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J. D. Forrester, Director

Geological reconnaissance of the Cassia Mountains region, Twin Falls and Cassia counties, Idaho

by

Walter Youngquist and Jerald R. Haegele

University of Idaho

Moscow, Idaho

FOREWORD

The Idaho Bureau of Mines and Geology is guided by the principle of being of service to all sections of Idaho and of making as much geologic information as possible available to the people. It is on the basis of such a precept that this excellent work by Messrs. Walter Youngquist and Jerald R. Haegele has been issued. The thorough and systematic study on which Pamphlet 110 is established is a credit to the authors and a distinct contribution to the geologic literature of Idaho.

J. D. Forrester
Director

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INTRODUCTION

The Cassia Mountains (locally known in the Twin Falls area as the "South Hills") are a broad uplift of Paleozoic and Cenozoic rocks which lie chiefly in Idaho (Fig. 1) but extend southward for a short distance into Elko County, Nevada. The Idaho portion of the Cassia Mountains embraces about 400 square miles and is located in southeastern Twin Falls County and southwestern Cassia County. It is bounded on the north by the southern margin of the Snake River Plain, on the east by the Goose Creek Basin, and on the west by the Salmon Falls Creek Basin.

This uplift is dissected by numerous small streams, many of which are intermittent. The highest point in the Cassia Mountains is Monument Peak, altitude 8132 feet. Valley altitudes adjacent to the Cassia Range approximate 4500 feet, giving a total relief of about 3600 feet. The present erosion cycle is one of late youth, for many upland areas are still essentially flat-topped and most of the streams occupy small, steep-walled valleys. Although total relief is about 3600 feet, the broad, gradual nature of the uplift makes local relief considerably smaller. Within a radius of a mile or two relief may approach 1000 to 1200 feet but the average is less. Also, Monument Peak, the highest point, is nearly equaled in elevation by several other nearby ridges (some essentially flat-topped), so that the region as a whole does not appear very rugged.

Igneous extrusives and welded tuffs cap many of the mountain ridges, including Monument Peak itself, and key volcanic beds can readily be recognized from one peak to another across adjacent intervening valleys. This feature adds further to the casual impression that the area is a simple upwarped dome. However, the structure of the Paleozoic rocks which underlie these Cenozoic extrusives (and associated ashes and sediments) is quite complex. Both folds and faults, particularly the latter, are numerous and some are large.

Although most of the drainage is to the exterior, this range can otherwise be regarded as part of the Basin-and-Range province. The climate is arid to semi-arid. Vegetation is sparse in the valley areas adjacent to the Cassia Mountains. Vegetation in the mountains proper is more abundant, but even here the trees are confined to the narrower valleys and the north and east-facing slopes of the ridges, with thin grassy and sagebrush areas covering the south-facing slopes and the broader valleys (such as that of Trapper Creek). Among the more common trees are lodgepole pine, Utah juniper, aspen, willow, and mountain mahogany. Shrubs and other plants include common sagebrush, chokecherry, lupine, Indian paint brush, and rabbit brush.

