GEOLOGY OF THE WANSHIP - PARK CITY REGION, UTAH

by

Donald Lee Mount

A thesis submitted to the faculty of the University of Utah in partial fulfillment of the requirements for the degree of

MASTER of SCIENCE

Department of Geology

University of Utah

June, 1952

Approved:

Chairman, Supervisory Committee

Head,

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to Norman C. Williams of the University of Utah, upon whose suggestion this problem was undertaken. His supervision and assistance in the field and in the preparation of the manuscript proved invaluable. Thanks are due Armand J. Eardley, William Lee Stokes, and F. W. Christiansen of the University of Utah for their aid on specific problems within the area and for their helpful counsel.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

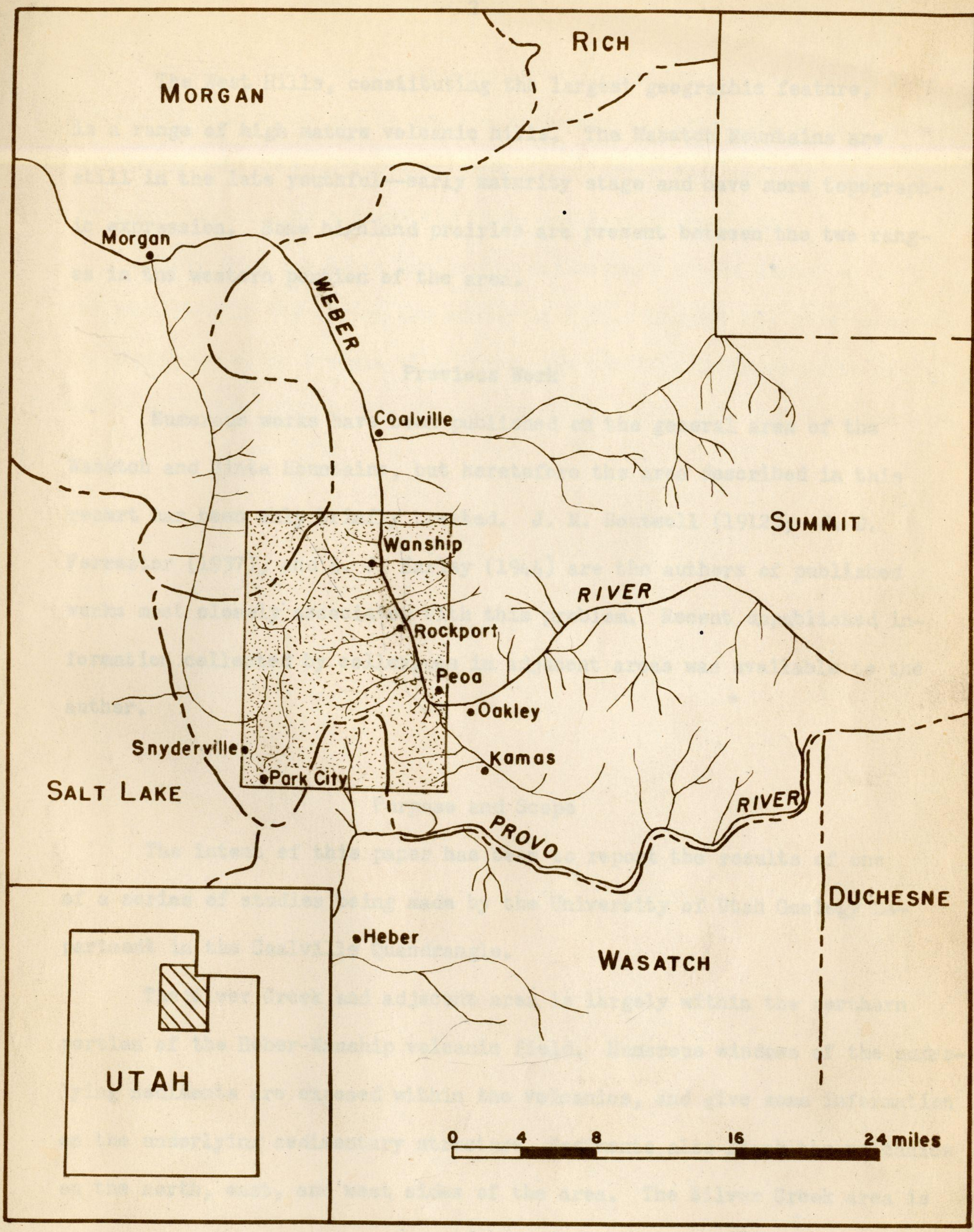
General Statement

The area of this report comprises approximately 85 square miles in the northern portion of the West Hills and the adjacent parts of the Wasatch Mountains in Summit and Wasatch Counties, Utah. The area includes parts of T1S, R4 & 5 E and T1N, R4 & 5 E SLB & M.

The region is easily accessible over hard-surfaced highways. U. S. Highway 40 borders part of the western and southern boundaries; U. S. Highway 189 parallels the east edge; Utah Highway 196 traverses the southern portion, and Utah Highway 530 crosses the north-central part. Numerous secondary roads lead from the main highways into the central parts of the area. The Union Pacific Railroad, Park City Branch, extends along Silver Creek Canyon from Wanship to Park City, Utah.

Vegetation and climate follow two distinct patterns within the area. The West Hills which are much lower in elevation than the Wasatch Mountains to the west, receive considerably less precipitation and support only a sparse, semiarid cover of sage brush, range grasses and scattered patches of Juniper, Scrub Oak, Mountain Mahogany, and Quaking Aspen. The Wasatch Mountains, which are of higher elevation, receive more precipitation and support a rather heavy growth of Quaking Aspen and Conifers with heavy undergrowth of Manzanita, range grass, Scrub Oak, and some sage brush.

Utilization of the land is mainly for transient sheep grazing, although dairy and dry farming is carried on in the highland meadows of the western portion of the area. Mining, restricted generally to prospect development, has been conducted intermittently during the 1920 and 1930's.



INDEX MAP - SHOWING LOCATION OF WANSHIP - PARK CITY REGION, UTAH

The West Hills, constituting the largest geographic feature, is a range of high mature volcanic hills. The Wasatch Mountains are still in the late youthful--early maturity stage and have more topographic expression. Some highland prairies are present between the two ranges in the western portion of the area.

Previous Work

Numerous works have been published on the general area of the Wasatch and Uinta Mountains, but heretofore the area described in this report has been only briefly treated. J. M. Boutwell (1912); J. D. Forrester (1937), and A. J. Eardley (1944) are the authors of published works most closely associated with this problem. Recent unpublished information collected by colleagues in adjacent areas was available to the author.

Purpose and Scope

The intent of this paper has been to report the results of one of a series of studies being made by the University of Utah Geology Department in the Coalville Quandrangle.

