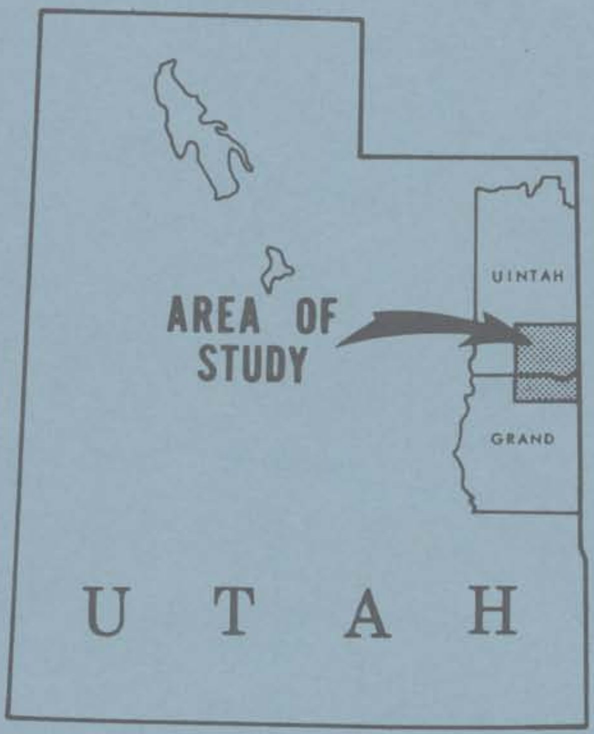
P. R. SPRING OIL-IMPREGNATED SANDSTONE DEPOSIT UINTAH AND GRAND COUNTIES, UTAH



Utah Geological and Mineralogical Survey

Special Studies 31

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ERRATA SHEET

for Special Studies 31
P. R. Spring Oil-Impregnated Sandstone Deposit,
Uintah and Grand Counties, Utah
by William D. Byrd III

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Page 19, Paragraph 2.
This paragraph should read as follows:

A triangular method (Park, 1949, p. 59-61) was used to compute the total barrels of oil in place (see pl. 5). Triangles were formed with stratigraphic section locations at the apices. A total saturation thickness was computed for each corner; care was taken to exclude saturation in a sandstone less than 3 feet thick. In addition, porosity and water content percentages were recorded from analyses made by Core Laboratories. An average figure was obtained for each of these three variables. Three readings of the total area with a planimeter average 250 square miles. In the southern portion of the area and in the deeply incised Bitter Creek and Sweetwater Creek drainages, erosion has removed the saturated sandstone beds from about 36 square miles. Consequently, about 214 square miles are underlain by saturated sandstone (see pl. 5). This figure, converted to acres, was used in the following formula (Todd, 1958, p. 795):

$$R = 7{,}758 \times A \times T \times P \times (1 - I) \times S \times F$$

Please note that the fifth line of this paragraph was omitted from the original printing and has been inserted above.

P. R. SPRING OIL-IMPREGNATED SANDSTONE DEPOSIT UINTAH AND GRAND COUNTIES, UTAH

by William D. Byrd II

Main Canyon Oil Seep near P. R. Spring, NE¼NE¼ Sec. 5, T. 16 S., R. 24 E.

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY
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University of Utah, Salt Lake City, Utah

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ILLUSTRATIONS

P. R. SPRING OIL-IMPREGNATED SANDSTONE DEPOSIT, UINTAH AND GRAND COUNTIES, UTAH

by William D. Byrd II[1]

ABSTRACT

Oil-impregnated sandstone beds underlie at least 214 square miles in the southeastern Uinta Basin and may extend northward beneath cover. One to as many as five principal saturated zones, 3 to 75 feet thick, occur in a 250-foot interval that dips gently northward. The northernmost outcrops are overlain by 250 feet of overburden. Average porosity obtained from 33 outcrop samples is 30.5 percent, and from four core holes drilled by Skyline Oil Co., 26.6 percent. Calculations by triangle method indicate approximately 3,700,000,000 barrels of oil in place.

