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Geology of the Northeast Quarter of the Soldier Summit Quadrangle, Utah

by

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GEOLOGY OF THE NORTHEAST QUARTER OF THE SOLDIER SUMMIT QUADRANGLE, UTAH

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by

Gerald V. Henderson

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ABSTRACT

Sixty square miles in central Utah near the town of Soldier Summit, previously studied and mapped by Spieker on a regional scale, was mapped in detail.

The stratigraphic section of lacustrine and fluviatile sediments exceeds 5,000 feet. The section begins with Cretaceous and Tertiary North Horn formation which is overlain by Tertiary Flagstaff limestone. The Eocene Colton formation lies above the Flagstaff limestone and is in turn overlain by the youngest strata present, the Green River formation of middle Eocene age. Detailed studies indicated that the Green River formation contains a basal oil shale zone approximately 1,000 feet thick and that the Colton formation thins to the northwest and northeast and pinches out a few miles to the west.

Broad folds and normal, north-south faults characterize the structure while a series of cuestas dominate the topography.

Correlation of ozokerite deposits with joints and fractures showed that joints controlled deposition of hydrocarbons in this area.

Natural resources found consist of solid hydrocarbons and recently discovered natural gas. The solid hydrocarbons are ozokerite (a mineral wax) and kerogen (oil) shales.

INTRODUCTION

Previous Work

R. J. Kroupa, of Provo, Utah, first discovered and analyzed ozokerite, a natural hydrocarbon, in 1885 and suggested detailed studies of an ozokerite field near Soldier Summit.

Taff and Smith (1905) published the first article on ozokerite at Soldier Summit and Colton, Utah areas, which spurred interest in the study of hydrocarbons in this area. Robinson (1916) later published a more detailed study of the origin and composition of ozokerite in this area.

Spieker and Reeside (1925) were the first to publish articles concerning the Cretaceous and Tertiary formations of the Wasatch Plateau in central Utah. They defined the North Horn, Flagstaff, and Wasatch formations as lower Tertiary in age.

Some of the terms and definitions in the above mentioned paper were later revised by Spieker in 1946 when he published a paper on late Mesozoic and early Cenozoic history of central Utah. He discovered dinosaur bones in strata of central Utah, previously described as Wasatch formation, and documented an orogenic epoch in the eastern part of the great Laramide folded belt of central Utah dating it as between middle and late Montana time instead of at the end of Cretaceous as previously described. He described, in detail, the North Horn, Flagstaff, Colton, and Green River formations in the vicinity of Price, Utah, southeast of the mapped area for this study. Hunt (1956) published a professional paper concerning the Cenozoic geology of the Colorado Plateau and endeavored to show, with correlation diagrams, the stratigraphy and structure of the Green River, Colton and Flagstaff formations in central Utah and western Colorado.

Purpose and Scope

The present work is a study of the general geology including a detailed study of the joint and fracture systems within one of the ozokerite fields in the northeast quarter of the Soldier Summit quadrangle. Another contribution of this paper is to define the lateral and vertical extent of the gradational contact between the Colton formation and the underlying Flagstaff limestone and the overlying Green River formation.

The joint and fracture systems of the area are of special interest in order to determine, if possible, the migration and accumulation of ozokerite deposits in a field, 12 miles by 4 miles, near the town of Soldier Summit, Utah.

An attempt is made to zone and correlate as far as possible, the Green River formation in the thesis area with that of the Green River in the Uinta Basin.

Location and Accessibility

The area, approximately 60 square miles, lies at the western edge of the Uinta Basin and the northern edge of the Wasatch Plateau in Wasatch and Utah Counties, Utah, in and around Soldier Summit (fig 1).

Meridians 111° 68' and 111° 00' west longitude bound it on the west and east respectively, and 40° 00' and 39° 52' north latitude bound it on the south and north respectively. Included in the area are part of townships 9, 19, 11 south, and ranges 7, 8 east, Salt Lake base and meridian (fig 1).

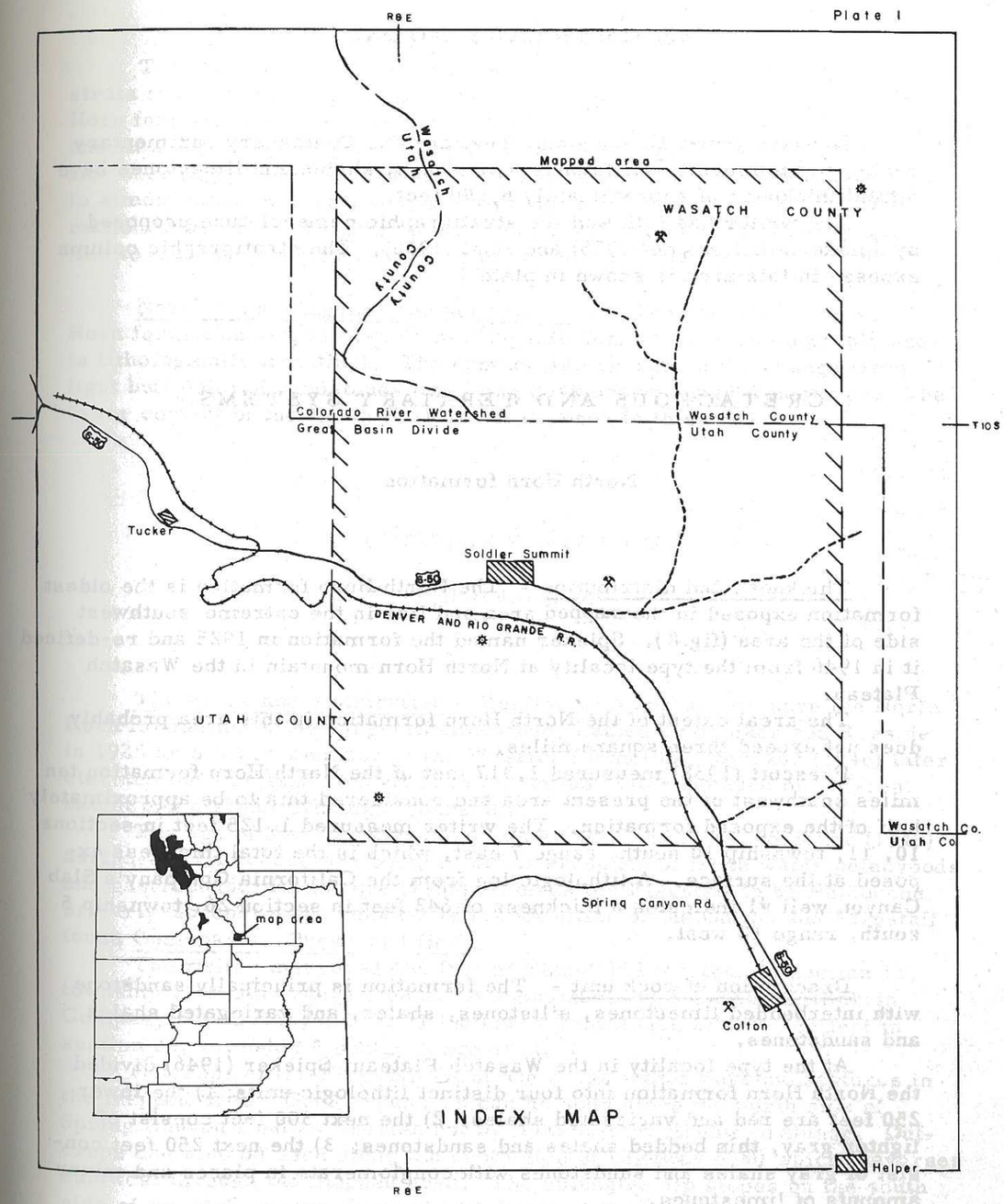
This region is accessible by automobile from the west on combined U. S. Highway 6-50, which extends from Springville, Utah through Spanish Fork Canyon, and approximately 38 miles to Soldier Summit. The summit can be reached from the southeast by way of Price, Utah on U. S. Highway 6-50. Soldier Summit is also on the main line of the Denver and Rio-Grande Western Railroad.

Relief and Drainage

The area is rugged and steep, except for a broad valley in the central part of the area, which is eroded by the drainage of the White River and its tributaries. The maximum relief of the area reaches 9,000 feet above sea level.

The geologic structure definitely controls the topography which in general consists of long, gradual, dip slopes dipping to the northeast. West of the summit the water drains into the Great Basin via Soldier Fork Creek which eventually flows into Utah Lake, 50 miles to the west. The eastern section of the area drains into Price River, part of the vast drainage system of the Colorado River. The steep canyons and rugged topography formed by the eroding streams, in this area, suggest a youthful stage of erosion.