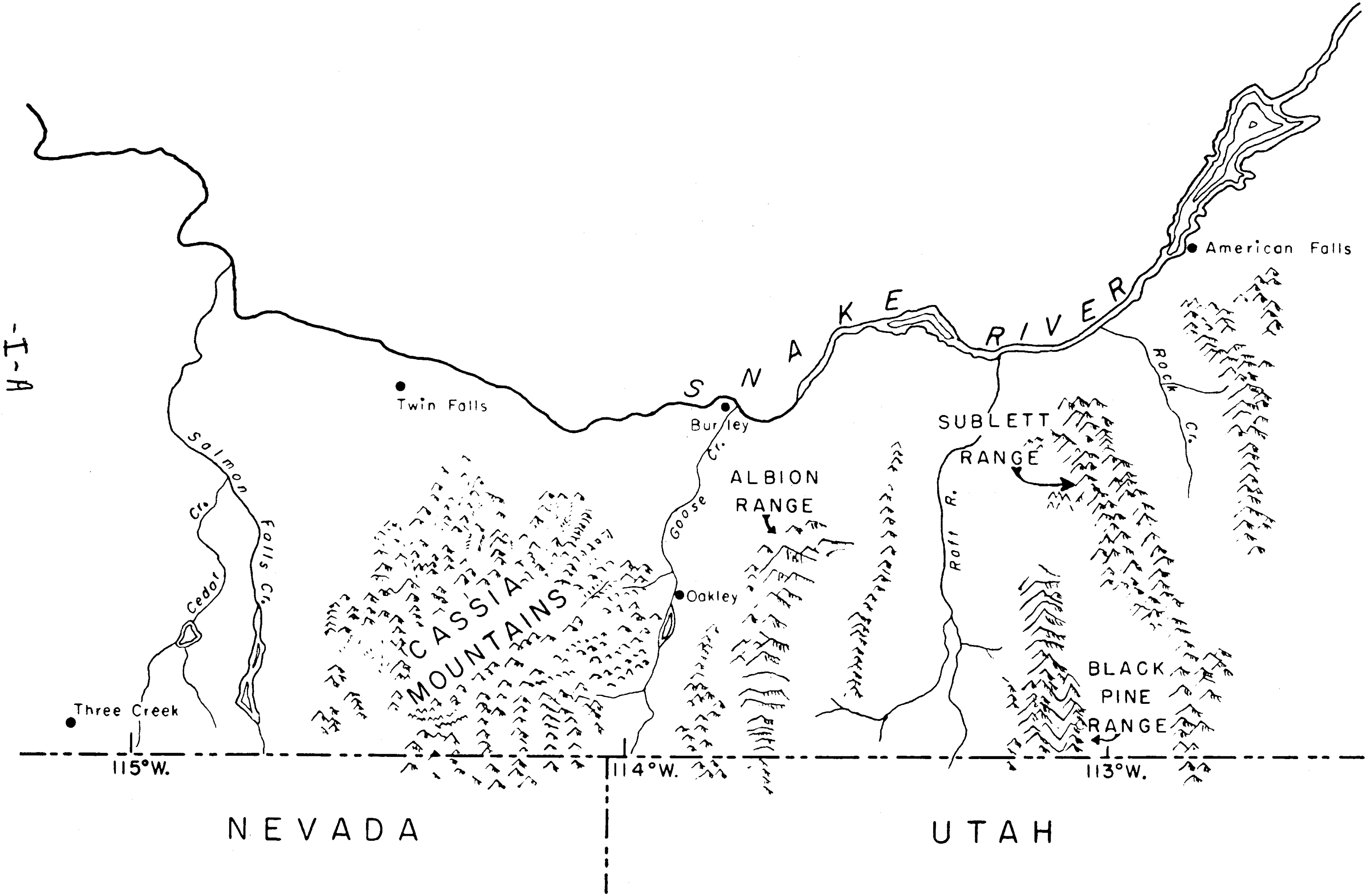

Fig. I. Location map of Cassia Mountains, adjacent ranges, and principal drainages.

PREVIOUS WORK

To date, no detailed consideration has been given to the geology of the Cassia Mountains themselves, but a few authors have touched on the area in relation to other studies, (e.g., Bowen, 1913). The relatively most detailed previous study was that by Piper in 1923 who mapped the drainage area of Goose Creek (Fig. 2) to the east of the Cassia Mountains. The western drainage divide for Goose Creek occurs somewhat west of the central portion of the range and therefore Piper's map includes a substantial part of this uplift. However, the Paleozoic rocks were considered only cursorily. No fossils were collected from these strata during that study, and the rocks were identified only as "Paleozoic." Previously, Bowen (1913), had stated that he had found no fossils in the Paleozoic rocks, but had tentatively identified them as "Carboniferous" in age.

Published maps (geologic and others) of the Cassia Mountains or portions thereof include: Piper's generalized geologic map of the eastern two-thirds of the area; U. S. Forest Service road maps on several scales (Cassia Division, Minidoka National Forest), U. S. Forest Service Timber Survey maps which are topographic maps on a scale of 4 inches/mile, contour interval 100 feet; Bowen's sketch map (localities and roads only) of the lignite deposit areas of the eastern portion of the Cassia Mountains; U. S. Coast and Geodetic Survey Triangulation diagram State of Idaho (1949), approximate scale 10 miles/inch; and the usual county highway maps. As might be expected because of the several surveys involved, some small discrepancies exist among these various maps with reference to boundaries and localities. At the present time no adequate topographic base map is available for detailed geologic mapping. All localities in this report are based on the U. S. Forest Service Map of the Minidoka National Forest, edition of 1949. (Note: As of 1956 this area is now part of the Sawtooth National Forest, rather than the Minidoka National Forest).

PRESENT STUDY

Because of the almost total lack of geological information concerning the Cassia Mountains, and the recent interest in oil and natural gas possibilities in the area, a portion of the 1950 field season was devoted to a brief reconnaissance of the region. Special consideration was given the Paleozoic stratigraphy of the area, but the structure of these rocks as well as the nature and structure of the Cenozoic sediments and volcanics also was considered. Samples of the predominant types of igneous rocks were collected and we are including some data on these specimens.

As a matter of historical record relative to recent interest by the oil companies in the Cassia Mountain area, we herein include a statement (letter from Frank Adler dated January 27, 1956) from the