Oil impregnation occurs in lenticular sandstone and siltstone in the uppermost Douglas Creek member of the Green River Formation 600 feet above the base. The top of the oil-impregnated zone is a few to 50 feet below the oil shale zone in the overlying Parachute Creek member. These lenticular sandstones and siltstones were deposited around the periphery of the basin in a fluvial-deltaic environment.

Mesozoic rocks at depth are draped over displacements on normal fault blocks in the Precambrian basement rocks of the Uncompahgre uplift. These folds, weakly reflected in the beds of the Green River Formation at the surface, have funneled the bituminous saturation to the area around P.R. Spring where it seeps onto the surface.

A FORTRAN IV computer program for cross-association of nonnumeric sequences was used to help correlate the lenticular stratigraphy in the study area. The program was used to find similarities, deletions, insertions, or inversions difficult to detect by visual methods. Cross sections illustrate the lenticular nature of the sands and facies changes in the upper Douglas Creek member.

INTRODUCTION

Location and Topography

The P.R. Spring oil-impregnated sandstone deposit is in the southeastern Uinta Basin of eastern Utah. The basin is bounded on the south by the Roan Cliffs (see fig. 1), a northward retreating, step-like bench on top of the Book Cliffs. The Roan Cliffs form the drainage divide between the Grand Valley (Colorado River) to the south and the Uinta Basin (Green River) to the north. The divide in this area, called Seep Ridge, is 8,000 to 8,450 feet above sea level, about 3,500 feet above the floor of Grand Valley.

The Uinta Basin is an asymmetric structural and depositional basin. Its axis trends east-west. The Basin's steep, south-dipping north limb has been complicated by uplift and

