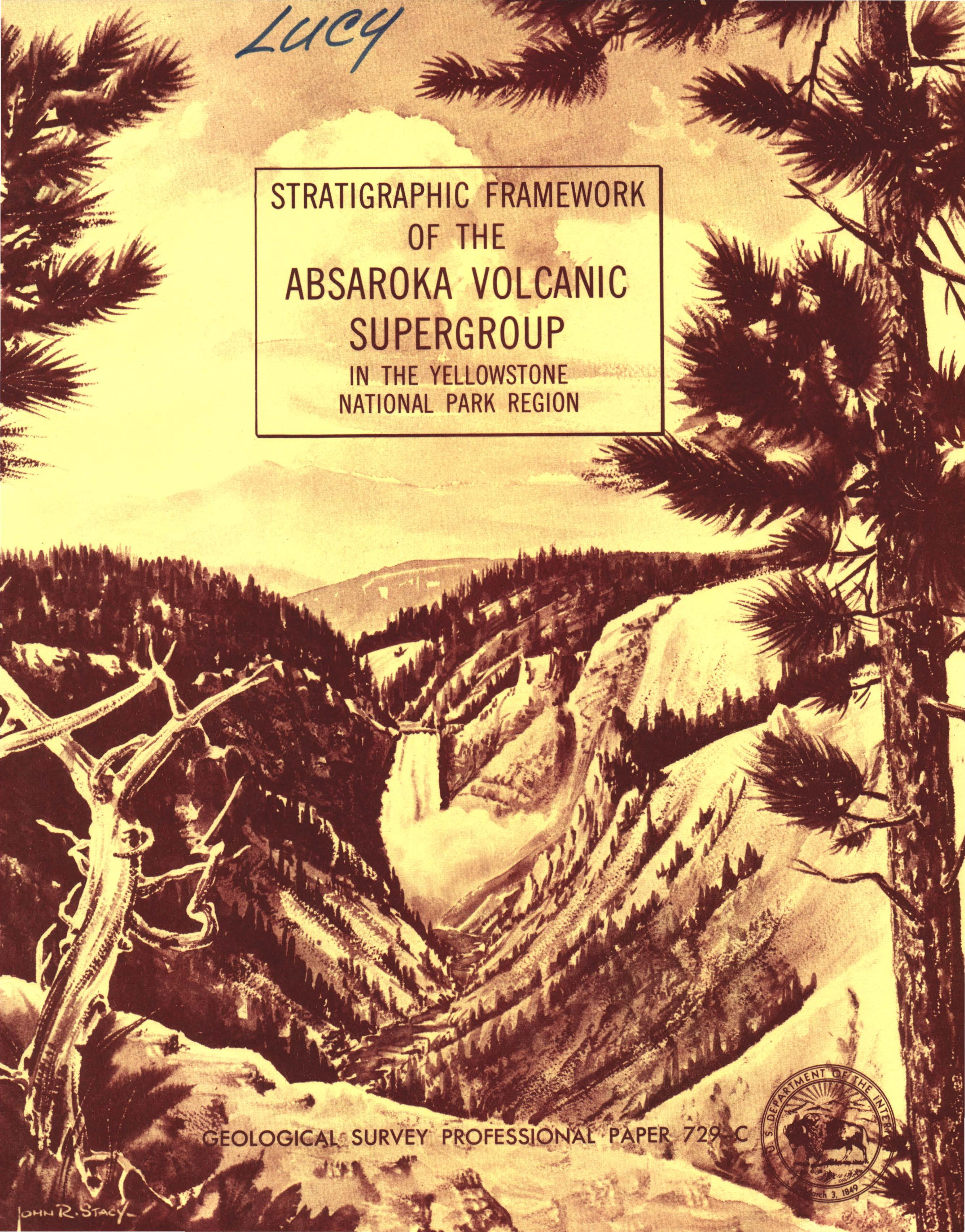
STRATIGRAPHIC FRAMEWORK OF THE ABSAROKA VOLCANIC SUPERGROUP IN THE YELLOWSTONE NATIONAL PARK REGION



GEOLOGICAL SURVEY PROFESSIONAL PAPER 729-C

Stratigraphic Framework of the Absaroka Volcanic Supergroup in the Yellowstone National Park Region

By HARRY W. SMEDES *and* HAROLD J. PROSTKA

GEOLOGY OF YELLOWSTONE NATIONAL PARK

GEOLOGICAL SURVEY PROFESSIONAL PAPER 729-C

A brief description of the stratigraphy of the Eocene Absaroka volcanic field, Wyoming and Montana. The Absaroka Volcanic Supergroup, three groups, five formations, and five members are defined

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Yellowstone National Park, the oldest of the areas set aside as part of the national park system, lies amidst the Rocky Mountains in northwestern Wyoming and adjacent parts of Montana and Idaho. Embracing large, diverse, and complex geologic features, the park is in an area that is critical to the interpretation of many significant regional geologic problems. In order to provide basic data bearing on these problems, the U.S. Geological Survey in 1965 initiated a broad program of comprehensive geologic and geophysical investigations within the park. This program was carried out with the cooperation of the National Park Service, and was also aided by the National Aeronautics and Space Administration, which supported the gathering of geologic information needed in testing and in interpreting results from various remote sensing devices. This professional paper chapter is one of a series of technical geologic reports resulting from these investigations.

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STRATIGRAPHIC FRAMEWORK OF THE ABSAROKA VOLCANIC SUPERGROUP IN THE YELLOWSTONE NATIONAL PARK REGION

By HARRY W. SMEDES and HAROLD J. PROSTKA

ABSTRACT

This report briefly describes the stratigraphy of the Absaroka volcanic field in and near Yellowstone National Park. The volcanics, mainly andesitic, basaltic, and dacitic volcaniclastic rocks, are herein named the Absaroka Volcanic Supergroup. The supergroup comprises, from oldest to youngest, the Washburn Group, Sunlight Group, and Thorofare Creek Group (new names). Within these groups, the following five new formations and five new members are defined: In the Washburn Group — Sepulcher Formation and its Daly Creek and Fortress Mountain Members, and Lamar River Formation. In the Sunlight Group — Mount Wallace Formation and its Slough Creek Tuff Member, and the Pacific Creek Tuff Member (of the Trout Peak Trachyandesite). In the Thorofare Creek Group — Langford Formation and its Promontory Member, and the Two Ocean Formation. The usage of some formerly established units is modified on the basis of new data, and correlations with rocks in outlying parts of the volcanic field are proposed.

This stratigraphic framework has been established by mapping of lithologic units and by potassium-argon age data and fossils.

INTRODUCTION

The Absaroka volcanic field of northwestern Wyoming and southwestern Montana (figs. 1, 3) consists of deeply eroded andesitic and basaltic stratovolcanoes and the coalesced deposits of epiclastically reworked material derived from them, some air-fall tuffs, and a variety of related intrusive rocks. These Eocene volcanic rocks constitute the main mass of the Absaroka Range for which the field is named, as well as much of the northern Gallatin Range and part of the Owl Creek Mountains (fig. 1). Similar rocks in the Madison and Centennial Ranges, to the west, may be part of the Absaroka field, but they are not included at this time, because too little is known about them.

The purpose of this paper is to define and briefly describe new geologic units mapped by us in the Absaroka volcanic field in and near Yellowstone National Park, to modify the usage of previously established formation names, and to suggest correlations with units in the more distant parts of the field.

The stratigraphic framework proposed in this paper is based on 6 years of detailed and reconnaissance mapping by us in and near Yellowstone National Park, field conferences with other workers in selected critical areas, and published detailed maps and stratigraphic studies (fig. 2). This report is intended to be used in conjunction with the new bedrock geologic map of Yellowstone National Park (U.S. Geological Survey, 1972).

The Absaroka volcanic field is the largest of the many volcanic fields emplaced during an episode of major widespread Eocene volcanism in the Northern Rocky Mountains (Steven and others, 1972). The field covers about 9,000 square miles (23,310 square kilometers); the volume of rock exceeds 7,000 cubic miles (29,000 cubic kilometers); and the maximum thickness in any one place is about 5,000 feet (1,500 meters). In addition, volcanic ash from this field is an important component of some of the Eocene sedimentary strata of the Wind River Basin (Love, 1939) and probably of other Tertiary basins farther away.

Some of these volcanic rocks constitute part of the Beartooth Mountains and are present north of the crest of that range; however, there is no evidence to indicate whether the volcanics ever extended farther north into the Crazy Mountains Basin (fig. 1). The only time-equivalent strata exposed north of the Beartooth block are sedimentary beds of Wasatchian (early Eocene) age, which are devoid of volcanic material from the Absaroka field.

Facies relations and thicknesses of the volcanic-rich strata along the present east edge of the volcanic field indicate that volcanic debris may have originally covered most of the Bighorn Basin, as was suggested by Love (1939). The presence of volcanic debris in the Wagon Bed Formation (Van Houten, 1964) in the Beaver Divide area of the Wind River Basin, 80 miles southeast of the present-day edge of the Absaroka field, also supports this view.

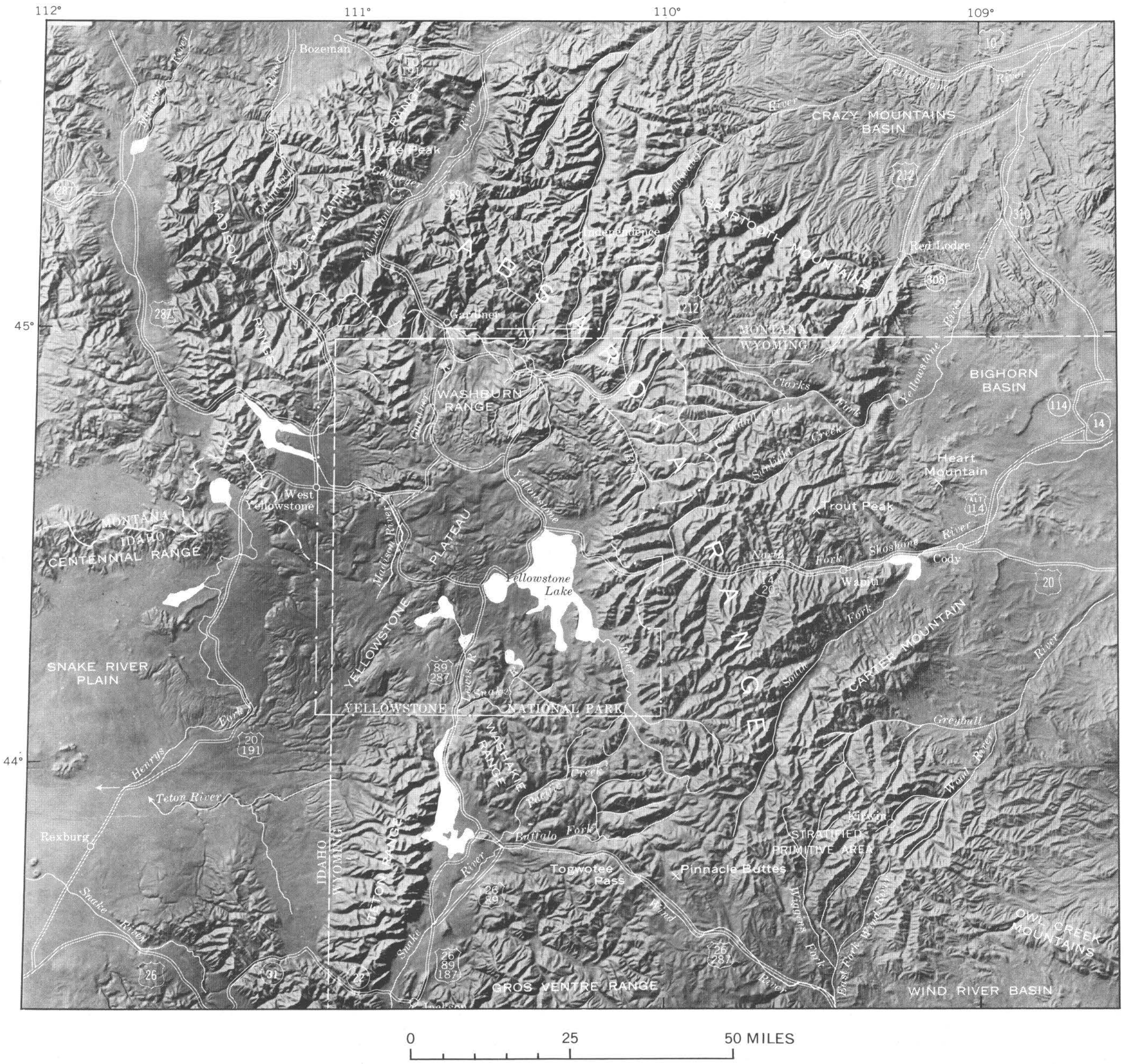


FIGURE 1. — Geographic features in the Absaroka volcanic field and vicinity.

Much of the southwestern part of the Absaroka field is covered by Quaternary rhyolites of the Yellowstone Plateau (fig. 1). The boundary between these two adjacent, but unrelated, volcanic fields is highly irregular; the older volcanics locally project above the rhyolites, and erosional remnants of rhyolite are scattered on top of the older volcanics (U.S. Geological Survey, 1972). Because of this overlap, it is considered desirable to have formal names for the rocks of each of these two volcanic fields. The Quaternary volcanics have been named by Christiansen and Blank (1972). The Eocene rocks have been informally called Absaroka volcanic rocks for many years; our proposal of the name Absaroka Volcanic Supergroup is to formalize a name already in common use among workers in the region. The name Absaroka Volcanic Supergroup is hereby proposed for the Eocene rocks of the Absaroka volcanic field and its outliers; the field and its outliers are the type area of the supergroup. Because the mapped

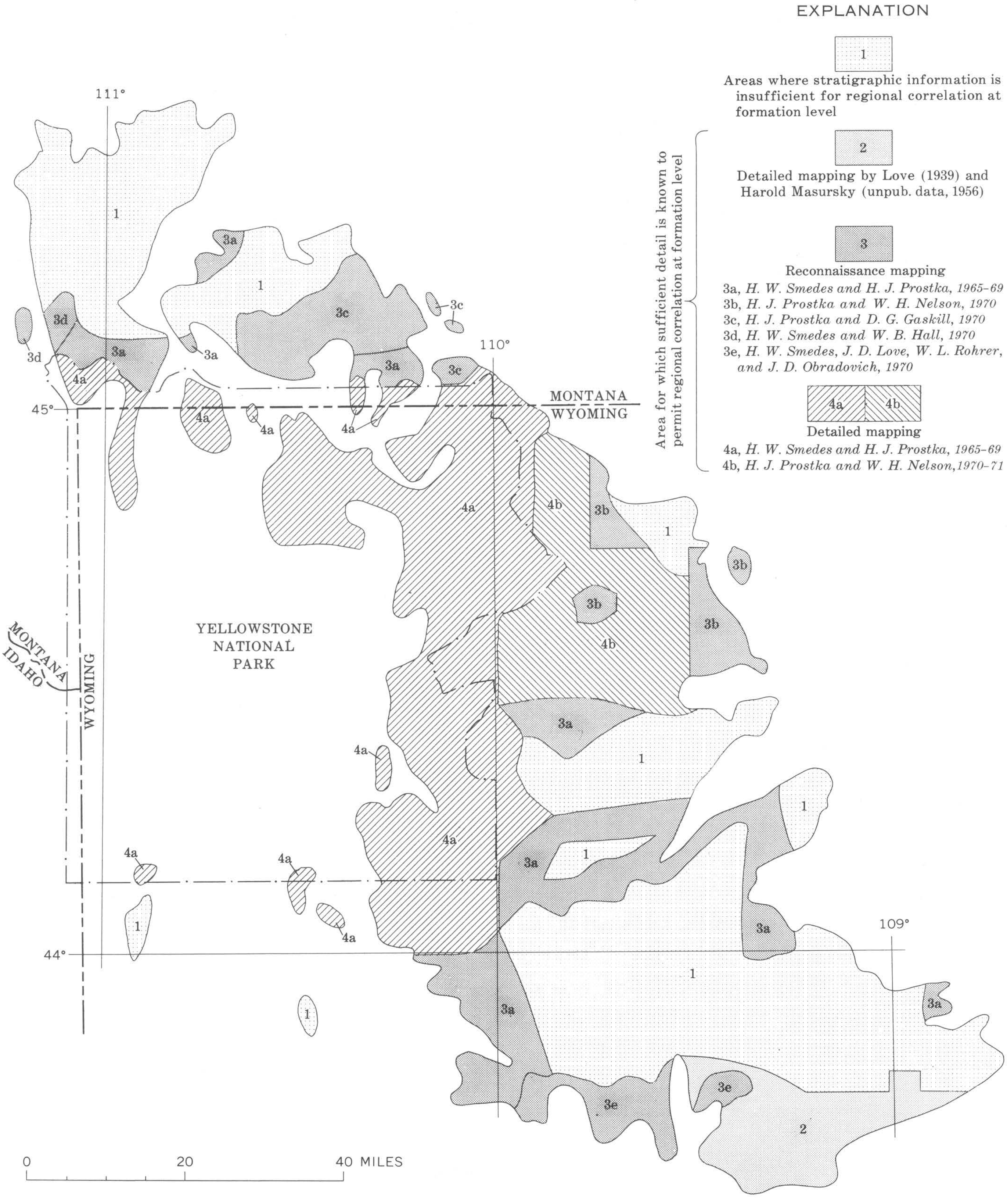


FIGURE 2. — Index map of the Absaroka volcanic field, showing extent of mapping and stratigraphic information.

formations and members constitute three natural stratigraphic groups, the need for an inclusive name dictated our choice of the term "supergroup."

