprise (Blank, 1959, p. 123-136).

Enterprise Basalt

The Enterprise Basalt is composed of an olivine-augite basalt flow with a maximum thickness of 300 feet southwest of Enterprise (Blank, 1959).

STRUCTURE

The structure is characterized by complex thrust faults and folds in the uppermost Precambrian-Paleozoic strata which are cut and tilted by later normal faults, including faults bounding at least one and probably two calderas. The principal normal faults trend northerly west of Delamar and form north-trending basins and ranges. Farther east the principal faults trend northwesterly and there are no distinct ranges, but instead, a moderately rugged highland.

PAHUTE MESA-BELTED RANGE

The Pahute Mesa-Belted Range area has a thick cover of relatively flat-lying Tertiary volcanic rocks which are locally disturbed by small rhyolite intrusives and cut by numerous northward-trending high-angle faults (E. B. Ekren, written commun., 1963; Colton and Noble, in prep.; D. C. Noble and E. J. McKay, written commun., 1964; P. P. Orkild, written commun., 1965; Rogers and Noble, 1967; and Sargent and others, 1965). The cross section is a few miles north and northeast of the Timber Mountain caldera and the west end of the cross section extends into the Silent Canyon caldera where the volcanic sequence is much thicker than to the east.

The Tertiary rocks are assumed to overlie a series of thrust plates composed of uppermost Precambrian to middle Paleozoic sediments (Harley Barnes, E. N. Hinrichs, F. A. McKeown and P. P. Orkild, written commun., 1963) which in turn unconformably overlie the Precambrian basement complex. The thrust sequence, for the most part, has been projected northwestward from the Yucca Flat area. The Paleozoic rocks are folded where they are exposed at the south end of the Belted Range, and the rocks comprising the thrust plates at depth are presumed to be moderately to strongly folded. A general west dip is projected for the thrust plates and assumed for the top of the Precambrian complex.

The Silent Canyon caldera may be underlain by a granitic intrusion of similar age by analogy with other calderas.

GROOM RANGE

The southern end of the Groom Range is composed of a north-striking east-dipping sequence of uppermost Precambrian to middle Paleozoic rocks which are overlain on the east by volcanic rocks and cut by north-trending high-angle faults (Harley Barnes and R. L. Christiansen, written commun., 1965; Humphrey, 1945; Tschanz and Pampeyan, 1961). The easternmost exposed Paleozoic rocks, Devonian, are interpreted as being part of an overriding thrust plate which is better exposed to the south in the Jumbled Hills and to the north at the west end of the Timpahute Range.

Emigrant Valley to the west is interpreted as a large faulted anticline as is Tikaboo Valley to the east, but the anticline beneath Tikaboo Valley is assumed to be underlain by a thrust and not to affect the Precambrian basement complex.

PAHRANAGAT AND EAST PAHRANAGAT RANGES

A large north-northwest trending syncline of lower to middle Paleozoic rocks, overlain by a thrust plate of similar but more steeply dipping rocks, forms these ranges (Reso, 1963; Tschanz and Pampeyan, 1961). Minor volcanic rocks cap the thrust plate and occur at the east edge of the East Pahranagat Range.

Two thrust faults are inferred to lie at depth beneath the ranges and above the gently west dipping surface of the

Precambrian complex. If no buried thrust faults are assumed, the top of the Precambrian complex would still be shown at approximately the same depth.

HIKO AND SOUTH PAHROC RANGES

The Hiko and South Pahroc Ranges are underlain by a relatively thin cover of volcanic rocks cut by high-angle faults into a series of north-trending tilted blocks (Dolgoff, 1963; Tschanz and Pampeyan, 1961). A mosaic of fault blocks composed of lower and middle Paleozoic rocks is inferred to lie beneath the volcanic rocks of these ranges and the adjacent valleys as this is the relationship 15 miles to the north. The faulted Paleozoic rocks are considered by analogy to the thrust at the southwest end of the Delamar Mountains, to be part of a thrust plate that has overridden Mississippian and Pennsylvanian sediments. The outcrops of Pennsylvanian rocks 30 miles to the north are interpreted as exposures of this lower plate. A lower thrust, with very little stratigraphic throw, is inferred to lie at about the base of the Cambrian.

DELAMAR MOUNTAINS

The west slope of the Delamar Mountains in the vicinity of Delamar is composed of an east-dipping sequence of north to northeast-striking Cambrian rocks which are cut by many faults, mainly trending northwest, and intruded by a few Tertiary rhyolite and basalt dikes (Callaghan, 1937). The crest and east slope of the range is formed of Tertiary volcanic rocks (Tschanz and Pampeyan, 1961).

The Cambrian sequence is assumed to be thrusted, although the Lower Cambrian clastic rocks are commonly the position of thrust faults in the eastern Great Basin, and the Precambrian basement complex is, therefore, close to the surface, because the Precambrian basement crops out only 34 miles to the south-southeast.

CLOVER MOUNTAINS

The crest of the Clover Mountains and the Clover Valley to the north are underlain by a sequence of relatively flat-lying volcanic rocks, which probably are greatly faulted locally and are covered in places by late Tertiary-Quaternary sediments (Tschanz and Pampeyan, 1961). The faults mapped in this area trend predominantly northwest. A caldera may exist east of Caliente and the south edge of a caldera with its thick volcanic filling is assumed to lie beneath Clover Valley.

A complex sequence of thrust plates of Paleozoic and Triassic rocks, such as is present to the south in the Tule Desert area, is projected beneath the volcanic rocks.

Several small dioritic intrusives crop out in this area, notably 10 miles northwest of Barclay and 13 miles south of Caliente. The age of the diorite and its structural relations to the volcanic rocks are unknown.

NORTHWEST WASHINGTON COUNTY

The area is underlain by a moderately thick sequence of Tertiary volcanic rocks, which are locally capped by late Tertiary sediments and Pleistocene basalt and cut by many high-angle faults, most of which trend northwest or west-northwest (Armstrong, 1963; Blank, 1959; Cook, 1960; Hintze, 1963a; Mackin, 1960).

The eastern edge of the belt of thrust plates, composed of Paleozoic and lower Mesozoic rocks, is present at depth. The easternmost thrust plate is a northward projection of the thrust exposed 16 miles southwest of Enterprise (Cook, 1960). Beneath and east of the thrust plates is a thick east-dipping series of Mesozoic sediments overlying a relatively thin Paleozoic sequence which in turn rests on the Precambrian basement complex, as in the Beaver Dam Mountains to the south.

CRUSTAL STRUCTURE

The crustal structure near the line of the cross section has been investigated by Ryall and Stuart (1963) by means of recording seismic motions from nuclear explosions at the Nevada Test Site. The crustal model chosen for the unreversed profile shows an increase in crustal thickness from about 25 km at the Nevada Test Site to about 42 km in the western part of the Colorado Plateau. Part of the profile on the Colorado Plateau was reversed and showed a thickness of slightly more than 40 km (Pakiser, 1963).

The crustal thickness beneath the Nevada Test Site has been assigned various values, but the best estimate to date is 28 km (John C. Roller, oral commun. to R. E. Anderson, 1965).

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