One major perennial stream and several small tributaries (plate 8) comprise the major drainage system of the mapped area. The White River, which flows to the southeast through the broad valley of Soldier Summit, has a drainage pattern formed by low angle dip slopes of the Flagstaff formation and unconsolidated nature of the Colton strata.



SEDIMENTARY ROCKS

Exposed Upper Cretaceous, Tertiary and Quaternary sedimentary rocks, predominantly sandstones, siltstones, shales and limestones have a total thickness of approximately 5,000 feet.

The writer has followed the stratigraphic nomenclature proposed by Spieker and Reeside (1925) and Hunt (1956). The stratigraphic column exposed in this area is shown in plate 2.

CRETACEOUS AND TERTIARY SYSTEMS

North Horn formation

Thickness and distribution - The North Horn formation is the oldest formation exposed in the mapped area and lies in the extreme southwest side of the area (fig 8). Spieker named the formation in 1925 and re-defined it in 1946 from the type locality at North Horn mountain in the Wasatch Plateau.

The areal extent of the North Horn formation in this area probably does not exceed three square miles.

Prescott (1958) measured 1,317 feet of the North Horn formation ten miles southwest of the present area and considered this to be approximately half of the exposed formation. The writer measured 1,125 feet in sections 10, 11, township 10 south, range 7 east, which is the total thickness exposed at the surface. A lithologic log from the California Company's Slab Canyon well #1 indicates a thickness of 642 feet in section 26, township 5 south, range 10 west.

Description of rock unit - The formation is principally sandstone with interbedded limestones, siltstones, shales, and variegated shales and sandstones.

At the type locality in the Wasatch Plateau, Spieker (1946) divided the North Horn formation into four distinct lithologic units: 1) the lower 250 feet are red and variegated shales; 2) the next 300 feet consist of lighter gray, thin bedded shales and sandstones; 3) the next 250 feet consist of gray shales and sandstones with conglomerate in places and minor amounts of limestones.

The lithologic units proposed by Spieker correlate with North Horn strata in the area mapped for this thesis. The lower portion of the North Horn formation is rather evenly bedded with interbedded sandstones, shales, and limestones showing thin layering. Midway up the section the formation becomes thicker bedded and shales predominate and are darker gray to almost black with sandstones interbedded. The upper part of the formation weathers to a lighter tan and consists of variegated sandstones, fine to medium-grained with some cross-bedding present.

North Horn-Flagstaff contact relations - The contact of the North Horn formation with the overlying Flagstaff formation is conformable and is lithologically indistinct. The contact was chosen on the change from light buff colored sandstones overlying dark brown sandy limestones. The lower contact of the North Horn is not exposed in this area.

TERTIARY SYSTEM

Flagstaff Limestone

Thickness and distribution - Resting with conformity upon the North Horn formation is the Flagstaff limestone, named by Spieker and Reeside in 1925 as a lower member of the Wasatch formation. Spieker (1946) later elevated the Flagstaff limestone to formation status because of its areal extent and distinct lithologic character.

The age of the Flagstaff is not known with certainty. Spieker (1946) assigned a Paleocene age because of the presence of fresh water pelecypods and gastropods. La Rocque (1955) believes the Flagstaff to be Paleocene or early Eocene in age because of the affinities of the Colton and Flagstaff fauna Goniobasis, Physa and Helix.

The writer measured 486 feet of Flagstaff limestone in section 11, township 10 south, range 7 east. A subsurface log from the California Company's Slab Canyon Unit #1 indicates a thickness of only 383 feet in section 26, township 5 south, range 10 west.

Outcrops of the Flagstaff form one of the major physical features in the mapped area. Good exposures can be seen along the north side of Spring Canyon road as Cuestas cut by intermittent stream drainage. Outcrops can also be seen along the south side of Highway 6-50 which traverses eastwest through the mapped area. The extensive dip slopes on the south side of the highway are covered with heavy timber and foliage.

Description of rock unit - The Flagstaff formation is predominantly limestones, with interbedded shales, and sandstones. Spieker (1946) noted minor amounts of gypsum, oil shale, and volcanic ash within the formation. It lacks the variegated colors of the underlying North Horn formation and can be distinguished from the other formations by its distinct lithologic character and high cliff-forming units.

Colors of the formation range from nearly white, through buff to tan, light to dark brown and gray, mottled and dark combinations. The limestones are dark blue to brown and sub-lithographic, and the shales are light to buff brown and interbedded with quartzose sandstones.

Flagstaff-Colton contact relations - Outcrops of the Flagstaff limestone cover most of the south half of the mapped area.

The contact with the Colton formation is lithologically distinct only in a few places. The top of the Flagstaff is a dark blue-gray organic-rich limestone and the Colton is variegated buff-colored sandstone. Heavy foliage and timber covers the Flagstaff limestone, whereas the Colton is distinctly less vegetated; this distinctive timber line is a good criterion for recognition of the contact between the Colton and Flagstaff formations.

La Rocque (1956) states that the affinities of the upper Flagstaff mollusca are with those of the Colton and that characteristic features appear in certain genera which permits differentiation between Colton and Flagstaff beds.

Colton Formation

Thickness and distribution - The Colton formation forms a broad valley that extends east-west through Soldier Summit. The upper member of the Wasatch formation was re-defined by Spieker (1946) as Colton formation. It consists of variegated red, buff colored sandstone beds between the Flagstaff limestone and the overlying Green River formation. The Colton strata are regularly bedded sandstones and show a striking contrast of colors compared to the green and gray shales of the Green River formation and the dark blue limestones of the Flagstaff formation. A convenient criterion for recognition and mapping is the variegated color and it represents a valid distinction between the two types of sediments. The Flagstaff is a lacustrine sediment and the Colton has a flood plain origin.

Spieker (1946) measured 1,500 feet of the Colton formation at the type area near Colton, ten miles east of the area mapped for this thesis and stated that it thickened eastward to 3,500 feet on Green River. Still

farther east the correlatives of the Colton are approximately 5,200 feet thick. The writer measured 960 feet in section 24, 25, township 10 south, range 7 east. Prescott (1958) measured a possibly complete section of 777 feet thick in section 21, township 10 south, range 7 east, of the Soldier Summit Quadrangle. The subsurface log from California Company's Slab Canyon well indicates a thickness of 570 feet, which proves north-eastward and north-westward thinning.

Description of rock unit - The Colton formation is dominantly clastic, including sandstones and shales of both flood plain and lacustrine origin (Spieker, 1946) but in places the lacustrine zone contains thin beds of limestone. Spieker (1925) previously stated that there were no limestones present in the Colton formation. Beds characteristically show bright colors, notably various shades of red, pink and lavender and bright bluish-gray.

Studies of insoluble residues and heavy minerals of the Colton formation indicate the following results from four samples taken at surface outcrops. One sample from each of the measured units in the Colton gave the following results:

Unit	Sample	Wt. of Sample	Type and Strength Acid	Wt. of Residue	Percent Insoluble Residue	Composition
1-2	1	5 gms.	HCL 1:4	3.8 gms.	76%	Predominantly qtz. Heavy minerals negative.
3	2	5 gms.	HCL 1:4	3.3 gms.	66%	Predominantly qtz. Heavy minerals negative.
4	3	5 gms. 5 gms.	HCL 1:4 HAC 1:1	4.1 gms. 4.4 gms.	83% 89%	Predominantly qtz. Heavy minerals less than 2%.
5	4	5 gms. 5 gms.	HCL 1:4 HAC 1:1	3.51 gms. 3.46 gms.	72% 69%	Predominantly qtz. Heavy minerals, pyrite, olivine, less than 2%.

In the type locality of the Colton formation, the formation is mainly red shale and brown weathered sandstone, but to the south a wider range of colors appear as it thickens and grades into and becomes the upper part of the Wasatch formation.

Colton-Green River Contact relations - The Colton formation exhibits a topographic expression of low valley forming units. It is eroded by drainage of Soldier Creek on the west and White River on the east.

The Colton thins toward the west and disappears near the town of Tucker, Utah (Prescott, 1958). It tongues out laterally and vertically into the Flagstaff below and the Green River above. Spieker (1946) points out that the Green River-Colton contact rises 1,000 feet stratigraphically between the towns of Colton and Green River, Utah.

Swain (1957) and others define the contact of the Colton-Green River formations as a transitional zone. The upper 400 feet plus of the Colton formation, or the lower 400 feet of the Green River formation, contain strata that correlate with the Douglas Creek member of the Green River formation in the Uinta Basin (Bradley, 1952). These transitional beds are indicative of a gradational stage from fluviatile to lacustrine deposits.

The transition zone is plainly evident in this area because of the lack of distinct lithologic change between these two formations. Variegated colors are present within the lower Green River and the upper Colton formations, and interfingering of maroon sandstones and light green shaly sands is exhibited.