The Silver Creek and adjacent area is largely within the northern portion of the Heber-Wanship volcanic field. Numerous windows of the underlying sediments are exposed within the volcanics, and give some information on the underlying sedimentary structure. Sediments also flank the volcanics on the north, east, and west sides of the area. The Silver Creek area is situated in the transition area between two major structural elements -- the Uinta Mountains to the east and Wasatch Mountains to the West. These elements have trends which are normal to each other, and exhibit complex geologic features in the area in which the trends intersect. The purpose of this study was to map the structure and stratigraphy and interpret these data in an attempt to understand better the geologic nature of the transitional area between the Uinta and Wasatch Mountains.

Field work was begun during the latter part of the summer of 1950 and continued in the spring and summer of 1951. Mapping was done on aerial photographs, at a scale of 1/31680. and the data transferred to planimetric maps, Nos. 79 and 59, obtained from the U. S. Soil Conservation Service.

LITHOLOGY

General statement

The exposed rocks of the area range in age from Permian to Quanternary and include marine, lacustrine, and continental sediments, metasediments, and extrusives and intrusive igneous rocks. The extrusives are dominantly agglomerates with a few interbedded flows and flow breccias. Intrusive forms are represented solely by dikes.

The sedimentary formations exposed in the areas where the volcanics have been eroded are dominantly the competent, ridge-forming beds. Few of the incompetent, less resistant formations outcrop in the volcanic area, but their presence is often indicated by soil color. Some outcrops were mapped, with some uncertainty, on the basis of back fill along a pipeline that crosses the southwestern portion of the area.

Sedimentary rocks

Permian system

<u>Park City formation:</u> The Park City formation is the oldest rock exposed in the area. Only the upper 100± feet of the section is visible within the area. An exposure near the bottom of Silver Creek, northeast of Park City, Utah, consists of a buff to gray limestone, arenaceous in part, and containing fine white,gray, and balck cherts. Boutwell (1912 P.251) named the formation and measured 590 feet for the total thickness in the type section in the Park City District, Utah.

Triassic system

Woodside shale: The Woodside shale overlies the Park City formation with conformity in adjacent regions, Boutwell(1912 P.52), but wherebest exposed in the Silver Creek area, 2 miles northeast of Park City, Utah, both upper and lower contacts of the Woodside shale are obscured by alluvium and contact relations were not determined.

The Woodside shale was first named by Boutwell (1912 P.52) at Woodside Gulch, 3 miles southwest of the Woodside exposure in Silver Creek. Here it is composed of fine grained, dark red shale with some thin bedded, brown siltstone. According to Boutwell (1912 P 52) the Woodside shale varies considerably in thickness: It is 1,090 feet thick in its type section in BigCottonwood Canyon, 700 feet thick in a mine shaft west of Woodside Gulch; Williams (1952) reports 758 feet in the Uinta Mountains 10 miles to the east; it was estimated to be 725 feet in the Silver Creek section.

Thaynes formation: The Thaynes formation has been subdivided into three units with an aggregate thickness of 1376 feet. The lower unit is esentially limestone and is referred to as the "lower lime". In general, the "lower lime" is composed of brown to bluish gray limestone, arenaceous in part, alternating with tan to gray calcareous sandstones, pure sandstones, and brown shales. The "lower lime" measures 425 feet at a section 2 miles northeast of Park City.

The middle unit is referred to as the "mid red" member and consists of red to lavender, fine grained, laminated sandstone with some thin-bedded, brown limestones and shales. The "mid red" member measures 115 feet at Park City. The unit thickens eastward, however, at the espense of the "upper lime" and lower lime" members, and in the Uinta Mountains the "mid-red" is about 250 feet thick.

The upper unit consists essentially of limestone and is termed the "upper lime". It overlies the "mid red" member and northeast of Park City is 741 feet thick. Here it consists of blue to gray limestone interbedded with gray and buff calcareous sandstones and brown sandy shales. The "upper lime" member contains more nearly pure limestones than the "lower lime" member.

Few fossils were found throughout the Thaynes formation, in the Silver Creek area, and these were mostly fragmentary. Some crinoids, Pentacrinus were found, however, in the "upper lime" member.

The type locality of the Thaynes lies at the southwest corner of the area (Boutwell, 1912, P.55).

Ankareh shale: The Ankareh shale crops out in several localities within the area studied, but is completely exposed only at a locality 3 miles north of Park City and 7 miles east of Ankareh Ridge, the type section. The Ankareh shale appears to be gradational into the underlying Thaynes formation. Red to lavender shale alternating with siltstones and sandstones are characteristic of the Ankareh lithology. A fresh water, very light gray, nodular limestone, 50± feet thick, is present 345 feet from the base of the shale.

Shinarump formation: The Shinarump formation is a competent, ridge-forming unit, which crops out persistently throughout the area. It lies disconformably upon the Ankareh shale, as defined in this paper, and varies considerably in thickness along its strike. In the Park City District Boutwell (1912, P.59) considered the Shinarump of this paper as the base of the Nugget sandstone, of Jurassic age. The Shinarump consists characteristically of a grayish white quartzite grit, locally conglomeratic. North of Park City the Shinarump splits into two well defined quartzitic grit beds separated by a red silty sandstone unit which thickens eastward into a series of interbedded white and lavender, fine to medium grained quartzites and red silty sandstones and shales. Continuing eastward this unit thins rapidly, and the Shinarump resumes its characteristic nature. Northeast of Park City the formation is 203 feet thick, but averages only 80 feet throughout its known extent in the area. A moderate amount of petrified wood is present in the formation.

Chinle formation: The Chinle formation is composed of medium to fine grained, variegated, red mudstones and siltstones. The formation is approximately 350 feet thick east of Round Valley where it lies conforably upon the Shinarump formation.

Jurassic system

Nugget sandstone: The Nugget sandstone is the most prominent and widely outcropping of the sedimentary formations in the area. It is a salmon colored, highly cross-bedded, medium grained sandstone, and is generally a very persistent ridge former. The section was not measured, but was estimated to be 1000 feet in thickness north of Round Valley.

Twin Creek limestone: The Twin Creek limestone consists largely of light gray, thin-bedded limestone, somewhat silty in the upper part. At the base, a 5 to 10 foot bed is sandy and appears to be reworked Nugget sandstone well cemented with lime. Several fossiliferous zones are present, especially in the lower part of the section. Pentacrinus asteriscus and Nerinea are particularly numerous.

The Twin Creek, though widespread throughout the area, may only be seen as a complete section at a point one mile north of Peoa, Utah, where it is approximately 1350 feet thick.

Preuss formation: North of Peoa, the Preuss conformably overlies the Twin Creek. Here the Preuss consists of approximately 350 feet of red to pink,interbedded silts and sandstones. It was identified in but few other localities. However, at an area north of the Cherry Canyon faults from the Weber River westward to Silver Creek, and thence up Tollgate Canyon rocks classed as Preuss were tentatively identified. These identifications were based upon lithology and stratigraphic position. The Preuss is probably the equivalent of the Entrada formation which occupies a similar stratigraphic position on the south flank of the Uintas.