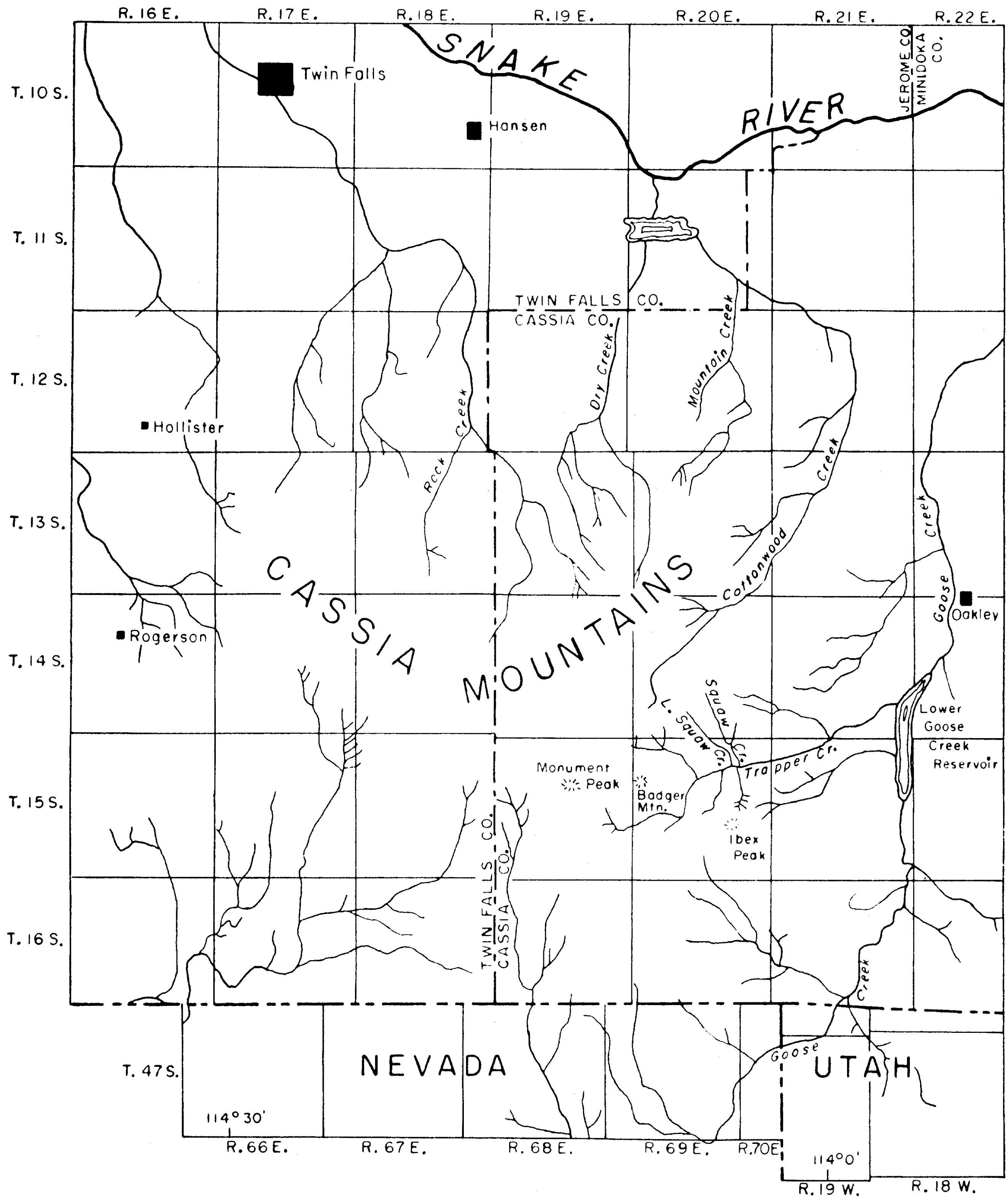

Fig. 2. Cassia Mountain area locality, map showing place names and drainage related to this report.

Phillips Petroleum Company summarizing the history of their leasing campaign of this area. They were one of the companies most interested in the area and they drilled the deep test on the Juniper anticline in the Sublett Range about 50 miles to the east of the Cassia Mountains. This company states that "six blocks of acreage were leased in the fall of 1948 covering about 85,000 acres in Twps. 12-16S, Rnges. 19-21E. These lease blocks were subsequently dropped in 1950 following additional field work." These areas can be identified by township and range on Figure 2.

STRUCTURE AND GEOLOGIC HISTORY

The structural history of the Cassia Mountains presented in the following discussion is merely a suggested chronology of events, which more detailed future work may modify considerably.

The oldest rocks known to us in the Cassia Mountains are marine Middle(?) Ordovician limestones and orthoquartzites which crop out on the extreme western side of the range. These are actually separated slightly geographically from the main mass of the Cassia Mountains, but are far more closely related to the Cassia Mountains than to any other uplift. Rocks of Middle(?) Ordovician to pre-Permian age may well occur in the Cassia Mountains proper, but we could find no fossils to indicate their presence. On the basis of the regional geologic history, presumably the area was submerged for most, but possibly not all of Paleozoic time. During the Permian, the area of the Cassia Range was negative and a very thick sequence of marine sediments was deposited. No marine deposits younger than Permian have been found in the Cassia Mountains proper, but marine Triassic rocks are reported to occur along the outer margins of the uplift and in Nevada some 15 to 20 miles south of the Cassia Mountains. There is, therefore, the possibility that Triassic seas also covered the Cassia Mountain region, and that later erosion removed whatever sediments may have been deposited.

Following deposition of the Permian rocks, the first major movements in the Cassia Mountains may have taken place during the Laramide Revolution, near the end of the Cretaceous. However, lack of both Jurassic and Cretaceous deposits in this region may mean that the area was above sea level by Jurassic times. The region of the Cassia Mountains may have been involved in the Mesocordilleran Geanticline (Cordilleran Geanticline of some authors), which extends northward through central Idaho and into Canada. Paleogeographic map number 67 (Upper Jurassic) of Schuchert (1955) shows this positive area very clearly, and it includes the Cassia Mountain region. In any case, movement came apparently in the middle and/or late portions of Mesozoic time. These movements resulted in the development of a number of folds. Some thrusting may have resulted also from these compressive forces. Later, faulting occurred; some faults have displacements of several thousand feet. Most of the faults we could identify seemed to be normal faults.

We are uncertain as to the exact time relations between the folding and the faulting in this area. However, it may be similar to other areas of the Basin-and-Range where folding, thrusting, and normal faulting have all occurred. Subsequent to the major movements, the larger structures were broken up into many smaller segments by short faults (mostly normal), which are characteristically forked in plan view, and give rise to displacements of many small blocks to the extent of a few feet to a few hundred feet. Many of the major structures have their axial trends somewhat east of north, but some of the minor structures as a result of these secondary faults are locally in sharp variance with the major trends. Several large anticlines were developed in the region. These were subsequently faulted along their crests, and the anticlinal structures are now appreciably modified by numerous faults.