The fossiliferous units in the Colton formation contain the following genera, collected and identified by the writer.

Pelecypods:

- Elliptio sp.
- Elliptio sp.
- Lampsilis sp.
- Sphaerium planum

Gastropods:

- Viviporus leai
- Viviporus sp.
- Viviporus washakensis
- Goniobasis simpsoni
- Goniobasis sp.
- Physa sp.
- Helix veterna
- Planorbis sp.

Green River Formation

Thickness and distribution - The Green River formation is the thickest stratigraphic unit in the mapped area. Hayden named the Green River formation in 1869 from the type locality in Green River, Wyoming. Bradley (1931) measured 4,900 feet in Indian Canyon, Utah, and Prescott (1958) measured 1,473 feet of the Green River formation near Tucker, Utah, and estimated this measurement to be about one-fourth of the total thickness present. The writer measured a complete section of 3,115 feet in section 3, 8, 17, 18, township 10, 11 south, range 7 east. The Green River formation is exposed over the entire north half of the area and covers an areal extent of approximately two-thirds of the total mapped area.

Description of rock unit - The lowermost portion of the Green River formation consists of tan, argillaceous, flakey, or papery shales, gray platy marlstones, thin oil shale beds and micaceous sandstones. Abundant mollusc remains are also present along with coquina beds in the lower Green River formation. The lower portion is overlain by a tongue of the Colton consisting of drab, buff, greenish-red mudstone and thick, lenticular beds of medium to coarse grained, dark reddish-brown sandstone. The base of the Green River, where the two formations intertongue, is the zone in which ozokerite is emplaced. These transition beds have been traced eastward to Duchesne where Carter Oil Company's Ute Tribal #1 well produces 1,600 barrels of wax penetrated oil per day from a depth of 9,357 feet. Carter Oil Company believes that this is the approximate depth of the transitional zone of the Colton and Green River formations. They attribute the origin of the heavy oil in Ute Tribal #1 to ozokerite. They also claim this is the first well of its kind to produce oil from ozokerite saturated strata.

Bradley (1931 p. 17) recognized four separate phases within the Green River formation at Indian Canyon, 15 miles east of this area. (1) The basal member, a tongue of Green River formation; (2) A tongue of Wasatch (Colton) formation; (3) A second lacustrine facies; (4) A delta facies.

Overlying the tongue of Colton, a second lacustrine facies of the Green River formation consisting of interbedded shale, marlstone and thin limestone and micaceous sandstone, is probably the "black shale facies" mentioned by Picard (1955), which he believes is exposed at the surface along the western edge of the Uinta Basin (the map of this thesis area defines part of the western edge of the Uinta Basin). Picard's description of the "black shale facies" in the Uinta Basin does not entirely fit the writer's description of the lower unit of the Green River formation in this area. Picard described the facies as consisting of green-gray shales and some thin beds of oil shale which are present in the unit but constitute a very small percentage and are not characteristic of the unit as a whole. The writer's descriptions (see stratigraphic measured sections, appendix) do not agree with

Picard's descriptions in that the oil shale beds are predominate in the lower part of the Green River formation in this area.

The upper part of the Green River in this area is composed of barren shales and marlstones with interbedded light green to buff colored limestones and probably correlates with Bradley's delta facies. Some beds are massive but generally less than one foot thick. Lenticular, massive, course grained, light brown quartzose sandstones are present throughout the upper part of the Green River formation.

Fossils collected in the Green River consist of Goniobasis, Viviparus, Unio, Helix, Physa, and ostracods. Others are listed in the paleontologic summary of this report. Ostracod samples taken in this area were from surface outcrops; samples studied by Swain (1956) were from subsurface well samples. Cypris pagei and Heterocypris sp. were identified from the paper by Swain (1956 p. 126) and correlate with his zone containing Cypris pagei, which extends throughout the Uinta Basin.

Green River contact relations - The Green River formation conformably overlies the Colton formation and grades laterally into it. The boundary between the Green River formation and the overlying Uinta formation does not outcrop in this area but is visible just a few miles north along the crest between Strawberry Reservoir and the valley that separates the western edge of the Uinta Basin from the Wasatch Plateau (Bissell, 1952, p. 616). The contact of the Green River formation with the underlying Colton formation is very indistinct and can only be mapped by color of strata. It is visible only in a few places, such as the north side of Highway 6-50 two miles west of Soldier Summit and near the middle fork and right fork of White River in section 19, township 10 south, range 7 east.

Swain (1956), Bradley (1925) and others, consider the lower 400 feet of Green River strata as a transitional zone of lacustrine and fluviatile sediments.

A list of fossils collected and identified by the writer is given below. They are summarized in Plate 6.

Pelecypods:

- Unio danae
- Unio shoshonensis
- Unio vetestus
- Unio sp.
- Elliptio sp.

Gastropods:

- Viviporus leai
- Viviporus panguitchensis
- Viviporus sp.
- Goniobasis simpsoni
- Goniobasis carteri
- Goniobasis sp.
- Physa pleromatus
- Physa sp.

Ostracods:

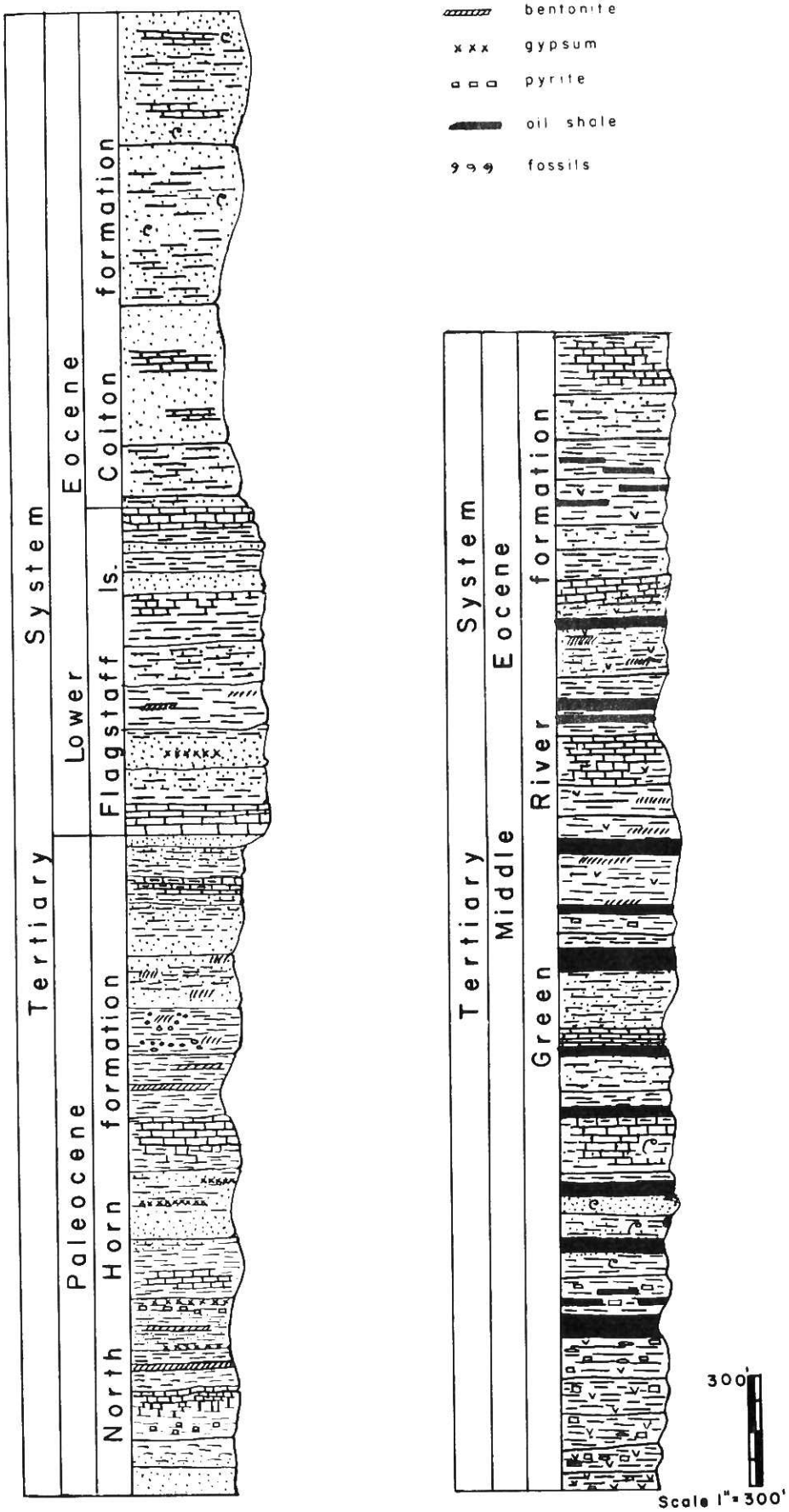
- Cypris pagei
- Hetercypris sp.