Stump formation: The Stump formation was studied in the area north of Peoa where the only complete and definite section is known to exist within this area. Here it consists of approximately 175 feet of light buff to tan, calcareous sandstone and arenaceous limestone. It is locally glauconitic and contains numerous restricted lenses of grit. Belemites have been found in the Peoa section, and are generally characteristic of the formation and its equivalents. The Curtis on the south flank of the Uinta Mountains is probably a correlative formation. The other localities were mapped as Stump because of lithologic resemblance and stratigraphic position.

Morrison formation: The contact of the Morrison formation with the Stump was placed at the base of a gray,nodular,fresh-water limestone containing Ostracods, which conformably overlies the Stump. The Morrison consists of a sequence of white to purple interbedded, friable sandstones and variegated silts. A few thin-bedded pebble conglomerates composed chiefly of chert with some "gastroliths" occur in the upper part of the formation and the fresh-water limestone at its base. A readily recognizable unit of orange-red silty sandstone is present in the center of the section. With the help of Dr. W. L. Stokes, a total thickness of 258 feet of Morrison was measured in the section north of Peoa. The Morrison also crops out in a great belt north of the Cherry Canyon fault, but the lower contact is obscured by mantle so the entire section is not exposed.

Cretaceous system

<u>Kelvin formation</u>: The Kelvin formation is composed of two well-defined units north of Peoa where it aggregates a total thickness of 2800± feet. The contact between the Morrison and Kelvin formations is indefinite but was placed at the base of a chert conglomerate, in accordance with the opinion of Stokes (1951), who accompanied the writer in the field. The basal unit of the Kelvin formation comprises four prominent conglomerate beds separted by red silty shales and sandstones. In the basal unit, the conglomerate beds progressively decrease in chert content up section and become mainly quartzitic with a few limestone boulders included. The boulders range from 1 to 8 inches in the Peoa section but increase in size and accumulated thickness westward toward East Canyon. The upper unit is composed of a sequence of interbedded variegated shales and sandstones. The shales vary from light gray to dark red in color and are for the most part silty and poorly laminated. The sandstones range from white, friable, coarse grained, and cross-bedded units to drab, dense beds.

A section in a horst north of Rockport, Utah, was mapped as Kelvin only because of its lithologic resemblance to the Peoa section. A section north of the Cherry Canyon fault was also mapped as Kelvin because of its lithologic semilarity to the section at Peoa and its similar stratigraphic position. This section traced on the surface almost continuously to the type section at Kelvin Grove (Mathews 1931,P.48) and not with the Peoa section as has been previously inferred (Eardley, 1944, P.838). The Kelvin has been assigned to lower Cretaceous although no fossils have been found.

Aspen shale: Overlying the Kelvin formation with no apparent unconformity is a sequence of black bentonitic shales containing abundant teleost fish scales, which are characteristic of the Aspen shale. The upper part of the sequence contains a few,thin,buff colored sandstone beds. The Thickness appears to vary considerably along the strike of the formation. It measures 709 feet in the Lost Creek section, but is reported orally by Professor Williams to be 525± feet thick in the Peoa section. Recent fossil identifications (Cobin and Reeside,1951) in Colorado,Wyoming, and Montana, indicate that the Aspen shale is lower Cretaceous.

Frontier formation: The Frontier formation is transitional from the underlying Aspen shale into a series of very prominent ridge forming, buff colored sandstones interbedded with less resistant sandstones and black to pink shales. The sandstones are medium grained, somewhat friable, and in large part calcareous. Local lenses of grit are numerous. The base of the Frontier was placed at the first prominent ridge former above the Aspen shale. A black bentonitic shale member approximately 850 feet thick is found about three-fourths of the way up the Frontier section between Peoa and Rockport, but appears to be thinning rather rapidly to the west. Fossil remains, plants and a few genera of pelecypods and gastropids, were numerous.

No complete section of Frontier is exposed within the region, although it is partially exposed in three different localities. A number of beds of low-rank bituminous coal are present within the sections.

Wanship formation(1): The "Wanship formation" overlies the Frontier formation with a marked angular discordance. The "Wanship" is rather indistinct in this area but may be more readily recognized to the east. The basal member is a coarse, brown to light gray conglomerate containing boulders up to a foot in diameter. It is composed mainly of quartzite, but numerous limestones, cherts, and some sandstones are cemented within the sandy, silty matrix. The basal member if 10 to 50 feet thick, and is followed by buff sandstone beds, in part grity to conglomeratic, interbedded with some gray shales, in part bentonitic and then a sequence of brick-red silty shale. The Cherry Canyon fault has cut the "Wanship formation", and the higher beds are omitted in the Silver Creek area. To the east, the upper beds consist of a sequence of interbedded buff to white sand-stones and gray and black shales containing abundant fossil leaves and some fossil animal remains of upper Cretaceous age.

The "Wanship formation" shows no appreciable discordance of dip at any of the contacts with the Frontier formation in this area but a mile to the east it truncates beds on the eastern nose of the Dry Canyon anticline. The author examined some beds of similar lithology and stratigraphic position in upper East Canyon, believed to be "Wanship" equivalant by the author and referred to as upper Cretaceous conglomerate by Granger and Sharp (1951), and also found that the same relationship exists between

(1) The "Wanship formation" has heretofore been refered to in recent previous work of this area as the "Post-Frontier formation." (Larsen, 1951.)

the two formations. The boulders in the East Canyon section are of larger dimensions and the conglomerate unit of thick proportion, which seemingly is evidence for a westward source. The author believes this unconformity and sequence of strata to be equivalent with that of the Current Creek formation (Walton,1944), on the south flank of the Uintas, and the Evanston formation in the southwest Wyoming (Veatch, 1906). The Current Creek formation has in turn been correlated with the Price River formation further to the south, by Walton (1944, P.112-20) and Bissell (1952,P 630). All contain a basal conglomerate and have the same general relationship to the underlying formation; they also have been placed in about the same time period.

Tertiary system

Wasatch group: Only the lower part of the Wasatch group was mapped and consisted of very coarse conglomerate with a red silty matrix. The boulders range up to 30 inches in diameter and consist of white quartzites, limestones, and sandstones. The Wasatch lies with a great amount of angular discordance upon the underlying formations. It has an approximate dip of 9° to the southeast, where studied. A few outlying erosional remnants are present as far as a mile or more south of the area of continuous Wasatch outcrop.

The Wasatch group has been subdivided (Veatch,1907, P.88) into three formations -- Almy, Fowkes, andKnight. In the Silver Creek area, however, no attempt has been made to differentiate the Wasatch group formations, and although only the lower part was mapped, it can not properly be disignated to correlate with the Almy. Regional mapping of the Wasatch group, now in progress (Eardley and Williams), is necessary to determine properly the subdivisions present in this area. At many localities elsewhere for example, the Almy and Fowkes are absent and the knight formation rests directly upon the pre-Wasatch formations.