1. Phillips Petroleum Company, Bartlesville, Oklahoma.

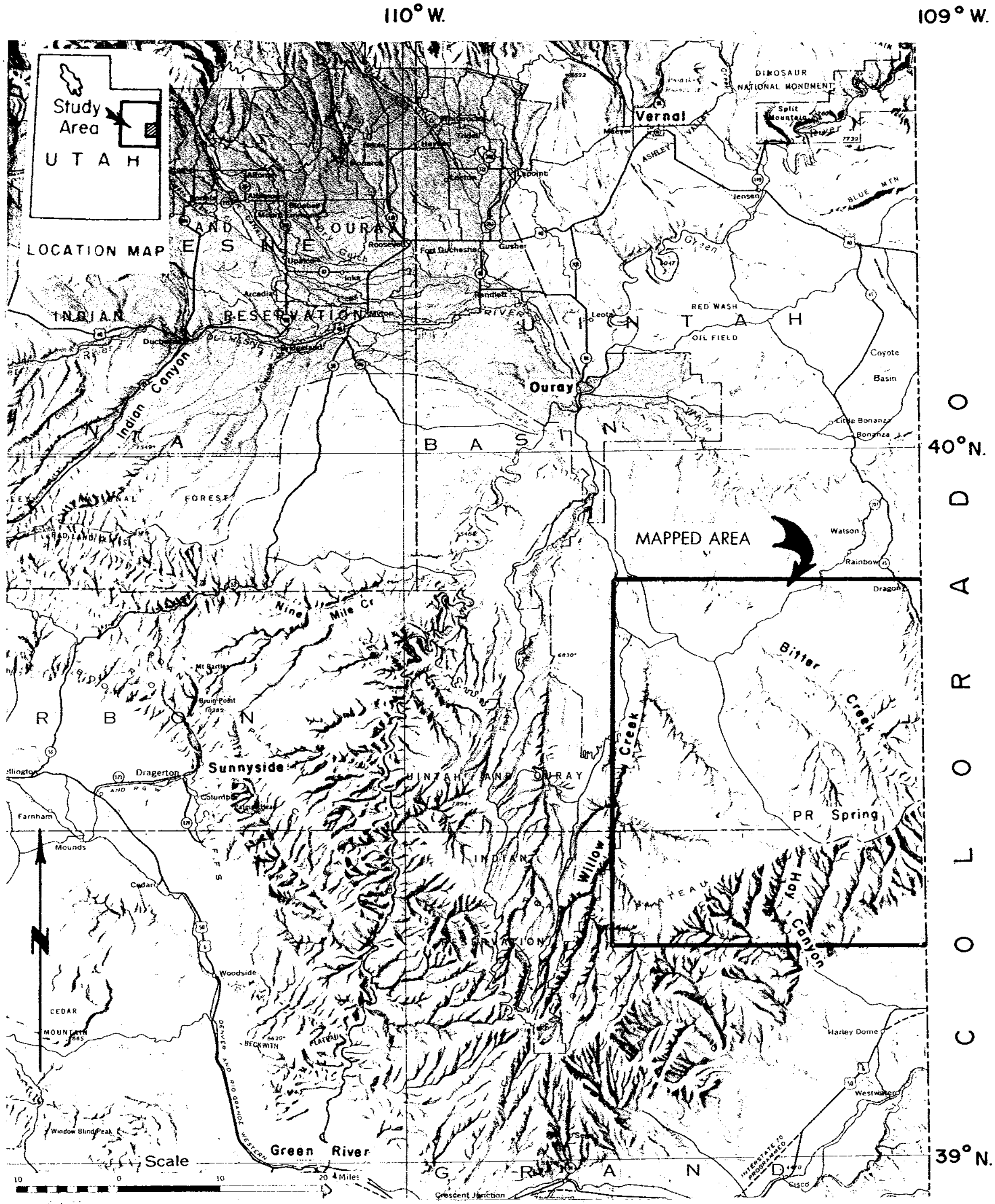

Figure 1. Index map of the southeast Uintah Basin.

faulting of the Uinta Mountains. Its gently north-dipping south limb is bounded by the San Rafael Swell to the southwest and by the Uncompahgre uplift to the southeast. The Wasatch Plateau forms the western boundary. The north-south Douglas Creek arch, which divides the Uinta and Piceance Creek basins, forms the eastern boundary along the Utah-Colorado boundary.

The study area centers around long 109°15' W. and lat 39°30' N. It extends 30 miles across the northern edge, 32.5 miles across the southern edge, and 37 miles from north to south. It is an area of approximately 1,200 square miles and includes Tps. 12-17, Rs. 21-26 E., SLBM[1].

Accessibility

The P.R. Spring area may be approached from the north by turning south off U.S. Highway 40 between Roosevelt and Vernal, Utah, onto Utah Highway 88 near Fort Duchesne, Utah. The road is not paved south of Ouray, where it crosses the Green and White Rivers. The only other crossing of the White River is 3 miles south of Bonanza on Utah Highway 45, which joins U.S. Highway 40, 10 miles southeast of Jensen, Utah.

Two unpaved roads ascend the Book and Roan Cliffs and enter the area from the south. San Arroyo Canyon road branches off U.S. Highway 6-50 near the Utah-Colorado State line, and Hay Canyon road (Westwater drainage) leaves U.S. Highway 6-50 in Grand Valley 3 miles northeast of Harley Dome, Utah. There are no settlements within the area. A recreational campsite with drinking water is located at P.R. Spring.

The Denver and Rio Grande Western Railroad traverses Grand Valley to the south. Cisco and Thompson, 14 miles south of the study area, are the nearest stations. Grand Junction, Colo., 50 miles southeast, is the closest point for air service or field vehicle rental.

The Grand Valley Transmission Co.'s 12-inch common-carrier pipeline (Mesa Pipeline) parallels the main north-south road from 10 miles south of Ouray to the San Arroyo gas field in northeastern Grand County. The line connects with the Mountain Fuel Supply Co. line near Ouray. This line runs west through the Clear Creek gas field in western Carbon County and on north to Provo, Utah, and the Salt Lake Valley.

Previous Work

Earliest published mention of the P.R. Spring deposit is contained in a restricted report for the U.S. Bureau of Mines (Ball, 1951). An open file report of the U.S. Geological Survey (Whittier and Becker, 1961) was based on fieldwork performed 10 years earlier. The deposit was depicted in sketchy fashion by Hunt, Stewart and Dickey (1954, p. 1672), and Covington (1963 and 1964) mentions the deposit and states that the extent and reserves are not known. An unpublished petrographic study (Wiley, 1967) related cementation to effective reservoir porosity, a controlling factor in the emplacement of the bitumen. The U.S. Geological Survey's Oil and Gas Investigations Map 153 by Cashion and Brown (1956), a study of the oil shale zone in the Parachute Creek member of the Green River Formation in Uintah County, Utah, mentions occurrence of bituminous sand-

1. Salt Lake Base and Meridian.

stone in the upper Douglas Creek member. U.S. Geological Survey Professional Paper 548 (Cashion, 1967) describes part of the P.R. Spring deposit and also contains detailed surface mapping, measured stratigraphic sections, and analytical information on the oil shale of the area.