QUATERNARY SYSTEM

The alluvium in the area is a thin veneer of gravel, sand, silt and clay. Difficulty in locating contacts was experienced due mainly to the presence of slope wash and gradational contacts. The area is generally undergoing active erosion which is evidenced by gullying and stream erosion and an unusual amount of slumping and sliding of unconsolidated material.

Talus, mud flows, landslides and slope wash present in this area are particularly concentrated upon the Colton and Green River formations. Mud flows and earth slides are prominent enough in the Green River formation to be mapped separately (plate 8).

It is apparent that a heavy load of detrital material is transported by all streams in the area during spring runoff because long valleyward alluvial fans are forming at the base of the Green River escarpments and are cut by deep ravines as a result of torrential intermittent runoff.



General Columnar Section

STRUCTURE

The Soldier Summit quadrangle lies on the northeastern flank of the Wasatch Plateau and is structurally associated with folding and faulting during the Laramide Orogeny. The structure controls the topography of the area.

The Flagstaff dip-slopes in this area form natural limbs of the arched Wasatch monocline. The regional structure consists of a broad, gently plunging anticline which trends in a northeast, southwest direction through the mapped area. This is probably an extension of the Clear Creek anticline mapped by Walton in the Scofield Reservoir area to the south (fig 3).

The Beaver Creek syncline, also mapped by Walton (1955), is adjacent to the Clear Creek anticline on the southeast. It traverses northeast southwest and falls just outside the area of this thesis (fig 3).

The Pleasant Valley graben, south of the mapped area, represents a fault system of economic importance. The writer believes that the local folds and faults in the area mapped are in concurrence with the Pleasant Valley graben system and the Pondtown Creek structure to the southwest. Small local faults and fault slivers are also recognized near the extreme eastern boundary of the mapped area and are probably extensions of Forge Mountain fault.

Folds

The largest fold in the area, the Clear Creek anticline, is situated in the central portion of the map. Its axis strikes approximately north 25° east, and is typified by gentle flank dips. The anticlinal trend extends south to the Scofield Reservoir area and extends north to the edge of the Uinta Basin where it plunges gently. This fold is probably associated with flexing and warping of the Wasatch monocline in late Eocene and early Miocene time as discussed by Spieker (1949).

One other major structural fold is evident in the area, the Beaver Creek syncline mapped by Walton (1955) in the Scofield and Clear Creek Reservoir areas (fig 3). It trends approximately north 20° east and

extends south beyond Schofield Reservoir and north to the edge of the Uinta Basin.

Small local warps and flexures appear in the northern part of the mapped area within the Green River formation, especially in the oil shale zones.

According to Spieker (1949) the folding is late Tertiary. The youthful stage of erosion shown by the topography of the Green River formation indicates folding preceding faulting. Walton (1955) and Spieker (1946) believe that the northern end of the Wasatch Plateau was also affected by pre-flagstaff folding and monoclinal arching from evidence of an unconformity between the North Horn and Flagstaff formations in the Six Mile Canyon area to the southwest.

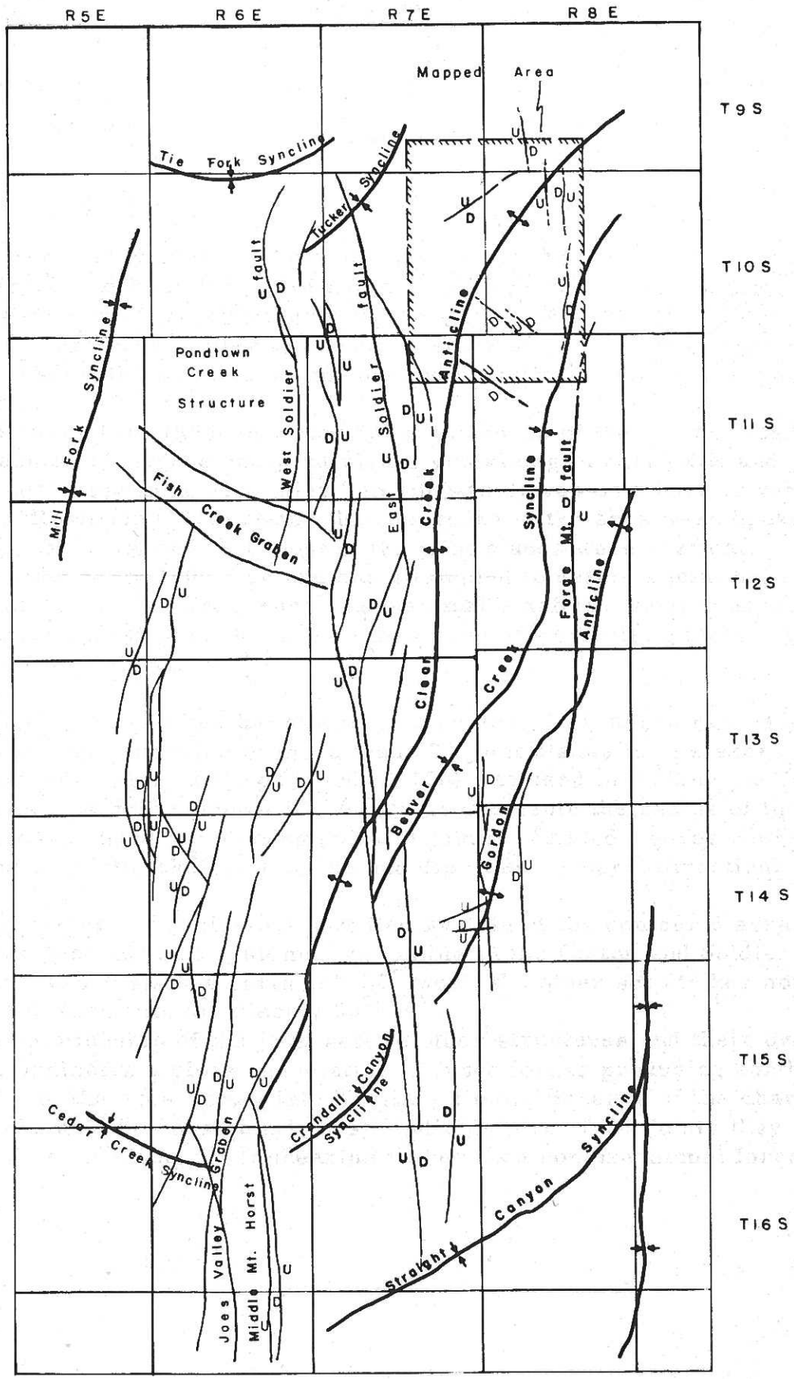
Faults

The mapped area lies north of a major fault system in the northern end of the Wasatch Plateau (fig 3). Forge Mountain fault on the east and East Soldier fault on the west bound the area, both faults were named by Walton in 1955 from the Wasatch Plateau. The East Soldier fault extends through the area to the south about four miles and dips approximately 50° northeast. Forge Mountain fault lies south of the mapped area but small north-south faults that are possible extensions of the main fault are evident in this area.

Spieker (1949 p. 80) believes that the faulting and flexing of the Wasatch monocline to the south took place some time between the deposition of the Flagstaff limestone and the Green River formations. The Colton formation intervenes between the two and conditions are sufficient to show that major faults must have occurred after the deposition of the Colton, it can be dated probably some time between late Eocene and Miocene time.

The major trend of the faults in this area is north 10° to 20° west. Most are normal faults having small displacement. The displacement is negligible due to the fact that the strata are unconsolidated and breaks cannot be easily recognized.

Plate 3



Structure Map - Wasatch Plateau

modified from Walton-1955

Joints

The rocks of the Soldier Summit area do not exhibit well defined joint patterns, because of the sedimentary origin of the rocks and unconsolidated property of the strata exposed; however, statements like the following prompted the writer to conduct a study of the joint systems in this area to show the relative abundance and direction of strike and dip of the joints.

Taff and Smith (1905) mentioned that the rocks of the Soldier Summit area exhibited fissure and joint planes containing mineral wax and that the shaft of the mine at Soldier Summit was driven on a band of vertical joints. Robinson (1916) stated that the rocks in the area were broken by a system of joints and that most of the joint planes were vertical.