ACKNOWLEDGMENTS

The broad stratigraphic framework of the Absaroka volcanic field was outlined late in the 19th century by the excellent pioneering work of Arnold Hague, J. P. Iddings, W. H. Weed, A. C. Peale, and their colleagues. We acknowledge our indebtedness to these early studies, as well as to the more recent published work which supplemented our own mapping. We extend special thanks to the following people for their stimulating discussions of the work as it was in progress, and for making available to us some of their unpublished data: I. S. E. Carmichael, R. A. Chadwick, B. R. Doe, F. S. Fisher, D. G. Gaskill, W. B. Hall, W. R. Keefer, J. D. Love, E. L. McCaskey, M. C. McKenna, W. H. Nelson, J. D. Obradovich, W. H. Parsons, Z. E. Peterman, W. G. Pierce, W. L. Rohrer, D. N. Rubel, C. H. Shultz, F. J. Vine, and W. H. Wilson. We were ably assisted with part of the mapping by Ivo Lucchitta, John M'Gonigle, and James Nicholls, each of whom contributed to the development of the concepts presented here. R. A. Chadwick, J. D. Love, M. C. McKenna, and W. H. Wilson also contributed as technical reviewers of the manuscript.

This report is one product of a comprehensive geological study of the entire Yellowstone National Park region conducted by many geologists under the overall direction of the late Arthur B. Campbell.

GENERAL GEOLOGIC RELATIONS

The Absaroka Volcanic Supergroup consists largely of calc-alkalic andesitic and dacitic extrusive rocks, of lesser amounts of potassic alkalic mafic lavas, and of minor amounts of rhyodacitic ash-flow tuffs associated with the mafic lavas. Small bodies of intrusive rocks are contemporaneous with the extrusive rocks. Where they can be genetically related to specific formations, these rocks are regarded as part of the supergroup; where their relationship is obscure; the intrusive rocks are regarded as being related to the supergroup, but are not included within it (U.S. Geological Survey, 1972). The stratified rocks are gently deformed and, in most places, rest unconformably on rocks ranging in age from Precambrian to Paleocene (Hague, Iddings, and others, 1899; Rouse, 1937; Love, 1939; Hall, 1961; Roberts, 1965; U.S. Geological Survey, 1972) that were strongly deformed locally during the Laramide orogeny.

As now known, the Absaroka Volcanic Supergroup consists, in ascending order, of the Washburn Group, the Sunlight Group, and the Thorofare Creek Group (fig. 3). The crude zonal distribution of these units reflects their progressive southward onlap onto the basement rocks (fig. 3; U.S. Geological Survey, 1972).

The Washburn Group is restricted to the northern part of the field and is the oldest part of the volcanic pile. It is overlapped, in most places unconformably, by the Sunlight and Thorofare Creek Groups (figs. 3, 4). Nearly everywhere, the Thorofare Creek Group overlies the Sunlight Group, but in the north-central part of the field, the lower part of the Thorofare Creek Group locally interfingers with the Sunlight Group or rests directly on the Washburn Group (figs. 3, 4, 5).

Petrologically, the Sunlight Group is the most mafic unit and contains the highest proportion of basaltic potassic rocks. Most of the rocks of the other groups are generally lighter colored and of andesitic and dacitic composition.

The vent areas for the volcanics were composite stratovolcanoes and shield volcanoes composed of autoclastic flow breccias, lava flows, mudflows, avalanche debris, and tuff (figs. 12, 13, 15). We refer to this chaotic assemblage of rock, which formed part of a volcanic cone, as vent facies (fig. 6). Primary dips of lava flows and breccias near the vents are commonly more than 30° and are locally irregular, although, in general, the rocks dip away from the vent centers. Stocks, plugs, laccoliths, and radial swarms of dikes are common features of most of the vent areas. Outward from the volcanic centers, the vent facies rocks interfinger with, and grade into, aprons of well-bedded reworked volcanic sedimentary rocks (figs. 6, 7), having primary dips of less than 5°—mainly volcanic conglomerate and breccia, volcanic sandstone and siltstone, and air-fall tuff (figs. 10, 11, 16). We refer to these deposits of tuff and reworked material as alluvial facies. This concept of vent and alluvial facies was first used in the Absaroka volcanic field by Parsons (1965, 1969) in the Sunlight-Crandall area (fig. 1). The classification and terminology used in this report for the volcaniclastic rocks are, for the most part, those proposed by Fisher (1960, 1961).

In the alluvial facies there is a general decrease in thickness of section, thickness of beds, and in clast size away from the volcanic centers, and a corresponding increase in the degree of sorting and rounding. Consequently, rocks of vent facies grade

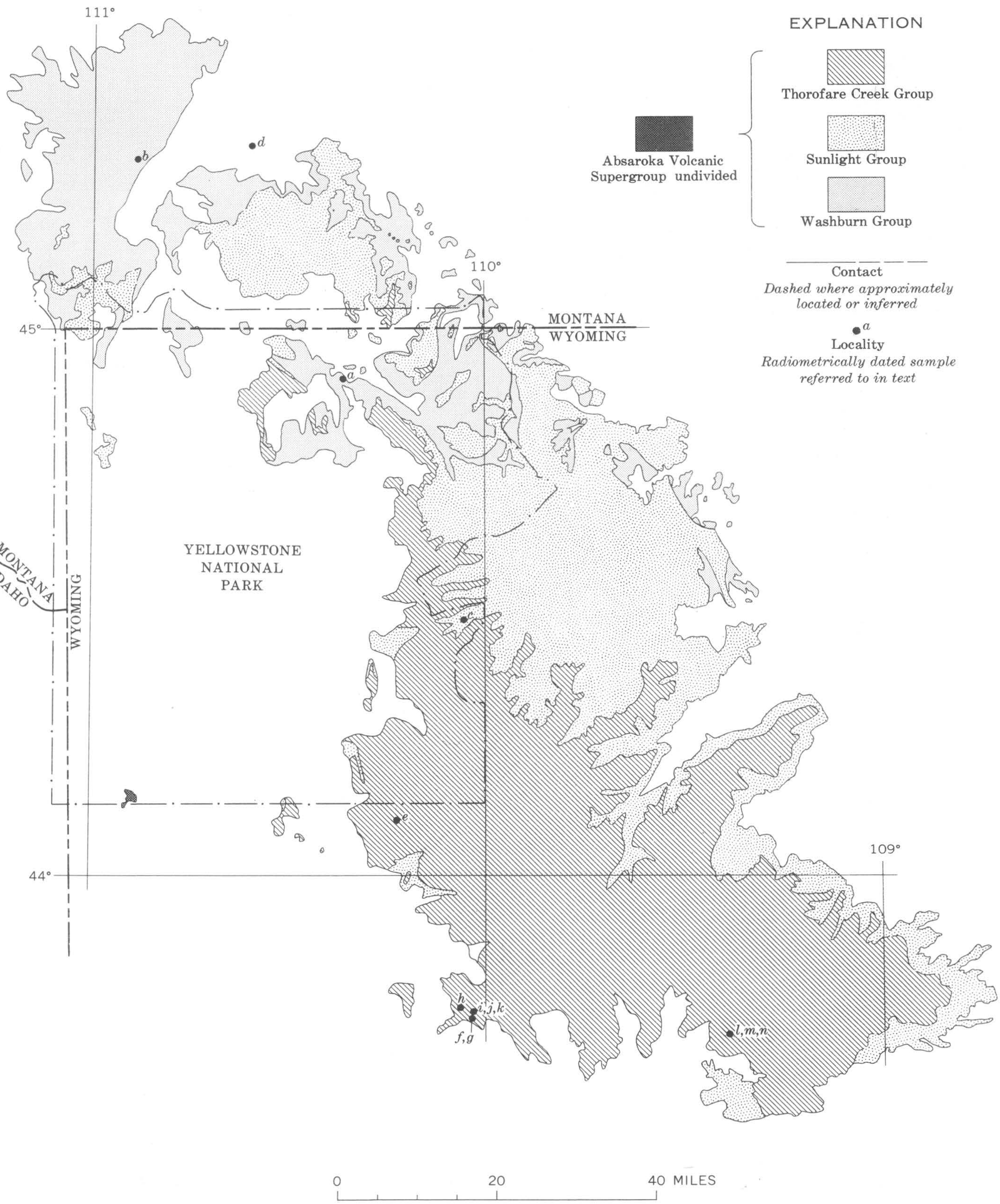


FIGURE 3. — Generalized geologic map of the Absaroka volcanic field. For simplicity, related intrusive rocks are not shown.

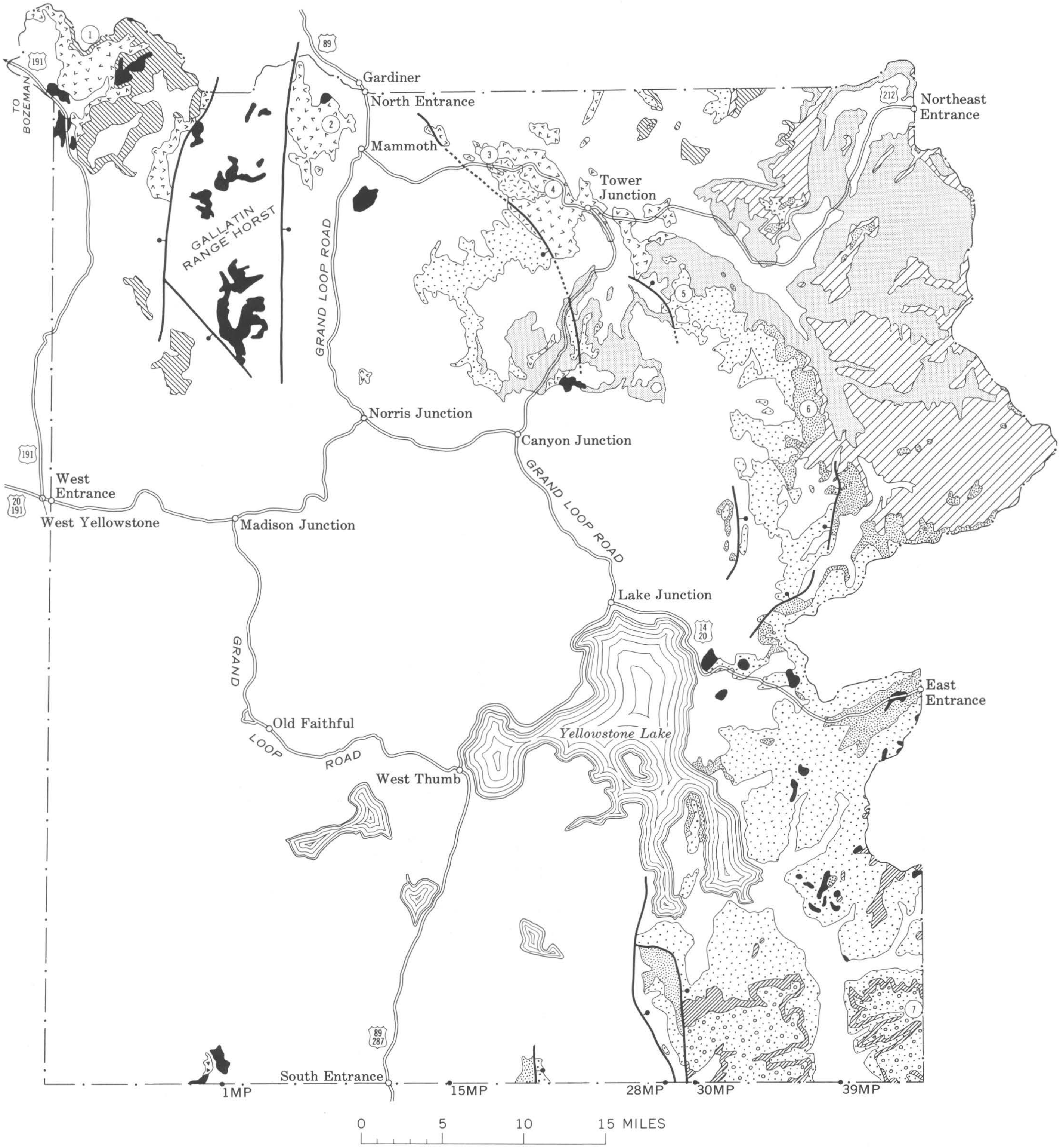


FIGURE 4. — Stratigraphic relations of the Absaroka Volcanic Supergroup and related intrusive rocks in Yellowstone National Park.

into coarse alluvial facies strata consisting mainly of volcanic conglomerates and breccias, which, in turn, grade outward into fine-grained alluvial facies beds containing a high proportion of volcanic sandstone and siltstone and air-fall tuffs (fig. 7). Because of their mobility, lava flows and some of the volcanic mudflows are laterally very extensive and occur in both the alluvial facies and the vent facies assemblages. Abundant fossil wood and standing stumps of trees are preserved in the alluvial facies,

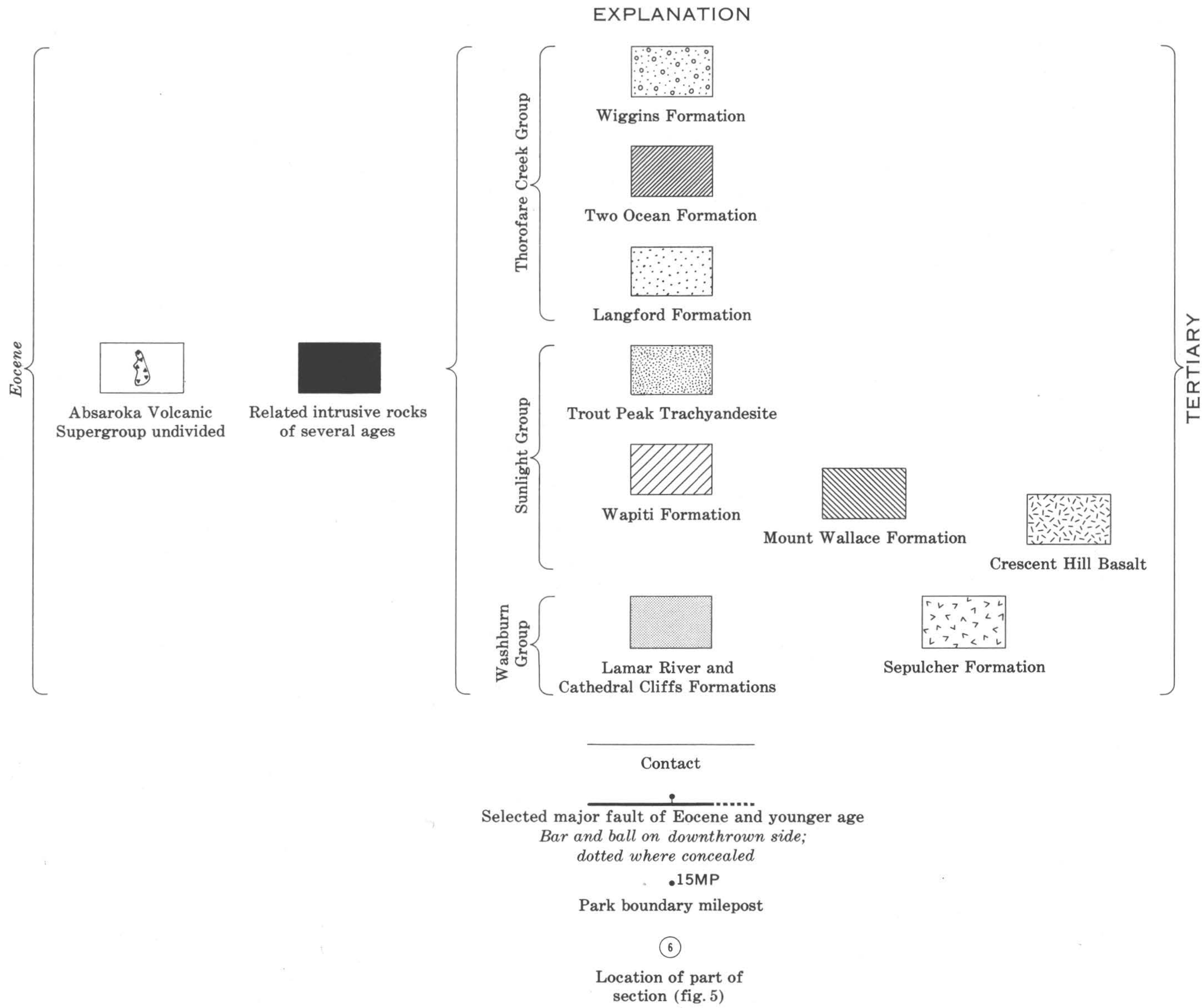


FIGURE 4. — Continued.

whereas only sparse fossil-wood fragments occur in the vent facies. Locally, forests were buried by, and preserved in, coarse mudflow deposits (Dorf, 1960, 1964; Wilson, 1965, fig. 23, p. 66). Fossil leaves are locally abundant in the fine-grained alluvial facies (fig. 10) and are moderately abundant in the vent facies (fig. 15), but they are virtually absent in the coarse alluvial facies from which the tuff and much of the finer grained epiclastic debris has been reworked basinward into the fine-grained alluvial facies. The massive coarsely bedded alluvial deposits (fig. 11) tend to be the most resistant to erosion. Vent facies deposits are somewhat less resistant and commonly erode to form hoodoo badlands (figs. 12, 15). Fine-grained alluvial deposits (fig. 10) are the least resistant to erosion and typically form subdued slopes.