"Peoa tuff": The "Peoa tuff" is a very discontinuous and irregular deposit of white to yellow volcanic ash, locally containing andesite pebble inclusions. The "Peoa tuff" rests unconformably on all older sediments where found. Stratification and fresh water gastropods are common and indicate that in part the tuff was deposited in fresh water lakes, and stream valleys. The tuff, where present, is transitional into the overlying volcanics but the tuff is not always present between the volcanics and older sediments. The discontinuous and irregular distribution suggests that the "Peoa tuff" was deposited in the lowland area of an early-mature topography,shortly prior to the volcanic activity.

The fresh water pastropods were identified by Yen (1951) to be anywhere from Eocene to Miocene. A. J.Eardley (1944,).845) has found vertebrate remains immediately to the north in the Norwood tuff, which were found to be Oligocene in age. The writer has traced the "Peoa tuff" to within a few miles of the Norwood tuff, and believes that the "Peoa tuff" is correlative to the lower part of the Norwood tuff. However, Eardley (1944,P.845) mapped some volcanics as Norwood tuff, while in the Silver Creek area; the term "Peoa tuff" has beenrestricted to the clearly water-deposited material.

Quaternary system

The Quaternary deposits of this area consist of unconsolidated alluvium, colluvium, pediment, valley fill, and dissected high level terrace gravels. Although these features were mapped, the interpretation of the geomorphic and geologic significance of them was beyond the scope of the present study.

Igneous Rocks

Extrusives

Andesite flows: The flows are from gray to green, generally porphyritic and frequently show flow structure. The phenocrysts comprise andesine feldspar, hornblende and biotite mica. Boutwell (1912 P. 73-4) has adequately described the microscopic features of the flows.

Vesicular, phlogopite andesite flows: A flow strikingly different from any of the other extrusive types was found in only one locality, and appeared to be a very late flow. This flow is a very vesicular, tan weathering rock with large flakes of phlogopite being especially conspicuous.

Andesite flow breccia: Some of the flows contain angular fragments of andesite of varying shapes and up to several feet in size. Their origin probably can be attributed to a crusted overactive flow which was broken up and then engulfed within the still fluid portion as the flow progressed.

Andesite agglomerate: The agglomerates consist of sub-round to sub-angular fragments of andesite and scarce sediments contained in a matrix of flow and tuffs. Along the central part of Lost Creek, a tributary of the Weber River south of Rockport, an andesite flow has included within it a large quantity of angular fragments of Nugget sandstone.

Intrusives

Diorite: The diorite was encountered within one locality in this area, Tollgate Canyon, and here represented as a dike. Megascopicly it is a fine, even grained, dark green appearing rock with a uniform mixture of light and dark minerals. Recognizable minerals were feldspar, hornblende, and biotite.

STRUCTURE

Regional

The Uinta Mountains have been described by Forrester (1937) as a broad open anticline somewhat overturned and arcuate to the north, with the azis trending approximately east-west. As a topographic feature, the range ends at Rhodes Valley where the axis of the broad fold plunges 20° westerly. Numerous minor folds, generally paralleling the Uinta axis, are present on the flanks of the range along its entire extent.

The Wasatch Mountains are a north trending range which, in its central area, possesses numerous transverse folds. The eastward plunging Park City anticline, the dominating structural feature of the adjacent Wasatch Mountains, in conjunction with the Cottonwood uplife, has been described by Boutwell (1912), Calkins (1018), Beeson (1935), Forrester (1937), and Eardley (1939), to be the westward extension of the Uinta axis, although the direction of pitch reverses. A syncline or small synclinorium has been postulated by some investigators; O'Toole (1951) mapped and named this structure the West Hills syncline.

Local

The Silver Creek and adjacent area is in the area of transition between the north trending Wasatch Mountains and the west trending Uinta Mountains.

The structure within the area mainly reflects the regional influence of the north flank of the Uinta and Cottonwood-Park City structures. The structure within the area may be referred to as a faulted homocline having an east-west orientation and dipping steeply to the north. The general homoclinal structure is considerably modified by numerous local folds and faults.

Crandall Canyon and Dry Canyon faults: The Crandall Canyon and Dry Canyon faults may be treated together because of their similarity in structure and time of development (Plate 11..). They are parallel east trending faults of high angle nature bounding a wedge of sediments, which has been faulted up, and which appears as a horst today. The fault bounded wedge consists of Kelvin(?) and is faulted against Frontier on either side. The wedge, and in part the adjacent blocks, has been greatly deformed and contorted in the Three Mile Canyon area. In the eastern part of the wedge, a prominent "Z" fold is present. Both faults appear to have a nearly vertical dip at present, but at the time of their development they were at a much lesser altitude and dipped approximately 45° to the north. They have attained their present altitude as the result of the Uinta Mountain arching. The faults came into existance originally during Wasatch Mountain diastrophism and have subsequently been tipped to their present high angle position by Uinta folding. The Crandall Canyon fault at the time of origin was developed as a high angle reverse fault

The Dry Canyon fault in Stevens Canyon nearly parallels the strike of the beds and is detectable only where a sudden change of strike and dip occurs on either side of the fault. A gouge and breccia zone along the fault has from place to place weathered into a minute trough, which sometimes serves as a drainage channel, and helps define the position of the fault.

Eastward, the fault has cut across the axis and south flank of the Dry Canyon anticline and is readily apparent. The Dry Canyon fault is truncated by the basal beds of the "Wanship formation" at the head of Dry Canyon and is lost to view beneath volcanics to the west.

The Crandall Canyon fault cuts across the axis and north flank of the axis and north flank of the Rockport syncline near Rockport, but eastward its trace is rather indistinct. It is believed to be truncated also by the Wanship formation, although overburden has obscured the critical areas in the vicinity of the head of Crandall Canyon. This fault is also buried by the volcanics in the West Hills area.

Schultz (1918) referred to these faults as a prominent east-west fault zone, somewhat complex, and Forrester (1937) classified them as the western estension of the north flank fault of the Uintas. This concept, in view of the relationship of these faults to the "Wanship formation," is invalid, and the faults appear to be related to early Wasatch cross-folding, not associated with Uinta diastrophism. The faults pre-date the time of faulting along the north flank of the Uintas considerably.

Peoa fault: On the northern edge of the town of Peoa a fault striking north-easterly has displaced Nugget sandstone against Twin Creek limestone with the south block being down thrown. Due to the type of movement along the fault plane it is believed also to have been related to the early Wasatch episode of deastrophism, and originally dipped to the north as a thrust. The actual amount of displacement is in question, although it probably is not much.

Exposure of the fault is poor and it disappears under terrace gravels and volcanics to the east and valley fill and volcanics to the west. Continuance to the west appears fairly certain, however, from data available in windows within the volcanics.