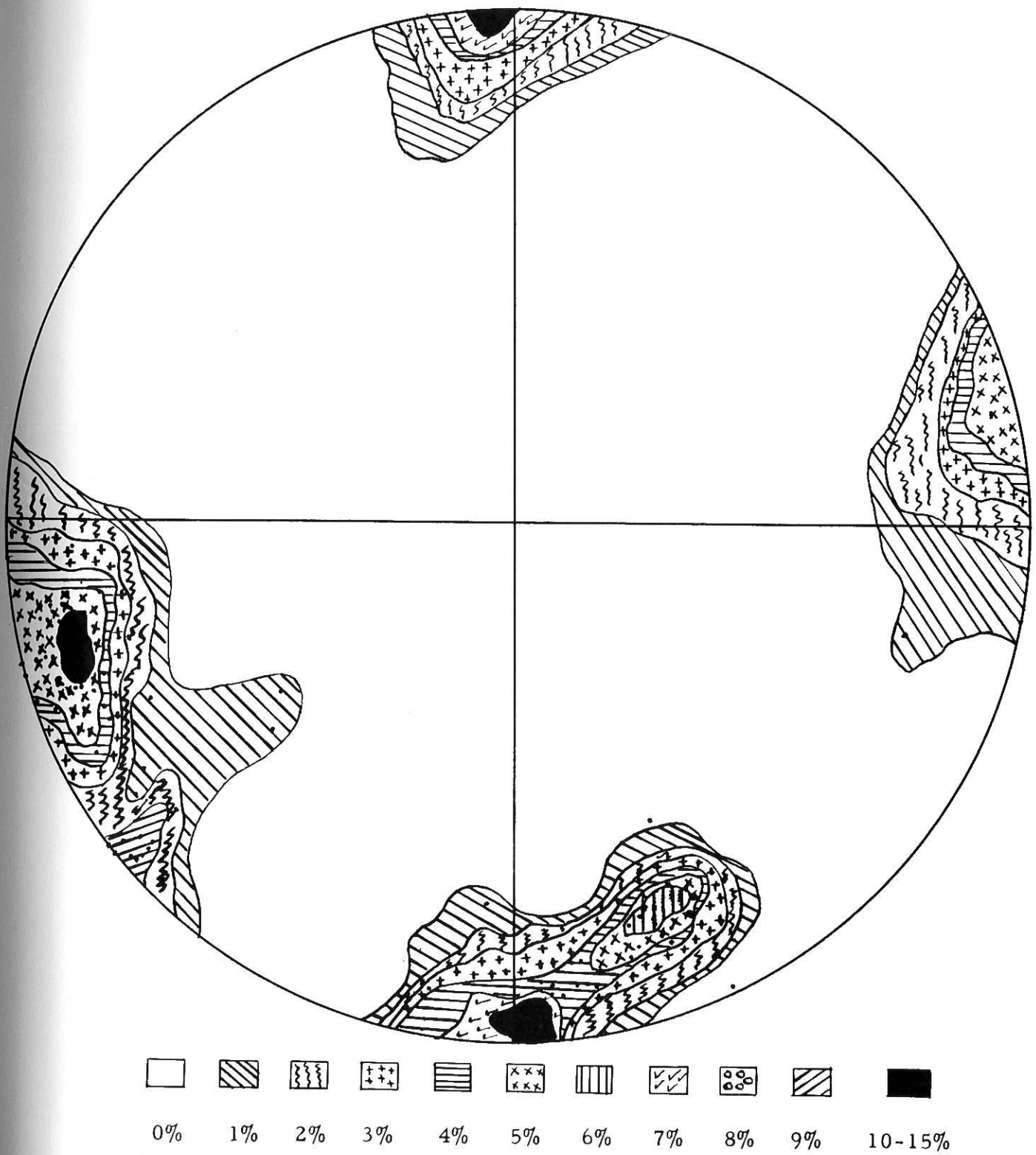
Since the early 1900's no one has attempted to define a joint pattern in the ozokerite area. The writer believes that a definite system of joints does exist and that they could be the influencing or controlling factor of mineral wax deposition.

Method - The writer has prepared a contour diagram to represent the abundance and direction of more than 200 joint planes in this area. The method outlined by Billings (1954 p. 108) was used in making the contour diagram. A grid composed of intervals one-tenth the radius of the large circle was used for plotting poles of joints. Shaded figures represent the percent of joints taken that strike and dip in one general direction.

Conclusions - Conclusions justified by data of the contour diagram are that two general joint systems are visible in the Colton and Soldier Summit areas: one strikes north 15^{o}-20^{o} west; the other set strikes north 90^{o}-95^{o} east; both sets dip steeply 80^{o}-90^{o}.

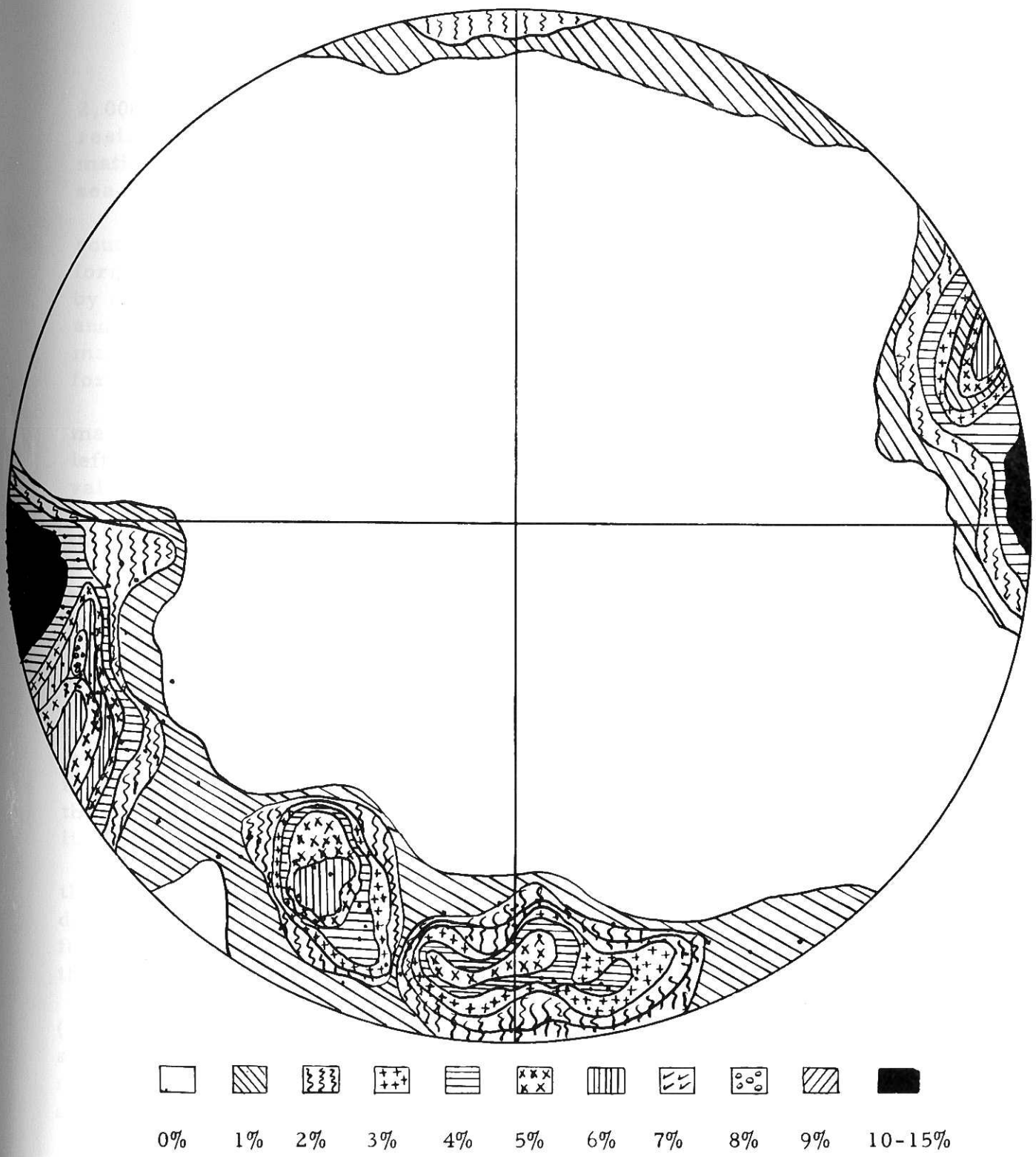
The relationship of the joint sets to other structures and their overall pattern indicates a close association with the forces producing north-south faults in the area during late Tertiary time. Because of the character of the breaks and the consistently systematic pattern of the joints they are interpreted as resulting from shearing rather then compressional forces.