Alluvial facies deposits are the lateral time equivalents of the vent facies deposits from which they were largely derived. Assemblages of vent facies and corresponding alluvial facies deposits are genetically related to pulses of volcanic activity. These somewhat heterogeneous, laterally variable units have been called "volcanogenic units" (Dickinson, 1968). In deciphering the history of a complex volcanic field, more can usually be learned from the mapping of these volcanogenic units than from delineating units that are lithologically uniform. Many of the formations and groups described in this report are volcanogenic units, which display considerable lat-

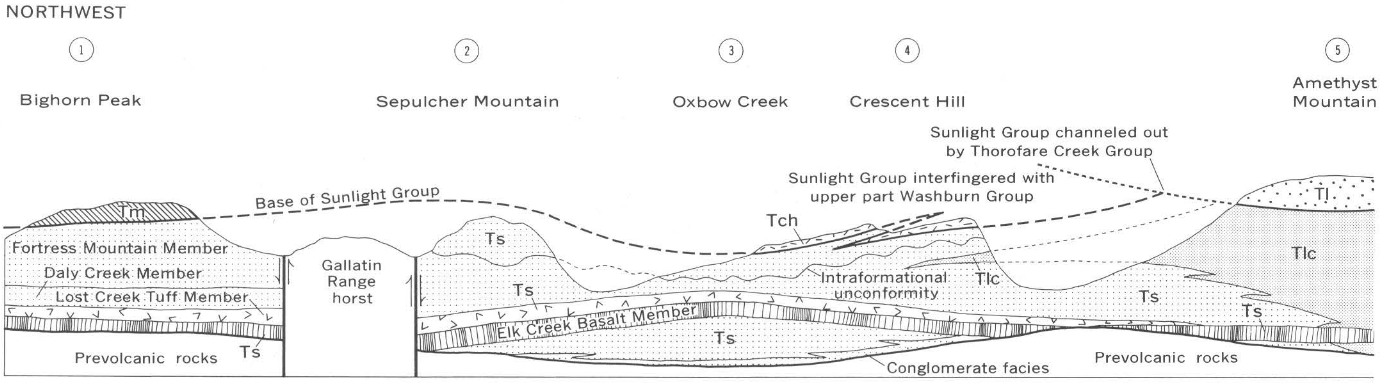


FIGURE 5.— Schematic section (not to scale) of part of Yellowstone National Park, showing stratigraphic relations in the faults which bound the Gallatin Range horst are shown. Circled numbers refer to localities shown in figure 4. Twi, Wiggins Tm, Mount Wallace Formation; Tch, Crescent Hill Basalt; Tlc, Lamar River and Cathedral Cliffs Formations undivided;

eral variation; therefore, it was not possible to designate a truly representative type section for each unit. Instead, as is customary in such terranes (Love, 1939, p. 79; Wilson, 1963, p. 13; Klepper and others, 1957, p. 32), we have designated type areas in which the fullest variety of rocks within the unit is exposed. Locations of representative sections of all formations and members are given, but detailed descriptions have deliberately been omitted from this general report.

Most of the formations consist of repetitious sequences of andesitic volcaniclastic rocks which, by themselves, are not distinguishable from one formation to another. For this reason, the recognition and mapping of many formations have depended to a large extent on tracing widespread unconformities and on mapping distinctive marker units, such as lava flows, within formations. Many of the groups and formations in the Absaroka volcanic field are bounded by major unconformities. Minor unconformities commonly occur within mapped units.

The base of the volcanic pile is at different stratigraphic levels from place to place because of the high relief on the prevolcanic surface and the effects of intravolcanic deformation and erosion. There is no single complete section of the volcanics; a composite section, about 12,000 feet thick, was pieced together from overlapping partial sections by using the distinctive flows and tuff beds as marker units to correlate the more widely separated sequences.

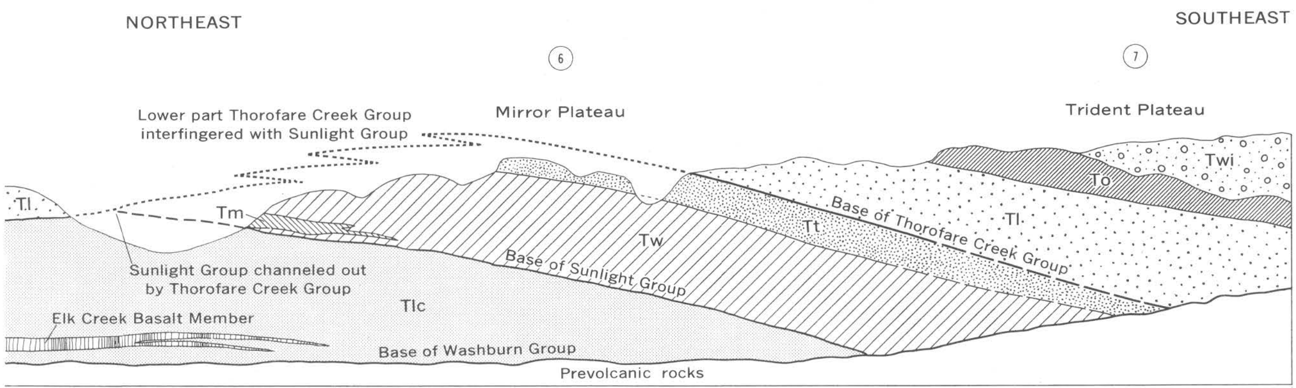
Rocks of the Absaroka Volcanic Supergroup in the Yellowstone National Park region are of early, middle and possibly late Eocene age (late Wasatchian, early Bridgerian, and possibly Uintan provincial age of Wood and others, 1941), as is indicated by fossils and numerous radiometric determinations (figs. 3, 8). The ages of individual units are discussed in detail in the sections that follow. Volcaniclastic rocks of early Oligocene and Miocene age, locally present south and southeast of Yellowstone National Park (Love, 1939, 1956a, b, c, d), previously have been regarded as part of the Absaroka volcanic field; however, because their distribution is not well known, they are not discussed in this report.

Studies of remanent magnetization are in progress. The available data indicate that most of the Washburn Group is of normal polarity, but that, high in the section in the northwestern part of the park, there is a reversal of short duration. Lavas of the Sunlight Group are normal except for a few in the lower part of the section which have reverse polarity. Because the lower part of the Sunlight Group is the same age as the upper part of the Washburn Group, the lavas of both groups may be recording the same magnetic events. Data on the Thorofare Creek Group are too sparse for any conclusions as to polarity.

WASHBURN GROUP

The name Washburn Group (new name) is proposed for the oldest part of the Absaroka volcanic pile. The group is named for the type area, the Washburn Range in north-central Yellowstone National Park, which is close to the center of known distribution of the group. These rocks make up much of the northern Absaroka Range, the Washburn Range, and the Gallatin Range (figs. 1, 3, 9).

The Washburn Group is more than 3,000 feet thick near vent areas in the Gallatin, northern Absaroka, and Washburn Ranges, and thinner elsewhere. The group consists mostly of lavas and related volcaniclastic strata composed of hornblende and pyroxene andesite, lesser amounts of biotite



Absaroka Volcanic Supergroup. Section extends from northwest to northeast (it bends 90°) to southeast. Only those Formation; To, Two Ocean Formation; Tl, Langford Formation; Tt, Trout Peak Trachyandesite; Tw, Wapiti Formation; Ts, Sepulcher Formation.

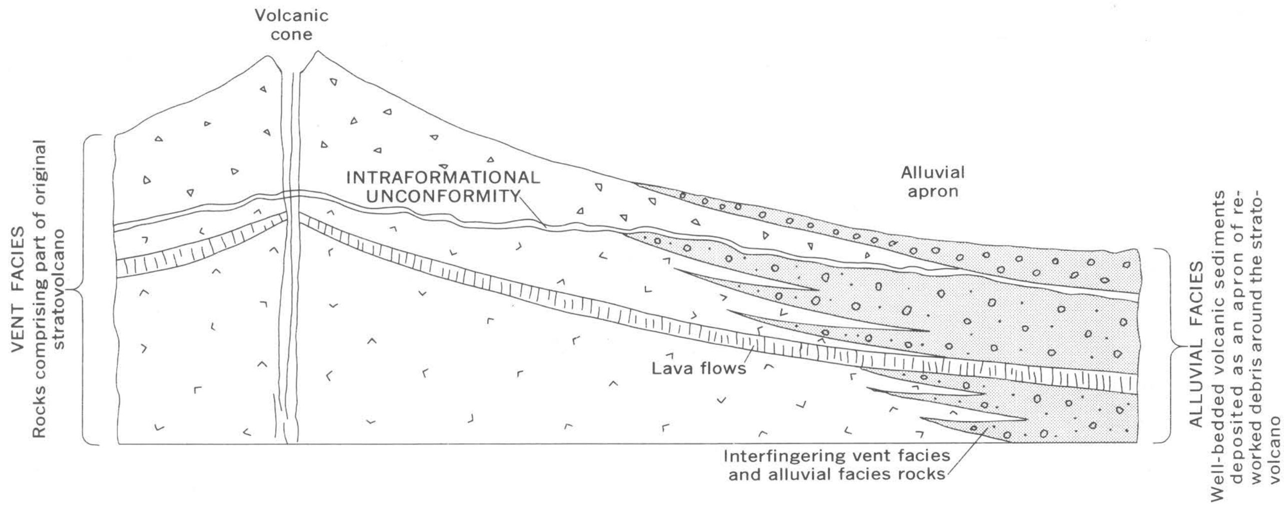


FIGURE 6. — Hypothetical cross section, showing relationships of vent facies and alluvial facies rocks.

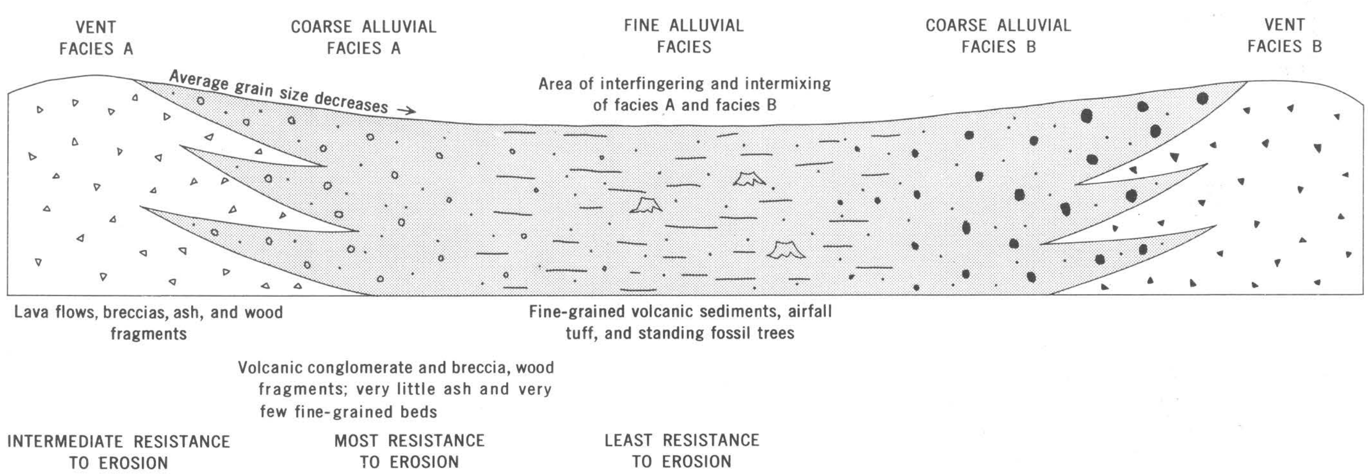
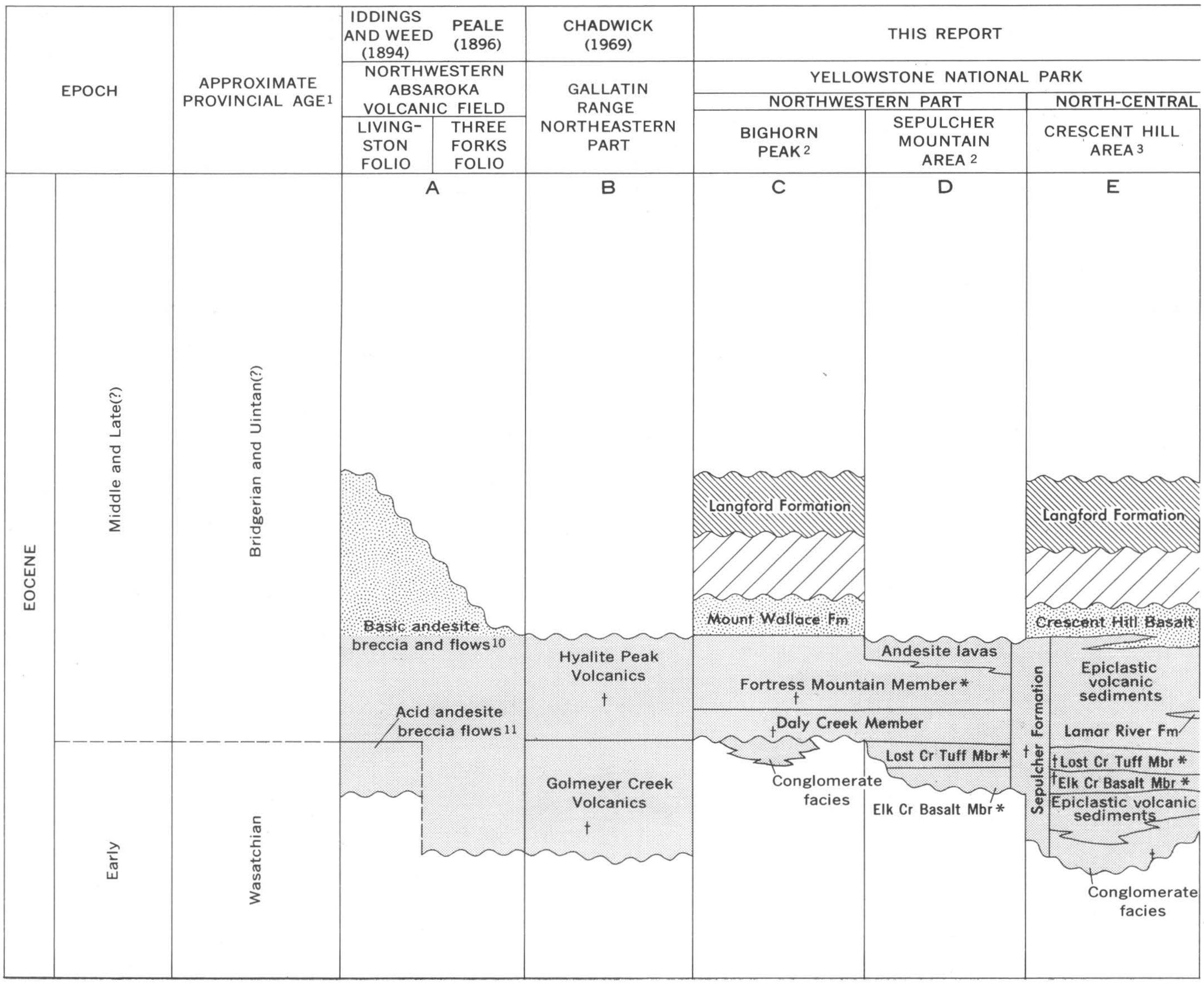


FIGURE 7. — Hypothetical cross section, showing facies relationships of two vent complexes (A and B) and the intervening volcanic sediments derived from them.



[1]Wood and others (1941).
[2]H. W. Smedes.
[3]H. J. Prostka.
[4]Upper part of Wiggins Formation.
[5]Wiggins, Two Ocean, and part of Langford Formations.
[6]Langford Formation.
[7]Trout Peak Trachyandesite.
[8]Wapiti, Langford, Mount Wallace, Lamar River, and part of Sepulcher Formations.
[9]Cathedral Cliffs, and parts of Lamar River and Sepulcher Formations.
[10]Mount Wallace, Hyalite Peak, Golmeyer Creek, and part of Sepulcher Formations.
[11]Part of Sepulcher, Golmeyer Creek, and Hyalite Peak Formations.

