UTAH GEOLOGICAL AND MINERALOGICAL SURVEY
affiliated with
THE COLLEGE OF MINES AND MINERAL INDUSTRIES
University of Utah, Salt Lake City, Utah

RECONNAISSANCE OF THE TERTIARY SEDIMENTARY ROCKS IN WESTERN UTAH

BULLETIN 75 • PRICE $1.25 • AUGUST, 1965

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

103 Civil Engineering Building
University of Utah
Salt Lake City, Utah 84112

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RECONNAISSANCE OF THE TERTIARY SEDIMENTARY ROCKS IN WESTERN UTAH

by E. B. Heylmun

Salt Lake Formation one mile east of Faust, Tooele County, Utah. Adits are in gently dipping outcrops of pumicite. (R. E Cohenour).

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by E. B. Heylmun[2]

INTRODUCTION

Non-marine Tertiary sedimentary rocks are exposed at numerous localities in western Utah, and wells drilled for oil, gas, and water have encountered Tertiary sediments under almost all the broad desert valleys. Oil discoveries in non-marine Tertiary rocks in Nevada help maintain a high level of interest in the Cenozoic sedimentary rocks throughout the Great Basin. Most exposures of Tertiary sedimentary rocks occur along mountain flanks or in upland areas, although there is evidence that the Quaternary valley fill in some valleys is not especially deep, and that Tertiary rocks are near the surface in the central areas of some valleys.

This report may be considered a sequel to that of Van Houten (1956) which discusses Cenozoic rocks in Nevada. Like that report, many of the conclusions are necessarily incomplete and some of the ideas undoubtedly will be proved wrong. However, since no summary of the Tertiary sedimentary rocks in western Utah has been published, a basic framework from which more detailed work can be done appears desirable. Parts of two summers were spent doing reconnaissance work which has led to the information expressed in this report.

The areas west of the Wasatch Line (Figure 1) where sedimentary units are best exposed include the Goose Creek and Grouse Creek Valleys, areas east and southwest of Park Valley, the northeast flank of the Pilot Range, the west side of the Silver Island Range, the Ibapah district of Utah and Nevada, the east side of the Stansbury Range, Rush Valley, the Boulter Summit-Tintic Valley area, and the Miller Basin-Sacramento Pass area just west of the Utah-Nevada line, northwest of the village of Baker, Nevada. Extensive areas of Tertiary rocks exposed in central Utah, some within the Great Basin, will not be discussed in this report as they are adequately covered in several other reports, notably Spieker (1931, 1946, 1949). Some other areas of Tertiary rocks east of the Wasatch Line will be discussed, however, as they pertain to the general problems encountered in the western part of the state. Figure 2 shows areas where Tertiary sedimentary rocks are exposed in western Utah, as well as the general geography of the region considered here.

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1. This report has been critically read by Dr. Armand J. Eardley, University of Utah and Dr. Joseph F. Schreiber, Jr., University of Arizona.

2. Fossil Fuel Geologist, Utah Geological and Mineralogical Survey, Salt Lake City, Utah.

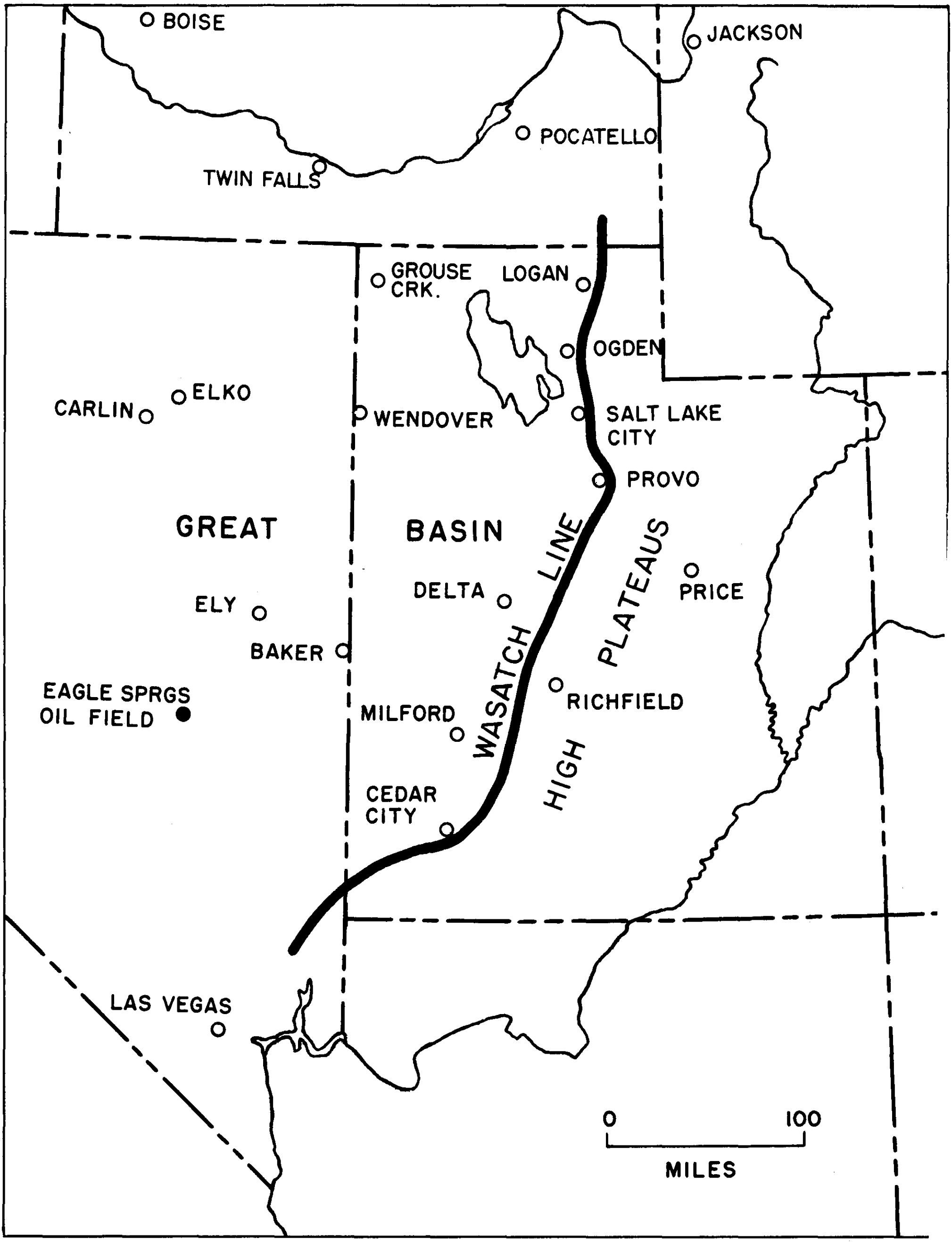

Figure 1. Index map showing approximate position of the Wasatch line.

PALEONTOLOGIC DATA

Although abundant diagnostic vertebrate fossils have been found in Nevada and Idaho in the Cenozoic sequences, very few were found during this reconnaissance in western Utah. Fossil mammals, of course, are by far the best age indicators when dealing with the continental Tertiary deposits of the western interior. With the wealth of vertebrate fossil material found in other parts of the west, it is odd that good Tertiary vertebrate fossil localities should be absent in western Utah.

Plant remains, mostly sedges and seeds, were found in lignite beds in northwestern Utah. These collections have not been identified. No search was made for spores and pollen. One fossil plant locality in Cache Valley, in northern Utah, has been described by Brown (1949).

Fossil ostracodes, diatoms, and charophytes are common in the non-marine Tertiary beds of western Utah. Most of these forms are wide-ranging and are not diagnostic as to age. Dr. F. W. Swain (1947) has identified ostracode collections from this area.

Fossil mollusks are commonly found in the Tertiary sedimentary rocks of western Utah. Freshwater snails, land snails, and clams are abundant in some beds, particularly the tan to white limestones. Since the limestone units are generally more resistant to erosion, they crop out more widely; and the mollusks, as a result, are frequently easier to find and to use than are most other fossil forms. Unfortunately, no definite age assignments can be given most of the assemblages, although, as with ostracodes, broad indications of age and stratigraphic position are possible. Mollusks collected in the course of the field work were identified by D. W. Taylor of the U.S. Geological Survey. A Late Pliocene assemblage of clams and snails, in a near-perfect state of preservation, has been described by Yen (1947). These fossils, as well as the ostracodes described by Swain, were collected at the crest of the Junction Hills in northern Utah. The molluscan fauna is similar to the so-called "Balkan fauna" found in the Idaho Group of Idaho, and particularly to the Late Pliocene-Early Pleistocene Glenns Ferry Formation (Malde and Powers, 1962, p. 1208) within the Idaho Group. The fossils described in published reports by Swain (1947) and Yen (1947) are not typical of the forms found in Tertiary rocks in most of western Utah.

Williams (1964, p. 271) obtained six potassium-argon age determinations on tuff beds in the Tertiary of Cache Valley. Williams questions the validity of some of the determinations, as there is conflict with good fossil information. The possibility that the tuffs were reworked from earlier deposits must be given consideration before radioactive age determinations can be fully accepted.