Plate 4



Contour diagram of 100 joints taken near Soldier Summit

Plate 5



Contour diagram of 100 joints taken near Colton, Utah

GEOMORPHOLOGY

The Soldier Summit area is of moderately high relief, approximately 2,000 feet from the valley of White River to the northern crest formed by resistant limestone and sandstone beds of the Green River and Uinta formations. The elevation of the highest point in the area is 9,300 feet above sea level.

The mapped area consists of a series of cuestas, bounded on the south by long gentle dip slopes of Flagstaff and North Horn strata which form the northern end of the Wasatch monocline, and bounded on the north by steep escarpments forming a ridge between the Soldier Summit valley and the Strawberry Reservoir area. The eastern and western edges of the map are strike valleys formed on less resistant sandstones of the Colton formation.

White River, which flows southeastward across the area, is the master stream. It enters from the north by way of three tributaries, the left, middle and right fork of the White River, which all flow south to the valley of Soldier Summit where they meet and from there traverse southeast to meet the Price River at Price Canyon. White River and its tributaries drain most of the area of this report.

A subsequent drainage pattern is expressed by the topographic alignment of streams with a general north-south pattern of faults. Evidence of late Tertiary faulting is found in the youthful stage or erosion of the streams which are probably controlled by faults and also by the evidence of streams dissecting major folds of the area.

The dividing line for the drainage of the Colorado River watershed and the Great Basin, extends along the ridge just north of Highway 6-50 through Soldier Summit in a general east-west direction (plate 1). All the drainage to the northeast from this ridge line eventually drains into the Colorado River system and all the drainage to the southwest from this line drains into the Great Basin system.

One major and three minor geomorphic elements are represented in this area. The major feature consists of a cuesta-escarpment topography developed in resistant and weak strata of the Flagstaff and Green River formations that have been tilted and eroded leaving steep escarpments facing the south and long slopes dipping to the northeast.

The three minor geomorphic elements represented in this area are: (1) alluvial fans; (2) slump structures in the unconsolidated Green River and Colton strata; (3) deeply incised ravines cut by heavily loaded torrential streams. The entire area expresses a dendritic stream pattern with subsequent topography in a youthful stage of erosion.

Cuestas

Cuestas are prominent topographic features over the entire mapped area. Resistant strata within the Green River formation form cuestas visible on the north side of Highway 6-50, and uptilted Flagstaff strata form cuestas visible on the south side of the highway and along the north side of Spring Canyon road. The slopes are fairly uniform in dip, 10^{o} - 30^{o} to the northeast, and are in places well defined bedding planes. Escarpments are visible on the north of Highway 6-50 and north of Spring Canyon Road.

Alluvial Fans

Large alluvial fans extending valleyward from the mouth of Tahbyune Creek Canyon and the canyon to the east were developed as a result of uplift along Forge Mountain fault extending into the slopes and ridges of the Green River formation near Colton, Utah. The absence of large fans west of Soldier Summit indicates a minimum of uplift and the exposure of more consolidated strata.

Slump Structures

Slump structures are prominently exposed in the Green River strata. Good examples of these structures are noted and mapped in section 16, township 9 south, range 8 east, and section 21, 22, township 10 south, range 8 east. The slump structures in zones up to 3,000 feet in length have moved more than 200 feet vertically. The slumping is a result of ground water saturation of the Green River sands and marlstones that lie on steep hillsides and terraces, with Forge Mountain fault possibly the activating force touching off the slides.

Ravines and Gullys

Deeply incised ravines and gulleys are particularly evident in the southeastern section of the mapped area. Torrential runoff from the steep slopes of the Green River strata have cut ravines ten or more feet deep and 20 to 30 feet wide in the alluvial fans and Quaternary deposits of the valley fill. The velocity and load of the runoff waters is evidenced by the large size cobbles and boulders found where the runoff drops its load.

PALEONTOLOGY

The paleontology of this report consists mainly of the collection of fossils throughout the mapped area with emphasis on sampling from the Colton and Green River formation and identifying genera and species.

The Flagstaff assemblage is characterized by an abundance of Goniobasis, Physa, and Viviparus while the Colton and Green River strata are represented by the same genus and species with the addition of Helix, Planorbis, Elliptio and Sphaerium.

La Rocque (1956) states that the genera in the Colton formation are the same as those found in the Green River formation with the exception of Helix and that all genera are also present in the upper Flagstaff formation. The Colton and Green River faunas are thought as being directly descended from the Flagstaff faunas. The lakes, during Colton and Green River time, were isolated from other areas of development permitting only certain fauna to migrate into the region.

The paleontology of this report is summarized in plate 6.

Paleontologic Summary

PELECYPODS	Flagstaff	Colton	Green River	Abundance
Unio Danae			X	common
Unio Shoshonensis			X	abundant
Unio wasakiensis			X	rare
Unio vetustus			X	common
Unio sp.			X	common
Elliptio sp.	X	X	X	common
Lampsilis sp.		X		rare
Sphaerium planum	X	X		abundant
GASTROPODS				
Viviporus leai		X	X	abundant
Viviporus panguitchensis			X	abundant
Viviporus sp.	X	X	X	common
Goniobasis simpsoni		X	X	common
Goniobasis carteri		X	X	abundant
Goniobasis sp.			X	common
Physa pleromatus		X	X	common
Physa sp.		X	X	common
Helix veterna		X		common
Planorbis sp.		X		common

OSTRACODS	Flagstaff	Colton	Green River	Abundance
Cypris pagei			X	abundant
Heterocypris sp.			X	common

ECONOMIC GEOLOGY

Natural gas, hydrocarbons and water offer the best economic potential in the mapped area.

Natural Gas

Possibilities for natural gas production is one of the most important economic aspects at the present time. Gas and oil companies interested in this area drilled several test wells in 1952 and 1956. Only three wells drilled in the surrounding area are located within the boundaries of this report. They are listed below, revised from Hansen and Scoville (1955).

County	Location	Operator	Field	Completed	Surface Elevation	Bottom
Utah	SENSW 25-10S7E	Nelson Gustaveson	Soldier Summit	8-8-52	Colton 7550'	?
Utah	11-11S7E	Ed Pauley Pan. Am.	Clear Creek	11-4-56	Flagstaff 8650'	? Dakota
Wasatch	E NWSE 26-5S10W	Calif. Co.	Slab Canyon Unit #1	9-16-52	Green R. 8626'	North H.

Of the three wells drilled in this area only one has indications of being commercial.

The underlying formations that have potential gas and oil producing horizons are the North Horn formation, Price River formation, Blackhawk formation, Star Point formation, Emery sandstone and the Dakota sandstone. One of the wells drilled in the area bottomed in the North Horn at 5600 feet and the other two wells were not recorded but the depth of the potentially commercial well is probably in the Dakota sandstone.

The writer believes the possibilities for natural gas production in this area will prove to be of considerable importance in the future. Several places may prove worthy of more detailed study in this area, namely the Clear Creek anticline, the East Soldier fault and areas directly south and east of the mapped area.

Oil Shales

The character and composition of the marlstones and oil shales of the Green River formation have been previously described in detail by Bradley (1931), Hunt, Stewart, and Dickey (1954) and others.

Most of the oil shales present throughout the Green River formation at Soldier Summit are contained in two general zones, one in the lower part and the other in the upper part of the Green River formation. The lower shale zone contains a large amount of organic matter and weathers to a blue-gray color; whereas the oil shales in the upper zone of the formation are lacking in carbonaceous matter and weather to a gray-brown and are not as resistant to erosion.

The bedding in the lower zone is thin to massive and regular except for local warping and contortions. This warped bedding is most common in rich oil shales and was probably caused by movements within and between the beds while they were in a plastic state Cashion, (1957 p. 135). Weathering reveals the thin bedding and also produces papery shale in very thinly laminated beds. Much of the lower shale horizon contains chert nodules and foreign material.

The oil shale in the upper horizon is not as rich in organic matter as is the lower horizon and is less extensive in area. The upper shales are not as well exposed and weather lighter brown to gray and are eroded into thin bedded paper shales.

Kerogen shales were mined during World War II at Kyune, Utah, 10 miles east of Soldier Summit, but the extent and tonnage of this operation is not known. Possibilities of mining oil shales in the area of this thesis are somewhat restricted by unfavorable conditions and lenses in the subsurface.

A survey made by the United States Geological Survey of the Uinta Basin kerogen shales, indicated a minimum of 9% bitumen content by weight, as "low grade" oil shales.

The writer of this paper, after detailed study of the kerogen shales in this area, concludes that the upper oil shale zone would not be as promising to mining possibilities as would the lower zone. The lower zone, which consists of alternating oil shales and sandstones, is approximately 1000 feet thick and contains a greater amount of carbonaceous material and has a greater specific gravity, a better color and texture than the upper oil shale zone. Good roads lead into the area and some of the better oil shale beds can be reached only a few yards from the road.