Dry Canyon anticline: Immediately north of Dry Canyon is a northeastward striking and plunging anticline, slightly asymmetrical. The south limb is the steeper, and the north limb flares out with no apparent closeure to the west. The Frontier and Wanship formations define the structure at the surface. The North limb and easterly nose are truncated by the Wanship formation and the Dry Canyon fault cuts out most of the south limb and crosses the axis in Weber Valley.

The anticline is of Wasatch trend, as expressed by its strike, and thus was originally overturned to the southeast prior to Uinta arching. Uinta arching partially restored the structure to the erect position by its present altitude.

Rockport syncline: The Rockport syncline is situated between Three Mile Canyon and the Crandall Canyon fault immediately west of the Rockport. The syncline strikes northeast and plunges to the southwest. It is somewhat assymetrical, being steeper on the north, but this is believed to be mostly due to drag on the Crandall Canyon fault, which has cut off most of the north limb and crosses the axis of the fold.

This structure, like the Dry Canyon structure, is believed to be of Wasatch trend and origin. The structure formed prior to the Crandall--Dry Canyon faulting and was probably directly related to the Dry Canyon anticline.

Park City nose: An anticlinal nose strikes and plunges northward off the main Cottonwood--Park City arch. The nose is in part concealed in part by volcanics along the eastern limb and part of the northern end. The structure includes sediments ranging from the Park City formation through the Twin Creek limestone within its exposed part in this area. The western limb is sharply down-folded while the east limb has a gentle curving trace, which indicates an asymmetrical fold.

The nose is believed to have formed as a lobe of, and contemporaneously with, the Cottonwood--Park City arch,which occurred at the same time as the northeastward trending folds of the early period of Wasatch diastrophism (Eardley,1951).

Snyderville syncline: The western component of the Park City nose is referred to in the paper as the Snyderville syncline, as a working term only. Only the eastern limb was mapped in detail but reconnaissance work of the western limb revealed a rather tight syncline to be present. The major part of the syncline,however, is covered with valley fill.

Silver Creek syncline: The Silver Creek syncline, a working term, is the eastern component of the Park City nose and appears only as a slight synclinal flexure in the Nuggent and Twin Creek, but is believed to tighten more to the south as stratigraphically lower horizons. It was mapped further to the south by Boutwell(1912) in the Park City district. Information is wanting in this particular area and accurate interpretation is impossible. It is believed by the author that this may be the northern extension of the West Hills syncline mapped by O'Toole (1951).

Cherry Canyon fault: The Cherry Canyon fault is very indistinct in this area but is eveident by stratigraphic repetition. The fault plane may be seen in Cherry Canyon where it is a high angle reverse fault with an apparant dip of about 55° to the northwest and has placed Kelvin(?) upon Wanship. Westward from this locality, the fault cuts diagonally across the beds to Bridge Canyon,where the Preuss (?) rests on Wanship. The fault disappears under the head of Bridge Canyon but reappears in the Silver Creek--Tolgate Canyon area with Preuss (?) still on Wanship, and is again lost under the andesites to the west. The fault is believed to be the same as a fault,further west, that has displaced the Twin Creek limestone near Gorgoza (Sharp,1952).

Silver Creek chaos: Numerous irregularly distributed, monolithic blocks, of brecciated sedimentary formations, many too small to map, are found within the boundaries of volcanics,and appear as windows.These blocks are collectively referred to as the Silver Creek chaos. Most of the chaotic blocks are composed solely of Nugget sandstone, although some are composed solely of the Shinarump formation and a few are found to consist of Twin Creek limestone, Thaynes limestone and red beds. The largest exposed, single,chaotic block is approximately 2000 feet across. Some of the blocks for the greater part are partially or wholely fractured and brecciated,and some have been altered beyond recognition by bleaching and silification, probably as the result of hydrothermal activity attendent to the extrusive volcanism. The areal distribution is nearly as wide-spread as the volcanics of this area, and the reason for restriction and preservation of the chaotic blocks within the volcanics may be accounted for by the coverage of the blocks by the volcanics. Thus the blocks were protected against erosion within the boundaries of the volcanics,while outside of this area peripheral erosion of the volcanic cover permitted rapid removal of chaotic blocks as soon as the volcanic cover was stripped.

The formation of the chaos followed a period of erosion subsequent to the initial arching of the Uintas, and occurred prior to the deposition of the Wasatch group. Boulders of chaotic Nugget are found as ccon-stituents of the lower Wasatch in this area. This time of formation of the chaos coincides approximately with the time postulated for the Bannock (Mansfield, 1927) and Willard (Eardley,1944) thrusts to the north and the thrusting reported on to the south by Calkins and Butler (1943),Baker (1948), and Bissell (1952), but dating of the chaos can be done more precisely within this area than dating of the thrusts in the above areas.

The actual relationship of the chaotic blocks to the underlying sediments was nowhere observed, but the chaos seemingly corresponds closely with a similar type structure in the south end of Death Valley (Noble, 1944) where the origin was attributed to overthrusting that took place at shallow depth and under a light load. The Death Valley chaos appears as an overthrust plate, broken into innumerable blocks and slices thrust over one another.

Other similar occurences have been reported, and have been referred to as megabreccia and sedimentary breccia, but they are attributed to ancient landslide activity. These landslides are of interbedded siltstones, sandstones, conglomerates, and volcanic rocks and resemble modern mud-flow and debris-flow accumulations. The chaotic breccia blocks of the Silver Creek area are, however, finely brecciated, composed of only one formation, and are tightly cemented within their own detritus. The chaotic blocks are for the most part of much larger dimensions than those of sedimentary breccia, as are those of the southern Death Valley region. A source for the Silver Creek chaos as an ancient landslide, cannot be demonstrated.

The possibility of some rafting of sedimentary blocks by the volcanic flows has been considered, but blocks of these dimension are believed too large to have been thus transported. Further, the presence of chaotic fragments within the Wasatch formation indicate a pre-volcanic time of origin.

At the present there is no evidence to substiantiate any single theory of origin of the Silver Creek chaos. However, in light of what is known, it appears that it may be the forepart of an extensive overthrust,of which the Silver Creek chaos represents, as a klippe. Such a thrust cannot yet be definitely correlated with other thrusts in the region.

Minor faults: A few visible monor faults have locally modified the general structure throughout the area, and it is believed a relatively larger number of minor faults are covered by the volcanics.

Post-Volcanic structures: Detail mapping of the volcanic rocks was not undertaken but folding and faulting on a minor scale is apparent. Folding is indicated in some tilted water work tuffs, which were presumably, originally horizontal. Immediately south of this area in a road cut on Utah Highway 34,is a series of minor anticlines and synclines in the volcanic flows (O'Toole,1951). Another indication of post-volcanic deformation is indicated by an extensive joint system within the volcanics, with north and northeasterly trending sets predominating. A gentle eastward regional dip is also exhibited by the volcanics and indicates that they were differentially uplifted and tilted to the east.