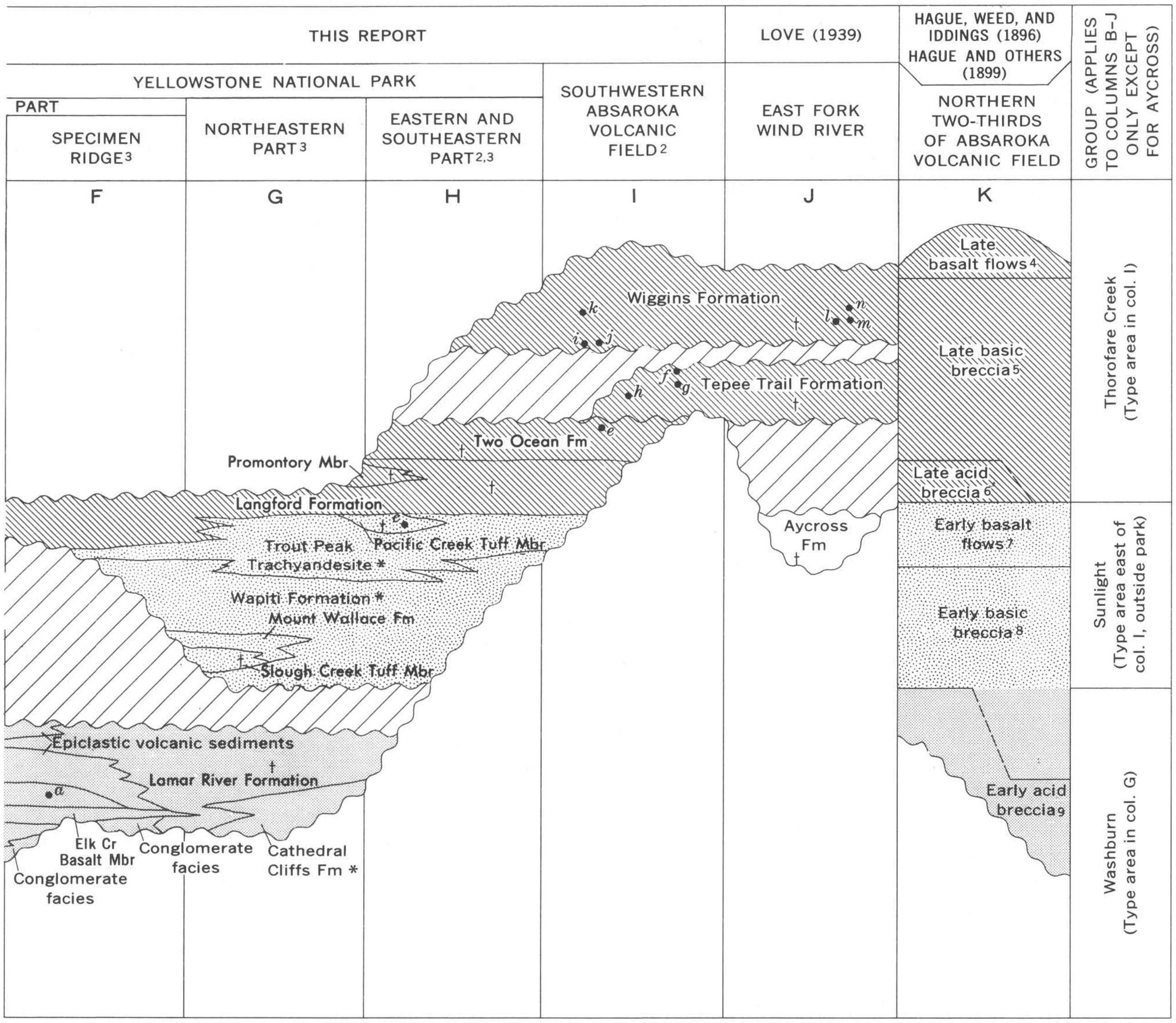
POTASSIUM-ARGON AGE DETERMINATIONS

[Age determinations, in millions of years, by J. D. Obradovich]

Locality	Age	Mineral	Locality	Age	Mineral	Locality	Age	Mineral
a	49.2±1.5	Sanidine.	*g*	49.3±1.4	Biotite.	*k*	44.4±1.4	Hornblende.
c	48.0±1.3	Biotite.	*h*	47.8±1.3	Sanidine.		45.5±1.3	Biotite.
e	47.9±1.3	Sanidine.		47.9±1.3	Biotite.	*l*	47.1±1.3	Do.
	48.5±1.3	Biotite.	*i*	46.2±1.8	Hornblende.	*m*	46.7±1.5	Do.
f	46.1±1.2	Sanidine.	*j*	46.5±2.3	Do.	*n*	44.6±1.2	Do.

FIGURE 8 (above and facing page).—Nomenclature, stratigraphic relations, and proposed correlation of units in the Absaroka Volcanic Supergroup in the park with units in adjoining areas. New names are in boldface; revised units are indicated by *; column in which the type area, locality, or section of a formation or member occurs is indicated by †. Vertical scale is not proportionate to thickness or time. (See fig. 3 for sample localities.)

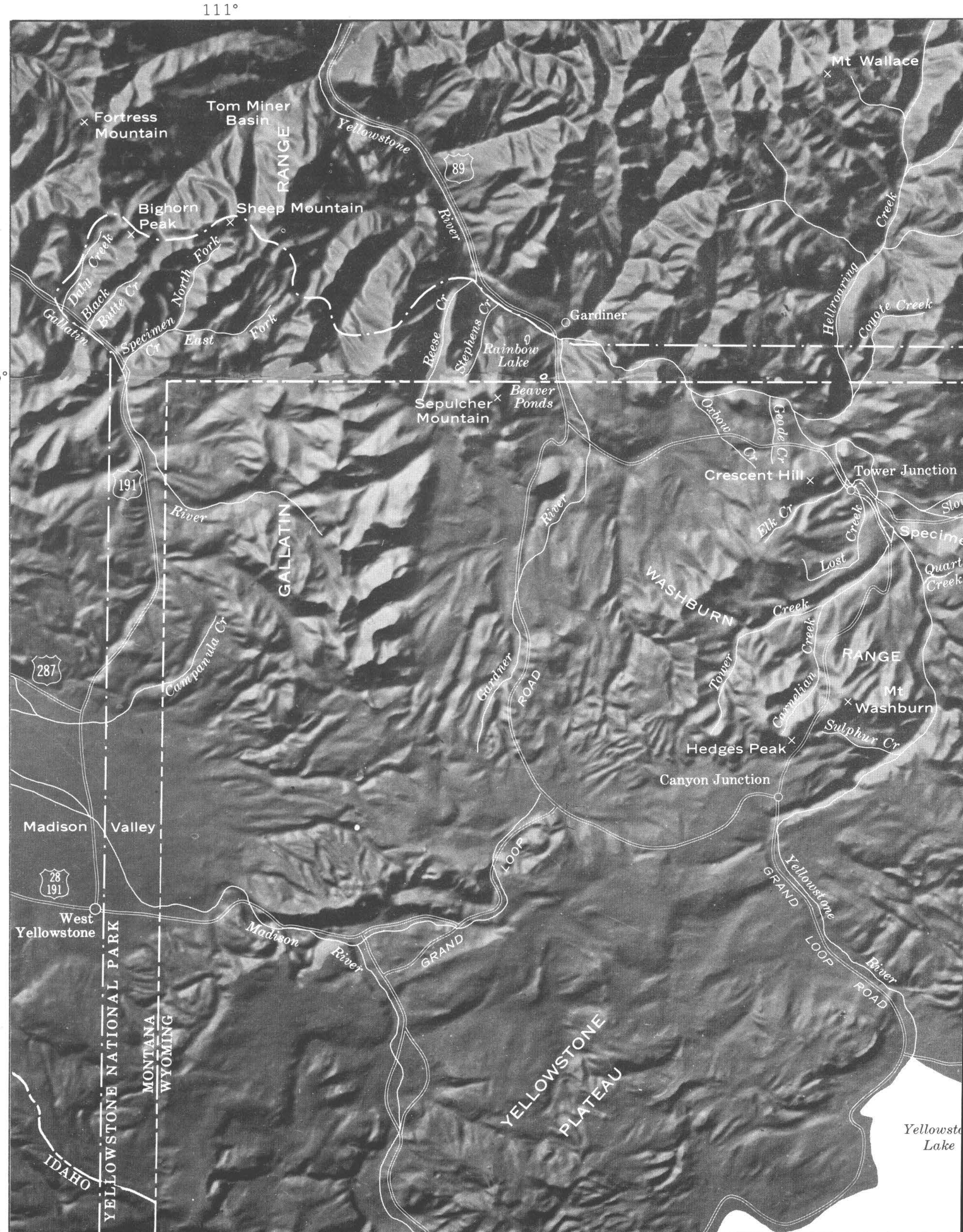
andesite and dacite, and minor amounts of basaltic lavas and rhyodacite ash-flow tuffs. Volcanics of the Washburn Group constitute the lower 1,500 feet or more of the volcanic section throughout northeastern Yellowstone National Park, where they form bold cliffs above the Lamar River and its tributaries.



Crescent Hill (fig. 9) and the southern part of the Washburn Range are other easily accessible exposures of these rocks. For several miles north of Gardiner, Mont. (fig. 9), these volcanics form the knobby reddish-brown hills west of the highway.

Most of the rocks of this group were erupted from several separate but nearly contemporaneously active centers whose deposits now comprise several laterally gradational, dominantly light-colored and dominantly dark-colored formations, which are volcanogenic units. Previously, the light-colored rocks were called early acid breccia or acid andesitic breccia and flows, and the dark-colored units were called early basic breccia, or basic andesite breccia and flows (Hague, 1899; Hague, Iddings, and others, 1899; Iddings and Weed, 1894; Peale, 1896).

The dominantly light-colored, locally biotitic Sepulcher Formation occurs in northwestern and north-central Yellowstone National Park (fig. 4). It grades southeastward into, and is partly overlain by, the darker colored nonbiotitic Lamar River Formation. The Elk Creek Basalt Member occurs in the lower part of both the Sepulcher Formation and the Lamar River Formation. The lower part of the Lamar River Formation interfingers northeastward with the light-colored Cathedral Cliffs Formation near the east boundary of the park. Near the northwestern part of the park, approximately the lower half of the Sepulcher Formation extends northward into the northern Gallatin Range and grades into the dark-colored Hyalite Peak Volcanics (Chadwick, 1969), also of the Washburn Group (fig. 8, col. B; McMannis and Chadwick, 1964). Locally, the Hyalite Peak Volcanics are underlain by the Golmeyer Creek Volcanics, which have no known correlatives in the park. The Golmeyer Creek Volcanics


111°
45°
Fortress Mountain
Tom Miner Basin
RANGE
Yellowstone
89
River
Mt Wallace
Bighorn Peak
Sheep Mountain
Daly Creek
Black Butte Cr
North Fork
Specimen Cr
East Fork
Gallatin
Reese Cr
Stephens Cr
Rainbow Lake
Gardiner
Hellroaring
Coyote Creek
Creek
Sepulcher Mountain
Beaver Ponds
Oxbow Cr
Geode Cr
Crescent Hill
Tower Junction
191
River
GALLATIN
River
Elk Cr
Lost Creek
WASHBURN
Creek
Creek
RANGE
Campanula Cr
287
Gardner
ROAD
Tower
Carnelian
Mt Washburn
Hedges Peak
Sulphur Cr
Canyon Junction
Madison Valley
28 191
LOOP
West Yellowstone
Madison
River
GRAND
Yellowstone
GRAND
LOOP
River
ROAD
YELLOWSTONE NATIONAL PARK
MONTANA
WYOMING
YELLOWSTONE PLATEAU
IDAHO

part of Yellowstone National Park and vicinity.

are the oldest rocks in the Washburn Group.

The Washburn Group unconformably overlies rocks of Precambrian to Paleocene age which have been strongly deformed during the Laramide orogeny (U.S. Geological Survey, 1972). The surface on which the volcanics rest is rugged; in many places the relief is as much as several hundred feet. Deformation of the Washburn Group is slight; structural tilt is generally less than 10° except locally near faults and later intrusives. Over most of the area, the Washburn Group either has an eroded top or is overlain by rocks of the Sunlight Group. Near Crescent Hill, however, uppermost strata of the Washburn Group interfinger with lavas of the Sunlight Group (fig. 5). In the Washburn Range and on Amethyst Mountain, the Sunlight Group is absent, and strata of the Thorofare Creek Group lie directly on rocks of the Washburn Group.

The Washburn Group is of early and middle Eocene age (Wasatchian and early Bridgerian provincial age). (See fig. 8.)

SEPULCHER FORMATION

The name Sepulcher Formation (new name) is here proposed for the dominantly light colored andesitic and dacitic rocks of the Washburn Group in the northwestern and north-central parts of Yellowstone National Park (fig. 4) and adjacent areas. The formation is named for the type area of Sepulcher Mountain (fig. 9), where the section is thick and well exposed. The upper half of the formation is coarse, rather dark vent facies. Other fairly accessible representative sections can be seen from the summit of Cresent Hill northward to the Yellowstone River and in the ridge 1 mile north of the mouth of Specimen Creek, in the northwestern part of the park (fig. 9). The Cresent Hill section and all but the basal 800 feet of the Specimen Creek section are of alluvial facies. The source for most of the Sepulcher Formation, as indicated by facies relations, was the area of the Gallatin Range horst (fig. 4). The laccolithic and crosscutting intrusive bodies of the Gallatin Range (fig. 4; U.S. Geological Survey, 1972) are chemically similar to the Sepulcher Formation and are of the same age. They are almost certainly subvolcanic intrusives that are genetically related to the Sepulcher Formation, but because their relationship to the extrusive rocks has not definitely been established, they are not included in the Absaroka Volcanic Supergroup.

The Sepulcher Formation was deposited on a surface having a relief of more than 500 feet. A basal conglomerate composed largely of Precambrian metamorphic rocks was deposited locally at different stratigraphic levels along the margins of bordering highlands. This basal conglomerate facies is overlain by a variety of andesitic and dacitic volcanic sediments which make up most of the Sepulcher Formation. Interlayered with the lower part of the Sepulcher Formation are trachybasalt lavas of the Elk Creek Basalt Member, overlain, in turn, by rhyodacite of the Lost Creek Tuff Member. In northwestern Yellowstone National Park, the andesitic volcaniclastic rocks above the Lost Creek Tuff Member are subdivided in this report into two units — the lower, light-colored Daly Creek Member (new name) and the upper, dark-colored Fortress Mountain Member (new name).

The Sepulcher Formation grades from dominantly vent facies near the Gallatin Range horst (fig. 4) to dominantly alluvial facies (fig. 10) in the northwestern and north-central parts of the park. Most sections also show an upward increase in vent facies aspect.

Fresh vent facies rocks are mostly dark reddish brown, brown, and gray, but where ash is abundant or where deuteric or hydrothermal alteration has been severe, the rocks are light colored — yellowish, greenish, and bluish gray and light gray.

In the northwestern part of the park (head of Daly Creek, fig. 9), the Sepulcher Formation thickens eastward from less than 1,000 feet to more than 2,300 feet; the Daly Creek Member grades from alluvial facies to vent facies; and the Fortress Mountain Member thickens from 800 to 1,400 feet and grades both eastward and upward from fine-grained alluvial facies to near-vent coarse alluvial facies.

The Daly Creek and Fortress Mountain Members extend north of the park as alluvial facies units to the vicinity of Fortress Mountain and Tom Miner Basin (fig. 9), where they contain a few lava flows (Todd, 1969; reconnaissance mapping by Smedes; W. B. Hall and R. A. Chadwick, written commun., 1969). The lower half of the Sepulcher Formation is probably correlative with the Hyalite Peak Volcanics (Chadwick, 1969), whereas the Golmeyer Creek Volcanics (Chadwick, 1969) are older and probably have no equivalents within the park.

At Sepulcher Mountain (fig. 9) the Sepulcher Formation is more than 3,000 feet thick and consists of coarse alluvial facies strata grading upward and southward into vent facies rocks. The upper 1,200 feet of section on Sepulcher Mountain consists of andesite lava flows and flow breccias, many of which contain conspicuous biotite phenocrysts. A nearly complete section of the formation is exposed in the spectacular cliffs on the north face of Sepulcher Mountain, which can be viewed from Gardiner.

FIGURE 10. — Thin-bedded fine-grained alluvial facies volcanic sandstone, siltstone, and air-fall tuff of the Sepulcher Formation along Quartz Creek, on the west side of Specimen Ridge (fig. 9).

From Sepulcher Mountain the formation thins eastward and grades from vent and coarse alluvial facies to fine-grained alluvial facies rocks in the vicinity of Crescent Hill (fig. 9). The thickest and best exposed section of the Sepulcher Formation in north-central Yellowstone National Park extends from the summit of Crescent Hill northward to the Yellowstone River, near the mouth of Hellroaring Creek (fig. 9). This section is about 1,900 feet thick; 1,200 feet of it consists of fine-grained alluvial facies volcanic sediments which were described in detail by Brown (1957), and 700 feet is the Elk Creek Basalt and Lost Creek Tuff Members.

At Oxbow Creek, 5 miles northwest of Crescent Hill, the Sepulcher Formation is only 500 feet thick because of a local, but prominent, intraformational unconformity (fig. 9). This unconformity can be seen along the road northwest of Crescent Hill. Coarse breccia and conglomerate, composed mainly of biotite-hornblende andesite fragments, discordantly overlie volcanic sandstone and siltstone. These coarse clastics probably are the lateral equivalent of the biotitic andesite flows and flow breccias which make up the upper part of the section at Sepulcher Mountain (fig. 8, col. D).

CONGLOMERATE FACIES

Coarsely bedded, dominantly nonvolcanic conglomerate and breccia and minor amounts of sandstone locally underlie and interfinger with the basal volcanic sediments of the Sepulcher Formation. The best exposed and most typical section is along the canyon of the Yellowstone River, just upstream from the mouth of Hellroaring Creek (fig. 9).

This distinctive conglomerate was previously referred to as Crandall(?) Conglomerate (Brown, 1961, p. 1175), as it was thought to be correlative with the Crandall Conglomerate (Pierce, 1957). However, that correlation is not valid, as the unit in the type area is a stream-channel deposit, made up almost entirely of clasts of Paleozoic carbonate rocks and predating the volcanic Cathedral Cliffs Formation. In contrast, the conglomerate facies of the Sepulcher Formation is a basin-margin fluvial deposit, composed of fragments of Precambrian igneous and metamorphic rocks, which underlies and interfingers with volcanic sediments of the same age as those of the Cathedral Cliffs Formation.