Ozokerite

The largest district in the United States in which ozokerite, a lower member of the hydrocarbon series, has been mined and prospected is at Soldier Summit, Utah, an area a little more than 12 miles long and one to four miles wide (fig. 7). It includes parts of township 10 south, range 7, 8 east, and township 11 south, range 8, 9 east, Salt Lake base and meridian, in Utah and Wasatch counties. Robinson (1916 p. 15), reported and described 17 ozokerite veins in the above described field. Most of which had been worked at one time or another.

The ozokerite deposits were first discovered at Soldier Summit as far back as 1879. The first mining claim was owned and operated by R. J. Kroupa in 1904. His operations consisted of 150' shafts and drifts, with vats and a reduction plant. Later during World War II ozokerite mining reached its peak producing over 1600 tons annually.

The old abandoned mine at Soldier Summit is now flooded out and caved in. David (1951 p. 67), indicates that there were three major ozokerite veins in the Soldier Summit area and two gilsonite veins. Only two of the ozokerite veins are within the mapped area and none of the gilsonite veins are found in the area. The Soldier Summit vein and an unnamed vein outcropping approximately two miles west of Soldier Summit. One vein strikes north 16° east and the other strikes north 13° west; they both dip steeply to the west. The Soldier Summit vein is the only one that has been mined commercially while the vein at Colton and the one west of Soldier Summit contain prospect pits but have never been mined. Two gilsonite veins are present in the northeastern part of the Soldier Summit area but have not been accurately plotted as to location because the author was not able to locate them on the surface. Davis stated that these veins were plotted only by information from interview with sheepherders in the area.

Ozokerite deposits in the Soldier Summit area occur in irregular vein deposits, in fissures and crushed zones in the sandstones and shales of the tranzition zone between the Colton and Green River formations. The deposits are not extensive and are found only in small quantities, sometimes three feet to one-fourth of an inch thick. A sample of ozokerite deposited in a fractured sandstone is on file with this report. Some veins extend more than a mile in length and others pinch out suddenly, depending on the rock fracture and porosity. The veins are caused by faulting and thus create an irregularity in the size and shape of the deposits.

The problem of origin involves an origin of the vein, the origin of ozokerite and the origin of fissures, and the emplacement of ozokerite.

Wurtz and Henry, (1950) stated that ozokerite is a lower member of the zietrisikites, rather than a higher member of the ozokerite series. Newberry, (1950) believes the black wax deposits to be true ozokerite with a melting point of 60°C and soluble in ether. Debate was, whether these were true ozokerites as compared to those in Galacia, Austria because of different fusing and melting points. Later experiments proved the deposits at Soldier Summit to be true ozokerite.

Abraham, (1938, p. 89) and Davis (1951, p. 64) listed the criteria characteristic of ozokerite deposits at Soldier Summit.

Abraham (1938, p. 129) stated that ozokerite is a native wax composed of higher members of the $C_nH_{2\ n-2}$ and C_nH_{2n} series of hydrocarbons. He believes that ozokerite could have been produced by either polymerization of metamorphosis.

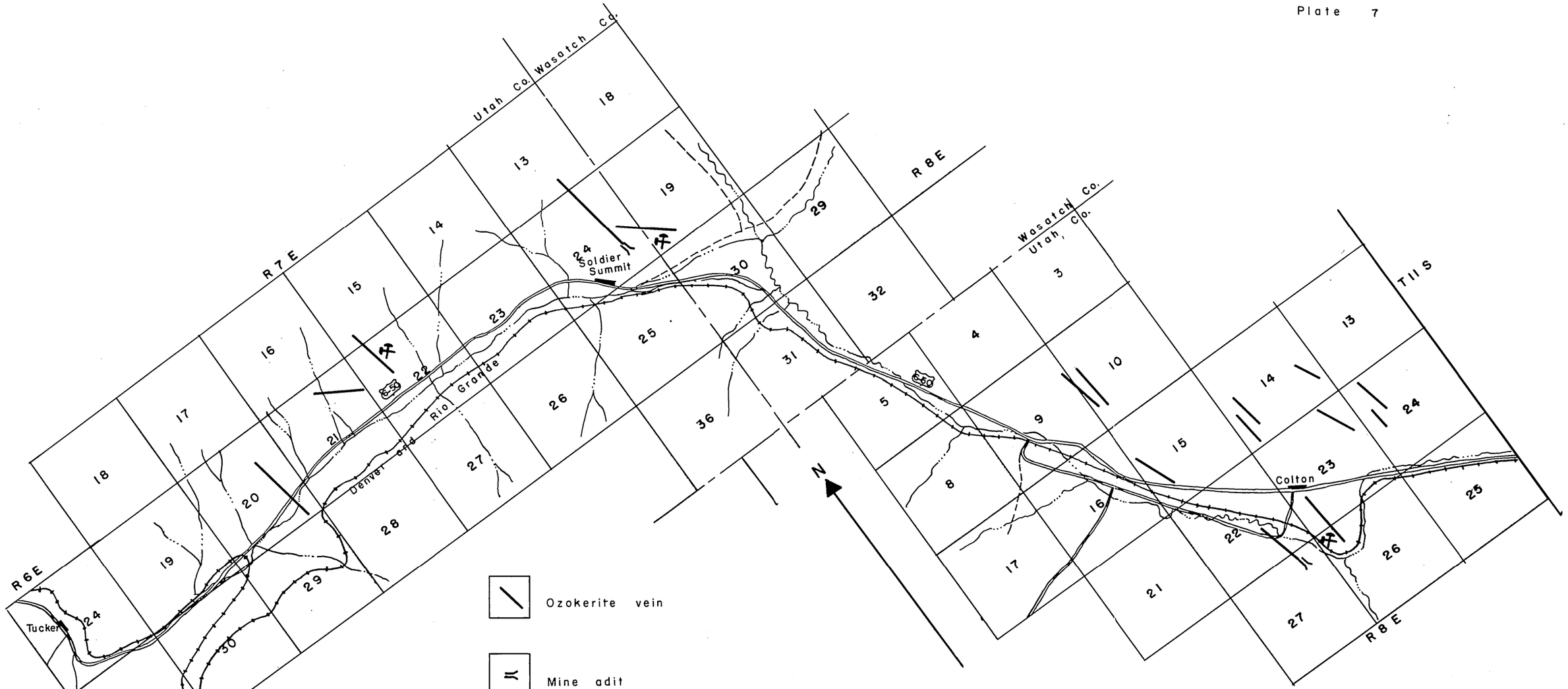
Crawford (1949, p. 257) stated that, while observing operations on the 600 foot level of the Soldier Summit mine, gas carried ozokerite was found being deposited as stalactites in old stopes along traces of fracture planes. He concluded that gases dissolved and transported the waxy constituents of source beds to open fractures in brecciated zones.

With recent discoveries of "solid petroleum" oil wells in the Uinta Basin and surrounding area and gas wells in the Wasatch Plateau, evidence heavily favors the theory of gaseous solvents as a major source for hydrocarbon wax accumulation in this area. The solvents act as separating agents for the hydrocarbons, oxidation and evaporation, when higher temperatures are reached, act to eliminate hydrogen and thus cause deposition of the heavier hydrocarbons such as ozokerite and gilsonite.

Water

Water is the most abundant mineral resource in the area. The watershed is characterized by steep slopes and broad canyon bottoms which traverse the area in an east-west direction. The area is dissected by a line separating the Colorado River watershed on the north and the Great Basin divide on the south (see index map).

White River forms the main drainage system and carries water into Price River which eventually drains into the Green River. East Soldier Creek drains the area on the west and carries water into Utah Valley 50 miles to the west.



Map of Ozokerite Field In Central Utah

scale- 0 1 2 miles

APPENDIX

DETAILED SECTIONS

Stratigraphic section of the Green River formation - The writer measured a total thickness of 3115 feet in section 3, 8, 18, 17, township 10, 11 south, range 7 east.