Following this first uplift which established the principal structural trends in the Cassia Mountains, the area was subject to erosion and had little relief by Miocene times, if not before. Beginning probably during the Miocene, this region was blanketed by repeated falls of volcanic ash. Some flows also occurred. Volcanic material appears to have covered the entire region, and key beds can be traced from mountain top to mountain top in a markedly regular fashion. Even the highest peaks in the area are capped by volcanic strata, which were laid over the complexly faulted Paleozoic rocks in such a way as to indicate that the region was of relatively low relief. The structural complexities of the range apparently showed little surface expression when the volcanic material was in the process of covering the area.

The lowermost Tertiary rocks in the Cassia Mountains are volcanic glass-like rocks, and other acidic rocks, which at first glance appear to be flows. Some of them may be flows but others are welded tuffs. Later eruptions deposited more than 1000 feet of acidic volcanic ash on the east side of the range (particularly well exposed in the middle and upper portion of the valley of Trapper Creek). A large amount was deposited also along the northern edge of the range, and smaller quantities of ash occur on the western and southern sides. One or two lava flows exist in the upper part of this thick ash sequence. Presumably because of the low relief of the area combined, perhaps, with the ponding effect of lava flows, drainage was poor and the ash was deposited in part in a series of lakes and ponds. Locally, "coal" (low grade lignite) beds developed. Most of these organic accumulations are found in the lower portion of the thick ash deposits, and they occur along the eastern side of the range in the Goose Creek drainage basin. A few very thin lignite zones, hardly more than organic partings in the ash, exist on the north side of the Cassia uplift. None appears to be of commercial importance at the present time (see Bowen, 1913).

It should be noted that although igneous rocks and deposits of volcanic ash are common in the Cassia Mountains, no volcanic vents or intrusive rocks have yet been found in the area of the Cassia Mountains proper to our knowledge. This fact is of special significance, and is discussed at greater length in the section dealing with the Cenozoic igneous rocks.

Subsequent to the explosive activity which gave rise to the volcanic ash, additional eruptions added to the volume of volcanic extrusives. Interbedded with these flows, however, are many welded tuffs indicating that explosive eruptions did not entirely cease with the deposition of the prominent light-colored volcanic ash deposits near the base of the volcanic rock sequence.

Probably coincidental with the uplift of many of the mountain ranges of western United States during late Pliocene or Pleistocene time, the Cassia Mountains were again uplifted, this time in a rather broad dome-like upwarp as evidenced from the present drainage pattern (see Fig. 2). This upwarping and subsequent erosion produced the present relief.

As might be expected, small structural adjustments took place in the Cassia Mountains during and following this last broad uplift. These are evidenced by the small faults clearly visible in the Cenozoic lava flows and ash beds. The faults individually have displacements usually less than 50 feet. Most of the faults are normal, with the upthrown side on the side toward the central part of the Cassia Mountains; however, a very few small reverse faults are present. Also, in general, many of the faults which have an approximate east-west trend show a tendency toward possessing a downthrown component to the north--that is, on the side toward the axis of the Snake River downwarp. Some small folds were caused by these last movements. For example, a small anticline is present in the Tertiary rocks (mostly ash here) in the valley of Little Squaw Creek in secs. 2 and 3, T. 15 S., R. 20 E., Cassia County (Fig. 2).

These small Tertiary structures probably in part reflect minor movements along previously established structural trends. However, these movements are so small that they give very little if any clue to the underlying rock structure, and in general the attitudes of the Tertiary rocks do not reflect to any great extent the older, fundamental, and significant structures of the Cassia Mountains.

Flat topped ridges are common in the Cassia Mountains today, and the area is in the stage of late youthful dissection. The most recent uplift of the mountains may have been accomplished by a series of uplifts rather than a single sustained movement. Several benches or terraces are present in the middle and upper portion of the valley of Trapper Creek. However, we believe that most if not all of these terraces are structural in origin, for some of them coincide with lava flows, welded tuffs, or other more resistant beds in the thick volcanic ash deposits of this area.

One feature of the structure of the Cassia Mountain area deserves special consideration. On the west side of the Cassia Mountain uplift, and separated geographically from the main mass of the uplift by some volcanics, there is a series of exposures which consist of dense limestones and some quartzitic rocks which are Ordovician in age. As all the Paleozoic rocks in the Cassia Mountains so far identified are Permian in age, this suggests that between these Ordovician rocks and the Cassia Mountains proper, there may be a large fault (or faults) with the downthrown side toward the Cassia Mountains. This is a simple explanation. More complicated solutions involving thrusts could be postulated. However, little has been published on the regional structural setting of this area, and the problem bears further study. These facts are mentioned merely to record them and to facilitate additional work which may eventually be done.

PALEOZOIC ROCKS

Previous to this report there has been no published attempt to determine in any detail the age(s) of the marine rocks which constitute the core of the Cassia Mountains. However, some authors have briefly touched on the area. Piper (1923, p. 24) stated that "assignment of this sedimentary series to any definite geologic period within the Paleozoic era is impossible from the information at hand." Recently, field surveys of this area by petroleum geologists, as well as our own field survey, have considered this problem. However, insofar as we are aware, these attempts, including our own, to assign a more definite age (or ages) to the Paleozoic rocks have been only moderately successful. All of the Paleozoic rocks of the Cassia Mountain area known to us are marine. The bulk of the section is composed of dense, siliceous limestones, some thin bedded more platy limestones, orthoquartzites, some darker limestones and cherts, and a shale section or two which may be slightly phosphatic in part. No stratigraphic names are in common usage for these rocks, and we intentionally have not applied any because the determination and application of valid names depend in part on the regional relationships of the Cassia Mountain section to other areas. These relationships are not well known at present.