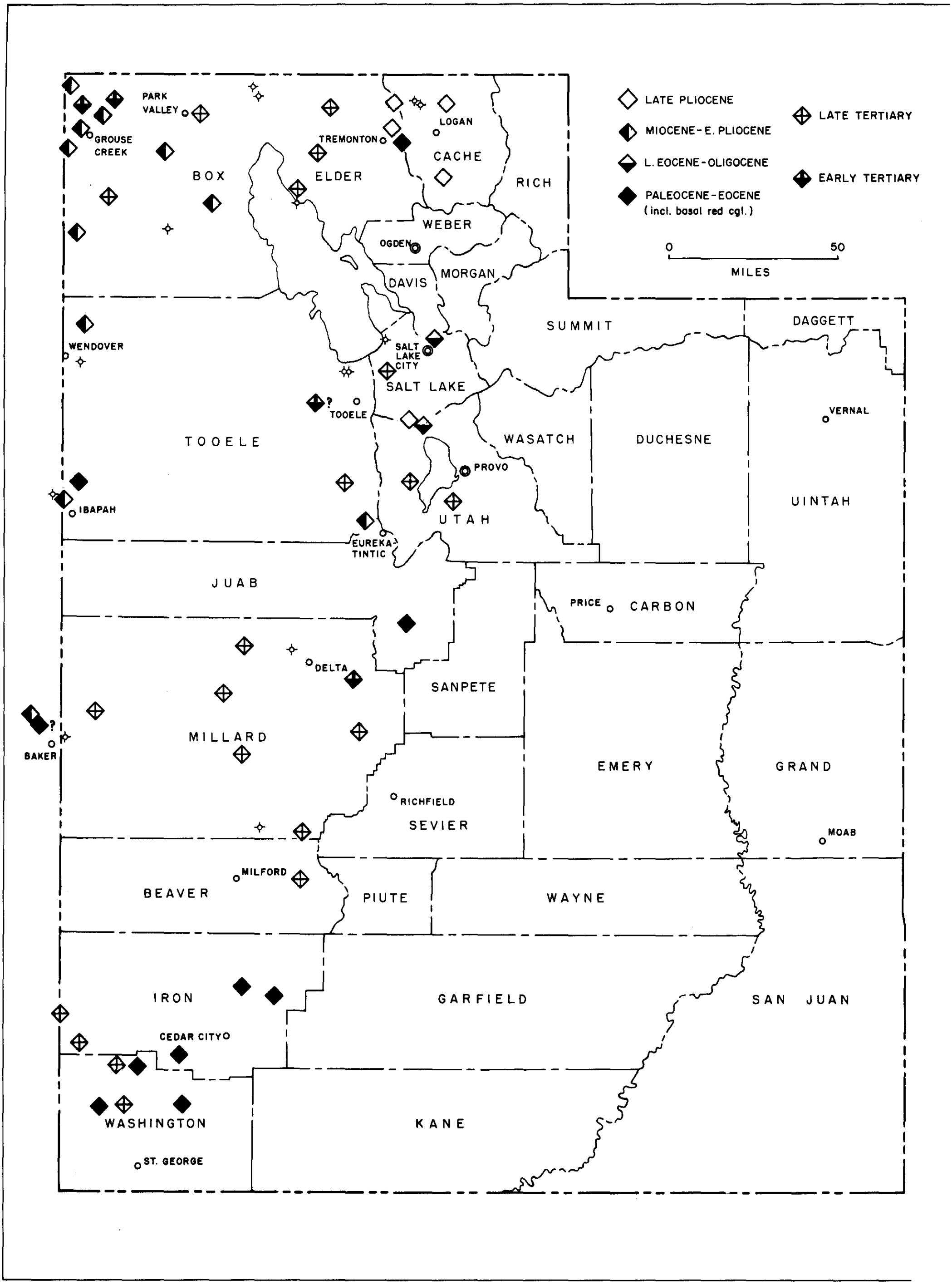

Figure 3. Map showing approximate ages of Tertiary exposures in western Utah. Tertiary rocks east of the Wasatch Line are not discussed in this report.

Figure 3 shows localities in western Utah where the approximate age of the Tertiary rocks has been determined on the basis of fossils and stratigraphic position. Most of the Middle to Late Tertiary sedimentary rocks in northern and western Utah have been included in the "Salt Lake" Formation or Group by various writers. Originally named by Hayden (1869, p. 92), the Salt Lake Formation was proposed for a sequence of light-colored tuffaceous rocks in Morgan and Salt Lake Valleys that are now included in the Fowkes Formation of Late Eocene or Early Oligocene age (Gazin, 1959; Eardley, 1959). In essence, the name "Salt Lake" is used promiscuously for almost any sequence of light-colored tuffaceous rocks that occurs in northern or western Utah. Since the various tuffaceous units are not conformable with one another and range in age from Late Eocene to Pleistocene, it appears advisable to reject the term "Salt Lake" entirely, even in the broadest sense.

Excellent reports by Regnier (1960) and Malde and Powers (1962) demonstrate that the Cenozoic stratigraphy in any one area or district is a complex series of sedimentary and igneous rocks, intimately associated with one another. Regnier noted no fewer than five unconformities within the section that he measured near Carlin, Nevada. Correlation of individual units over any distance at all is hazardous at best, but broad groupings of units with similar characteristics is perhaps possible. This report is based on the assumption that such broad groupings are possible, at least in certain regions or districts.

Formational names are not used here, even though it is apparent that certain units may be continuous over sizeable areas in western Utah. For example, the Tertiary sedimentary rocks exposed along the west side of the Silver Island Range are almost certainly equivalent to beds that crop out around the northeast flank of the Pilot Range, 25 miles to the north. The faunal and lithologic similarities are marked. There are other units which can be similarly correlated, but it will be left to other workers doing detailed work in the region to establish formation or group names. Various sequences will be described here, and possible correlations will be suggested.

BASAL CONGLOMERATES

Conglomerates of Paleozoic pebbles and cobbles with a red silty and calcareous matrix, appear to be the lowest Tertiary units in many areas. Beds of sandstone, mudstone, and limestone are frequently interbedded within the conglomerates. The conspicuous red conglomerates are not accurately dated, and may not be everywhere of the same age. The red conglomerates around the edges of Cache Valley, in northern Utah, are considered by Williams (1948, 1962) to be equivalents of the Wasatch Group of Paleocene or Early Eocene age. There is considerable algal-limestone within the Wasatch Group in this region. The beds are lithologically similar to other Paleocene and Early Eocene units in central Utah and western Wyoming, and, according to Williams (1948, p. 1146), can be traced into the type locality of the Wasatch Formation near Evanston, Wyoming.

It is difficult even to hazard a guess as to the age of some of the isolated exposures of red and brown pebble and cobble conglomerate in western Utah. Red and brown Paleozoic and Mesozoic pebble conglomerates are exposed six to ten miles north of the village of Grouse Creek, on the flanks of the Goose Creek and Vipont Mountain. Land snails collected from a bed in the conglomerate sequence indicate an Early Tertiary possible Wasatch, age for the unit (A. R. Young, personal communication). Steeply dipping reddish-brown conglomerate, interfingering with non-marine limestone and mudstone of possible Eocene age, is well exposed in Sacramento Pass, T. 15 N., R. 68 E., White Pine County, Nevada (Van Houten, 1956, p. 2806). A red conglomerate underlies the White Sage Formation of Eocene (?) age in the Ibapah-Gold Hill area of western Utah (Nolan, 1935, p. 42). Red Paleozoic pebble and cobble conglomerates can be found in the Tintic-Boulter Summit-Fivemile Pass region of Tooele, Juab, and Utah Counties, Utah, which are referred to the Apex Conglomerate of Eocene (?) age (Morris and Lovering, 1961, p. 123). Red conglomerates crop out along the east side of the Stansbury Range, T. 3-4 S., R. 6 W., Tooele County, Utah. There are many other limited exposures of indurated red pebble and cobble conglomerates in western Utah, most of which appear to be at the base of the Tertiary sequence.

Other workers have suggested various dates from Cretaceous to Pliocene for the occurrences of red conglomerates in the region. The absence of volcanic debris in the conglomerates tends to indicate an age older than Late Eocene, when the earliest widespread vulcanism is believed to have started in western Utah and Nevada (Mackin, 1960). Christiansen (1952, p. 733) favors a Cretaceous age for many of the conglomerates, whereas Van Houten (1956, p. 2807) suggests that most of them could be equivalent to the Wasatch Group of central and northern Utah. On the basis of stratigraphic relations and meager fossil evidence, an approximate Wasatch age appears to be most logical.

The presence of finer conglomerates close to existing mountain ranges, and coarse cobble conglomerates at localities distant from present mountain ranges, suggests that the source areas at that time were considerably different from those in evidence today. Also, some of the conglomerates contain pebbles that are foreign to the area of deposition. For example, the red conglomerates north of Grouse Creek, Utah, contain Paleozoic and Mesozoic pebbles and cobbles and virtually no metamorphic rocks, despite the fact that the nearby Grouse Creek and Raft River highland areas are composed largely of Precambrian quartzite and schist.

The red conglomerates in western Utah lie with angular discordance on an uneven surface of older, highly indurated rocks at localities where the base is exposed. Unfortunately, the Tertiary rocks are in fault contact with older rocks at most localities in the region, and sedimentary contacts are relatively rare.