The conglomerate facies is patchy in distribution and seems to be restricted to the north-central and northwestern parts of Yellowstone National Park. A 40-foot tongue of the conglomerate is interlayered with ash flows of the Lost Creek Tuff Member along Geode Creek (fig. 9). Along the Lamar River, near the confluence with Slough Creek (fig. 9), the conglomerate directly underlies the Lost Creek Tuff Member and contains a bed of crossbedded crystal-vitric tuff compositionally like the Lost Creek. Other occurrences of the basal mainly nonvolcanic conglomerate and fanglomerate or breccia are present on the north spur of Sepulcher Mountain, between Reese and Stephens Creeks; near the head of Daly Creek in the Gallatin Range; in the Washburn Range along Carnelian Creek; and on the southeast flank of Hedges Peak, just above the Grand Loop Road. At the last-named locality, the conglomerate contains quartzite pebbles like those of the Pinyon Conglomerate of Cretaceous and Paleocene age (Hague and others, 1896; Love, 1947), as well as Precambrian clasts.

At the head of Campanula Creek (fig. 9), in the northwestern part of the park, is a unit of dominantly chert-pebble conglomerate several tens of feet thick and containing sparse volcanic fragments, which we refer to the conglomerate facies. The deposit rests on Precambrian rocks; its top is eroded, but it is topographically just below the base of volcanic strata less than 1 mile away.

The widespread occurrence of the conglomerate facies throughout more than 450 feet of the lower part of the Sepulcher Formation near its onlap onto prevolcanic rocks suggests that the conglomerate facies is a time-transgressive, mainly nonvolcanic marginal facies of the Sepulcher Formation. Where the conglomerate facies is absent, the lower 250–300 feet of the Sepulcher Formation commonly contains sparse to abundant locally derived nonvolcanic fragments.

A thin black shale bed in the conglomerate facies near the mouth of Hellroaring Creek contains plant remains of Eocene age (Estella Leopold, written commun., 1967).

ELK CREEK BASALT MEMBER

The Elk Creek Basalt was named by Howard (1937) for exposures west of Elk Creek, northeast of Crescent Hill (fig. 9). At the type locality, the unit consists of four or more dark-reddish-brown to black lava flows and flow breccias of potassic basalt or shoshonite containing abundant large phenocrysts of plagioclase and augite. Howard (1937) and, later, Brown (1961) miscorrelated the type Elk Creek Basalt with upper Cenozoic phenocryst-poor olivine basalts, and from this concluded that the Elk Creek Basalt and overlying Lost Creek Tuff were late Cenozoic in age. Our mapping, however, shows that the Elk Creek Basalt is interlayered with the lower part of the Sepulcher Formation and with the Lamar River Formation; hence, we redefine it as a member of both formations.

The Elk Creek Basalt Member — as a member of the Sepulcher — is sporadically present along the northeast base of Sepulcher Mountain and is well exposed near the road north and northwest of Crescent Hill and along Coyote Creek in the north-central part of the park (fig. 9). To the southeast the Elk Creek is present in the lower part of the Lamar River Formation along the Lamar River and along Soda Butte, Pebble, Cache, and upper Miller Creeks, but it is absent in the southern Washburn Range (fig. 9).

Where the Elk Creek Basalt Member occurs in the Sepulcher Formation, its lava flows rest directly on one another with few or no interbedded volcanic sediments; in the Lamar River Formation, however, there are volcaniclastic sequences as much as 320 feet thick separating the four lava flows of the Elk Creek Basalt Member. Locally, some of the flows pinch out, and there are as few as two. The Elk Creek Basalt Member as defined herein includes only the lava flows, not the sedimentary interbeds. The maximum aggregate thickness of these flows is about 300 feet.

In the Sepulcher Mountain region, the Elk Creek Basalt Member ranges in thickness from a few feet to about 60 feet and is discontinuously exposed along the northeast base of Sepulcher Mountain, from Beaver Ponds northwestward to about 1 mile beyond Rainbow Lake (fig. 9). Fraser, Waldrop, and Hyden (1969, p. 41, pl. 1) mapped some of these exposures and interpreted the basalts to be younger than the rocks which we assigned to the Lost Creek Tuff Member. However, these basalts are not in contact with other volcanic rocks in any of the exposures that they mapped (Fraser and others, 1969). Our subsequent studies in the same area and in an area to the south, near Beaver Ponds, disclosed several outcrops in which the basalts are unconformably overlain by the Lost Creek Tuff Member, which, in turn, is overlain by the Daly Creek Member of the Sepulcher Formation.

The Elk Creek Basalt Member rests on volcanic sediments of the basal part of the Sepulcher and Lamar River Formations, or directly on prevolcanic rocks. It is overlain by the Lost Creek Tuff Member as far east as Specimen Ridge; east and southeast of there, it is overlain by the Lamar River Formation.

The Elk Creek Basalt Member is approximately the same age — early or early middle Eocene — as the Sepulcher and Lamar River Formations with which it is interlayered. It is overlain by the Lost Creek Tuff Member, which is dated as 49.2±1.5 m.y. (million years).

LOST CREEK TUFF MEMBER

The Lost Creek Tuff Member was first called trachytic rhyolite by Hague, Weed, and Iddings (1896) and by Hague, Iddings, and others (1899); it was named Lost Creek Trachyte by Howard (1937) and Lost Creek Tuff by Brown (1961). The type area is near Lost Creek, northwest of Tower Junction (fig. 9). Both Howard and Brown thought the Lost Creek Tuff was late Cenozoic in age because it overlies exposures of Elk Creek Basalt, which they interpreted to be upper Cenozoic intracanyon basalt flows. Our mapping shows the tuff to be interlayered with the lower part of the Sepulcher Formation and, hence, of Eocene age, as originally suggested by Hague, Weed, and Iddings (1896). For this reason, we have redefined it as a member of the Sepulcher Formation.

The Lost Creek Tuff Member is a sequence of yellowish-gray rhyodacite welded ash-flow sheets containing abundant phenocrysts of sanidine, andesine, and biotite, and sparse amounts of hornblende, but few or no phenocrysts of quartz. Flattened pumice, rock fragments — mainly of Precambrian metamorphic rocks — and charred wood, are common. The columnar and platy-jointed central densely welded zone is best exposed; the upper and lower partly welded zones are rarely exposed in the type area.

The Lost Creek Tuff Member is present at or near the base of the Sepulcher Formation along the north flank of Sepulcher Mountain and throughout the north-central part of the park as far south as the southern Washburn Range, and as far east as the mouth of Lamar Canyon (fig. 9). The unit is well exposed along Quartz Creek, west of Specimen Ridge; in the gravel pit north of Crescent Hill; and north of Sepulcher Mountain, at the base of the long low ridge between Reese and Stephens Creeks (fig. 9).

The Lost Creek Tuff Member is about 350 feet thick near the type area; it thins eastward and pinches out northeast of Specimen Ridge (fig. 9). It thickens westward to a maximum of about 1,000 feet north of Sepulcher Mountain, between Reese and Stephens Creeks (fig. 9), where it consists of three units that rest unconformably on Upper Cretaceous rocks equivalent to the Livingston Group (called Landslide Creek Formation by Fraser and others, 1969). The lower unit is 400–500 feet thick and consists of dozens of biotite rhyodacite nonwelded and welded ash-flow tuffs, a few inches to a few tens of feet thick, interlayered with tuffaceous sandstone and siltstone; the ash-flow tuffs become thicker (as much as 100 ft) and more densely welded upward. The lower ash-flow tuffs contain abundant fragments of Precambrian metamorphic rocks and locally contain charred logs. The middle unit rests unconformably on the lower unit, and consists of thick sheets of coarse block and ash-avalanche breccia intercalated with thin tuffaceous sandstones. The upper unit rests unconformably on the middle unit, and consists of about 80 feet of andesite lava flows overlain by 20–25 feet of poorly welded ash-flow tuff. Southward, the middle and upper units are eroded away, and the lower unit is directly overlain by the Daly Creek Member.

Calvert (1912) proposed the name Reese Formation for a sequence of strata that includes the Cretaceous sandstone and conglomerate, a lens of the conglomerate facies, and the lower and middle units of the Lost Creek Tuff Member. The upper unit of the Lost Creek Tuff Member and the remainder of the Sepulcher Formation were called "igneous flows" (Calvert, 1912, p. 411). The name Reese Formation is abandoned, as suggested by Pierce (1963, p. 19).

Because of rugged prevolcanic topography, the Lost Creek Tuff Member rests on a variety of rocks — prevolcanic rocks, the conglomerate facies, and the Elk Creek Basalt Member. It is overlain by volcanic sediments of the Sepulcher Formation.

Potassium-argon dating of sanidine phenocrysts from the Lost Creek Tuff Member on Specimen Ridge (fig. 9) by J. D. Obradovich (written commun., 1968) yielded a late Wasatchian or early Bridgerian provincial age of 49.2±1.5 m.y. (figs. 3 and 8, loc. *a*).

DALY CREEK MEMBER

The name Daly Creek Member (new name) is here proposed for the lower part of the Sepulcher Formation in the Bighorn Peak region of the southern Gallatin Range (fig. 1; fig. 8, col. C). It is a sequence of light-colored volcaniclastic strata unconformably overlying highly deformed rocks of Late Cretaceous or Paleocene age (Hall, 1961) and underlying the Fortress Mountain Member. It consists of hornblende andesite, pyroxene andesite, and hornblende pyroxene andesite volcaniclastic rocks of vent and alluvial facies. The type area is the headwaters region of Daly Creek in the northwest corner of the park (fig. 9). The Daly Creek Member consists of more than 800 feet of vent facies rocks near the mouth of Specimen Creek and grades northwestward to about 400 feet of fine-grained alluvial facies strata on the ridge at the head of Daly Creek (fig. 9).

Northward from there, Hall (1961) mapped a sequence of strata, as much as 2,000 feet thick, of dominantly alluvial facies, which may include the Lost Creek Tuff Member and older rocks, as well as the Daly Creek Member as here defined.

The Daly Creek Member is equivalent to the upper part of the unnamed lower member of Hall (1961, p. 89–91; this report, fig. 8). A welded-tuff sheet in the upper part of that sequence probably correlates with the Lost Creek Tuff Member.

At the head of Black Butte Creek (fig. 9) vent facies breccias of the Daly Creek Member contain fragments of Precambrian metamorphic rocks. North of the junction of East and North Forks Specimen Creek (fig. 9), there are spectacular exposures of dozens of horizons of fossil forests in the upper part of the Daly Creek Member and throughout the Fortress Mountain Member. Biotite is common, though inconspicuous, in the fine-grained pumice and ash matrix of the coarse alluvial facies conglomerates in that section.

Strata in the Sepulcher Mountain region which, on the basis of stratigraphic position and facies trends, are correlated with the Daly Creek Member, are 600–800 feet of dark volcanic conglomerate and mudflow breccia of vent and coarse alluvial facies. These are well exposed in the lower part of the north face of Sepulcher Mountain.

The Daly Creek Member is of late Wasatchian or early Bridgerian provincial age: it rests directly on the Lost Creek Tuff Member which has been dated as 49.2±1.5 m.y., and is overlain by the Fortress Mountain Member, which contains plant fossils reportedly of early middle Eocene age (Hall, 1961).

FORTRESS MOUNTAIN MEMBER

The name Fortress Mountain Member is proposed for the upper, darker colored part of the Sepulcher Formation that overlies the Daly Creek Member. The type area is at Bighorn Peak (fig. 9).

The Fortress Mountain Member in the type area is mostly dark-gray coarse alluvial facies andesitic volcaniclastic rocks containing abundant hornblende and lesser amounts of pyroxene and biotite. The member is divided into three informal units that are well exposed on the south slope of Bighorn Peak: upper and lower dark-gray cliff-forming units of crudely bedded, poorly sorted conglomerate, and a middle unit of light-gray poorly resistant conglomerate with varicolored clasts in an ashy matrix. All three units contain tuffaceous sandstone, siltstone, and mudstone and abundant petrified trees concentrated in more than 30 distinct fossil forest horizons. These fossil forests are well exposed north of the junction of the East and North Forks Specimen Creek (fig. 9; U.S. Geological Survey, 1972). Many of the trees exceed 4 feet in diameter and are preserved upright in their growth position. They are probably of early middle Eocene age (Hall, 1961).

About 2 miles northeast of Bighorn Peak is a 5° local angular unconformity between the middle and upper units of the Fortress Mountain Member, resulting in a southwestward wedgeout of the middle unit and an eastward thickening of the upper unit. Except for this local feature, the three units appear to be conformable.

In the Sepulcher Mountain region (fig. 9), strata thought to be correlative with the Fortress Mountain Member are 800–1,200 feet thick. They consist of alternating vent and alluvial facies rocks (though dominantly vent facies) which rest unconformably on vent facies rocks correlated with the Daly Creek Member. This sequence in the Sepulcher Mountain region becomes more ventlike southwestward.

The Fortress Mountain Member extends north of the park into the northern Gallatin Range, and probably is equivalent to the Hyalite Peak Volcanics (R. A. Chadwick, written commun., 1969; Smedes, reconnaissance mapping, 1970).

ANDESITE LAVAS

The andesite lavas occur only in the uppermost 1,200 feet of the Sepulcher Formation on Sepulcher Mountain (fig. 9). This unit consists of complexly interlayered biotite-hornblende andesite lava flows, breccias, and tuff resting unconformably on the Fortress Mountain Member. This unconformity has a relief of more than 400 feet and an angular discordance of 10°–20°. The proportion of lava flows and flow breccias to mudflow breccias increases north and northwestward from the summit area.

The lavas in approximately the upper half of this unit are normally magnetized, but those in the lower part are of reverse polarity. The polarity of the underlying Fortress Mountain Member is unknown, but the Elk Creek Basalt Member near the base of the Sepulcher Formation is of normal polarity, so there must be a magnetic reversal in the interval between the Elk Creek Basalt Member and the base of the andesite lavas of Sepulcher Mountain.

In the Crescent Hill and Oxbow Creek areas (fig. 9; fig. 8, col. E), the top of the Sepulcher Formation consists of coarse andesite breccia and conglomerate that are lithologically very similar to the andesite lavas of Sepulcher Mountain. This coarse alluvial facies rests unconformably on well-bedded epiclastic volcanic sandstone and is considered to be a rubble facies of the andesite lavas of Sepulcher Mountain.

AGE

The Sepulcher Formation grades laterally to the south and southeast into the Lamar River Formation by interfingering and intermixing (figs. 5, 8). A westward-thinning tongue of the Lamar River Formation extends from near Tower Junction to the northwest end of Crescent Hill (fig. 9). Tongues of the Sepulcher Formation underlie the Lamar River Formation at Specimen Ridge and in the southern Washburn Range (fig. 9); in some places the contact between these formations is gradational, and in other places it is abrupt and discordant. In the Crescent Hill–Oxbow Creek area (fig. 9), the uppermost part of the Sepulcher Formation intertongues with Crescent Hill Basalt, a formation belonging to the Sunlight Group.

Dorf (1960, p. 258) reported that the fossil flora from the early acid breccia (part of the Sepulcher Formation in this report) in north-central Yellowstone National Park "is interpreted as spanning the time interval between late early Eocene and early middle Eocene as presently understood, i.e., late Wasatchian to early Bridgerian." An assemblage of fossil leaves from the Fortress Mountain Member has been reported as probably early middle Eocene (Hall, 1961). Radiometric ages are in remarkably good agreement. Potassium-argon age determinations on sanidine from the Lost Creek Tuff Member in the lower part of the Sepulcher Formation (figs. 3, 8) gave an age of 49.2±1.5 m.y. (J. D. Obradovich, written commun., 1968). Biotite from the Big Creek stock in the Gallatin Range (figs. 3, 9) was dated by Obradovich at 49.5±1.5 m.y. (Chadwick, 1969). This stock cuts the Hyalite Peak Volcanics, which are a lateral equivalent of the lower half of the Sepulcher Formation.

LAMAR RIVER FORMATION

The name Lamar River Formation is here proposed for a sequence of medium-brown andesitic lavas and volcaniclastic rocks and minor mafic lava flows (Elk Creek Basalt Member — which is also a member of the Sepulcher Formation) in north-central and northeastern Yellowstone National Park (fig. 4) and vicinity. The formation is named and the type area selected for exposures along the rugged valley walls of the Lamar River and its tributaries (fig. 9), where nearly all of the lithologic variation in the formation is displayed. The Lamar River Formation was formerly included in the early basic breccia of Hague, Iddings, and others (1899). The lower, slightly lighter colored part of the early basic breccia in northeastern Yellowstone National Park is the Lamar River Formation. It is overlain with slight unconformity by the darker colored, more massively bedded breccias of the Wapiti Formation (Sunlight Group), which are the upper part of the early basic breccia.

Throughout most of its extent, the Lamar River Formation consists of well-bedded coarse alluvial facies volcanic conglomerates, breccias, and tuffs that contain some of the most impressive and best preserved fossil forests in the park. Representative sections can be seen in the northeast side of Specimen Ridge (fig. 11), and the lower half of the valley walls of Soda Butte Creek. Most of Barronette Peak and Abiathar Peak (fig. 9) near the northeast entrance to the park are made up of the Lamar River Formation. These strata are the coalesced deposits of epiclastically reworked material and air-fall tuffs derived from several andesitic volcanoes. Only one of these source volcanoes is now exposed in Yellowstone National Park — the Mount Washburn volcano (Shultz, 1963, 1969). The southern Washburn Range is the deeply eroded north flank of this composite stratovolcano and consists of vent facies lava flow, flow breccia, and debris flow deposits having primary dips of as much as 30°. The old road from Canyon Junction to the summit of Mount Washburn and the Grand Loop Road north of Sulphur Creek (fig. 9) are good places to see the vent facies of the formation. These vent facies rocks grade northward and eastward into strata of alluvial facies.