In general, these strata are not very fossiliferous, but in a few localities fossils are abundant. Their preservation, however, is poor for they commonly occur silicified in a siliceous limestone matrix and do not weather free, nor can they be etched out with acid in the laboratory very successfully. During the present study, fossils which could be identified with reasonable certainty were found at only a few localities. Several other fossil zones (chiefly brachiopods) were observed but the preservation of the material was so poor as to preclude a useful identification.

Dr. E. L. Lucas of Phillips Petroleum Company kindly called our attention to a single fusulinid zone in the Cassia Mountains. This zone is located near the head and on the north side of Cottonwood Canyon in the northeast portion of the Cassia Mountains. At this plade the rocks locally are steeply dipping. They are a crystalline medium gray limestone with small flecks of limonite. Fusulinids are not abundant and they are only moderately well preserved. A single centered but oblique fusulinid section obtained from rocks at this locality was sent to Dr. M. L. Thompson for identification. He states that: (letter dated June 7, 1951)

> "This specimen is probably referable to Parafusulina, but may possibly belong to Schwagerina. If it is the former genus, it is either a primitive or immature specimen. Tentatively, the containing beds can be dated as Wolfcampian or early Leonardian."

The other fossil locality is on the west side of Badger Mountain (Fig. 2) in the SW¼SW¼ sec. 7, T. 15 S., R. 20 E., Cassia County. Fossils found here include bryozoans, crinoid stems, and brachiopods; the last is the most conspicuous element. The fossils are largely silicified and show this by differential weathering on outcrop. The preservation, however, is poor. Samples of this material were sent to Dr. G. A. Cooper who stated by letter, dated March 13, 1951, that "The specimens are somewhat smashed but they seem to me to be unmistakably Productus nevadensis . . . ." This species occurs in the upper part of the Phosphoria formation (Branson, 1930). The age of the Phosphoria is not yet definitely settled, but a current student of the problem, Ralph King, advises us by personal communication that he would regard the fossil evidence cited above as indicative of a Leonardian or Guadalupian age for the containing beds.

The section which included these fossils was measured and its description follows: Section measured on west slope of Badger Mountain beginning where the Paleozoic rocks crop out below the Cenozoic volcanics covering Badger Mountain, in SW¼SW¼SW¼ sec. 7, T. 15 S., R. 20 E., Cassia County.

	West end Stratigraphic top, topographic bottom Thickness in feet
Covered, in narrow valley, heavy growth of small aspen	
Limestone, medium gray, fine grained, unfossiliferous, with small irregular masses of brown and black chert; dip 37° West, strike N. 15° E.	95

	Thickness in feet
Quartzites, fine grained sandstones, and arenaceous limestones, thin bedded brown, light to medium gray.	165
Limestone, medium gray, unfossiliferous.	29
Limestone, abundantly fossiliferous, thin bedded (6″ beds). Fossils silicified and weather out to form fretwork of silica, but fossils mostly fragmentary and poorly preserved. Productus nevadensis common. Dip 64° West; strike N. 20° W.	136
Limestone, dense, fine grained, dark gray, weathering to light brown along certain bedding planes, unfossiliferous. Dip 54° West; strike N. 8° W.	399
Extrusive volcanics and welded tuffs on west flank of Badger Mountain and continuing to summit of Badger Mountain	not measured
Total measured section	824 feet

The general lack of diagnostic and persistent fossil zones makes it difficult to piece together a satisfactory stratigraphic column for the Cassia Mountains. In addition, there is only a moderate variety to the Paleozoic lithologies. No well defined shale beds were seen in the uplift proper, and the bulk of the sediments are siliceous limestones, and orthoquartzites, with a few beds of sandstone, and thin-bedded black siliceous limestones. In the month used for this reconnaissance study we were unable to locate any key beds which were sufficiently distinctive and were represented in outcrop over a sufficiently wide area in the Cassia Mountains to aid us in mapping. To further complicate the problem of securing a complete stratigraphic column for this region, the Paleozoic rocks are broken into many small blocks by numerous faults. Without key lithologic or fossil zones, the displacement of most of these faults could not be determined. Although we walked a complete east-west traverse across the Cassia Mountains starting at the upper end of the Goose Creek Reservoir, and including Badger Mountain and the highest point in the Range, Monument Peak, we were unable to compose a satisfactory Paleozoic section in the brief time available for this survey. However, the thickness of marine sedimentary rocks is undoubtedly great, almost certainly they have a minimum vertical extent of 8,000 to 10,000 feet. Other geologists have suggested to us that an even greater minimum thickness exists. The largest section which we were able to measure with the reasonable assurance that it is a normal unfaulted section was on the east side of Badger Gulch. It started at the base of a prominent breccia which is firmly cemented by a ferruginous siliceous matrix. The angular fragments are light gray to dark gray cherts which are up to six inches in diameter. A few rounded pebbles are also present. This section, beginning at the topographic and stratigraphic top and going northward in $SE\frac{1}{4}$ sec. 16, T. 15 S., R. 20 E., Cassia County, is as follows:

	South end Topographic and Stratigraphic top Thickness in feet
Igneous rocks covering Paleozoic rocks above top of measured section. Included are amygdaloidal welded tuff, with sparse sodic labradorite plates; some zircon present. Welded tuff with andesine plates. Welded tuff with small angular fragments of plagioclase.	not measured
Breccia, orange to reddish brown ferruginous siliceous matrix composed of many small ($\frac{1}{2}$ - 4 mm) fragments of light to dark gray chert, and reddish ortho(?) quartzite. Larger (up to 150 mm) fragments consist mainly of light to medium gray chert, and some dark gray and dark red ortho(?) quartzite. Fragments show no preferred orientation and no sorting. Entire mass very firmly cemented.	94
Orthoquartzite, medium gray, locally limonite stained, dense, very fine grained. The unit is massive in outcrop, but in detail appears to be thin bedded. However, this apparent bedding may be in part due to a series of closely spaced joints. Dip approximately 32° S; strike N. 85° E.	747
Gray orthoquartzite with dark chert zones; some limestone and black chert near top of interval; a few white quartz veins. Dip approximately 30° S; strike N. 85° E.	94
Gray to tan dense fine grained thin bedded orthoquartzite and chert; small zone of brecciated black chert near top of interval; thin bedded gray sandy limestone at base. Dip approximately 30° S; strike N. 85° C.	237

	Thickness in feet
Sandy gray or medium brown thin bedded limestone and some thin bedded orthoquartzite at top of interval grading downward to light gray to nearly white, thin bedded (1 - 6 inches thick) arenaceous limestone.	377
Yellow-brown to rusty-brown thin bedded fine grained sandstone, locally quartzitic and very dense. Buff colored fine grained sandstone at base of interval.	325
Medium gray to dark gray thin bedded limestones with a few orthoquartzite and chert stringers. Small brecciated zone (fragments up to 10 mm in length) of light gray limestone in mid-portion of section. A few poorly preserved gastropod and crinoid remains in limestone at base of interval.	461
Thin bedded medium to dark gray sandy limestone (beds 1 - 6 inches thick), including small cherty zones. Dip approximately 22° S; strike N. 90° E.	371
Massive gray limestones, thinner zones of sandy limestones; a few stringers of black and brown chert. Dip approximately 20° S; strike N. 90° E.	177
Base of section, valley flat, and adjacent creek on southeast side of road.	
Total thickness of measured section	2883 feet

UNEXPECTED OCCURRENCE OF ORDOVICIAN ROCKS

As previously stated, the entire main mass of the Cassia Mountains seems to consist of Permian rocks capped by Cenozoic volcanics. Accordingly, the occurrence of Ordovician rock outcrops on the western side of the Cassia Mountains was somewhat unexpected. We are indebted to Dr. E. L. Lucas for calling these outcrops to our attention.

These Ordovician rocks crop out on the extreme western flank of the Cassia Mountains, occurring as a series of low elongate ridges which appear to be block faulted. They strike approximately N. 9° E., have a steep topographic western slope apparently as a result of faulting, and an eastern dip slope of about 30°. A line of hot springs marks the western margins of the blocks. These ridges are in secs. 6, 7, and 18, T. 13 S., R. 17 E., Twin Falls County. They are entirely surrounded by Cenozoic volcanics and are geographically isolated from the main uplift of the Cassia Mountains. An inlier of rocks which appears to be similar to those just mentioned occurs in the SW$\frac{1}{4}$ sec. 16, T. 13 S., R. 17 E. No fossils were found at this place, and this outcrop likewise is isolated from other Paleozoic marine sediments by a blanket of intervening volcanics.

A section of these rocks measured from east to west in approximately the south-center sec. 7, T. 13 S., R. 17 E., is as follows:

	Thickness in feet
Covered interval from base of volcanics capping ridge to east of measured section to top of exposed sedimentary rocks.	420
Irregularly bedded (thick and thin) buff colored silty silicified limestone. Beds from 1 inch to 1 foot thick.	61
Light buff to gray silicified limestone beds up to 1 foot thick. Some beds finely laminated. No fossils.	41
Same as interval above but rather uniformly thin-bedded ($\frac{1}{2}$ inch beds). In abrupt contact with interval below. No fossils.	116
Light gray silicified dolomitic limestone with a few dark chert nodules and some reddish iron-stained zones. Beds 6 inches to 2 feet thick. A few very poorly preserved small straight-shelled cephalopods. Some brachiopods.	242
Dark gray silicified dolomitic limestone weathering locally to pink and reddish tints. A few white quartz seams.	177
Medium gray to tan silicified dolomitic limestone (much like interval above but lighter in color). Beds massive near base with white quartz seams, and thinner beds (4 to 6 inches thick) above. A few straight and a very few coiled, poorly preserved cephalopods, more numerous large gastropods (_Maclurites_ sp. and _Trochonema_ sp.).	67

	Thickness in feet
Light gray to tan dolomitic limestone with black chert nodules.	56
Dark gray to medium gray dense silicified dolomitic limestone, with a few quartz seams. Small straight-shelled cephalopods and a few gastropods in the lower and middle portions of this section. Upper 83 feet iron-stained.	218
Gray, very dense quartzite, with a few white quartz seams, may be an orthoquartzite.	143
	1541 feet

Measured section of Paleozoics (exclusive of 420-foot covered interval to base of volcanics) totals 1121 feet.