LOWER LACUSTRINE SEQUENCE

Western Utah Region

Overlying basal red conglomerates in the Ibapah-Gold Hill area, T. 7 S., R. 18-19 W., Tooele County, Utah, is a sequence of non-marine argillaceous limestone, algal limestone, and cherty limestone. Most of the beds are brownish on fresh fracture, but weather to lighter colors. Nolan (1935, p. 42) named this sequence the White Sage Formation, and assigned it to the Eocene (?). He measured an incomplete section that totalled approximately 600 feet in thickness. Mollusks collected by me from the White Sage Formation at its type locality have been identified by D. W. Taylor as follows:

Freshwater snails
- Hydrobiidae, indeterminate
- Bulinus
- Reesidella

Land snails
- cf. Spelaeodiscus
- cf. Acanthinula

Dr. Taylor (personal communication) states, "The fossil mollusks are not varied enough to warrant an age assignment more precise than Cretaceous to Early Tertiary. From negative evidence, a Paleocene or Early Eocene date is more likely than Cretaceous." This statement would suggest a possible equivalence with units in the Wasatch Group, such as the Flagstaff and Claron Formations of central and southern Utah. There is no recognizable volcanic material in the White Sage Formation, which indicates that this unit is possibly older than Late Eocene. Some of the clay and other impurities in the limestones of the White Sage Formation could be altered volcanic ash, however.

Farther to the west, in east-central Nevada, a relatively thick sequence of petroliferous, cherty, and lithographic limestones, sandstones, siltstones, and claystones has been named the Sheep Pass Formation (Winfrey, 1960, p. 126). Fossil mollusks and ostracodes indicate an Early to Late Eocene age. The unit is best exposed in the Egan Range, south of Ely, where it is over 2,500 feet in thickness. The Sheep Pass Formation is responsible for the high pour-point oil currently being produced at the Eagle Springs oil field, in Nye County, Nevada. This fact leads one to speculate on the possible equivalence of this unit with the Eocene Green River Formation of eastern Utah, which is responsible for the production of oil with similar characteristics (Picard, 1960, p. 237). It can be said with a degree of certainty that the Sheep Pass Formation was deposited in a system of freshwater lakes in much the same manner as the Green River Formation was deposited. However, if the units are in any way equivalent, it is doubtful if there were large lakes in western Utah at that time. Aside from the occurence of the White Sage Formation in the Gold Hill-Ibapah area, no Eocene lacustrine rocks have been recognized, either at surface exposures or in wells, in western Utah west of the Wasatch Line. An 1,800 foot thick sequence of reddish shale, siltstone, and arkosic sandstone in the Gulf Oil No. 1 Gronning, section 24, T. 16 S., R. 8 W., Millard County, Utah, at a depth between 6,255 and 8,016 feet (total depth), might be referrable to the Claron Formation of Paleocene or Eocene age in southwestern Utah. However, the lithologic characteristics of this unfossiliferous zone suggest a correlation with Triassic redbeds, similar to those exposed in the Pavant Range, 50 miles to the southeast. Much of western Utah appears to have been an upland area in Early Tertiary time, and lacustrine sediments were apparently not deposited.

A pre-Late Eocene age is suggested for the White Sage Formation, but the fossils are not diagnostic. It is entirely possible that the unit correlates at least in part, with the Sheep Pass Formation in Nevada. Beds similar in appearance and lithology to the White Sage Formation crop out in the Miller Basin area north of the village of Baker, Nevada, in the N $\frac{1}{2}$ of T. 14 N., R. 69 E., White Pine County, Nevada. No fossils were found in a search of these exposures.

The large fresh-water lake or system of lakes in which the Sheep Pass and White Sage Formations were deposited might be compared to some of the large tropical or sub-tropical lakes in existence today. There remains the possibility, too, that these lakes were in fact relict seas, much like the present day Caspian Sea. Certain fossil forms have marine affinities, which might help explain the petroliferous nature of the beds.

Central Utah Region

Further east, in the region of the Wasatch Line in north-central, central, and southwestern Utah, there are numerous exposures of sedimentary rocks of Paleocene and Eocene age. Many of the units are continuous with those in the Wasatch Plateau and Uinta Basin to the east. It is beyond the scope of this paper to review these occurrences, as they are described in considerable detail in a number of published reports, notably those by Spieker (1931, 1946, 1949). The poorly dated tuffaceous beds that are exposed at scattered localities along the Wasatch Line, in north-central and northern Utah, will be discussed here as they pertain directly to some of the problems farther west. Two such areas are in City Creek Canyon, within the city limits of Salt Lake City, and at Jordan Narrows, 24 miles south of downtown Salt Lake City. Different workers have assigned ages to these beds that vary from Paleocene to Pliocene, as no diagnostic fossils have been found.

An extensive search was made of the white tuffaceous limestones in City Creek Canyon, and well-preserved land snails were found in a small, obscure outcrop. The snails were found in association with a number of large faecal pellets. Dr. Taylor (personal communication) identified the specimens as *Oreoconus*, and he states, "On the basis of known occurrences of *Oreoconus* I think the rocks in City Creek Canyon might be correlative with the upper part of the Flagstaff Formation, the main body or higher parts of the Wasatch Formation, or younger Eocene rocks." The presence of considerable volcanic material in the City Creek Canyon rocks suggests an age younger than Flagstaff, as volcanic eruptions were apparently not widespread until Late Eocene and Oligocene time. The deposition of these beds was probably concurrent with igneous activity in the Wasatch Range, and the tuffaceous beds in City Creek Canyon may correlate with the Fowkes Formation in Morgan Valley, 18 miles to the northeast, as suggested by Granger and Sharp (1952, p. 16). Gazin (1959, p. 137) considers the Fowkes Formation to be Late Eocene in age.

Land snails collected from water-laid tuff beds beneath an andesitic flow north of Peoa, Utah, 30 miles east of the exposures in City Creek Canyon, indicate that those beds are also equivalent, in part, to the Fowkes Formation. Slentz (1955, p. 21) has described as the Jordan Narrows unit, a 300-2,000 foot thick sequence of fresh-water limestones, siltstones, and tuffaceous beds in the Jordan Narrows, 24 miles south of the outcrops in City Creek Canyon. These beds have many of the same lithologic characteristics as do those in City Creek Canyon. They have non-diagnostic ostracodes and charophytes. Slentz suggests an Oligocene or Early Miocene age for the unit, but it is entirely possible that the Jordan Narrows unit represents the Fowkes Formation. If so, the relations of this unit with the volcanic rocks exposed near Jordan Narrows would have to be clarified. near Jordan Narrows would have to be clarified.

Two potassium-argon age determinations were obtained from tuff beds at the south end of Cache Valley by Williams (1964, p. 271). Stratigraphic relations suggest that these beds belong to the Fowkes Formation, but the age determinations indicate ages of 68 ± 8 m. y. and 74 ± 8 m. y., which is latest Cretaceous or Paleocene. Williams believes that the radioactive age determinations might be in error.

Beds equivalent to the Fowkes Formation in the eastern fringes of the Great Basin, along the Wasatch Line, cannot be found with any degree of certainty in western Utah. Some of the undated tuffaceous beds in parts of western Utah could be equivalents of the Fowkes Formation. Although the Fowkes Formation and its equivalents are included in the Lower Lacustrine sequence in this report, the unit is decidely younger than the previously described White Sage and Sheep Pass Formations.

LOWER VOLCANIC SEQUENCE

Extensive deposits of rhyolite, latite, dacite, andesite, agglomerate, and welded tuff are found over much of western Utah and adjoining parts of Nevada and Idaho. Basalt is the predominant rock type in younger flows. Considerable water-laid and air-fall ash beds are interbedded with the flows and ignimbrites in some areas. Whereas some of the volcanic units are very local in extent, others, particularly the welded tuffs, are widespread and can be correlated over considerable distances (Mackin, 1960). For ease in discussion, the volcanic sequences will be divided into three stages, lower, middle, and upper, the stratigraphic limits of which are, admittedly, poorly defined. A number of radioactive age determinations have been made on volcanic rocks in the Great Basin (Mackin, 1960, Cook, 1960a, 1960b, Armstrong, 1963, Bassett, et al., 1963), and, in time, the volcanic units will possibly be the best-dated rocks in the entire rock column.

Commencing in the Late Eocene (Mackin, 1960), there was widespread volcanic activity in the Great Basin and surrounding regions. The vulcanism was characterized by violent nuées ardentes, or glowing avalanches. This volcanic activity reached a peak in the Oligocene and Early Miocene, then subsided enough to permit sedimentary deposition in fresh-water lakes later on in the Miocene. Great thicknesses of andesites, latites, rhyolites, agglomerates, and welded tuffs were deposited at this time, and these units are especially well-developed in central, west-central, and south-western Utah. The Lower Volcanic unit overlies the Lower Lacustrine sequence where it is present, and unconformably overlies Mesozoic and Paleozoic rocks where the Lower Lacustrine sequence is absent. The sequence is present between 3,518 and 6,255 feet in the Gulf Oil No. 1 Gronning, section 24, T. 16 S., R. 8 W., Millard County, Utah, where it apparently overlies Triassic redbeds. The lower volcanic unit is by far the thickest and most important of the three volcanic stages considered here, but it is not everywhere present. The unit is not as well developed in northwestern Utah as it is farther south, and appears to be absent in several areas. Tuffaceous sedimentary units such as the Fowkes Formation may have been deposited concurrently with one or more of the volcanic outpourings at this time.

The Lower Volcanic sequence is mineralized at a number of localities in Utah and Nevada, and ,as a result, the volcanic rocks are described in detail in excellent published reports. Many large intrusive bodies, some of which are responsible for rich mineralization, appear to have been emplaced during the time of the extrusion of the Lower Volcanic sequence. For the most comprehensive discussion of the volcanic rocks of the region, the interested reader is referred to Mackin (1960), and Cook (1960a, 1960b). Some reports of interest in specific areas include those by Butler, et al. (1920), Kerr, et al. (1957), and Staatz and Osterwald (1959).

LATE MIOCENE — EARLY PLIOCENE SEQUENCE

Overlying the main mass of volcanic material is a complex series of lacustrine, fluvial, and aeolian rocks that appear to be divisible into at least two groups. Since fossil evidence does not permit any further divisions, the unit is considered under one general heading in this report.