Numberous post-volcanic faults of minor displacement have affected the flows, but mapping of these minor features was not undertaken.

Basal Wanship unconformity: The basal Wanship, as previously discussed, truncates the underlying Frontier and Kelvin formations in the vicinity of Dry Canyon. Here the angle of discordance varies from a few degrees to nearly 90°, but elsewhere in the region the angular discordance is slight.

Basal Wasatch unconformity: The Wasatch, except locally, was deposited upon all older sediments with marked angular discordance.

Basal Peoa unconformity: The "Peoa tuff" was deposited, in part, in in fresh water lakes, upon Mesozoic and older sediments with a great angle of discordance, but where deposited on the Wasatch group, there is but slight discordance.

GEOMORPHOLOGY

The West Hills are high,mature hills composed essentially of volcanic material. They have a relief ranging from 600 to 1400 feet above adjacent valleys, but nevertheless, appear as low indiscriminate hills when viewed from the adjoining western hig land praries. From the Weber River Valley to the east, howeverk give the impression of being high and rugged hills. This may be attributed to the difference in elevation of the two valley floors, and also accounts for the position of the crest being on the extreme western side of the hills.

The drainage systems in the West Hills form several patterns within the area described. The east slope drainage south of Brown's Canyon,and in Ross Canyon on the western slope, is controlled by a set of north-easterly trending joints. The minor tributaries, though in part controlled by joints, are dendritic in the interjoint areas. Kent and Stevens Canyons,and the lower part of Three Mile Canyon,are essentially strike canyons within the Cretaceous sediments. The lower portion of Bridge Canyon seems to be controlled mainly by the Cherry Canyon fault. All other drainages on both slopes are primarily dendritic in pattern with only local joint control.

It appears that the pre-volcanic topography was of greater relief and more rugged than the present topography. For example, near the confluence of Silver Creek and Tollgate Canyon, a sequence of volcanics up to 700 feet thick is revealed adjacent to some 'windows of characteristic ridge forming sediments, and in the Keetley area, south of this area, O'Toole (1951) has demonstrated 1500 feet of pre-volcanic relief. This concept has been advanced by Boutwell (1912) and Forrester (1937).

Remants of an old terrace, referred to here as the "Oakley terrace", are well preserved on the eastern slope of the West Hills adjacent to the Weber River between Peoa and Rockport. Only actual terrace surface remnants were mapped, but gravels of similar nature are present in many areas, and indicate generally the extent and elevation of the old surface upon which they were deposited. These gravels probably mark the surface established during the last glacial epoch, when the Weber River, drained both the north and south flanks of the western Uinta Mountains. Since this time, the area has been rejuvinated and stream piracies (O'Toole, 1951) and drainage adjustment have occurred. Streams have, in general, become entrench, and earlier surfaces partially destroyed. This also probably accelerated the headward erosion that resulted in the capture of the south flank drainage of the Weber River, now comprises the upper Provo River (Anderson, 1915), and leaving the Weber River in its present underfit status.

The Wasatch Mountains have a relief of about 3500 feet average above the adjacent valleys, which border on the east. The Wasatch Mountains stream pattern, unlike that of the West Hills, seems to be mainly controlled by the relative resistance of the stratigraphic units. In the Wasatch group of formations a very definite dendritic pattern has developed. In areas of Paleozoic and Mesozoic formations the drainage control seems to have been established along easily eroded contacts and soft beds, although some deviation from the general pattern may be seen where faults transect the sedimentary formations.

On the high praries and adjoining slopes on the north part of the West Hills, remnants of an ancient pediment that has for the most part been highly dissected, is present. The boulders are dominantly of the more resistant formations of Weber quartzite, or younger age. Boulders up to several feet in diameter are common. The author believes these surface remnants to be correlative with the Weber Valley surface (Eardley, 1944,P.874) of the north-central Wasatch Mountains,which is also described as an old pediment. Eardley (1944,P.877) believes the Weber Valley surface to be Pliocene in age. This scheme, as Eardley states, agrees very well with the time of development and elevation of the Bear Mountain surface (Bradley,1934-35) in the Uinta Mountains and probably correlates with it.

The present drainage of the highland praries is both easterly,via Silver Creek, and northwesterly, via Kimballs Creek--East Canyon Creek, although both drainages contribute ultimately to the Weber River. The headwater tributaries of both drainage systems interlock or dovetail. This relationship serves to illustrate the incompletely adjusted drainage system of the area. On the prarie north of Park City, the incomplete adjustment is even more evident. Here the divide of two major streams exists within the prarie and the two drainage systems interlock with one another in an area having less than 5 feet of relief.

The northwesterly draining streams flow a considerably shorter distance to the Weber River confluence than do the easterly flowing streams, which,via Silver Creek and Weber River, arrive at the confluence of East Canyon Creek and Weber River through a much more circuitous route. The streams draining via East Creek,therefore, descend more or less the same elevation in a much shorter distance. Accordingly,other things being equal, the East Canyon drainage is more vigorous and is therefore ultimately destined to capture progressively greater portions of streams now tributary to Weber River by Silver Creek, although at the moment because of the extremely steep gradient of Silver Creek Canyon as compared to the relatively low gradient of upper East Canyon,Silver Creek is the aggressive stream.