Green River formation

UNIT	DESCRIPTION	THICKNESS
9	Shale, light to dark gray-blue. Silty, calcareous, same as below. Limestone interbedded, same as below, light brown to gray-brown. Some sandstone present, light yellow-brown, fine grained, quartzitic and calcareous. Alternating sandstone and shale as below.	630'
8	Limestone, with sandstone and shale interbedded. Sandstone is fine grained, angular to sub-angular grains, calcareous and quartzitic. Shale, light gray-green, drab, silty, siliceous, and calcareous. Same as below. Limestone is buff to light brown and gray, weathered surface is gray, fresh surface is dark brown and finely crystalline, sub-lithographic. Limestone becoming predominant.	423'
7	Shale, silty and interbedded marlstones with sandy siltstone. Lighty gray to light pale green. Same as unit 6. Siliceous bentonite and calcareous sandstones. Thinly bedded limestones interbedded with shale and sandstone. Limes are silty and light blue-gray, sub-lithographic, dense. Ostracods present. Unit not as fossiliferous as lower units. Shales are drab light bray-green and sandstones are light yellow-brown to ocher-yellow.	538'

6	Shale, dark to light gray-blue, thinly laminated, with fractures. Interbedded sandstones, calcareous and siliceous. Fine grained, thin to medium bedded and similar to unit 5, covered, and not as well exposed.	368'
5	Shale, oil shale, purple to light blue on weathered surface. Fresh surface is black and carbonaceous. Thinly laminated bedding, paper shale, silty, sandy and argillaceous, calcareous. Chert nodules present. Sandstones weather light ocher-yellow, dirty, silty, light gray on fresh surface.	226'
4	Sandstone, shale, light to dark brown, interbedded with oil shale. Sandstone thin bedded to medium bedded, sub-angular quartz grains, light ocher-yellow to brown-yellow on weathered surface. Silty and sandy shale thin to medium bedded. Coquina bed, thin bedded, containing pelecypods and gastropods. Highly fossiliferous oil shale beds above and below the coquina bed.	434'
3	Shale, thinly laminated paper shale, fresh surface is black and very carbonaceous, weathers blue-gray to purple. Locally folded and indurated. Dark brown to black chert nodules in oil shales.	116'
2	Shale, with sandstone and silty shale interbedded. Part of the tranzition zone between the Colton and Green River formation. Intertonguing of maroon and variegated sandstones with gray-green shales. Calcareous, silty sandstones, thinly bedded.	212'
1	Sandstone and shale, interbedded. Salt and pepper colored quartzitic sandstone and silty shale. Medium to thin bedded, variegated beds of shale and sandstone. Tranzition zone and partly covered. Contact visible only in a few places.	168'

Stratigraphic section of the Colton formation - The writer measured a total thickness of 960 feet in section 24, 25, township 10 south, range 8 east.

Green River formation

(Gradational contact)

Colton formation

UNIT	DESCRIPTION	THICKNESS
5	Sandstone, shale and limestone. Tranzition zone of alternating maroon and light gray-green sandstone and limestone. Ostracodal and oolitic limestone. Marly limestone and shale. Medium to massive bedded. Intertonguing of sandstone and shale. Contact not visible. Salt and pepper quartzitic sandstone interbedded with light gray to green mudstone and limestone. Unit covered. Ledge forming unit near the top.	415'
4	Shale and sandstone interbedded, maroon and light gray colored, becoming lighter gray with predominance of shale. Salt and pepper sandstone present. Very easily weathered quartzose sandstone. Friable, medium grained and medium bedded.	185'
3	Sandstone, similar to unit #2. Slope forming, variegated to buff and tan colored sandstone, shale and siltstone. Predominantly sandstone. Weathers light gray to maroon. Medium grained to fine grained. Thin bedded in places but generally unconsolidated. Valley former.	200'
2	Sandstone, maroon, salt and pepper colored with shale and mudstone. Unconsolidated and friable, earth flows present and is a valley forming unit. Covered.	35'
1	Sandstone, variegated maroon to tan and red. Siltstone and shale present. Very irregular and weathers easily. Friable quartzitic sandstone thin to medium bedded. Covered.	65'

Stratigraphic section of the Flagstaff limestone - The total thickness of the Flagstaff, measured in section 11, township 10 south, range 7 east, is 486 feet thick.

Colton formation
Flagstaff limestone (Gradational contact)

UNIT	DESCRIPTION	THICKNESS
5	Limestone, light to dark gray-brown in part, dense and sub-lithographic. Weathers lighter blue, carbonaceous and fossiliferous. Argillaceous with some interbedded shale and streaks of bentonite. Shales predominate.	25'
4	Shale, very fine grained, with sub-rounded grains, minute micaceous flakes and calcareous. Some limestones, light to dark blue-gray, sub-lithographic. Shales interbedded and are lighter brown in color and thin bedded.	100'
3	Shale, predominantly gray to brown with gypsum, bentonite and shaley sandstones. Some sandstone weathers light gray to brown and very find grained, sub-rounded grains, calcareous in part.	55'
2	Sandstone, shale, black and carbonaceous. Sandstones light brown to dark gray. Limestone interbedded with sandstone and shale. Shale with streaks of limey calcareous material. Compact and traces of pyrite are present.	145'
1	Shale, weathers red-brown, argillaceous, with some glauconite present. Fractured limestones, dark blue-gray and carbonaceous. Sandstone with shale interbedded and traces of calcareous material. Limestone light to dark blue-gray, sub-lithographic, dense and fine crystalline.	58'

Stratigraphic section of the upper North Horn formation - The writer measured a total thickness of 1125 feet in section 10, 11, township 11 south, range 7 east.

Flagstaff formation (Gradational contact)

North Horn formation

UNIT	DESCRIPTION	THICKNESS
9	Shale, sitlstone, sandstone and mudstone, Weathers tan to dark brown and yellow-gray. Mostly shale and siltstone with some thin bedded crystalline limestone. Contains some algal masses. Massive bedded.	330'
8	Sandstone and limestone interbedded with shale and siltstone. Weathers tan to gray-brown. Medium grainted and massive bedded. Sandy shale and crystalline limestone that weathers lighter near the bottom of the unit. Outcrop covered.	100'
7	Sandstone, fine to medium grainted. Silty quartzose sandstone, weathers tan to gray above and darker gray below. Predominantly pink quartz grains. Unit covered.	85'
6	Sandstone and shale, predominantly shale. Similar to upper part of unit #5. Ledge forming unit, fine to medium grained with some limestone and siltstone interbedded. Weathers gray to light tan. Unit covered.	55'
5	Sandstone, tan to dark tan and yellow-brown. Fine grained, thick bedded, silty quartzitic sandstone with shale interbedded. Abundant small pebble conglomerate. Grades upward into quartzitic sandstone.	27'
4	Sandstone and conglomerate, red, white and pink quartzose sandstones. Some chert pebbles in the conglomerate. Unit partly covered. Light brown-yellow shales and siltstones. Weathers tan to gray-tan and fine to medium grained.	120'

3	Sandstone, tan to dark brown. Medium to coarse grained. Massive bedded ledge former. Quartzitic sandstone with pink quartz grains. Unit covered.	143'
2	Shale and sandstone, thin bedded sandstone and siltstone interbedded. Same as unit #1. Unit covered.	195'
1	Siltstone and sandstone, mostly yellow-brown quartzitic sandstone. Thin to medium bedded and fine grained. Unit covered.	100'

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PLATE 8

111°07'30" 40°00' R. 7 E. 5' R. 8 E. 111°00' 40°00'

T10S

T11S

39°52'30" 111°07'30" R7E

T. 10 S.

55'

R8E 111°00'

Base from U.S.G.S. Soldier Summit Quadrangle

EXPLANATION

Sedimentary Rocks

Quaternary	Qal	Alluvium
Tertiary	Tgr	Green River formation
	Tc	Colton formation
	Tf	Flagstaff formation
Cretaceous	K-Tnh	North Horn formation

SYMBOLS

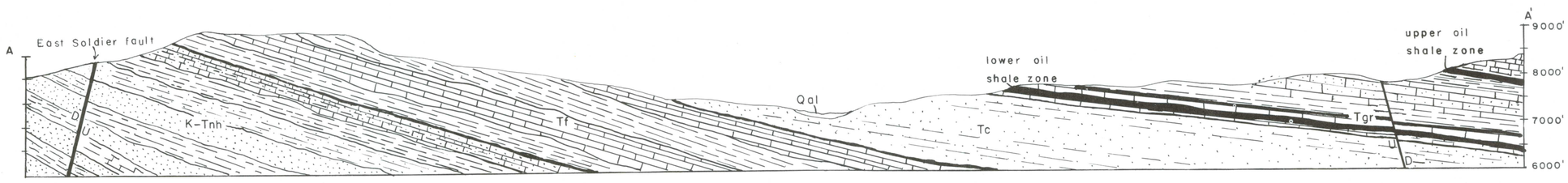
- Gas well
- 10° — Strike and Dip
- Fault — Dashed where inferred
- 14798 — Fossil Locality
- Anticline, Syncline
- Measured section
- Ozokerite vein
- Prospect pits
- Oil Shale

True North / Magnetic North 16 1/2°

0 1 mile

Scale

Contour interval 50 feet



Geologic Map and Structure Section of the Northeast Quarter of the Soldier Summit Quadrangle Utah

by

Gerald V. Henderson

1958