The oldest rocks of the sequence are yellowish to tan, platy, partly to wholly silicified limestones, drab claystones which are frequently silicified, along with tuffs, lignites, and green-to brown-stained sandstones and Paleozoic-pebble conglomerates, which are included in the "eastern sedimentary sequence" of Van Houten (1956, p. 2,810). Petroliferous limestones and carbonaceous shale can also be found in the unit. There are steeply-dipping tan paraconglomerates exposed about four miles east of Grouse Creek. The silicified limestones might be the result of deposition in lake waters which were highly charged with silica due to continued volcanic eruptions at that time. The beds appear to have been laid down under temperate fluvial and lacustrine conditions, as evidenced by the faunal assemblages.

Generally speaking, the oldest rocks of the Late Miocene-Early Pliocene Sequence have suffered considerable faulting and tilting, and are steeply-dipping to nearly vertical at some localities. This is particularly true of the units exposed northeast and east of the village of Grouse Creek, near the heads of Kimber, Pine, and Red Butte Creeks. In this area, the units are in marked angular discordance with the younger sedimentary rocks.

Eight miles north of Grouse Creek, along the road to Junction Valley, several lignite beds are exposed on a hillside, along with interbedded siltstone and conglomerate beds. Tan to yellowish silty limestones crop out in a sizeable area centering about T. 13 N., R. 18 W., Box Elder County, Utah. These beds carry limonitic casts and molds of the fresh-water snail identified by D. W. Taylor as <u>Bulimnea</u>. The form is not diagnostic as to age. In the vicinity of Tanner Reservoir, six to eight miles west of Grouse Creek, conglomerates, siltstones, claystones, tuffs, and lignites crop out. Ostracodes collected at a locality in section 9, T. 11 N., R. 19 W., Box Elder County, Utah, were identified by F. M. Swain as follows:

<u>Candona</u> sp.
<u>Cypricercus</u> sp.
<u>Limnocythere</u> sp.
<u>Cypris</u>? sp.

The forms are not diagnostic. Dr. Swain, however, suggests a possible Miocene age. Fossilizied wood is also common in this area. The beds are separated from overlying sediments by a volcanic unit, here termed the "Middle Volcanic sequence," which will be described later in this report.

This volcanic sequence appears to be absent in the area east of Grouse Creek, although it might be represented by one or more of the unaltered vitric tuff beds that are present.

The nature of the contact of this sequence of rocks with underlying rocks is obscure, but the unit appears to overlie unconformably the basal Early Tertiary red conglomerates in the areas north and west of Grouse Creek. In many areas, however, the unit is in fault contact with older rocks.

Northwest of Grouse Creek, in the Goose Creek district of extreme northwestern Utah and adjoining parts of Idaho and Nevada, this older part of the Late Miocene-Early Pliocene sequence is recognized, and has been tentatively correlated with the Payette Formation of Idaho (Mapel and Hail, 1959, p. 224). Fossil diatoms, leaves, and seeds indicate a Late Miocene or Early Pliocene age for the unit. In this area, the beds are only in slight angular discordance with younger sediments.

Without mapping the various units in detail, it appears that the oldest rocks of the sequence are the platy, silicified limestones, claystones, and green- to brown-stained sandstones and conglomerates exposed north and northeast of Grouse Creek and perhaps present in the subsurface as far east as Rozel Point, on the north shore of Great Salt Lake. These beds are certainly no younger than Late Miocene, and could be older.

Yellowish to tan limestone, in part silicified, interbedded with tan and gray sandstone, siltstone, vitric tuff, Paleozoic pebble-conglomerate, and carbonaceous shale crop out on the east and north sides of the Pilot Range, and along the west side of the Silver Island Range north of Wendover, Utah. In both areas, the beds underlie rhyolite and andesite porphyries referrable to the "Middle Volcanic Sequence," discussed later in this report.

In the Pilot Range area, the unit is over 2,500 feet thick (Blue, 1960, p. 44) and dips valleyward, to the east. In the Silver Island area, the unit is over 2,800 feet thick (Schaeffer, 1960, p. 111), and also dips valleyward, to the west. The base of the sequence is not exposed in either area. Some of the limestone beds are fossiliferous, and the fossils are characteristically stained with iron oxide. Forms identified by D. W. Taylor include the following:

Freshwater clam
- *Sphaerium*

Freshwater snails
- *Valvata*
- Viviparidae, cf. *Bellamya turneri* (Hannibal)
- *Helisoma* (*Carinifex*)
- Hydrobiidae, indeterminate
- Lymnaeidae, indeterminate
- Planorbidae, indeterminate

Dr. Taylor states that these collections are probably Late Miocene to Early Pliocene in age. Ostracodes, identified by F. M. Swain, include the following forms:

Candona sp.
Cypris sp.
Pseudoeucypris sp.
Limnocythere sp.

Dr. Swain suggests a Miocene age for these collections.

As stated earlier, the beds cropping out in the Pilot Range and Silver Island areas are so strikingly similar, both lithologically and faunally, that it seems likely that they represent the same formation, even though the localities are 25 miles apart. It is not at all certain if these beds correlate with part of the Payette Formation of Idaho, but such a correlation is suggested by Van Houten (1956, p. 2,813).

Apparently unconformably overlying the older sequence of rocks in the Grouse Creek region is a series of chalk-white to gray limestones, vitric tuffs, claystones, and Paleozoic pebble-conglomerates. These beds may underlie, or are possible lateral equivalents of, the "vitric tuff unit" of Van Houten (1956, p. 2,814). It appears advisable to abandon this terminology in western Utah, as considerable thicknesses of altered and unaltered vitric tuff can be found throughout the section from Late Eocene to the Pleistocene. The white limestone beds are well exposed north of the village of Grouse Creek, where they seem to provide ideal conditions for juniper growth. Paleozoic-pebble conglomerates and unaltered vitric tuffs are well developed both east and west of Grouse Creek, and many of the low hillocks in the area are composed of greenish-gray to brownish bentonitic claystone which weathers to near white and light tan colors. Fossils collected from the chalk-white limestone beds include the following forms, identified by D. W. Taylor:

Freshwater clam
- Sphaerium

Freshwater snails
- Valvata humeralis Say
- Viviparidae, Bellamya turneri (Hannibal)
- Planorbarius
- Lymnaeidae, Radix or Pseudosuccinea
- Lymnaea (Stagnicola)
- Promenetus?

Dr. Taylor states that the collections are probably Late Miocene or Early Pliocene in age. The fauna is similar to that found in the limonitic limestones in the Pilot Range and Silver Island areas, but lack the iron staining.

In section 7, T. 13 N., R. 18 W., Box Elder County, Utah, fossils found in the white limestones are opalized.

Many of the fossil mollusks, such as the common form Valvata humeralis Say, have closely related forms living in fresh waters today, so they are of little value for definitive age determinations. In the absence of vertebrate fossils, much reliance must be placed on stratigraphic relations as observed in the field, and this is often a difficult task due to poor and discontinuous exposures.

In the Goose Creek district in extreme northwestern Utah, Mapel and Hail (1959, p. 235) collected fossil mollusks, vertebrate remains, pollen, spores, diatoms, leaves, and seeds from beds of this sequence. Despite the volume of fossil material collected, no age assignment closer than Late Miocene to Middle Pliocene could be made, although Mapel and Hail favor an Early to Middle Pliocene age. The thin welded tuffs interbedded with the sediments in the Goose Creek area can not be found in the Grouse Creek region. Mapel and Hail (1959, p. 229) place the sequence in the Salt Lake Formation. As indicated earlier in this report, the term "Salt Lake" was originally proposed for tuffaceous beds which are now considered to be Late Eocene or Early Oligocene in age, and the term should not be used in northern or western Utah.

The sequence in northwestern Utah, above the previously described yellowish to tan platy, silicified limestones, may be older than the Idaho Group farther north, or may be represented by the lowermost units within the Idaho Group. The sequence is definitely older than the so-called "Salt Lake" Formation or Group in most of the Cache Valley region of northern Utah, but might be correlative, at least in part, with the Carlin Formation (Regnier, 1960, p. 1,198) of north-central Nevada, which is the middle member of the "Humboldt Formation" of Sharp (1939).

Unaltered to partly altered vitric and pumice lapilli tuffs, claystones, and limestones crop out at isolated localities elsewhere in northwestern Utah. There are noteworthy occurrences around the flanks of the Raft River Mountains, on the flanks of the Grouse Creek Mountains, and in the Hogup Mountains (P. Stifel, personal communication). In an area of low hills in T. 11 N., R. 14 W., Box Elder County, Utah, 12 miles southwest of the village of Park Valley, an unmeasured sequence is relatively well exposed. Ostracodes collected from the unit include the following forms, identified by F. M. Swain:

Candona sp.
Pseudoeucypris sp.

The forms are not diagnostic as to age, but Dr. Swain suggests an age approximately equivalent to the Middle or Lower "Humboldt Formation" in Nevada.

In the Boulter Summit-Tintic Valley region of central Utah, 150 miles southeast of the exposures in the Grouse Creek region, similar chalk-white to gray limestones crop out, along with a thick sequence of grayish-green claystone, siltstone, and vitric tuff. An additional feature is beds of dark, fetid pellet and micritic limestone. Ostracodes and charophytes collected from these beds were identified by F. M. Swain as follows:

Pseudoeucypris sp.
Candona sp.
Potamocypris sp.
Chara sp.