Methods of Study

Fieldwork was undertaken during the summers of 1965 and 1966. Aerial photographs, 9-inch by 9-inch, 1:24,000 scale (1 inch = 2,000 feet) released by Pacific Natural Gas Exploration Co., were used to plot outcrops of the oil-impregnated sandstones. Flight lines were mostly in northern Grand County and included only the southern 2 miles of Uintah County. Soil Conservation Service controlled-mosaic aerial photographs at a scale 1 inch = 2,640 feet (2 inches = 1 mile), available for the entire area, were used for orientation and accurate plotting of sample localities and measured section locations. Land grid and township protraction diagrams were obtained from the U.S. Bureau of Land Management. Topographic maps were not available in 1966, but are in preparation at the present time (1969).

Thirty-eight stratigraphic sections of the oil-impregnated zones were measured with a Jacob's staff equipped with an Abney clinometer to compensate for the shallow, regional dip (see plates 1A-1L). Stratigraphic sections were correlated by a computer program (plates 2 and 3).

Samples from outcrops were analyzed by Core Laboratories, Denver, Colo. Complete cores from four core holes drilled in the area by Skyline Oil Co., Salt Lake City, Utah, during the summer of 1966 were donated to the Utah Geological Survey Library of Samples for Geologic Research. Representative saturated zones in these cores were analyzed by Core Laboratories, Casper, Wyo. Oil extracted from the aforementioned cores and from surface seepages was analyzed by the U.S. Bureau of Mines, Laramie, Wyo. Analyses of the above samples, of cores, and of extracted and seep oil are shown in the appendix, tables 1-3.

STRATIGRAPHY

General Statement

Six formations, ranging in age from Cretaceous to Eocene, are exposed in the Book Cliffs and Roan Cliffs in the southeast portion of the Uinta Basin. From oldest to youngest, these are: Mancos Shale (Cretaceous), Mesaverde Formation undifferentiated, and Tuscher Formation (Late Cretaceous and Paleocene), Wasatch Formation undifferentiated (Paleocene-Eocene), Green River Formation (Eocene), and the Uinta Formation (Eocene). The Mancos Shale and the Mesaverde and Tuscher Formations form the Book Cliffs, the Wasatch and Green River Formations, the bulk of the Roan Cliffs, and the Green River and Uinta Formations, the north-dipping slopes that extend into the Uinta Basin.

Since the purpose of this report was to study the oil-impregnated zones in the lower portion of the Green River Formation, other formations in the area were checked for orientation and position in the stratigraphic section, but were not studied in detail. An excellent, brief, regional summary of these formations was published by Abbott and Liscomb (1956).

Tertiary

Wasatch Formation

The Wasatch Formation rests with slight unconformity on the Tuscher Formation; where the Tuscher Formation is missing, the Wasatch rests with greater angular discordance on the Mesaverde Formation. The Wasatch Formation consists of light-brown sandstone beds and varicolored, mottled, red-brown or gray-green shale beds (Murany, 1964, p. 146). Following Murany, the top of the Wasatch Formation "is placed at the first occurrence upward of ostracodal and oolitic limestones ... of the overlying Green River Formation" (Murany, 1964, p. 145-146).

Green River Formation

Hayden (1896) gave the name Green River Formation to the middle Eocene beds along the Green River in Wyoming. During the middle Eocene, similar basins were being filled on both the north and south sides of the east-west trending Uinta Mountains and eastward into northwestern Colorado. The basin to the south of the Uintas was divided (at least part of the time) by the Douglas Creek arch, which trends north-south. The Piceance Creek Basin in northwestern Colorado and the Uinta Basin in northeastern Utah are modified segments of this Eocene basin.