This appears to be a normal, unfaulted section, with the quartzite stratigraphically on the bottom. However, in the Ordovician rock ridges to the south at one place there is a massive gray limestone which appears to be stratigraphically below the quartzite. However, this is an area of some solution features apparently related to faulting and the apparent stratigraphic sequence may not be the real one. Also, it should be noted that in areas to the south of the measured section that a substantially thicker section of the uppermost thin-bedded limestones are exposed and whereas in the measured section we found 218 feet of these rocks (upper three Ordovician units of measured section), that these thinly bedded very finely laminated rocks probably achieve a thickness of 500 feet or more. We were unable to find any fossils in these thin-bedded strata although some probably exist. However, these rocks appear to succeed the denser and more massive lower units conformably and tentatively we are regarding them as of Ordovician age also.

In summary fossils in portions of these rocks are moderately abundant, but are not well preserved. Crinoid stems, bryozoans, brachiopods, gastropods, straight-shelled (and a few coiled) cephalopods occur. However, the very dense, highly siliceous nature of the matrix precludes satisfactory collecting, and only the gastropods can be identified with any certainty. This scanty fossil evidence precludes satisfactory correlation of these rocks. Furthermore, there are no other Ordovician beds known to us in the general region. However, Dr. J. B. Knight has commented (letter dated April 27, 1951) that these gastropod "specimens are referable to Maclurites sp. and Trochonema sp. Neither are identifiable specifically. These probably are of Middle Ordovician age . . . but one cannot be absolutely sure."

Cephalopods were also collected from an exceedingly dense bed of siliceous limestone. These were poorly preserved. They have been submitted to Dr. A. K. Miller for study who has written us (letter dated August 8, 1950), that the specimens can be "identified only tentatively and they suggest the containing beds are late Early Ordovician or perhaps Middle Ordovician in age." The Paleozoic paleography (particularly of the early Paleozoic) of this portion of Idaho and adjacent Nevada is but poorly known at present. However, these rocks are of about the same age and are lithologically similar to portions of the Pogonip limestone (sometimes called Pogonip group) of east-central Nevada, and may represent an extension of that complex.

For the sake of completeness, it should be added that these Ordovician rock outcrops were revisited in 1956 in company with Dr. L. R. Laudon and his field party and at this time in a recently dug prospect pit Laudon discovered what appears to be a very small basic intrusion into these Ordovician rocks. This intrusion occurs in the measured section. If it is an intrusion it is the only intrusion known for certain to us in the Cassia Mountain area. None is known in the Cassia Mountains proper.

CENOZOIC SEDIMENTARY ROCKS

The Cenozoic sedimentary rock column in the Cassia Mountains includes a variety of lithologies. In general, these sediments are best developed and exposed along the east flank of the range. The Trapper Creek drainage basin (Fig. 2) is the site of most of our observations.

The Cenozoic sedimentary rocks include thick beds of light-colored volcanic ash, (we are including the ash beds in the discussion of the igneous rocks, also), which locally weather to form high walls, and pinnacles. Other less conspicuous elements are lake and/or stream deposits (clays, sands and marls), several beds of lignite (Bowen, 1913), thin conglomerate zones and thin beds of sandstone only moderately well cemented. In the Trapper Creek area (south side of Trapper Creek) we measured a total section of 2039 feet of Cenozoic volcanics. Most of this section consists of white to buff colored volcanic ash beds associated with minor amounts of other sediments. Welded tuffs and/or flows also are present. Tributary valleys into the Trapper Creek drainage from the south exhibit numerous pinnacles and wall-like areas of the volcanic sediments, very well exposed.

Bowen (1913, p. 256) regarded the lignite-bearing volcanic ash and related beds as Eocene in age. However, Piper (1923, pp. 32-35) has summarized Bowen's arguments as well as his own and concludes that the Tertiary sediments exposed in the Goose Creek Basin (which includes the eastern flank of the Cassia Mountains) are most probably Miocene and/or younger. We concur in this conclusion. Both Bowen and Piper state, however, that they had no faunal or floral evidence for a close determination of the age of these Tertiary rocks.

Near the base of the Tertiary section exposed in a tributary to the upper portion of Trapper Creek, Bowen has described the Worthington lignite bed which is exposed, as Bowen stated, in the limbs of a small anticline. Samples of this lignite bed (about 2 feet thick) were collected from the drainage area of Little Squaw Creek (see Fig. 2) and sent to Dr. L. R. Wilson for study and identification. He has written us (letter dated November 17, 1950) that from the samples he was

> "able to secure some very excellent material. In fact, I have not seen any finer preservation of spores and pollen. The flora consists of four, probably five species of conifers of the following genera: spruce, fir, pine, and possibly Podocarpus. The last is essentially an Asiatic element which I hesitate to recognize until further study. Conifers are the most abundant fossils. In addition, there is a very distinctive new species of alder, and at least two species of heaths, probably some birch, two species of ferns, and many types of fungi. The ecology of the assemblage is probably mountain of rather low altitude. It is too early yet to give an age determination. However, the species and assemblage is unlike anything I know of through the Tertiary up to the Miocene. There are species of spores and pollen in the assemblage that closely resemble some in the Miocene and Pliocene of Europe."

In a subsequent letter, dated March 20, 1951, Dr. Wilson reaffirms his conclusions on the age of the assemblage, stating that the flora is "probably Late Tertiary."