Once again, these forms are not diagnostic as to age. Freshwater snails similar to those found in the Late Miocene-Early Pliocene rocks of northwestern Utah were also collected. Morris and Lovering (1961, p. 127) suggest an Early Pliocene age for the sediments in the Boulter Summit-Tintic Valley region on the basis of ostracodes, and tentatively correlate the sequence with the "Salt Lake" Formation. The relationship of these sediments with those exposed in Rush Valley, 15 miles to the northwest, is not clear.

At the south end of Rush Valley, centering about Faust Station on the Union Pacific Railroad, a thick sequence of vitric and lithic tuffs, grayish-green to brownish claystones, and oolitic and tuffaceous limestones is exposed. Despite the tendency of the more resistant tuff and limestone beds to crop out, the dominant lithology is probably claystone. This is an excellent area in which to study the alteration of tuff and limestone beds, to be briefly discussed later in this report. Figure 4 shows a generalized stratigraphic column for Rush Valley, and includes a geologic map of part of the area. The exposed stratigraphic section is over 8,000 feet in thickness, but may be partly duplicated by faulting. At least 5,000 feet can be measured in unfaulted continuity, dipping mostly between 15 and 40 degrees to the west. Thin vitrophyres, algal limestones, silicified dark gray limestones, and pebble conglomerates can be found in the upper part of the section. One thin but prominent conglomerate bed in the upper part of the sequence, about a mile west of Faust Station, contains pebbles of Paleozoic and Precambrian rocks similar to those cropping out in the Sheeprock Mountains (Cohenour, 1959), 15 miles to the southwest. As the conglomerate bed is traced a short distance southward, the pebbles appear to become coarser, suggesting a source in the Sheeprock Mountain area.

Friable, unaltered vitric tuff, possibly best described as pumicite, forms distinctive light gray beds in the Rush Valley section. Some of the beds have been mined and are over 100 feet in thickness. The best occurrences are in the middle part of the measured section, south-east of Faust Station.

An extensive search for fossils was made in the thick Rush Valley section, without success. It can only be assumed, on the basis of regional relationships, that the sequence is Late Miocene or Pliocene in age.

In the Ibapah region of extreme western Utah, including much of Deep Creek Valley, calcareous sandstones, claystones, tuffs, and conglomerates are exposed, totalling several thousand feet in thickness. Most of the sandstones might logically be described as "grit," and Nolan (1935, p. 49) uses this term in discussing the unit. The better exposures of the sequence are west of the Utah-Nevada line, and some of the best outcrops are in the vicinity of White Sage Flat, northwest of the village of Ibapah. This has led to confusion of the sequence with the nearby Early Tertiary White Sage Formation, previously described. This unit and the White Sage Formation are shown with the same symbol on the new 1:250,000 geologic map of Utah, but the lithology of the two formations is distinctly different and the difference is readily apparent in the field.

As noted by Nolan, thin, resistant calcareous beds containing casts of tubes, possibly representing borings or plant roots, are characteristic of this series of rocks. Fossil teeth, bones, and antlers were collected from the sequence by K. C. Thomson, Utah Geological Survey, and the teeth have been identified as Merycodus (W. L. Stokes, personal communication), or probably Late Miocene in age.

Ostracodes found in calcareous claystones were identified by F. M. Swain as Pseudoeucypris sp., of possible Miocene age.

The Gulf Oil No. 1 Ibapah, section 20, T. 26 N., R. 70 E., White Pine County, Nevada, three miles west of the Utah-Nevada line, spudded in the Late Miocene-Early Pliocene sequence and penetrated sandstones, claystones, and tuffs to a depth of 820 feet, where a 930 foot thick rhyolite flow, or series of flows was topped. Permian limestones were encountered at a depth of 2,215 feet. The volcanic unit encountered at 820 feet is probably part of the Lower Volcanic sequence in the region.

The sedimentary units in the Ibapah region are unlike those included in the Late Miocene - Early Pliocene sequences in northwestern Utah, both in lithology and in degree of induration. The fossil information, together with the relationship to underlying and overlying volcanic sequences, however, suggests a similar age. Further work may eventually clarify the regional relationships.

A thick sequence of beds is well-exposed in Miller Basin, north of Baker, Nevada. Most of the best exposures are in T. 15 N., R. 69 E., White Pine County, Nevada, about 10 miles west of the Utah-Nevada line. This series bears a close resemblance, lithologically, to the beds exposed in the Ibapah region, even to the thin calcareous rocks with the casts of tubes. A nondiagnostic freshwater snail, identified by D. W. Taylor as an indeterminate

Lymnaeidae, was found in calcareous beds in the unit. The upper part of the sequence consists of a massive, thick conglomerate, well-exposed along Miller Basin Wash.

The hard, silicified tan limestones found in the lower part of the Late Miocene-Early Pliocene sequence have been recognized in Utah only in the Gulf No. 1 Rozel State, sec. 17, T. 8 N., R. 7 W., Box Elder County, between 1,734 and 2,356 feet. The Gulf Oil No. 2 Wilkins Ranch, section 19, R. 39 N., R. 69 E., Elko County, Nevada, near the town of Montello, encountered tan limestones, tuffaceous siltstones, and bentonitic claystones between 4,135 and 4,707 feet, which also appear to be part of the lower Late Miocene-Early Pliocene sequence. There does not appear to have been any deposition of this earlier phase of silicified limestones in western Utah, east or south of Rozel Point in western Utah. Most of western Utah was probably slightly elevated during the first 40 million years of the Cenozoic Era and was undergoing block faulting, but was not high enough to prevent its being swept by nuées ardentes and other phenomena associated with volcanic outbursts (Eardley, 1962, p. 575-78, 510-14).

As shown here, however, slightly younger units in the Late Miocene-Early Pliocene Sequence are widespread throughout western Utah, and some of the localities have been described. These units are found in a number of oil, gas, and water wells in western Utah.

MIDDLE VOLCANIC SEQUENCE

A sequence of silicic volcanic rocks, mostly rhyolites, latites, andesites, and welded tuffs, unconformably overlies Late Miocene-Early Pliocene sedimentary rocks in parts of northwestern Utah. Volcanic ash beds underlie, overlie, and are interbedded with the main mass of volcanic rock. The unit appears to mark the base of the Pliocene in some areas. Detailed work might eventually show that the Middle Volcanic Sequence in the region correlates with all or part of the Idavada Volcanics of Malde and Powers (1962, p. 1,200) in southwestern Idaho and possibly even with the Palisade Canyon Rhyolite of Regnier (1960, p. 1,198) in north-central Nevada. Mackin (1960) and Cook (1960b) describe the widespread nature of certain volcanic units, and how they might prove to be correlatable over extensive areas. If the volcanics do have such widespread distribution and can be correlated with radioactive dating methods, they will act as excellent markers for further stratigraphic work.

Farther south and east in western Utah, in areas where Late Miocene-Early Pliocene sedimentary rocks do not manifest themselves, the Middle Volcanic sequence probably rests directly on rocks of the Lower Volcanic Sequence. In such instances, the various units probably cannot be divided except by means of radioactive dating. The great volcanic pile of central and southwestern Utah, with its interbedded volcanic ash beds, ranges in age from the latest Eocene to the Pleistocene, according to radioactive age dates. Certain units within the thick sequence, however, have distinct characteristics which permit them to be mapped over extensive areas. The Middle Volcanic sequence could be represented in central and southwestern Utah by one or more of the distincitve units in the upper part of the volcanic section.

A unique, concentric volcanic feature, about a mile in diameter, forms a jagged hill immediately south of the hamlet of Etna, five miles southwest of Grouse Creek, Utah. It appears to be associated with the Middle Volcanic sequence and probably deserves special study.

LATE PLIOCENE — PLEISTOCENE SEQUENCE

Late Pliocene sedimentary and igneous units have been accurately dated at only a few localities in northern and western Utah, but are probably fairly widespread in the eastern part of the Great Basin, adjoining the Wasatch Line. Over 5,000 feet of Late Pliocene sediments are exposed in the Cache Valley region of northern Utah (Adamson, et al., 1955; Williams, 1948, 1962), where they have been designated the "Salt Lake Formation." Williams (1962, p. 133) has divided the so-called "Salt Lake" into three units, consisting of a lower conglomerate unit, a middle tuff unit, and an upper conglomerate and sandstone unit. Fossil plants, mollusks, and ostracodes have been collected from these beds by J. Stewart Williams and others, and most collections have been determined as Late Pliocene in age (Brown, 1949; Yen, 1947; Swain, 1947).

Fossil mollusks and ostracodes in a near-perfect state of preservation were collected from a fine silt bed interbedded with oolitic limestones and Paleozoic-pebble paraconglomerates with an oolite matrix, at the crest of the Junction Hills in section 16, T. 13 N., R. 2 W. These beds are included in the upper conglomerate and sandstone unit by Williams (1962, p. 134). At the village of Collinston, six miles to the south, occur similar beds which are placed in the lower conglomerate unit of Williams (1963, p. 133). The paraconglomerates at Collinston are fossiliferous. The fauna was described by Chamberlin and Berry (1933). According to D. W. Taylor (personal communication), this fauna is identical to that found in the Junction Hills. Since the beds are lithologically similar, and the fauna is identical, it appears that the beds at the two localities are part of the same formational unit. Granted, the fossil forms have a wide range, and some forms are living today, but the similarities between the two units are striking. If the two units are, in fact, the same formation, then it is apparent that the upper conglomerate and sandstone unit of Williams overlaps the basin edges, and the lower conglomerate unit may not exist as such, at least in the Collinston-Mendon area around the north end of Wellsville Mountain. The middle tuff unit of Williams might rest directly on Paleozoic rocks at some localities, a basal conglomerate zone being absent. In the Cache

Valley No. 1 Gossner, section 19, T. 13 N., R. 1 E., Cache County, Utah, a conglomerate zone between 900 and 2,000 feet might be equivalent to the Late Pliocene conglomerates and silts exposed in the Junction Hills, 9 miles to the west. The beds between 2,000 feet and the top of the Paleozoic at 5,024 feet may be largely equivalents of the Fowkes Formation of Late Eocene or Oligocene age.