The famous fossil forests on Specimen Ridge (fig. 9) are preserved in strata of the Lamar River Formation. The remnants of these fossil forests cover an area of more than 40 square miles. Many hundreds of petrified trees in at least 27 different horizons were observed by Dorf (1964). Most of these are stumps which are still standing upright in their original growth position. In addition to the tree trunks, thousands of fossilized leaves, twigs, needles, cones, and seeds of more than 100 different species of trees and shrubs have been found (Dorf, 1964).

South of Mount Washburn along Sulphur Creek (fig. 9) is a plug of fine- to medium-grained diorite. Dikes of andesite similar to the lavas of the Mount Washburn volcano radiate from this plug, which is in the core of the volcano (U.S. Geological Survey, 1972). The plug probably is an intrusive phase of the Lamar River magmas.

Brecciated andesite intrusives, from a few tens of feet to more than 5 miles across, are locally present in the lower part of the Lamar River Formation; these intrusives occur as sheets and lenses and, less

FIGURE 11. — Well-bedded alluvial facies volcanic breccias, conglomerates, sandstones, and air-fall tuff of the Lamar River Formation in the Fossil Forest, along the northeast side of Specimen Ridge (fig. 9).

commonly, as irregular bodies. They are thickest and most abundant in the northeast corner of Yellowstone National Park, where they constitute as much as 1,000 feet of the total section (U.S. Geological Survey, 1972).

The Lamar River Formation is thickest in the southeastern part of the Washburn Range, where the vent facies deposits are more than 3,200 feet thick. In general, the alluvial facies deposits are thinner, ranging from a maximum thickness of 2,200 feet along Soda Butte Creek to less than 500 feet along Slough Creek.

In the Specimen Ridge area, the Lamar River Formation grades laterally westward into the Sepulcher Formation. In the northeastern part of the park, northeastward-thickening tongues of the light-colored Cathedral Cliffs Formation interfinger with the lower one-third of the Lamar River Formation (fig. 8, col. G; U.S. Geological Survey, 1972).

The Lamar River Formation is the basal volcanic unit in much of northeastern Yellowstone National Park; it overlies rocks ranging in age from Precambrian to middle Eocene. In the Washburn Range, the Lamar River Formation unconformably overlies faulted and tilted strata of the Sepulcher Formation. This local angular unconformity, like many others in the Absaroka field, probably reflects local volcano-tectonic deformation and a geologically insignificant break in time.

The Lamar River Formation is unconformably overlain by the Langford Formation on Amethyst Mountain and in the Washburn Range. East of Amethyst Mountain, rocks of the Sunlight Group (Wapiti Formation) unconformably overlie the Lamar River Formation. This unconformity is slightly angular and has as much as 1,000 feet of erosional relief.

AGE

The Lamar River Formation is late Wasatchian to early Bridgerian provincial age (late early Eocene to early middle Eocene), as it grades laterally into the well-dated Sepulcher Formation of that age. Dorf (1960, p. 259) assigned the Lamar River fossil flora an early Bridgerian age.

CATHEDRAL CLIFFS FORMATION

The name Cathedral Cliffs Formation was introduced by Pierce (1963) to replace the early acid breccia of Hague, Weed, and Iddings (1896) and Hague, Iddings, and others (1899). At the type section at Cathedral Cliffs, some 17 miles east of the park (fig. 9), the formation is exposed in an allochthonous Heart Mountain fault block (Pierce, 1963), but Pierce's suggested correlation of this section with rocks we call Sepulcher Formation is supported by our mapping. We have used the name Cathedral Cliffs Formation for the light-colored basal volcaniclastic rocks only in the northeast corner of the park because the laterally equivalent dark-colored Lamar River Formation intervenes between this area and that of the Sepulcher Formation. Moreover, the Sepulcher and Cathedral Cliffs Formations were derived from different sources, and, thus, are different volcanogenic units.

The Cathedral Cliffs Formation occurs primarily east and north of the park, but southwestward-thinning tongues of the Cathedral Cliffs Formation are present in the lower part of the Lamar River Formation in the northeastern part of the park.

East of the park, the Cathedral Cliffs Formation is dominantly light-colored fine-grained alluvial facies volcanic sandstone, tuff, breccia, and conglomerate that occur as parts of Heart Mountain fault blocks. North of the park the formation is autochthonous, and it thickens and coarsens toward a northwest-trending line of vents extending from Independence to Daisy Pass (fig. 9).

The Cathedral Cliffs Formation is 500 feet thick at the type section and somewhat thicker in other areas east of the park (Pierce, 1963, p. 15).

AGE

Pierce (1963, p. 16) considered the Cathedral Cliffs Formation to be of late early Eocene or early middle Eocene age. This age is consistent with its interfingering relations with strata of the same age (the Lamar River Formation) to the west. Two small collections of plant fossils indicate an early or middle Eocene age, or both. The overlying breccias (Wapiti Formation) yielded plant and vertebrate fossils, indicating that they are not younger than early middle Eocene and may be as old as late early Eocene (Pierce, 1963).

SUNLIGHT GROUP

The new name Sunlight Group is here proposed for a sequence of mainly dark colored pyroxene andesite lava flows and volcaniclastic rocks and potassic basalts that comprise the middle group of the Absaroka Volcanic Supergroup. The group is named for the type area of Sunlight Creek (fig. 9), which flows through a major vent area east of the park and through the thickest known accumulation of these rocks. The Sunlight Group comprises, in ascending order, the following: Mount Wallace Formation and its Slough Creek Tuff Member, Crescent Hill Basalt, Wapiti Formation and its Jim Mountain Member, and the Trout Peak Trachyandesite and its Pacific Creek Tuff Member.

The Sunlight Group overlies the Washburn Group throughout the northern part of the volcanic field, but to the south, the Sunlight Group rests directly on prevolcanic rocks (fig. 3). Rocks of the Sunlight Group are easily accessible and magnificently exposed southwest of Clarks Fork Yellowstone River, along Sunlight Creek, and along the road between Wapiti, Wyo., and the east entrance of Yellowstone National Park (fig. 9). Within the park, the Sunlight Group is largely confined to high divides and fairly inaccessible areas. The regional relations of the formations and members are shown diagrammatically in figures 5 and 8, and are shown in more detail on the geologic map of Yellowstone National Park (U.S. Geological Survey, 1972).

The Mount Wallace Formation — the oldest formation in the Sunlight Group — is as much as 2,000 feet thick and consists mostly of lava flows. It is thickest and most extensive north of the park. It thins markedly to the south, and in northern Yellowstone National Park it underlies or interfingers with the lower part of the Wapiti Formation. The Crescent Hill Basalt in the north-central part of the park is believed to be an outlier of the Mount Wallace Formation.

Overlapping the thinned southeast edge of the Mount Wallace Formation in the park are the Wapiti Formation and the Trout Peak Trachyandesite, which attain a total thickness of nearly 6,000 feet just east of the park. The Wapiti Formation consists dominantly of pyroxene andesite volcaniclastic rocks of vent and alluvial facies with local, mostly thin lava flow sequences. The Trout Peak Trachyandesite is a massive sequence of dominantly mafic lava flows that overlies the Wapiti Formation. The Trout Peak lavas grade into breccias indistinguishable from Wapiti breccias in the Sunlight-Crandall area. There, the Wapiti Formation and the Trout Peak Trachyandesite are laterally gradational; the base of the Trout Peak, defined as the base of the massive lava flow sequence, is not a time line, but a time-transgressive lithologic break. In the northeastern and north-central parts of the park, these formations interfinger with the Langford Formation of the Thorofare Creek Group (fig. 3; fig. 8, col. G; U.S. Geological Survey, 1972).

Southeast of Carter Mountain (fig. 1) the Wapiti Formation grades into, and interfingers with, a fine-grained alluvial facies called the Pitchfork Formation (Hay, 1956). The Pitchfork Formation, in turn, seems to be correlative with strata mapped as Aycross Formation farther south by Harold Masursky (unpub. data, 1956), but, as yet, it is uncertain whether those strata are equivalent to the type Aycross (Love, 1939). We include the Pitchfork Formation in the Sunlight Group, but — because of uncertainties in correlations — not the Aycross Formation.

Rocks of the Sunlight Group disappear southwestward beneath the Thorofare Creek Group and probably pinch out locally at depth against the largely buried northwest-trending Washakie Range (fig. 1). Remnants of the Trout Peak Trachyandesite rest directly on deformed prevolcanic rocks on the west flank of the partly exhumed Washakie Range along the southwest margin of the Absaroka field (U.S. Geological Survey, 1972).

Remanent magnetism in lava flows of the Mount Wallace Formation are of normal and reversed polarity (Smedes and Prostka, unpub. data, 1967, verified by E. L. McCaskey, unpub. data, 1968). Lavas in the Wapiti Formation and the Trout Peak Trachyandesite are of normal polarity (F. J. Vine, written commun., 1968).

AGE

The Sunlight Group is almost entirely of early Bridgerian provincial age; it overlies the Washburn Group of late Wasatchian and early Bridgerian age.

MOUNT WALLACE FORMATION

The new name Mount Wallace Formation is here proposed for a sequence of andesite, trachybasalt, and latite lava flows and flow breccias, rhyodacite welded ash-flow tuff, and interlayered volcanic sediments. These rocks were originally called basic andesite breccia and flows (Iddings and Weed, 1894). The Mount Wallace Formation occurs chiefly north of Yellowstone National Park and makes up most of the Sunlight Group in that region. The formation has a maximum thickness of about 3,000 feet in the type area — a remote rugged region south of, and including, Mount Wallace. The unit thins markedly to the southwest, south, and southeast from there and becomes a lenticular and discontinuous unit of mafic lavas and welded tuff in the park. In the type area the rhyodacite welded ash-flow sheet (Slough Creek Tuff Member) is about in the center of the Mount Wallace Formation, but in the park the lower half of the formation has wedged out, and only the Slough Creek Tuff Member and upper mafic lavas are present.

Between Slough Creek and Buffalo Creek (figs. 4, 9), Mount Wallace Formation fills local depressions in the prevolcanic surface and is as much as 1,000 feet thick. In these areas the mafic lavas are locally underlain by rhyodacite welded ash-flow tuff (the Slough Creek Tuff Member). Southeast of Slough Creek (fig. 9), the Mount Wallace Formation is 0–400 feet thick and occurs as lenticular lava flow sequences beneath or interlayered with the lower part of the Wapiti Formation (U.S. Geological Survey, 1972). Mount Wallace Formation does not occur southeast of Soda Butte Creek (fig. 9). Outliers of mafic lavas in the north-central part of the park, called Crescent Hill Basalt, are here interpreted to be equivalent to part of the Mount Wallace Formation. In the northwestern part of the park, the Mount Wallace Formation caps high ridges and thins from about 1,000 feet thick near Sheep Mountain to less than 200 feet toward the west. Several patches of Mount Wallace Formation occur at the south end of the Gallatin Range northeast of Madison Valley (figs. 4, 9).

In the type area, the Mount Wallace Formation consists of about 2,000 feet of lenticular lava flows and flow breccias of andesite, trachybasalt, latite, and minor amounts of dacite interbedded with variable thicknesses of volcanic sediments. The composite sheet of rhyodacite welded ash-flow tuff — the Slough Creek Tuff Member — is approximately in the middle of the section.

Throughout most of its extent, the Mount Wallace Formation rests on strata of the Washburn Group or on prevolcanic rocks. West of Buffalo Creek the Mount Wallace Formation is locally overlain by the Langford Formation, and southeast of Buffalo Creek it is overlain by, and partly interlayered with, the Wapiti Formation (fig. 4).

SLOUGH CREEK TUFF MEMBER

The Slough Creek Tuff Member (new name) of the Mount Wallace Formation is a composite sheet of rhyodacite welded ash-flow tuff. It is known to occur in only two areas in the park — (1) in the type area west of Slough Creek 2 miles south of the park boundary (figs. 4, 9), where it is as much as 700 feet thick and underlies mafic lava flows, and (2) along Buffalo Creek. It thickens to the northwest and is a distinctive well-exposed continuous unit as much as 1,000 feet thick in the middle of the Mount Wallace Formation over a broad area southwest and southeast of Mount Wallace. The sheet is a compound cooling unit in which the ash flows contain variable proportions of quartz, sanidine, and biotite phenocrysts. Fragments, mostly andesites and basalts of the Mount Wallace Formation, are abundant.

Studies of remanent magnetism are still in progress. The Slough Creek Tuff Member and a lava flow several hundred feet below it in the type area are of normal polarity. The lavas (interpreted to be in the upper part of the Mount Wallace Formation) that are interlayered with the Wapiti Formation in northeastern Yellowstone National Park and the Crescent Hill Basalt are of normal polarity (F. J. Vine, written commun., 1968). Lavas of the Mount Wallace Formation in the northwestern part of the park are of normal and reversed polarity, but their stratigraphic relation to those of the type area is unknown.

AGE

The Mount Wallace Formation is of early Bridgerian provincial age. The Mount Wallace Formation overlies the Washburn Group of late Wasatchian and early Bridgerian age. It is overlain by, and intertongues with, the Wapiti Formation and the Trout Peak Trachyandesite. The Pacific Creek Tuff Member at the top of the Trout Peak is dated at 48.0± 1.3 m.y. (fig. 8, col. H). The Mount Wallace Formation is cut by an intrusive (fig. 3, loc. *d*) dated at 47.7±1.5 m.y. (J. D. Obradovich, written commun., 1968). We found no fossils, and none have been reported in the literature.

CRESCENT HILL BASALT

The Crescent Hill Basalt was named and defined by Howard (1937) as the basalt overlying the early acid breccia in the Crescent Hill area. The Crescent Hill Basalt consists of two flows of scoriaceous, partly pillowed trachybasalt which have an aggregate thickness of about 250 feet. Only the lower flow is present on Crescent Hill; the upper, thicker flow is well exposed as rimrocks above the road between Oxbow and Geode Creeks (fig. 9). The lower flow is exposed along the road one-fourth mile west of Geode Creek. The two flows are separated by a northwestward-thinning tongue of the Sepulcher Formation.

The Crescent Hill Basalt is restricted to north-central Yellowstone National Park (fig. 4; U.S. Geological Survey, 1972). On the basis of lithology and stratigraphic position, it is interpreted to be correlative with part of the Mount Wallace Formation. It is retained as a separate formation for historical reasons and because the correlation with the Mount Wallace Formation is not absolutely certain.

AGE

The Crescent Hill Basalt overlies, and is partly intertongued with, the uppermost part of the Sepulcher Formation. South of Crescent Hill it is overlain by the Langford Formation (fig. 4; fig. 8, col. E; U.S. Geological Survey, 1972).

If the correlation of the Crescent Hill Basalt with part of the Mount Wallace Formation is valid, then the basalt is probably of early Bridgerian provincial age.

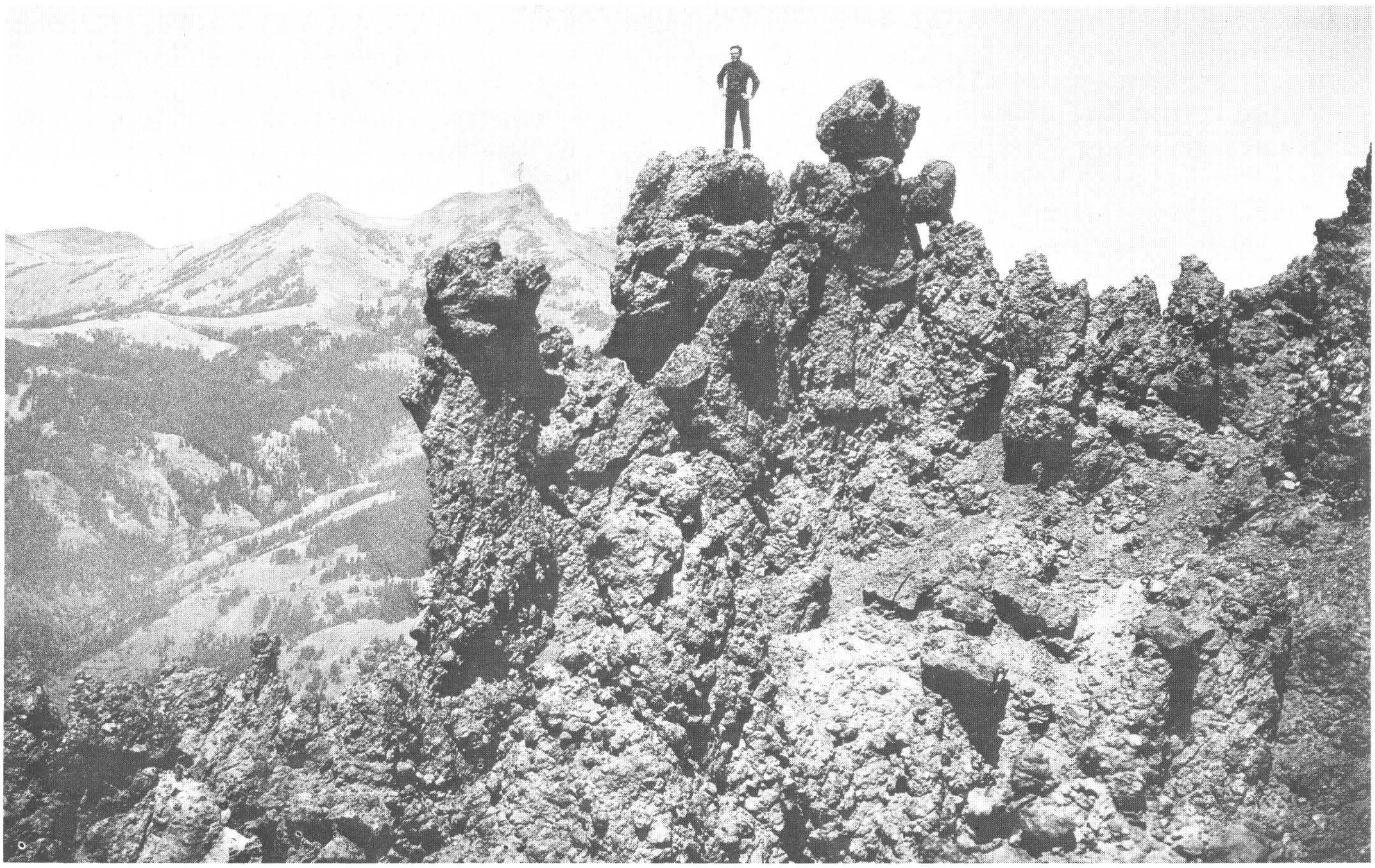


FIGURE 12. — Vent facies autoclastic flow breccias of the Wapiti Formation, along the northeast ridge of Pollux Peak (fig. 9).