Accordingly, it seems probable that the oldest Tertiary rocks which lie directly on the Paleozoic marine section in the Cassia Mountains are of Miocene or later age. The relief of the Cassia Mountains was apparently small at that time. The geographic distribution and structural relations of the volcanic ash beds and associated sediments suggests to us that several basins of accumulation existed in the Cassia Mountains. Some of the ash beds show rudimentary stratification and are interbedded in places with clayey and sandy materials indicating deposition in a shallow lake where the sediments were partially reworked by wave action, or perhaps were washed in by streams. At one place in cliffs along the north side of the Trapper Creek road on the lower portion of the creek, the volcanic sediments are exceedingly well exposed and show both normal and inverse graded bedding in remarkable detail.

CENOZOIC IGNEOUS ROCKS

Although this study is primarily concerned with the marine Paleozoic rocks of the Cassia Mountains, several aspects of the Cenozoic volcanics deserve special mention.

We did not attempt to compile a stratigraphic section for the Cenozoic volcanics but they total several thousand feet in thickness. Ash beds make up most of the section but a few flows--or what seem to be flows--are present.

At the base of the section in places there is a very thin (6 inch) bed of a rock which superficially looks like obsidian. A sample of this rock was taken as a matter of routine. It was later thin-sectioned and examined microscopically. It was a surprise to find that this rock was apparently fragmental. Dr. R. B. Travis later studied the rock and has confirmed this observation, and kindly called our attention to a publication dealing with a similar phenomenon in southeastern Idaho (Mansfield and Ross, 1935). These authors note (op. cit., p. 314--explan. to Plate III-A) the occurrence of "a typical obsidian with apparently complete homogeneity and perfect conchoidal fracture. The microscope, however, reveals typical tuff structures." This type of rock also occurs in the Cassia Mountains.

In commenting on the distribution of welded tuffs in southeastern Idaho Mansfield and Ross (pp. 308, 309) state that "the wide distribution, the varied physical character, and the perfection with which the tuffaceous structures are retained appear to make the southeastern Idaho localities outstanding examples of welded volcanic tuffs." They add that "it is perhaps the ubiquity of the tuff that at first attracts attention. One finds it in patches, knobs, and plateau-like remnants on top of the mountains at altitudes of more than 7400 feet in the quadrangles named." These remarks are equally applicable to the volcanics of the Cassia Mountain area. Also, a very thick section of welded tuffs is present to the west of the Cassia Mountains in the vicinity of Salmon Falls Creek and on the northern flank of the Elk Mountains which nose into Idaho from Nevada south of the Idaho village of Three Creek (Fig. 2). Accordingly, welded tuffs are apparently very abundant in most of Idaho south of the Snake River. We would like to state frankly that we are uncertain as to the true origin and nature of many of the flow-like rocks in the Cassia Mountain area, for closer inspection and studies have shown that many of what we regarded in the field as true flows are probably welded tuffs. We suggest this as an interesting field for further research.

The source of all of these pyroclastics is a problem. We do not know of any igneous intrusions or volcanic vents in the Cassia Mountains, although some may exist. We do not believe that any great amount, if any, of this pyroclastic material came from any source within the area of the present outlines of the Cassia Mountain uplift. Nevertheless, numerous and large sources must have existed somewhere in the general area to provide this thick volcanic section. In connection with ground water studies, Stearns, Crandall, and Steward (1938) have made important contributions to the knowledge of the volcanics of the Snake River Plain and adjacent areas. They have commented that (op. cit., p. 41) "the amount of rhyolite and associated volcanic rocks in and on the borders of the Snake River Plain is much greater than can be accounted for by known vents in the region." And these authors go on to suggest that "some of the vents from which these silicic volcanics issued may be buried beneath the copious Pliocene and later basalt flows. The hypothesis that one of the major sources of the silicic flows was a chain of volcanoes extending from the Yellowstone National Park toward Boise along the axis of the Snake River Plain accords with the known facts within this region, although it is supported by little direct evidence." We have no better suggestion, and the idea just cited has merit, although the problem certainly can be further studied to advantage.

CONCLUSIONS

The chief conclusions reached from this reconnaissance study of the Cassia Mountains include the following:

1. The Cassia Mountains consist chiefly of a core of late Paleozoic rocks. These rocks are most silicified limestones and orthoquartzites.

2. Fossils are neither abundant nor well preserved in these Paleozoic rocks; brachiopods and fusulinids have been identified and these are Early to Middle Permian in age. Older and/or younger marine rocks may exist. However, it seems certain that a substantial portion of the exposed section is referable to some part of the Permian.

3. The total thickness of the section could not be ascertained precisely because of the intricate local faulting and the lack of any significant number of key beds or fossil zones which could be used for mapping. However, the thickness of this Paleozoic section probably exceeds 10,000 feet.

4. Ordovician rocks crop out on the northwestern flank of the Cassia Mountains, a short distance away from the uplift proper. The structural reason for these outcrops and their structural relation to the Cassia Mountains is unknown but movements of considerable magnitude are probably involved.

5. Volcanics cap most of the peaks in the Cassia Mountains, and may have blanketed the entire area at one time.

6. These volcanics are chiefly pyroclastics. Welded tuffs are especially common.

7. Obsidian-like rocks are present in the volcanic section but these rocks are known to be fragmental in origin. A similar occurrence of "fragmental obsidian" has been reported from southeastern Idaho.

8. No igneous intrusives are known in the range proper. The source of the volcanics is unknown at present.

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