In the Junction Hills area, Williams (1964, p. 272) obtained a potassium-argon age determination on a tuff bed which overlies the Late Pliocene fossil locality described by Yen (1946) and Swain (1947). The age of the tuff, by radioactive methods, is 18.9 ± 1.6 m. y., indicating an approximate Late Miocene age. Either the determination is incorrect or the tuff was reworked from an older source.

The fossil mollusks and ostracodes found in the Late Pliocene beds in the Cache Valley region are totally unlike those found in the Late Miocene-Early Pliocene sequence of western Utah. The mollusks are more closely related to the forms found in the Pliocene-Pleistocene Idaho Group to the northwest, particularly to the forms found in the Glenns Ferry Formation of that group (Malde and Powers, 1962, p. 1,208). This is the so-called "Balkan" fauna of Dall (1925).

The Late Pliocene deposits of northern Utah are mostly fluvial and lacustrine in origin, and apparently deposition took place in basins that were similar in location and extent to the basinal areas in evidence today. Undoubtedly, the mountain ranges have been block-faulted and elevated in recent times, probably at some time during the Early or Middle Pleistocene, as the Late Pliocene sediments exposed at the crest of the Junction Hills are at an elevation of 5,800 feet and over 6,000 feet at places in the north part of Wellsville Mountain. The present elevation of the floor of Cache Valley is around 4,450 feet, so block faulting of considerable magnitude is demonstrated. Certain conglomerate beds in the hills behind the North Bench of Salt Lake City, within the city limits, reportedly contain Pliocene ostracodes. Some of the beds are nearly 1,500 feet above the present level of the valley floor to the west. Remnants of erosion surfaces can be found along the mountain fronts in the Wasatch Range area, both in northern and central Utah. If these old surfaces and erosional notches are Late Pliocene in age, then the relief at that time was probably much more subdued than it is today, and the lowland areas were filled with large freshwater lakes. As indicated by Axelrod (1956), a cold temperate climate probably prevailed at that time.

In the Jordan Narrows area, 24 miles south of downtown Salt Lake City, Slentz (1955, p. 18) describes a travertine unit containing vertebrate remains dated as Late Pliocene (Blancan) in age, unconformably overlying older Tertiary sedimentary units. Slentz attributes the formation of the travertine to hot spring activity, which is, of course, entirely possible.

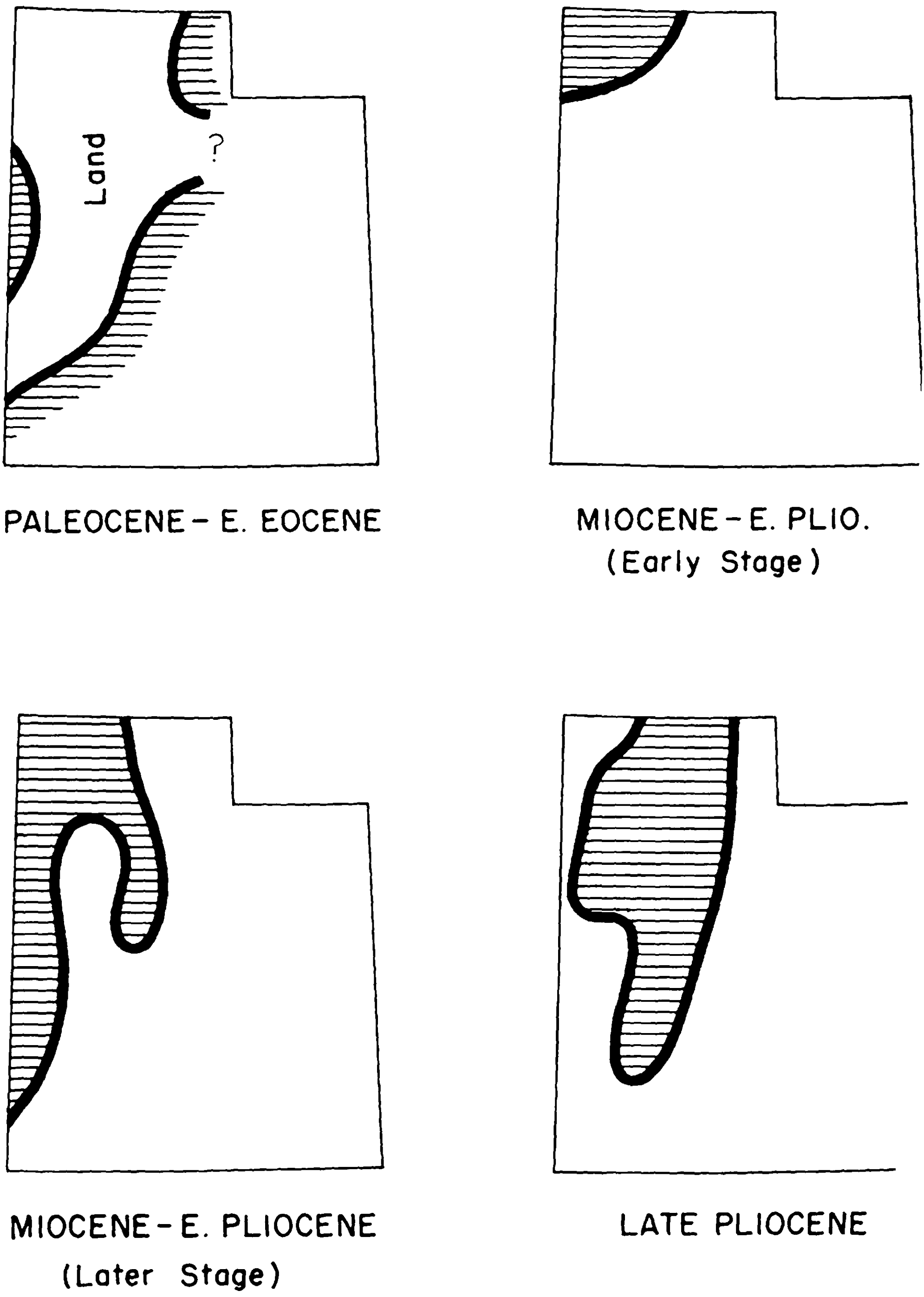

Figure 5. Illustration showing approximate development of lake systems in western Utah at certain times in the Tertiary. The areas submerged by lake waters are lined.

However, an alternate explanation seems to be that the travertine, which might better be described as tufa, was formed as the result of the accumulation of thick mats of lime-secreting blue-green algae which perhaps clogged many of the lakes at that time.

Stringham and Sharp (1950) describe a considerable thickness of limestone at the south end of the Lake Mountains in the Fox Hills, in T. 7 S., R. 1 W., Utah County, Utah. The beds, which also contain halloysite clay, are undated, but Stringham and Sharp suggest an Eocene age. The beds appear to overlie volcanic rocks, which would make an Eocene age highly improbable. There is a distinct possibility that the porous algal limestones in the sequence correlate, at least in part, with the travertine unit described by Slentz at Jordan Narrows. There are oolitic and pisolitic limestones in the lower part of the exposed section. A search for fossils proved unfruitful. The unit is overlain, with slight angular unconformity, by a basalt flow of unknown age.

At Rozel Point, on the north shore of Great Salt Lake in T. 8 and 9 N., R. 7 W., Box Elder County, Utah, over 3,000 feet of oolitic and micritic limestone, claystone, tuff, and interbedded basalt crop out in a line of low hills. There is some algal-mat limestone similar to that described above and intraformational limestone breccias form a distinctive feature of the rocks at this locality. No fossils were found during a brief search, but A. J. Eardley (personal communication) reports that ostracodes have been found in the unit and that some paleontologist, now forgotten, suggested a Late Miocene age. It is not known if the ostracodes were collected from surface exposures or were found in well cuttings. As mentioned earlier, beds with lithologic characteristics similar to those found in the early phase of the Late Miocene-Early Pliocene sequence in northwestern Utah were encountered between 1,734 and 2,356 feet in the Gulf No. 1 Rozel State, sec. 17, T. 8 N., R. 7 W. Lithologically, the exposed rocks resemble some of the Late Pliocene sediments further east and south. In all probability, the interbedded basalt flows are related to the Snake River basalt flows in Idaho, which have been dated as Late Pliocene and Pleistocene in age. There would be a tendency here to accept lithologic evidence over faunal evidence in establishing an age for the exposed beds at Rozel Point, especially since ostracodes found in Tertiary rocks in Utah have not been diagnostic.

Asphalt is found oozing out of recent lake sediments just south of the exposures at Rozel Point. Asphalt has been found in the Quaternary and Tertiary beds in wells drilled at the seeps, and it is assumed that the asphalt, which has peculiar properties, originated either in the late Tertiary beds, or in the recent lake sediments. The stratigraphy and asphalt occurrences are discussed in detail by Eardley and Slentz (1956, p. 37).

Basalt flows cover sizeable areas in the region north of Great Salt Lake, and these flows, as mentioned, are probably associated with the Snake River basalts of Late Pliocene and Pleistocene age. The flows might be considered an "Upper Volcanic group," but they are so intimately related to the Late Pliocene and Early Pleistocene sedimentary units that they are not separated from them in this report.