The Green River Formation of the Uinta Basin is principally a lacustrine deposit, which varies widely from place to place across and around the fringes of the basin. Bradley (1931) found it difficult to correlate the formation from the southwestern part of the Uinta Basin, into the Piceance Creek area of Colorado, through the eastern Utah sections at Hell's Hole Canyon and the general area east of Bitter Creek in Utah (see fig. 1). He set up an eastern and a western basin terminology with Bitter Creek as the dividing line. Bradley's terminology has been used for this study, but some contact positions have been modified.

Basal Member

The basal member of the Green River Formation overlies the Wasatch Formation and underlies the Douglas Creek member of the Green River Formation. This interval represents a transition in depositional environment from fluvial to typical lacustrine. In Indian Canyon in the western portion of the basin, Bradley (1931, p. 17) recognized three units in this basal member (see fig. 2): a lower lacustrine facies; a tongue of the Wasatch Formation; and a second overlying lacustrine facies. Bradley's (1931) three units are present in the Hay Canyon area of this investigation, but each unit is considerably thinner than reported by Bradley; the lower lacustrine facies is about 60 feet thick, the tongue of the Wasatch Formation, approximately 100 feet thick, and the upper lacustrine facies, about 40 feet thick. The lower lacustrine facies consists of locally sandy, light-green siltstone and orange to yellow-brown, oolitic, ostracodal limestone. Fragments of larger fossils are present only in localized areas.

The tongue of the Wasatch Formation consists mainly of reddish-brown siltstone and light-brown, cross-bedded, lenticular, fine- to medium-grained sandstone. Limestone is absent. The upper lacustrine facies consists of the same type of rocks as the lower