GEOLOGIC HISTORY

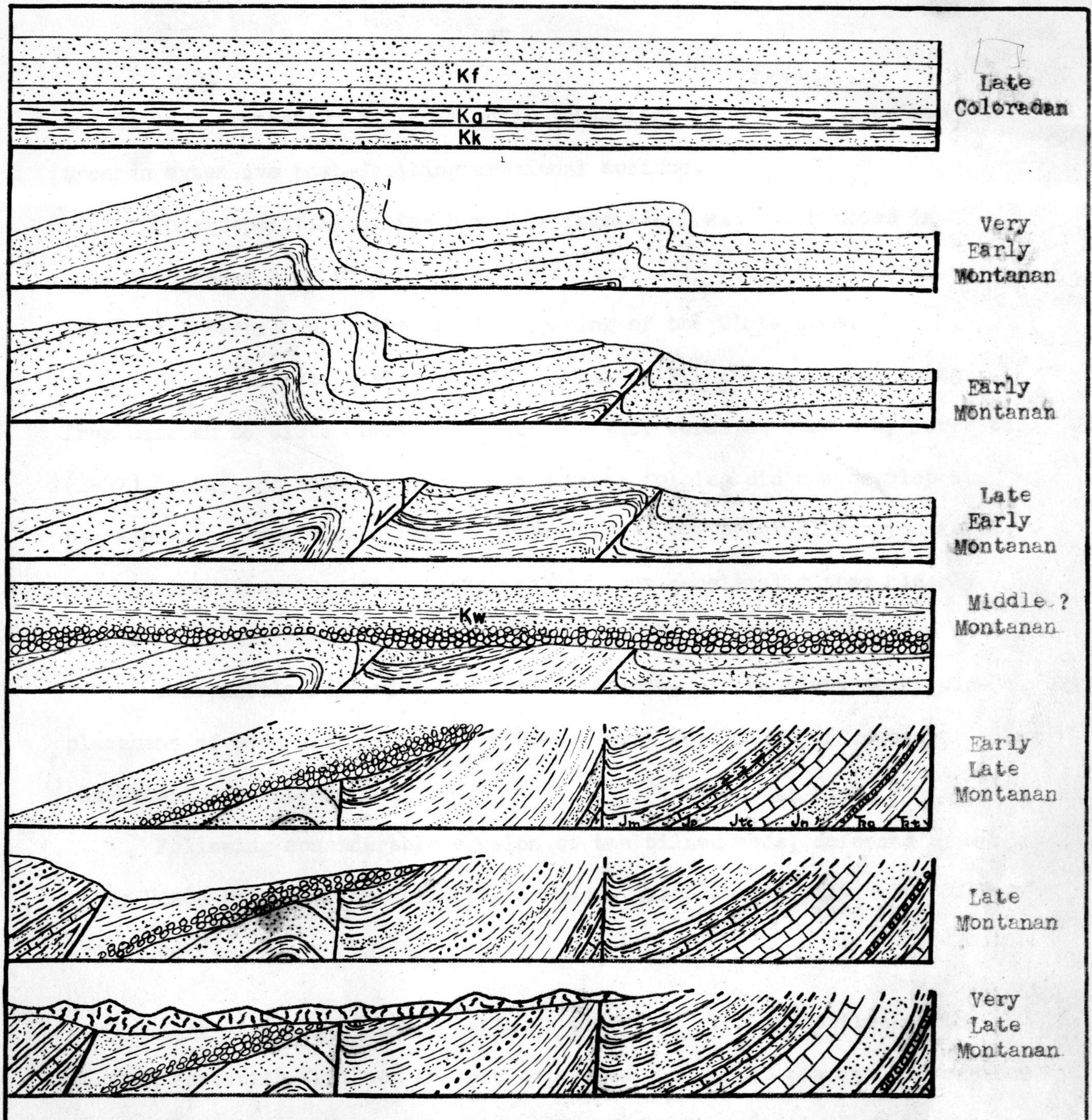
General Statement

The pre-Laramide history of the area was largely a history of sedimentation. The detailed stratigraphic history prior to the Laramide revolution has been treated by Williams (1952),Hooper (1951),Boutwell(1912), and others, and does not warrant repetition here.

The more or less continuous deposition was uninterrupted by diastrophism in the Silver Creek area until the Frontier formation of Coloradoan age had been deposited, although an early Cretaceous highland was formed weat of the area of the present study, as indicated by the Kelvin formation (Eardly, 1944, P.859).

Laramide orogeny

Montana phase (early Laramide orogeny): Shortly after the deposition of the Frontier formation the first stage of the early Laramide orogeny affected the area and formed numerous folds in the Silver Creek area contemporaneously with the Cottonwood-Park City uplift and the northeasterly trending folds immediately to the west in the Wasatch Mountains. The folds of this phase of the orogeny are represented in the Silver Creek area by the Dry Canyon anticline,Park City nose, and the Rockport,Silver Creek and Snyderville synclines. Following the folding, or associated with it, but before deposition of the Wanship formation, there was a period of faulting, also assigned to this phase of the Laramide orogeny. The faulting of this phase is represented by the Peoa,Dry Canyon and Crandall Canyon faults,which



SCHEMATIC SECTIONS SHOWING DIASTROPIC EVOLUTION IN THE TRANSITION AREA

WITH THE WANSHIP-PEOA SECTION TAKEN AS TYPE AREA are in turn truncated by the "Wanship formation", which was deposited upon an extensive post-faulting erosional surface.

This deposition of the "Wanship formation" was interrupted in late Cretaceous time by a second stage of the early Laramide orogeny, which is interpreted as the initial folding of the Uinta arch.

This indicates that the trends of minor structures do not swing from Wasatch to Uinta Mountain trends and vice versa, as stated by Forrester (1937), P.654) and that the Wasatch and Uinta folding did not develop at precisely the same time. Some modification of the original Wasatch folds has resulted from the later Uinta arching, but genetically they clearly developed at different times, and from different forces.

Immediately following the initial folding of the Uinta arch, displacement of beds along the Cherry Creek fault took place, offsetting the Wanship formation.

Following considerable erosion of the tilted beds, deformed by the early Uinta folding, the thrusting or major landsliding created the Silver Creek chaos.

<u>Paleocene phase (middle Laramide orogeny)</u>: The deposition of the Wasatch formation followed and was deposited with great angular discordance upon all older formations with which it is found in contact. These sediments, as stated by Eardley (1951), P.331), were spread eastward from the western mountainous country, but local derivation of the desiments appears to have been pronounced, being derived from the topography produced by the major folding within the area. The Unita arch, Cottonwood-Park City uplift, and Silver Creek chaos contributing the larger porportion of debris.

<u>Eocene phase (late Laramide orogeny)</u>: Gentle folding affected the Wasatch formation of this area, and corresponds to the middle or late Eocene

system of broad gentle north-south folds immediately to the north as reported by Eardley (1944,P 862).

The Uinta Mountains were then subjected to vertical uplift and large scale faulting in late Eocene (Forrester, 1937. P.649), along more or less its present position. This period of faulting offset the Wasatch formation along the north flank of the Uinta Mountains, to the east in the upper Weber River Canyon, but the exact relationship of the faulting to the gentle tilting of the Wasatch formation in this area is not known.

Post-Laramide orogeny

During latest Eocene or early Oligocene time, the "Peoa tuff" was deposited in irregular basins and pockets unconformably on the gently folded Wasatch formation and the more intensely folded Mesozoic sediments where the Wasatch had been stripped. Deposition of the "Peoa tuff" was immediately followed by extrusive activity, as flows, breccias, and agglomerates, and intrusive dikes.

The tuffs, extrusives, and intrusives were in turn gently folded during the post Laramide orogeny, which may be considered as the Absarokan orogeny (Eardley 1951,P.336). This folding was probably contemporaneous with the folding of the Norwood tuff (Eardley,1944, P.862), which is the equivalent of the "Peoa tuff".

An epeirogenic uplift of the region which began in late Miocene time (Eardley,1944,P.964) probably followed, but no evidence of this event exists within the area. Remnants of pre-regional uplift surfaces preserved in adjacent areas, such as the Gilbert Peak and Herd Mountain surfaces, are absent in this area.

A period of quiesence again prevailed and the Weber Valley surface (?) of this area and the North Central Wasatch Mountains was formed during Pliocene time (Eardley, 1944, P. 877).

Basin and Range faulting followed, presumably in very late Pliocene or early Pleistocene time (Eardley, 1944,)877) and the block faulting of the Wasatch Mountains along the Wasatch fault at this time probably produced a rejuvination which greatly eroded and dissected the surface.