There are a number of exposures of white limestone, tuff, and claystone elsewhere in northern Utah, such as along the west side of Blue Creek Valley. As these exposures were not studied, no remarks can be made about them, except that they are probably Late Tertiary in age. Figure 5 shows an interpretation of the extent of lake systems at various times in the Tertiary.

Pre-Lake Bonneville sediments, Early to Middle Pleistocene in age, are found in valley areas throughout western Utah. The beds consist of clay, sand, gravel, cobbles, and locally, gypsum and peat. Considerable tuffaceous material can be found which possibly has been reworked from Tertiary sediments. Most of the units were laid down under fluvial and lacustrine conditions in a cold temperate climate. It is not known whether or not Early Pleistocene sedimentation was continuous with that of the Late Pliocene in Utah, as it was in the Idaho Group of southwestern Idaho. It might be noted that whereas much has been written concerning Lake Bonneville and its sediments, very little has been written on the Pleistocene lake systems which precede Lake Bonneville. The most important paper dealing with pre-Lake Bonneville Pleistocene sediments is one by Eardley and Gvosdetsky (1960, p. 1323-1344).

ALTERATION

Alteration, mostly as a result of weathering and ground-water circulation, has affected many of the Tertiary sedimentary units, particularly the tuffs. Many kinds of intergrades between different rock types can be found in the Tertiary section of western Utah.

Much of the claystone found in Tertiary sequences is the product of volcanic ash and dust which has been altered, either by lake waters or by ground-water activity, to montmorillonite and other clay minerals. Many of the claystones are bentonitic, and weather to light tan, gray, light green, or white. Many of the claystones are calcareous and grade into rock which is popularly termed "marlstone."

Some tuff beds have been zeolitized, but apparently not to the extent that they have been in parts of Nevada. Regnier (1960, p. 1205) describes large-scale zeolitization of vitric tuffs in north-central Nevada.

In the Rush Valley area, there are limestone beds that do not exhibit any positive evidence for having been deposited in water. These limestones are tuffaceous. There is a distinct possibility that many of these limestones were formed as the result of calcium carbonate replacing volcanic glass, possibly by ground-water circulation. R. L. Smith (personal communication) suggests the possibility of calcareous replacements of volcanic ash beds, and notes that many gradations can exist between pure ash and limestone. If this is, in fact, the manner in which some of the calcareous tuffs and tuffaceous limestones in the Tertiary of western Utah were formed, it is possible that these beds were deposited under aeolian conditions rather than in large fresh-water lakes. The beds were later subjected to ground-water circulation. The tuffaceous limestones bearing freshwater fossils are, of course, excepted from this hypothesis, as they were undoubtedly laid down in large lakes.

Silicified limestones are commonly found in the section, along with silicified tuff and claystone. The possible origin of these beds has been previously discussed.

SELECTED WELLS

Approximately 100 wells have been drilled for oil and gas in western Utah, and some significant oil and gas shows have been encountered in Cenozoic sediments in a few wells. The Farmington gas field, in T. 3 N., R. 1 W., Davis County, Utah, on the east shore of Great Salt Lake, produced 833 B. T. U. gas for a period of 19 months in 1896-97. The production was from Pleistocene sands at shallow depths. A small amount of heavy black asphalt, with properties similar to ichthyol, has been produced from shallow wells at Rozel Point, on the north shore of Great Salt Lake in T. 8 N., R. 7 W., Box Elder County, Utah. The production and asphalt seeps at this locality appear to be associated with Quaternary or Tertiary beds. There have been oil and gas shows at other wells, but there has been no commercial oil or gas production in western Utah. The Eagle Springs oil field, located in Nye County, Nevada, has been producing commercial quantities of oil from Early Tertiary rocks since 1954, when Shell Oil Company drilled the discovery well. Recent drilling has expanded the field and has created new interest in the Tertiary rocks of the Great Basin.

Some oil, gas, and water wells of interest in western Utah include the following:

Southern Pacific No. 1 Lemay, section 29, T. 7 N., R. 14 W., Box Elder County, Utah. A well was drilled for water on the Great Salt Lake Desert at Lemay siding (Schreiber, 1954, p. 5) penetrating to a depth of 2,502 feet. Unconsolidated clays, sand, and gypsum were found down to 470 feet, where a more indurated sequence of claystone, tuff, and sandstone was encountered. Brown limestone probably belonging to the Late Miocene-

Early Pliocene Sequence was topped at 1,385 feet, and volcanic flows probably belonging to the Lower Volcanic sequence were topped at 1,690 feet. The volcanic flows rest directly on an eroded surface of Paleozoic rocks which are encountered at a depth of 2,108 feet.

Utah Southern No. 2 Federal, section 6, T. 14 N., R. 9 W., Box Elder County, Utah. Drilled in Curlew Valley, this well bottomed in Paleozoic rocks at a depth of 7,569 feet (Peace, 1956, p. 30). A possible division of the Cenozoic units encountered in the well, without fossil evidence, is as follows:

Late Pliocene-Pleistocene (40 to 1,400 feet).

Consists of gravels and volcanic ash beds, with two basalt flows, between 160 and 205 feet, and 390 and 570 feet.

Late Miocene-Early Pliocene (1,400 to 3,080 feet).

Consists of dark claystone, vitric, tuff, sandstone, thin conglomerate, and white limestone. The thickest limestone is a 270-foot-thick chalk white unit near the top of the sequence.

In this well, vitric tuff beds lie directly on the eroded surface of Paleozoic rocks at the depth of 3,080 feet. Aside from the basalt flows in the well, which probably are associated with the Upper Volcanic sequence, there are no other volcanic units recognized in the well, suggesting that the Lower and Middle Volcanic sequences were either not deposited or have been removed by erosion. The Cenozoic section in this well can be correlated, in a general way, with the 3,880-foot-thick Cenozoic section found in the Utah Southern No. 1 Gov't--Gabrielson well, five miles to the northwest (Peace, 1956, p. 28).

Cache Valley Dairy No. 1 Gossner, section 19, T. 13 N., R. 1 E., Cache County, Utah. Only a driller's log of questionable accuracy, aided by an electric log, is available for this well, which was drilled in the central part of Cache Valley. The well penetrated to a depth of 5,500 feet, topping Paleozoic rocks at 5,024 feet. Claystones, tuffs, sandstone and pebble and cobble conglomerates were found in the Cenozoic sequence, with a particularly thick conglomerate unit between 900 and 1,980 feet. It is impossible to correlate the Cenozoic units in this well with any exposed on the surface, even though surface outcrops are less than 4 miles away. Significant limestone units are apparently missing, as is a basal conglomerate zone. Claystones lie directly on the eroded surface of Paleozoic (Pennsylvanian?) limestones. Several gas sands were encountered during the course of drilling operations (Heylmun, 1963, p. 298).

Shell Oil No. 1 Salduro, section 4, T. 2 S., R. 18 W., Tooele County, Utah. Located on the Bonneville Salt Flats, this well bottomed in basic igneous rocks at a depth of 2,949 feet. The Cenozoic sedimentary section extended from the surface down to 1,375 feet, where a series of volcanic flows and agglomerates possibly belonging to the Lower Volcanic Sequence was topped. The Cenozoic beds consist of claystone, gypsum, oolitic limestone, and siltstone. There is no evidence of beds referrable to the Late Miocene-Early Pliocene sequence, even though such beds crop out 12 miles to the north. In all probability, the Cenozoic sequence above the volcanic units in the Salduro well are entirely Late Pliocene and Pleistocene in age, deposited on an eroded surface of volcanic rocks.

Hickey No. 1 Cassity, section 13, T. 2 S., R. 5 W., Tooele County, Utah. The stratigraphy of this well was examined by Slentz (1955, p. 45-46). The beds are poorly consolidated and consist primarily of clays, gravels, and sands. Gyraulus, Lymnaea, Vertico, and Physa are reported by Slentz in various zones between 1,170 and 4,120 feet, being similar to forms found in the Late Pliocene sediments of northern Utah. Paleozoic (Pennsylvanian or Mississippian) limestones, shales, and quartzitic sandstones were topped at 4,830 feet. Oil and gas shows were encountered in the Paleozoic rocks (R. E. Cohenour, unpublished report). Rocks referrable to the Late Miocene-Early Pliocene sequence have not been recognized in this well, and it is possible that all sediments above the Paleozoic are Pliocene and Pleistocene in age. Some of the lower units could correlate, however, with the Fowkes Formation.

Walker-Wilson No. 1 Woodlay-Garson, section 14, T. 2 S., R. 5 W., Tooele County, Utah. Located only one mile west of the aforementioned Hickey well, the Walker-Wilson well went to a depth of 7,979 feet and failed to encounter the Paleozoic rocks found in the Hickey well at 4,830 feet. Cenozoic sediments were penetrated to total depth, consisting of claystone, siltstone, pebble conglomerate, and tuffaceous sandstone. Either extreme relief on the Paleozoic surface or normal faulting is indicated, the later being most likely.