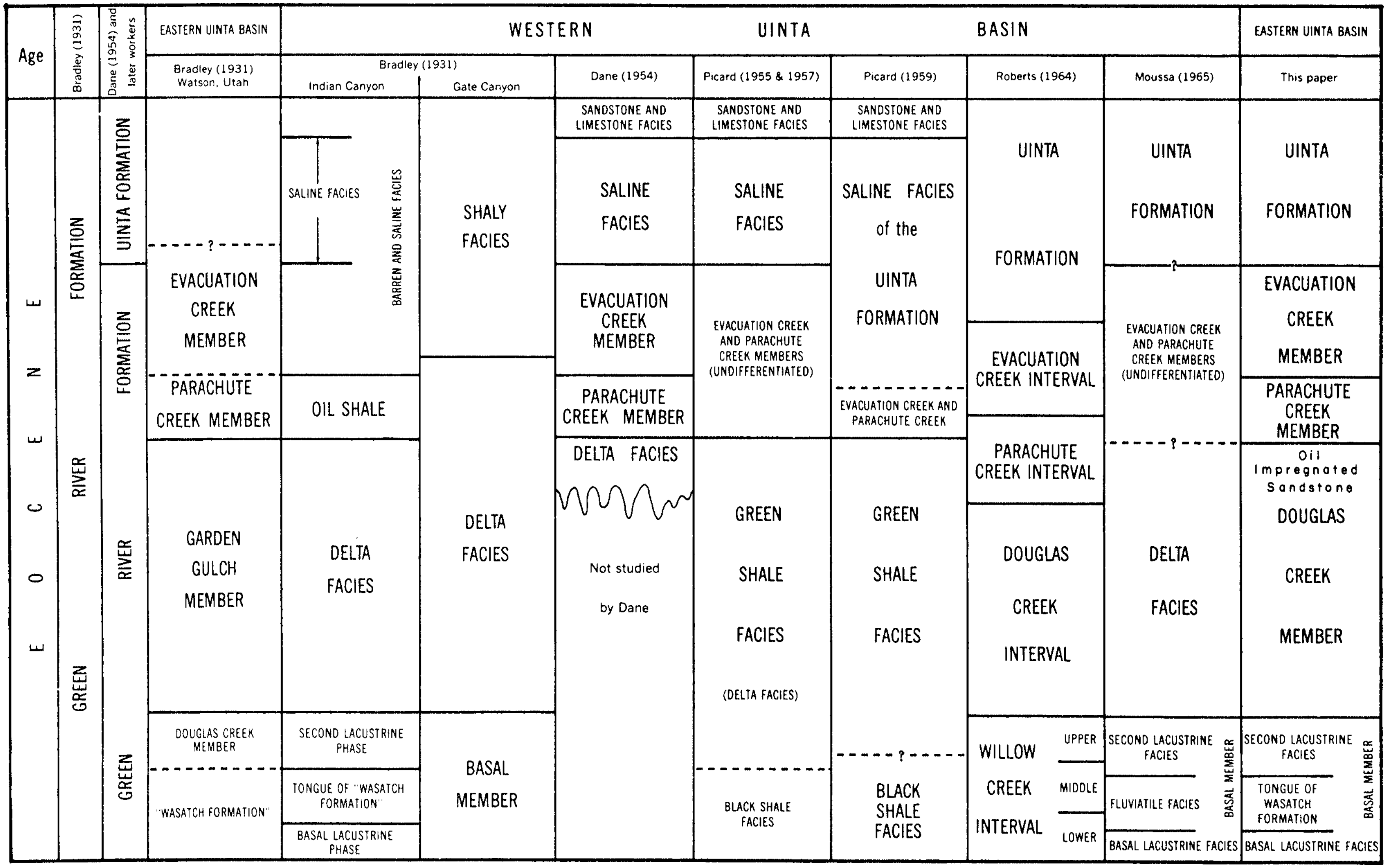

Figure 2. Summary of the stratigraphic subdivisions and nomenclature of the Green River Formation in the Uinta Basin (modified from Moussa, 1965).

lacustrine facies. In contrast to Bradley's Indian Canyon section, there are no oil shale beds in this unit in the Hay Canyon section. No formal name has been proposed for this basal interval, but it is equivalent to the "Black Shale Facies" of Picard (1955 and 1957) and to the Willow Creek interval of Roberts (1964; see fig. 2).

Douglas Creek Member

The Douglas Creek member of the Green River Formation overlies the basal member and underlies the Parachute Creek member. Bradley's (1931, p. 17) description of the "delta facies" of the Indian Canyon area matches closely with the Douglas Creek section on Seep Ridge.

The base of the Douglas Creek member is drawn at the top of a prominent ostracodal limestone zone which is the top of the upper lacustrine facies of Bradley (1931), and the top of the Willow Creek interval of Roberts (1964). Other ostracodal limestones are scattered throughout the Douglas Creek member, but those at the top of the upper lacustrine facies form a well-defined zone.

Although Bradley (1931) described the Douglas Creek section in Colorado some 15 to 20 miles east of P.R. Spring as being characterized by a sequence of silty and sandy marlstone and shale, the shoreward facies of this unit to the south contains an abundance of sandstone, oolitic, ostracodal and algal limestone, and some light-green siltstone. This shoreward facies correlates well with the "deltal facies" of Picard (1955), which was later termed Green Shale facies (Picard, 1957). In his study of the entire basin, Roberts (1964, p. 90) recognized two other facies of this interval, the offshore zone characterized by brown, gray, and black shale and marlstone, and an intermediate mixed zone characterized by a mixture of rock types from the other two zones.

As the Douglas Creek member is traced eastward from P.R. Spring, the section contains algal limestone beds which become more numerous and thicker. At one point on the Colorado-Utah border, there are more than 200 feet of algal limestone. As the unit is traced westward from P.R. Spring the algal limestone in the section decreases to about 1 percent and may be represented by only one or two 6-inch beds. Often the algal limestone beds are accompanied by thin oil shale units lying directly adjacent to or within a few inches of them. Oil shale, however, is not a major constituent of this unit. Carbonized fly larvae impressions in siltstone are common in localized areas along Seep Ridge.

The sandstone beds of the Douglas Creek member are light brown to light yellow-brown, cross-bedded, massive, fine- to medium-grained, and micaceous. The sand grains, both quartz and feldspar, are subangular to subrounded. There are oscillation ripple marks on some bedding planes, and mud cracks in siltstone beds. Frequently, lenticular sandstone beds contain turtle carapaces, other bone fragments, and pieces of carbonized wood. Caraphytes are found in many sandstone beds. The top of the Douglas Creek Member in the southern part of the Uinta Basin is usually picked at the top of the stratigraphically highest light-brown to gray, massive, fine- to medium-grained sandstone below the "Mahogany Ledge" oil shale zone. This sandstone in most localities is impregnated with oil. Several ostracodal, oolitic, algal limestone beds and marlstone beds directly above this massive sandstone may correlate with the calcareous zone Roberts (1964) determined on electric logs. In most parts of the basin, the overlying Parachute Creek Member is devoid of massive sandstone and consists mainly of light-gray, silty marlstone and oil shale.