WAPITI FORMATION

The Wapiti Formation, defined by Nelson and Pierce (1968), is a sequence of andesitic volcaniclastic rocks and lesser amounts of interlayered lava flows of trachyandesite and minor dacite. In the type section near Wapiti, Wyo. (fig. 9), it is equivalent to the early basic breccia of Hague (1899). The formation has been mapped continuously from the type section, north of Wapiti, Wyo. (fig. 9), northwestward through the Sunlight Creek region into Yellowstone National Park. In the northeastern part of the park, the Wapiti Formation constitutes only the upper one-third of what Hague, Iddings, and others (1899) called early basic breccia — the lower two-thirds being the slightly lighter colored Lamar River Formation. The Wapiti Formation in the Sunlight Creek and Crandall Creek regions, and in the east-central part of the park (figs. 12, 13) consists entirely of vent facies rocks cut by swarms of dikes and a variety of other intrusives. From there, it grades outward into interfingered vent and alluvial facies rocks in northeastern Yellowstone National Park and in the area of the type section near Wapiti. Southeastward from Wapiti, the formation grades laterally from predominantly volcanic breccia and conglomerate to predominantly volcanic sandstone and siltstone. This finer grained equivalent is called the Pitchfork Formation (Hay, 1956; Nelson and Pierce, 1968). A thick wedge of the Wapiti is interbedded with the Pitchfork Formation along the South Fork Shoshone River (fig. 1).

The Wapiti Formation is as much as 5,000 feet thick in the Crandall-Sunlight area; it thins to about 4,000 feet near the type section and becomes even thinner farther south.

The Wapiti Formation overlies the Willwood Formation at the type section and is the basal volcanic unit of the area from there southeastward to Carter Mountain (fig. 1). To the northwest, the Wapiti overlies the Lamar River Formation or the Cathedral Cliffs Formation. East of the park, the pre-Wapiti formations have been extensively disrupted by sliding along the Heart Mountain detachment fault. There, the tectonically denuded fault plane and allochthonous blocks of Paleozoic strata and pre-Wapiti volcanic rocks were buried by the Wapiti Formation immediately after the

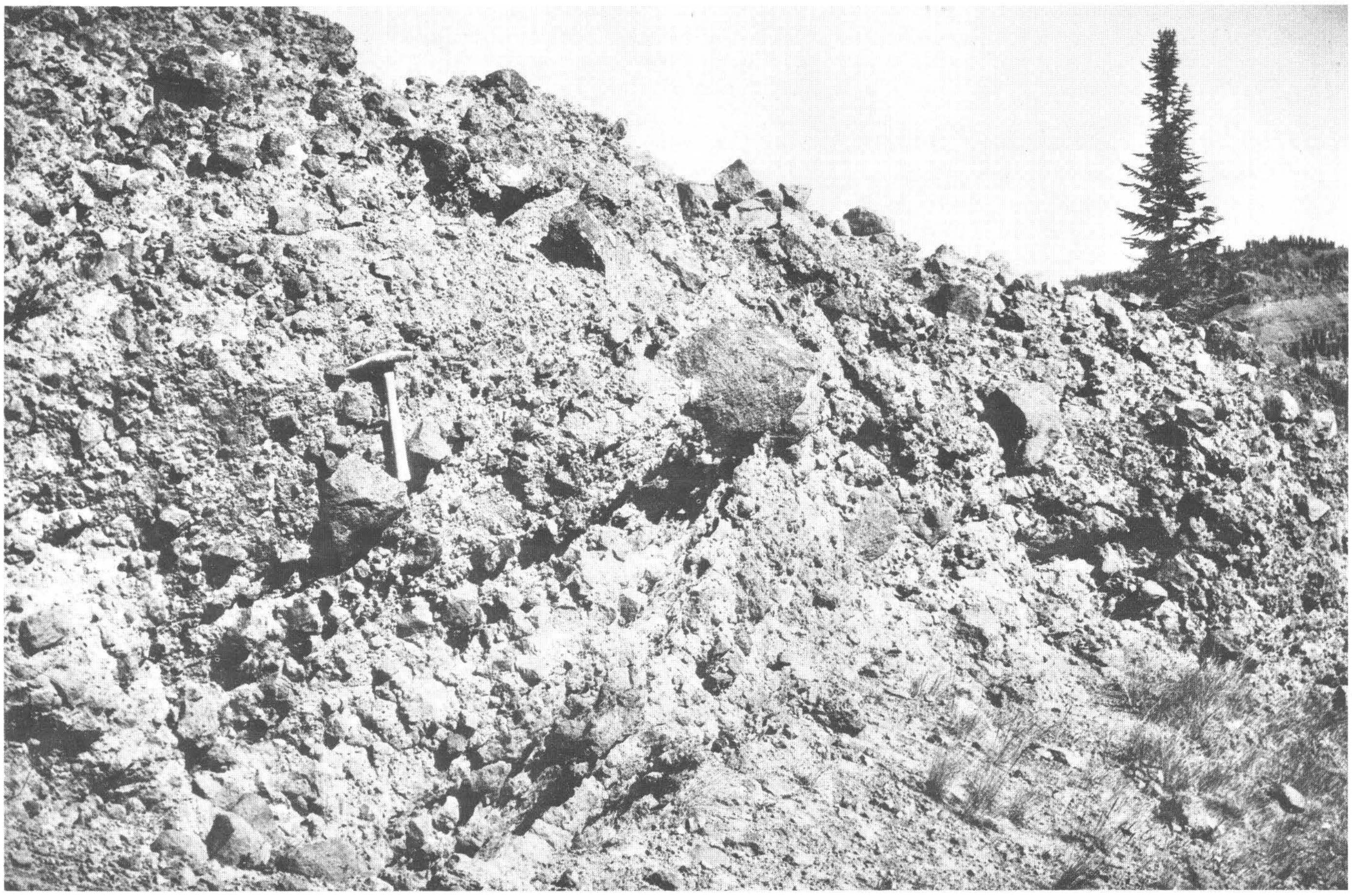


FIGURE 13. — Closeup view of vent facies autoclastic flow breccia of the Wapiti Formation, along ridge south of South Cache Creek near east boundary of park (fig. 9).

sliding occurred (Pierce, 1957; Prostka and W. H. Nelson, unpub. data, 1970, 1971).

The Wapiti Formation in places is unconformably overlain by, and in other places interfingers with, the lower part of the Trout Peak Trachyandesite (fig. 8, cols. F, G, H).

JIM MOUNTAIN MEMBER

The type section of the Wapiti Formation contains a sequence of trachyandesite lava flows, about 1,000 feet thick, called the Jim Mountain Member, which thins to the southeast (Nelson and Pierce, 1968). Westward from the type section, the Jim Mountain Member grades into vent facies deposits of the Wapiti Formation (W. H. Nelson and Prostka, unpub. data, 1971).

AGE

The Wapiti Formation overlies strata of the Washburn Group of early Bridgerian age, and it interfingers with, and is overlain by, the Trout Peak Trachyandesite of early Bridgerian age. The laterally equivalent Pitchfork Formation contains late Wasatchian–early Bridgerian vertebrate faunas, and a flora which has been dated as middle Eocene (Hay, 1956, p. 1883–1884). The most probable age of the Wapiti Formation is early middle Eocene.

TROUT PEAK TRACHYANDESITE

The Trout Peak Trachyandesite, defined by Nelson and Pierce (1968), is a massive sequence of trachyandesite and trachybasalt lava flows with minor amounts of interbedded volcaniclastic rocks. It is approximately equivalent to the early basalt flows of Hague, Iddings, and others (1899). The formation is well exposed over a wide area from the type section at Trout Peak (fig. 9), northwest of Wapiti, Wyo., northward and westward into Yellowstone National Park (U.S. Geological Survey, 1972), southward for several miles beyond the Greybull River (Wilson, 1963) and southwestward to the west edge of the Absaroka field (fig. 3). It is present near Two Ocean Pass (fig. 14; Love, 1956d) and along North Buffalo Fork and Soda Fork of North Buffalo Fork (fig. 14).

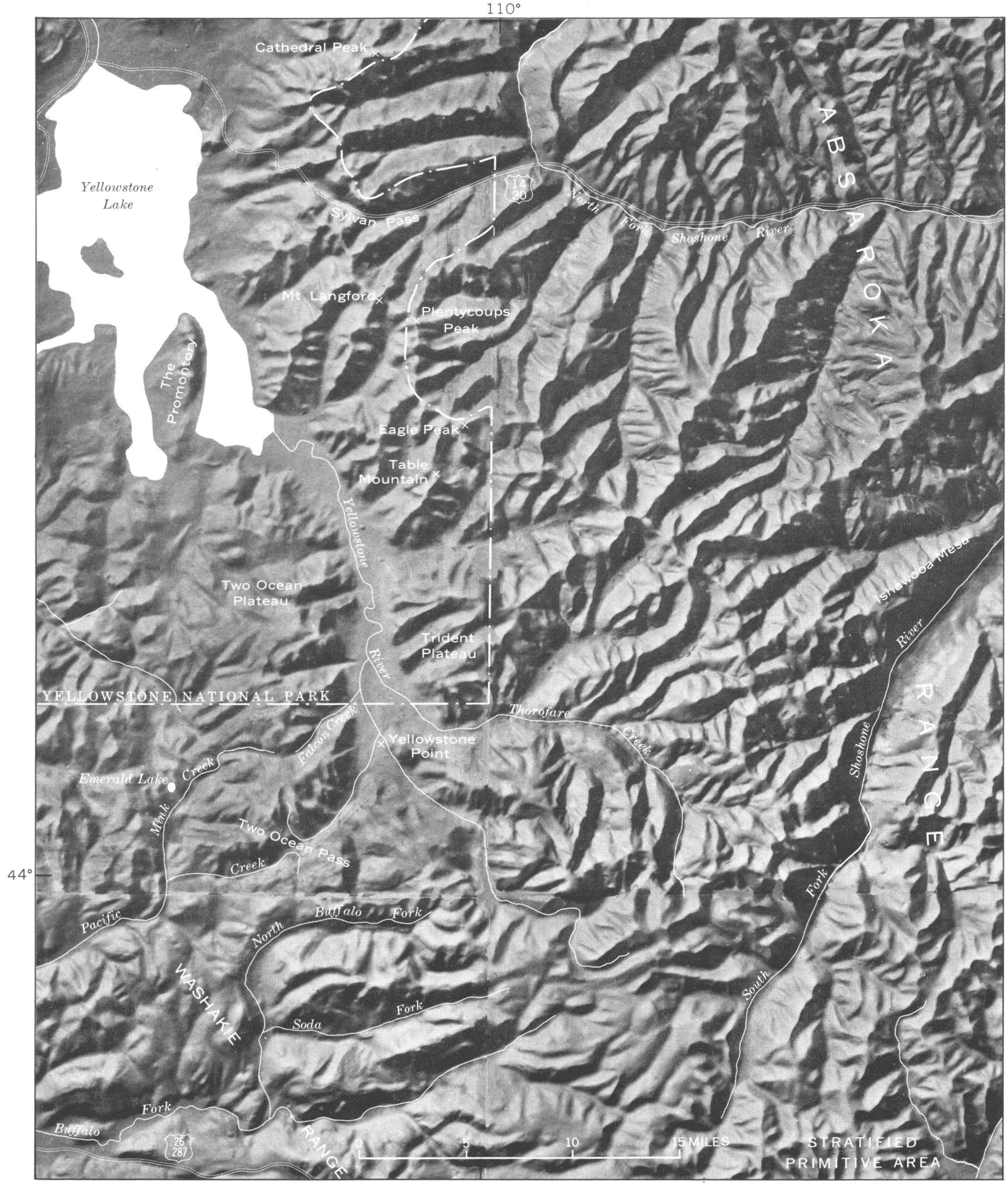


FIGURE 14. — Geographic features in the southeastern part of Yellowstone National Park and vicinity.

The Trout Peak Trachyandesite is about 800–1,200 feet thick in the type section and in east-central Yellowstone National Park. It gradually thins southward and finally pinches out in the region between the Greybull and Wood Rivers (fig. 1; Wilson, 1963). Its source was primarily the Sunlight-Crandall region (fig. 1), the same as the source of the Wapiti Formation. This is indicated by numerous dike swarms and central stocks compositionally similar to the lava flows. We include these dikes as part of the Trout Peak Trachyandesite. A secondary source along the south margin of the Absaroka field is suggested by compositionally similar dikes and plugs that cut strata equivalent to the Pitchfork Formation and are overlain by the Tepee Trail Formation (Harold Masursky, unpub. data, 1956).

The Trout Peak Trachyandesite overlies, and partly interfingers with, the Wapiti Formation (fig. 8, cols. F, G, H). In northeastern Yellowstone National Park, the Trout Peak Trachyandesite interfingers with light-colored volcaniclastic strata of the Langford Formation. This relationship is well displayed at the north end of Mirror Plateau, and in the southeast face of Mount Hornaday (fig. 9). In the Crandall-Sunlight region, the Trout Peak Trachyandesite is the stratigraphically highest unit present; to the south and southwest it is overlain by the Langford Formation, and to the southeast it is overlain by strata which have been called Wiggins Formation (Nelson and Pierce, 1968; Wilson, 1963).

PACIFIC CREEK TUFF MEMBER

The Pacific Creek Tuff Member (new name) of the Trout Peak Trachyandesite is a rhyodacite welded ash-flow tuff that locally overlies or is interlayered with the uppermost lava flows of the Trout Peak Trachyandesite. It is named for the type area at Pacific Creek, near Two Ocean Pass (fig. 14), where the unit is well exposed. This unit is extensive but discontinuous, owing to intravolcanic erosion. In most places, this unit is too thin or scattered to be mapped separately from the Trout Peak Trachyandesite. It is about 80 feet thick at the type area and about 300 feet thick in east-central Yellowstone National Park. The Pacific Creek Tuff Member is a pale-brown to yellowish, poorly resistant, partially welded ash-flow tuff containing abundant phenocrysts of anorthoclase and biotite.

AGE

A potassium-argon determination (figs. 3, 4, 8) on the biotite in the Pacific Creek Tuff Member by J. D. Obradovich (written commun., 1968) gave an age of 48.0±1.3 m.y. — middle Eocene (early Bridgerian). This age is slightly younger than the one quoted by Nelson and Pierce (1968, p. H11), which was a preliminary determination on the same sample analyzed by Obradovich.

THOROFARE CREEK GROUP

The name Thorofare Creek Group (new name) is proposed for the formations of middle and late Eocene age that lie above, and locally interfinger with, the Sunlight Group. The name is taken from the type area of the region of Thorofare Creek, near the southeast corner of Yellowstone National Park (fig. 14), where most of the group is well exposed.

The Thorofare Creek Group is more than 6,000 feet thick. It consists, from oldest to youngest (fig. 8), of light-colored volcaniclastic strata and andesite lavas of the Langford Formation, the dark-colored coarse volcaniclastic Two Ocean Formation, the fine-grained green and brown Tepee Trail Formation (present only southeast of the park), and the distinctive well-bedded light-gray Wiggins Formation. These formations make up most of the southern half of the Absaroka volcanic field. All these units except the Tepee Trail Formation can be traced almost continuously from the southeastern part of the park south to the Togwotee Pass area (fig. 1). At Togwotee Pass Wiggins Formation rests on Tepee Trail Formation, but half a mile to the west, the Tepee Trail Formation wedges out against the Two Ocean Formation, and both are unconformably overlain by Wiggins Formation. From there, the Wiggins Formation can be followed eastward almost continuously to its type area (J. D. Love, oral commun., 1968; unpub. reconnaissance data by Love, Smedes, W. L. Rohrer, and J. D. Obradovich, 1970, and Smedes and Obradovich, 1971).

Along the south and southwest margins of the volcanic field (fig. 3), strata of the Thorofare Creek Group locally rest directly on prevolcanic rocks. In northeastern Yellowstone National Park, the Langford Formation (basal Thorofare Creek Group) interfingers with the Sunlight Group (fig. 8, cols. F, G; U.S. Geological Survey, 1972), but in most places the Langford rests directly on rocks of either the Sunlight Group or the Washburn Group (fig. 8, cols. C, E, F, H). The Langford Formation is the only unit of the Thorofare Creek Group that extends northward across and beyond the park.