Gulf Oil No. 1 Gronning, section 24, T. 16 S., R. 8 W., Millard County, Utah. This well, drilled in 1956-57, penetrated to a depth of 8,061 feet, at a location eight miles northwest of Delta, Utah. Sands and clays in the uppermost 250 feet contain considerable gypsum, along with fossil snails and ostracodes. Several species of snails, including Valvata sp. and Gyraulus sp., are present. Tan claystone, sandstone and pebble - conglomerate constitute the upper part of the section, to a depth of 2,510 feet, where a series of basaltic flows, separated by beds of claystone and sandstone are found between 2,510 and 3,350 feet. At 3,518 feet, a sequence of volcanic rock, mostly agglomerate and coarse sandstone composed of volcanic fragments, was topped, extending to a depth of 6,255 feet. This volcanic zone probably represents the Lower Volcanic sequence of Late Eocene to Middle Miocene age. The age of the red shales and reddish to gray arkosic sandstones which underlie the volcanic unit remains in doubt. Topped at 6,255 feet, and extending down to total depth, these beds might be equivalent to the Paleocene or Eocene Claron Formation of southwestern Utah, or, more likely, to the Triassic redbed sequence exposed in the Pavant Range, 50 miles to the southeast, and in the Wah Wah Range (Miller, 1963, p. 96), 100 miles to the southwest. The well had no recorded oil or gas shows.

Union Pacific Water Well, Neels, Utah, approximate section 29, T. 20 S., R. 8 W., Millard County, Utah. Drilled in 1906, this well went to a depth of 1,998 feet. Claystone, sandstone, ash, and basalt was penetrated to a depth of 1,950 feet, where igneous rock possibly belonging to the Lower Volcanic sequence was topped. Considerable hot water and steam was encountered during the course of drilling the well, along with gas and oil shows (W. T. Lee, 1908).

Beaver Valley No. 1 James, section 20, T. 25 S., R. 9 W., Millard County, Utah. This well was drilled 35 years ago to a depth of 3,490 feet at a location in Beaver Valley, 17 miles northeast of Milford, Utah. An interpretation of the driller's log suggests that Lower Paleozoic rocks, which reportedly contained a 6 foot oil sand, were topped at 3,140 feet. Above the Paleozoic rocks are undated Cenozoic rocks consisting of claystone, siltstone, sandstone, and some gypsum. Some of the "gray sandstones" reported on the driller's log are probably tuffs. There are at least two basalt flows interbedded with the sediments, one between 813 feet and 887 feet, the other between 1,547 and 1,593 feet. A white limestone forms the surface, extending to a depth of 135 feet. In all probability, the basalt flows are Pliocene or Pleistocene in age, but no other estimates of the age of the sequence can be postulated.

ECONOMIC GEOLOGY

It is beyond the scope of this report to analyze the economic potential of the Tertiary sedimentary rocks in western Utah, as this would entail a detailed study in itself. While halloysite is probably the most important sedimentary product being mined at present, the Tertiary contains a number of materials which could become important should the market develop.

Lignite is an important constituent of Tertiary rocks in northwestern Utah, and some of the lignite beds and rocks associated with them are uraniferous (Mapel and Hail, 1959). Petroliferous limestones and carbonaceous to bituminous shales have been noted at a few localities, which enhances the possibilities for commercial oil and gas production from Tertiary sedimentary rocks. Heavy asphalt has been produced from basalts within the Tertiary sequence at Rozel Point on the north shore of Great Salt Lake.

Bentonite, diatomite, pumicite, and gypsum have been noted in Tertiary sedimentary rocks in western Utah, and, in a few places, these deposits have been prospected. Locally, certain beds in the Tertiary could be used for gravel and for building stone. A variety of different types of clay is undoubtedly present, such as halloysite, and some of these different clays will find commercial use in the future. The Tertiary sedimentary rocks of western Utah contain a greater variety of potentially commercial products than generally has been recognized.

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STRATIGRAPHIC SECTION

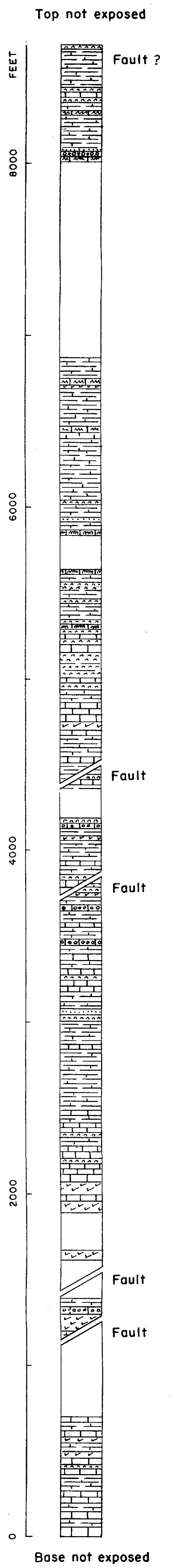
TERTIARY ROCKS - RUSH VALLEY

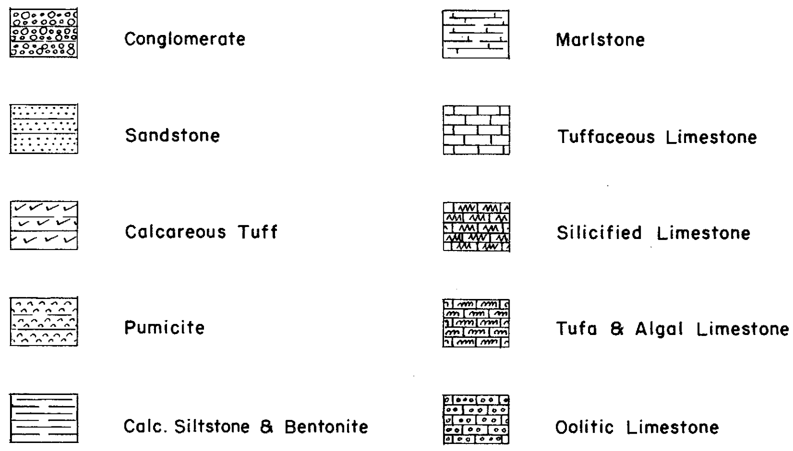
TOOELE COUNTY, UTAH

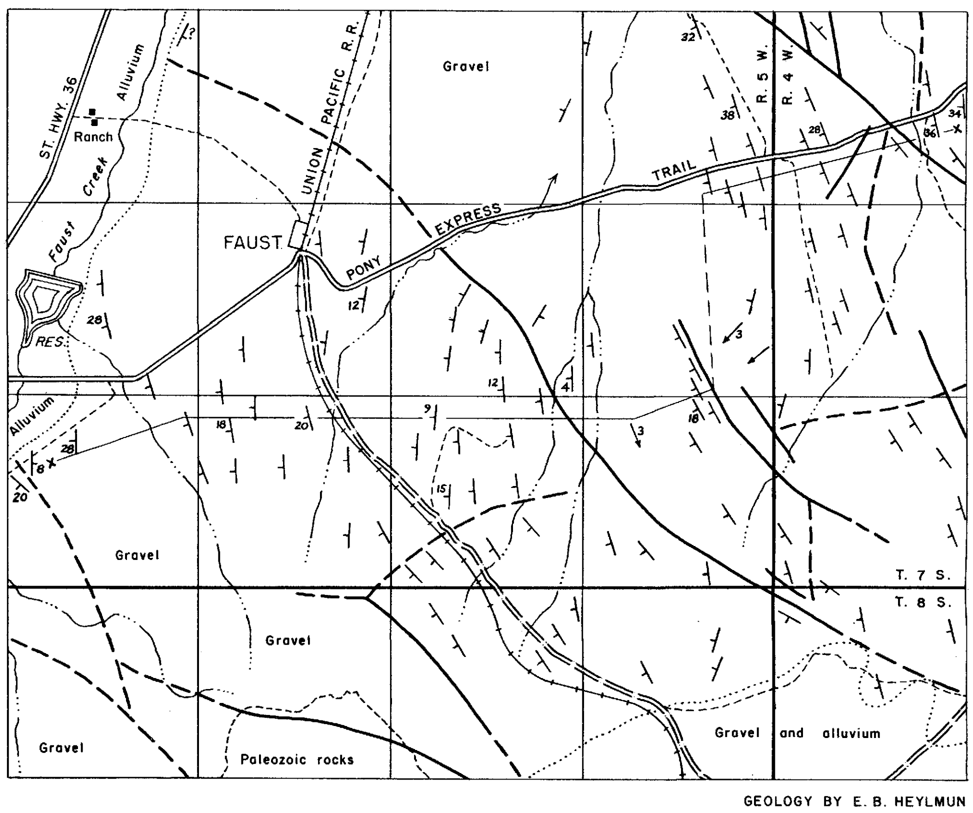
Measured by:

EDGAR B. HEYLMUN

1963







PHOTOGEOLOGIC MAP

SHOWING LINE OF SECTION

0 1 2

SCALE

Figure 4.


NORTHWESTERN UTAH
SCALE OF MILES
TRANSVERSE MERCATOR PROJECTION
EXPOSURES OF LATE TERTIARY SEDIMENTS (INCLUDES VOLCANICS LOCALLY)
APPROX. SHORELINE LAKE BONNEVILLE
WELLS PENETRATING LATE TERTIARY SEDIMENTS
E. B. HEYLMUN - 1962
IDAHO
UTAH
NEVADA
GREAT SALT LAKE
GREAT SALT LAKE DESERT
SEVIER DESERT
SALT LAKE CITY
OGDEN
LOGAN
BRIGHAM CITY
TOOELE
DELTA
NEPHI
EUREKA
WENDOVER
LUCIN
GRANTSVILLE
DUGWAY
CALLAO
IBAPAH
GOLD HILL
SNOWVILLE
TREMONTON
FARMINGTON
MAGNA
AMERICAN FORK
VERNON
PARTOUN
GROUSE CREEK
PARK VALLEY
LAKESIDE
BOX ELDER COUNTY
TOOELE COUNTY
JUAB COUNTY
MILLARD COUNTY
UTAH LAKE
SEVIER LAKE

Figure 2.