Garden Gulch Member

The Garden Gulch member, described by Bradley (1931) and later by Cashion and Brown (1956), is recognized in the Piceance Creek Basin in Colorado, but is not sufficiently well-defined in the Uinta Basin to merit member status. Therefore, in this study, the Parachute Creek member is considered to overlie the Douglas Creek member. This contact corresponds with that chosen by both Roberts (1964) and Cashion and Brown (1956).

Parachute Creek Member

The Parachute Creek member overlies the Douglas Creek member and underlies the Evacuation Creek member. The lowest portion consists of light-colored siltstone and organic marlstone that form the basal slope of the resistant "Mahogany Ledge," the rich oil-shale unit. An excellent exposure of the contact between the Douglas Creek and Parachute Creek members and of the steep "Mahogany Ledge" is near the mouth of Cooper Canyon, Sec. 12, T. 13 S., R. 23 E. This is also the location of stratigraphic section No. 35 (see plate 1L).

The upper contact of the Parachute Creek member has been placed at several different positions in the stratigraphic section by students of the Green River Formation. Cashion and Brown (1956) have included a zone of light-gray to light-brown marlstone directly above the main oil-shale zone in the Parachute Creek member. They considered the base of the Horse Bench sandstone (where present) as the contact with the overlying Evacuation Creek member. Roberts (1964) has included within this marlstone unit a zone of volcanic ash beds, traceable in the subsurface from logs and sample cuttings, as the contact between the Parachute Creek and Evacuation Creek members. Bradley (1931) and Dane (1954) have placed the contact at the top of the "Mahogany Ledge" and the marlstone unit in the Evacuation Creek member.

Evacuation Creek Member

The Evacuation Creek member, the uppermost unit of the Green River Formation, overlies the Parachute Creek member and underlies the Uinta Formation. Its lower boundary has been discussed in a previous section. This basal interval varies in lithology, depending on where the boundary is placed, but usually it consists of light-gray to light-brown marlstone. In certain shoreward facies, fine-grained sandstone and siltstone are present. The marlstone becomes more organic in the western part of the basin, and some intervals are rich enough in organic material to be called oil shale (Roberts, 1964, p. 118). The Horse Bench Sandstone, best developed in the type locality near the mouth of Nine Mile Canyon, Sec. 22, T. 11 S., R. 18 E., in the south-central portion of the basin, is present throughout most of the southernmost outcrops of the Evacuation Creek member. But in the west, it is either absent or inconspicuous. It can be traced eastward across the Green River into the Hill Creek and Willow Creek drainages, but the drainage east of Willow Creek is not incised sufficiently to expose it. It crops out again in the deeper Bitter Creek drainage as a zone, 5 to 10 feet thick, of light-brown, fine-grained sandstone with interbedded light-brown to light-green siltstone and shale beds. In the Bonanza-Dragon area, Cashion and Brown (1956) described the Horse Bench bed as "... gray and brown, limy and micaceous, ledge-forming siltstones" 2 to 5 feet thick.

In the western portion of the basin where the Horse Bench Sandstone is not present, a change in the color of the marlstone (light gray to reddish brown) marks the upper contact. In the south-central portion of the basin, this color change is approximately 475 feet stratigraphically higher than the Horse Bench Sandstone (Bradley, 1931, p. 16). In the eastern portion of the basin, the entire Evacuation Creek member ranges from 140 feet in Hell's Hole Canyon to 165 feet in Bitter Creek Canyon (Cashion and Brown, 1956). Here, an upper marly unit contains many solution cavities. Bradley (1931) described these cavities, and later, Cashion and Brown (1956) wrote:

> Many cavities, some of which are believed to have been formed by the leaching of nahcolite from the marlstone, occur in a zone in the upper part of the Evacuation Creek member. The zone is locally called the "bird nest" zone and is well-developed near the mouth of Evacuation Creek.