AGE

Radiometric dates (about 44–49 m.y.; fig. 3) and sparse fauna and flora indicate that the Thorofare Creek Group ranges from middle Eocene to possibly late Eocene in age. However, it should be emphasized

FIGURE 15. — Distant view of chaotic, indistinctly bedded vent facies rocks of the Langford Formation, along the east ridge of Plentycoups Peak (fig. 14). About 550 feet of relief is shown.

that the Eocene is not yet well calibrated (M. C. McKenna, written commun., 1971).

LANGFORD FORMATION

The name Langford Formation (new name) is here proposed for a thick section of dominantly light-colored andesitic volcaniclastic strata and lava flows of vent (fig. 15) and alluvial facies that overlies the Trout Peak Trachyandesite and is unconformably overlain by the dark-colored Two Ocean Formation in east-central Yellowstone National Park (fig. 4). In the type area, at Mount Langford (fig. 14), a complete section about 2,000 feet thick is well exposed.

The alluvial facies of the formation is mainly light gray and was called late acid breccia by early workers in the area (Hague, Weed, and Iddings, 1896; Hague, Iddings, and others, 1899; Hague, 1899). The dark andesite flows and breccias of the vent facies and, locally, some of the dark alluvial facies tongues interbedded with the light alluvial facies were called late basic breccia.

The Langford Formation extends northward beyond the park, where it unconformably overlies Mount Wallace Formation; in the Washburn Range (figs. 1, 4) it rests directly on strata of the Washburn Group, but to the east it overlies and partly interfingers with the Wapiti Formation and the Trout Peak Trachyandesite. The Langford Formation is thickest in the southeastern part of the park; it extends to the southwest edge of the Absaroka field, but its extent east of the park is unknown.

Throughout most of its mapped extent, the Langford Formation is light colored and of alluvial facies. The volcaniclastic strata are composed of hornblende and pyroxene andesite fragments, some of which are very dark gray and nearly glassy and have a subvitreous luster and subtle perlitic structure. The overall light color of the formation is due largely to its light-gray ash-rich matrix.

In a principal vent center in the Eagle Peak region (fig. 14), near the east border of the park, the entire section of the Langford Formation is dark vent facies lava flows, flow breccias, and agglomerate. There, small breccia dikes and irregular intrusive bodies, ranging in size from a few inches to a few feet across and from a few feet to tens of feet long, locally cut the vent facies rocks and are included with them in the formation (U.S. Geological Survey, 1972).

North of Cathedral Peak (fig. 14) the Langford is made up entirely of alluvial facies rocks. From the Cathedral Peak area southward and southeastward, the basal part of the formation consists of vent facies deposits (fig. 15) erupted from numerous centers in the Sylvan Pass, Eagle Peak, and Ishawooa Mesa regions (fig. 14); and the upper part is largely coarse alluvial facies with subordinate amounts of interbedded vent facies. The proportion of vent facies rocks increases southward and southeastward.

PROMONTORY MEMBER

The name Promontory Member (new name) is here proposed for several eastward-thinning tongues of dark massive volcanic conglomerate and breccia interbedded with the more typical light-colored strata of the Langford Formation. These tongues, which pinch out toward the east and appear to thicken and merge toward the west, are interpreted to be parts of a single thick dark-colored sequence, which lay to the west, but which is now buried by rhyolites of the Yellowstone Plateau (fig. 1). The name is taken from the type area of The Promontory (fig. 14), a peninsula separating the Southeast Arm and South Arm of Yellowstone Lake, where 600 feet of these dark-colored strata is well exposed. Rocks of the Promontory Member seem to be restricted to the southeastern part of Yellowstone National Park.

AGE

The Langford Formation is underlain by the Trout Peak Trachyandesite and overlain by the Two Ocean Formation, both of which are early middle Eocene in age (about 48 m.y.; fig. 8, cols. H, I).

TWO OCEAN FORMATION

The name Two Ocean Formation (new name) is here proposed for a sequence of dark-colored thick-bedded coarse andesitic volcaniclastic strata which overlie the Langford Formation in the southeastern part of the park. These rocks are mainly coarse alluvial facies strata in the park, but they grade into vent facies or interbedded alluvial and vent facies rocks near the border and east of the park. The formation is named for the type area along the precipitous east edge of Two Ocean Plateau (figs. 4, 14), where the strata are exposed in prominent dark cliffs between the light-colored less resistant Langford Formation below and the Wiggins Formation above (U.S. Geological Survey, 1972). This unit was previously called late basic breccia in most places, but some relatively inaccessible exposures were called late basalt sheets (Hague, 1899). The extent of the Two Ocean Formation east and southeast of the park is largely unknown because of the paucity of detailed mapping in those areas.

The base of the Two Ocean Formation is marked by an erosional, locally angular, unconformity having several hundred feet of relief. The formation is unconformably overlain by the Tepee Trail and Wiggins Formations. Because of these unconformities, the formation is locally absent along the south edge of the Trident Plateau, but it has a maximum thickness of more than 2,000 feet in the Eagle Peak region (figs. 4, 14). On the northeast side of Table Mountain (fig. 14), there is a prominent intraformational unconformity in which the lower half of the Two Ocean Formation and part of the underlying Langford Formation have been channeled out and filled by the upper part of the Two Ocean Formation.

The clasts are cobbles and boulders of subvitreous to stony porphyritic andesite, containing phenocrysts of hornblende or pyroxene, or both, as well as plagioclase and sparse amounts of biotite in a matrix of sand, silt, and ash. Locally, there are beds of very light gray water-laid ash, some of which contain chunk air-fall pumice rich in biotite.

AGE

Potassium-argon age determinations (J. D. Obradovich, written commun., 1969) on minerals from pumiceous tuff about 20 feet below the top of the Two Ocean Formation just west of the Falcon Creek–Mink Creek divide (fig. 14; fig. 3, loc. *c*) gave ages of 47.9 ± 1.3 m.y. (sanidine) and 48.5 ± 1.3 m.y. (biotite), both of which are middle Eocene (fig. 8).

TEPEE TRAIL FORMATION

The name Tepee Trail Formation was proposed by Love (1939, p. 73) for a sequence of volcaniclastic rocks along the south margin of the Absaroka field, unconformably overlying the Aycross Formation and older rocks, and unconformably overlain by the Wiggins Formation. Strata of the Tepee Trail Formation are composed of green and brown fine-grained well-bedded clay- and ash-rich deposits of a dominantly andesitic alluvial facies.

The formation is thickest near the type section in the basin of the East Fork Wind River (fig. 1), where 1,500–2,000 feet of strata is preserved. Increase in average grain size and vent facies aspect northward led Love (1939, p. 74) to conclude that its chief source was only a short distance to the north beneath the Wiggins Formation. The formation has been traced eastward into the western Owl Creek Mountains (fig. 1; Harold Masursky, unpub. data, 1956). Strata assigned to the Tepee Trail have been mapped west of the type section (Keefer, 1957; Ketner and others, 1966; Rohrer, 1966); however, these strata wedge out northwest of Togwotee Pass and do not occur in Yellowstone National Park.

AGE

On the basis of sparse and fragmentary vertebrate remains and relations with other rocks in the type section, Love (1939, p. 78) provisionally correlated the Tepee Trail Formation with upper Eocene strata.

Recently, however, Rohrer and Obradovich (1969, p. B61) cited an opinion by G. E. Lewis that the fauna are equally indicative of a middle Eocene age, and Rohrer (1966) reported a middle Eocene flora from strata 30 miles west of the type Tepee Trail Formation which he assigned to the Tepee Trail. On the basis of this, Rohrer and Obradovich (1969, p. B61) concluded that the Tepee Trail Formation, from west to east, ranges in age from middle to late Eocene.

Potassium-argon determinations (J. D. Obradovich, written commun., 1969) on air-fall tuff from about 400 feet below the top of a sequence of strata which Rohrer (1966) assigned to the Tepee Trail Formation 35 miles to the east, at a locality one-half mile northwest of Togwotee Pass (fig. 1; fig. 3, loc. *h*), gave ages of 47.8±1.3 m.y. (sanidine) and 47.9±1.3 m.y. (biotite). Altered biotite from a bentonitic ash less than 100 feet below the top of similar strata in the Pinnacle Buttes area (fig. 1; fig. 3, loc. *g*) was dated as 49.3±1.4 m.y., and sanidine from an ash a few tens of feet below the top of that interval gave an age of 46.1±1.2 m.y. (fig. 3, loc. *f*; J. D. Obradovich, written commun., 1970). Thus, strata in the Togwotee Pass–Pinnacle Buttes area that have been correlated 30–35 miles to the type Tepee Trail have an average radiometric age of 48 m.y., which is consistent with a middle Eocene paleontologic age. We emphasize, however, that there are no potassium-argon age determinations from the type Tepee Trail and Aycross Formations, that the age of vertebrate fossils from the Tepee Trail is not certainly known, and that considerable disagreement exists as to how the rock units in the type area of the Aycross and the type section of the Tepee Trail correlate with the dated strata near Togwotee Pass.

Strata 130 miles southeast of Togwotee Pass, in the Badwater area near Lysite, Wyo., have been called Tepee Trail Formation. They yielded a vertebrate fossil assemblage of late Eocene age (Black and Dawson, 1966, p. 331; Tourtelot, 1957, p. 11; Gazin, 1956) and contain a tuff having biotite dated at 41.2±1.4 m.y. (Black, 1969). These rocks cannot be equivalent to either the Tepee Trail Formation in the Pinnacle Buttes–Togwotee Pass area or the type Tepee Trail. The Tepee Trail seems most likely to be middle and late(?) Eocene age.

WIGGINS FORMATION

The name Wiggins Formation was proposed by Love (1939, p. 79) for a light-colored sequence of coarse andesitic volcaniclastic strata more than 3,000 feet thick unconformably overlying the Tepee Trail Formation and making up the high ridges of the southern part of the Absaroka Range. The name is taken from the Wiggins Fork Wind River (fig. 1). We have traced the formation continuously northwestward to the Trident Plateau and Two Ocean Plateau in Yellowstone National Park (figs. 8, 14). Wilson (1963) correlated lithologically similar strata on Carter Mountain with Wiggins Formation.

The Wiggins Formation consists of biotite-hornblende andesite volcaniclastic rocks and subordinate lavas. Its characteristic aspect is that of thick beds of light-olive-gray mudflow breccia; interbedded coarse medium-gray fluvial sandstone and conglomerate; and thin beds and lenses of very light gray and white pumice and ash mixed with silt and sand (fig. 16). Petrified forests are preserved locally (Ketner and others, 1966). Some of the dark lava flows high in the section were called late Basalt flows by Hague (1899).

The facies relations indicate several major and minor source vents. One of the larger vents is inferred to lie in the present site of Yellowstone Lake. Others lie northeast of the headwaters of Wiggins Fork near Kirwin (fig. 1; Wilson, 1959, 1964), and a cluster of vents east of Eagle Peak (fig. 14).

The Wiggins Formation lies unconformably on Tepee Trail Formation throughout much of the southern Absaroka field, but to the north and northwest the Tepee Trail wedges out, and the Wiggins lies directly on the Two Ocean Formation. The Wiggins Formation is the youngest unit of the Absaroka Volcanic Supergroup.

Excellent exposures of the Wiggins Formation can be seen in the cliffs north of Togwotee Pass and in the upper part of Pinnacle Buttes (fig. 16).

AGE

The Wiggins Formation was originally thought to be early Oligocene in age, on the basis of fragmen-

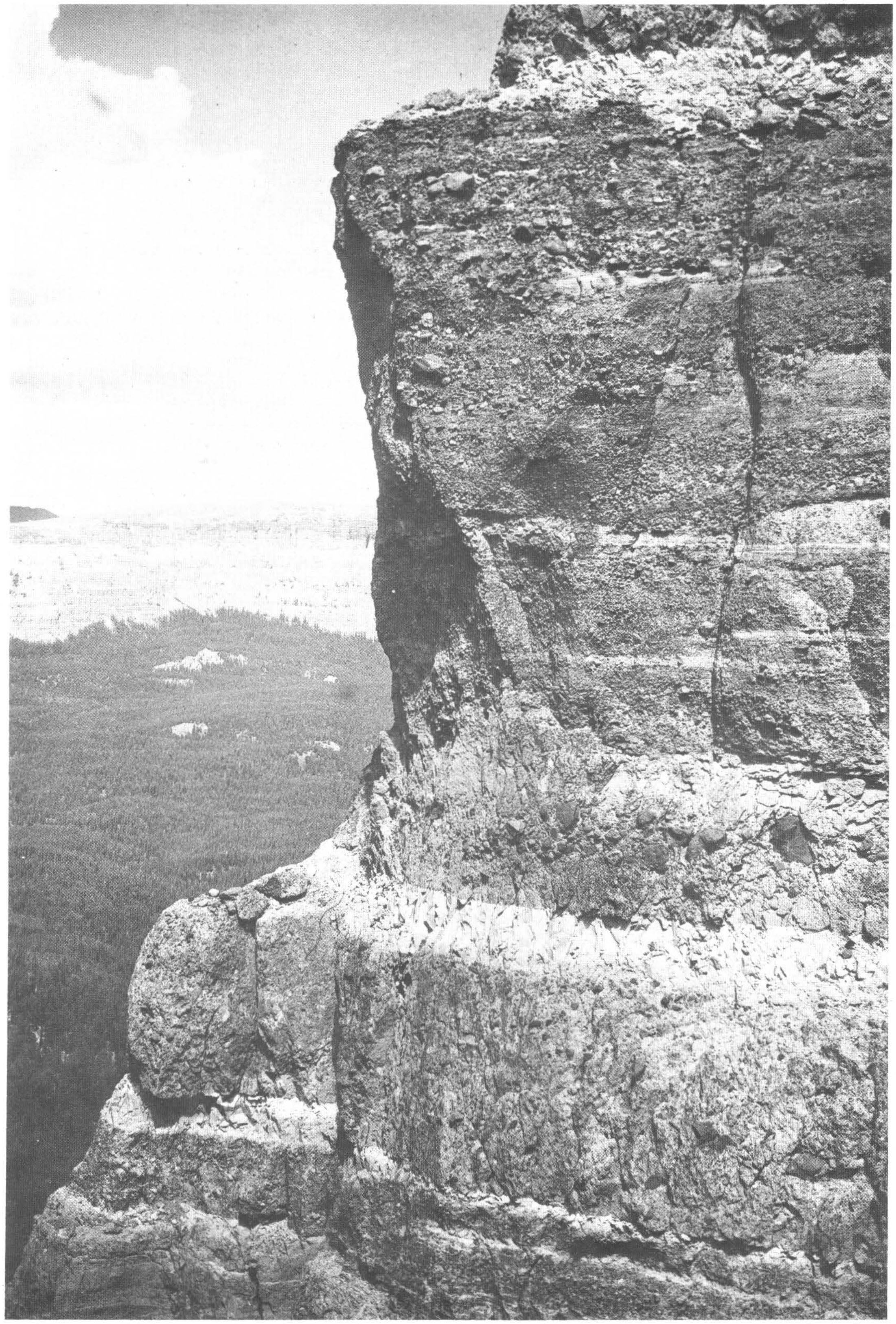


FIGURE 16. — Alluvial facies volcanic sedimentary rocks of the Wiggins Formation at Pinnacle Buttes (fig. 1). About 14 feet of section is shown.

tary vertebrate remains found in the Wiggins Fork area (Love, 1939). Fossil leaves from the Wiggins Formation in the Stratified Primitive Area (fig. 1) were considered to be early Oligocene, although it was admitted that they could be as old as late Eocene (Ketner and others, 1966; H. D. MacGinitie, written commun. to W. R. Keefer, 1965). Ash-rich sandstone and siltstone near Emerald Lake (fig. 14), previously thought to be Wiggins Formation, contains a fauna of early Oligocene age (Chadronian provincial age; Love, 1956a). Reexamination of field relations and petrology of this deposit conclusively demonstrated that it is a younger channel-fill deposited on eroded Wiggins (J. D. Love, M. C. McKenna, J. D. Obradovich, and Smedes, unpub. data, 1971). This Oligocene deposit is not considered to be part of the Absaroka Volcanic Supergroup.

Potassium-argon age determinations on six samples, three of which were from the Wiggins Fork area, all yielded middle and late Eocene ages. Rohrer and Obradovich (1969) reported ages of 46.2±1.8 m.y. and 46.5±2.3 m.y. on hornblende from a lava flow and a boulder at the base of the Wiggins Formation at Pinnacle Buttes (fig. 1; fig. 3, locs. *i, j*). An air-fall tuff about 800 feet above the base of the formation in the same area (fig. 3, loc. *k*) yielded potassium-argon ages of 44.4±1.4 m.y. (hornblende) and 45.5±1.3 m.y. (biotite) (J. D. Obradovich, unpub. data, 1969). In the Wiggins Fork area (fig. 3, locs. *l, m, n*), biotites from ash beds about 500 to 600 feet above the base of the Wiggins Formation yielded ages of 47.1±1.3 m.y. and 46.7±1.5 m.y., and biotite from a lava flow of vitrophyre about 150 feet higher in the section gave an age of 44.6±1.2 m.y. (J. D. Obradovich, unpub, 1970). On the basis of the foregoing, the Wiggins Formations seems most likely to be of late Bridgerian and possibly early Uintan provincial age — late middle Eocene to possibly early late Eocene (fig. 8).

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