The volcanics show evidence of a gentle, eastward,regional dip which is probably related to this period of disturbance, although it could have been contemporaneous with folding during the Absarokan orogeny. No evidence exists to ascertain the relationship.

Quiescence once again prevailed and during a period of equilibrium the "Oakley terrace" was formed, probably during the last cycle of glaciation in the Uinta Mountains,when the Weber River was a depositing stream in that area instead of an eroding stream as it is today (Williams, 1952).

ECONOMIC ASPECTS

Mineral resources in the Silver Creek and adjacent area are wanting, and transient sheep graxing and dairying are the greatest economic enterprises.

In Kent Canyon, Stevens Hollow, and the crest of Dry Canyon anticline, several coal mines were operated in the past, but there has been no recent activity.

Numerous mining prostpect pits, tunnels, and shafts are throughout the area, but no recorded production is known.

CONCLUSIONS

Geologic information accumulated in Silver Creek and adjacent areas, when combined with the observations of investigators of adjoining areas, permits a rather complete interpretation of the geologic history of the transition zone between the Uinta and Wasatch Mountains. The discovery of the Silver Creek chaos is interpreted as evidence of a great thrust, or debris resulting from a thrust. It correlates in time with a period of thrusting in nearby areas, but can be more precisely dated.

The tectonic history of the transition area after the deposition of the Frontier formation is divisible into several episodes. These are briefly:

I. First stage of early Laramide orogeny (Montana phase).

(a) Development of northeasterly trending folds and thrusting in the Wasatch Mountains and adjacent areas.

(b) Normal faulting which followed very shortly stage Ia. This episode is represented by the Dry Canyon fault.

(c) Deposition of the "Wanship formation" upon eroded fold structures and faults of Ia and Ib.

II. Second stage of early Laramide orogeny (Montana phase).

(a) Initial arching of the Uinta Mountains.

(b) High angle reverse faulting, shortly after, and probably in part contemporaneous with IIa. This episode is exemplified by the Cherry Canyon fault.

(c) Following a period of considerable erosion of the arched beds of the Uinta Mountains, thrusting or major landsliding formed the Silver Creek chaos.

III. Middle Laramide orogeny (Paleocene phase).

(a) Deposition of the Wasatch group on highly contorted beds.

IV. Late Laramide orogeny (Eocene phase).

(a) Gentle folding affecting the Wasatch group within the area.

(b) Main uplift of the Uinta Mountains and normal faulting along the flanks.

V. Absarokan Orogeny

(a) Vulcanism of region and local extent.

(b) Subsequent, gentle folding of the volcanics.

VI. Development of a post-mature surface - the Gilbert Peak and Herd Mountain surfaces.

VII. Epeirogenic uplift of the region.

VIII. Formation of the Weber Valley surface by a process of pedimentation.

IX. Block faulting to the west effected this area by a minute regional tilt to the east.

BIBLIOGRAPHY

Anderson, G. E. (1915) Stream Piracy of the Provo and Weber Rivers,Utah, Am.Jour. of Sc.,4th series Vol.40.

Baker, A.A. (1918) Stratigraphy of the Wasatch Mountains in the vicinity of Provo,Utah, V.S. Geol. Survey Preliminary Chart 30.

Beeson,J.J. (1935) Mining Districts and their Relation to Structural Geology, Am. Inst. Mining and Metal. Eng. Tr.,No.1300-1.

Bissell,H.J. (1952) Stratigraphy and Structure of Northeast Strawberry Valley Quadrangle, Utah, Am. Assoc. Petroleum Geol.Bull.,Vol 36, No. 4,pp.575-634.

Boutwell,J.M.(1907) Stratigrapht and Structure of the Park City Mining District,Utah.Jour. Geol. Vol 15, pp. 434-358.

__________(1912) Geology and Ore Deposits of the Park City Mining District, Utah, U. S. Geol. Survey, Prof. Paper 77.

Calkins,F.C.,et. al. (1920) Ore Deposits of Utah, U. S. Geol. Survey, Prof. paper 111.

__________ and Butler(1943) Geology and Ore Deposits of the Cottonwood-American Fork Area,Utah, U.S.Geol.Survey,Prof.Paper 201.

Cobban, W.A. and Reeside, J. B.,Jr. (1951) Lower Cretaceous Ammonites in Colorado, Wyoming and Montana, Am. Assoc. Petroleum Geol. Bull., Vol 35, No. 8, pp. 1892-1894.

Eardley, A. J. (1939) Structure of the Wasatch -Great Basin Region. Geol. Soc. of Am.Bull.,Vol 50,pp 1277-1310.

__________(1951) Structural Geology of North America, New York,Harper Brothers.

Forrester, J. D. (1937) Structure of the Uinta Mountains, Geol.Soc. Am.Bull.,Vol 48,pp. 631 -666.

Hooper, W.G.(1951) Geology of The Smith and Morehouse-South Fork Area, Utah, unpublished M.S. Thesis, University of Utah.

Johns, R.H. and Engle A.E.(1950) Chaotic Breccias in Southern California: Tectonic or Sedimentary, Geol. Soc. Am. Bull. Vol. 61, No. 12, pp.1474 (Abstract).

Larsen, K. W. (1951) The Areal Geology of the Rockport-Wanship Area, unpublished M. S. Thesis, University of Utah.

Longwell, C.R.(1915) Megabreccia Developed Down-Slope from Large Faults, Am. Jour. of Sci., Vol. 249, pp 343-355.

Mansfield, G.R.(1927), Geography, Geology, and Mineral Resources of Part of Southeastern Idaho, U.S.Geol. Survey, Prof. Paper 152.

Mathews, A.A.L.(1931) Mesozoic Stratigraphy of the Central Wasatch Mountains, Oberlin Coll.Lab., Bull., n. ser., No. 1.

Noble, L.F.(1941) Structural Features of the Virgin Spring Area, Death Valley, California, Geol.Soc., Am. Bull., Vol 52, No.7, pp.941-1000.

O'toole, W.L.(1951) Geology of the Keetley-Kamas Volcanic Area, M.S.Thesis, University of Utah.

Schultz, A.R.(1919), Reconnaissance of Uinta Mountains, Utah, U.S.Geol. Survey, Bull. 690, pp.31-92.

Sharp, B.J.et-al.(1915) Geology of the Fort Douglas Quadrangle, OralCommunications, U.S.Geol. Survey.

Veatch, A.C.(1907) Geographt and Geology of a portion of Southwestern Wyoming, U.S Geol. Survey, Prof. Paper 56.

Walton, P.T.(1944) Cretaceous of the Uinta Basin, Utah, Geol.Soc.Am.Bull., Vol. 55, pp. 91-130.

Williams, N.C.(1952) Geology of the Coalville Quadrangle, Utah, unpublished, Dept. of Geol., University of Utah.

Yen, Teng-Chien (1951) Personal Communications.