The Uinta Formation appears to overlie conformably the Evacuation Creek member of the Green River Formation. However, it is the consensus of previous writers that the Uinta Formation was deposited in the regressive phases of Lake Uinta and that underlying muds eroded. Cashion and Brown (1956) state:

> ... erosion and possibly differential compaction of the underlying marls of the Green River Formation have formed an undulating boundary between the two formations, but the bedding in the two formations is essentially parallel.

TERTIARY STRUCTURE AND SEDIMENTATION PATTERNS

At the end of the Cretaceous period, Laramide tectonic forces created new structures and rejuvenated older ones in the Uinta Basin area (Osmond, 1964, p. 55). Seas regressed and differential uplifting formed intermontane basins. The "Washakie-Bridger" basin formed north of the Uinta Mountains, and the "Uinta-Piceance" basin to the south (Crowley, 1957, p. 28). Clastic sediments of the Tuscher Formation (Late Cretaceous-Paleocene), the Fort Union Formation (Paleocene), and the Wasatch Formation (Paleocene-Eocene), derived from surrounding uplifts, were the first continental sediments to be deposited in the "Uinta-Piceance" basin. That the Douglas Creek arch had positive tendencies during the deposition of the Wasatch Formation is evidenced by the absence of complete sections of the Wasatch across the arch (Osmond, 1964, p. 56). Relative subsidence of the basin during the early Eocene, due partly to the weight and compaction of Wasatch sediments and partly to minor rejuvenations of the surrounding uplift, formed closed basins in which fresh water lakes formed and in which sediments of the Green River Formation were deposited. Fluvial-deltaic sediments were laid down around the peripheries of the basins, and these interfinger with lacustrine limestone and shale deposited in the center. Later in the Eocene, the Douglas Creek arch was rejuvenated and the Uinta and the Piceance Creek basins were separated. The lake in the Uinta Basin, referred to as Lake Uinta, slowly retreated and became saline. Abbott (1956, p. 102) wrote:

> This retreat is marked by the complex interfingering of the fluvial and lacustrine sediments of the Uinta Formation. These sediments reflect the closing stage of lacustrine deposition. The Duchesne River Formation represents the last extensive fluvial sediments to be deposited in the Uinta Basin.

Southeastern Uinta Basin

Strata of the Green River Formation have a shallow regional dip of 2° to 4° from the Roan Cliffs into the basin to the north. This regional dip results partly from the compaction of the sediments deposited in the basin and partly from minor rejuvenations of the uplifts that surround the basin.

Mesozoic rocks are draped in gentle folds over normal fault blocks in the Precambrian basement rocks of the Uncompahgre uplift. In the vicinity of the Uintah-Grand County line (see pl. 4), these folds are reflected weakly at the surface in the beds of the Green River Formation. In the study area, six weakly developed northwestward plunging anticlinal structures are present (see pl. 4). Gas and some condensate emanate from the more strongly folded Mesozoic rocks below the Wasatch Formation. Production is mostly from lenticular channel sandstones in the Dakota and Morrison Formations of Early Cretaceous and Jurassic age. There is shut-in gas and oil production from the Wasatch Formation in the Sweetwater Creek unit. In most cases, the shallow, possibly oil-impregnated Green River Formation sandstones were not observed for hydrocarbon content during drilling and were "cased-off" within a few hundred feet of the surface. Wells drilled in the area of the P.R. Spring deposit are summarized in Table 4.

Hill Creek-Winter Ridge anticline (see pl. 4) is on the same northwest trend as the Jack Canyon-Peters Point anticline in northeastern Carbon County across the Green River some 36 miles to the northwest. The steeper southwestern limb of the Hill Creek-Winter Ridge anticline suggests that this fold may be draped over a basement fault. The extensive set of faults and fractures on the south flank of the Jack Canyon-Peters Point anticline support this view.

Little faulting is evident at the surface in this portion of the Uinta Basin. Some of the northwest-trending tension faults and fractures in the northeastern portion of the mapped area have been filled with gilsonite, but large veins of economic importance lie north of the mapped area.

OIL IMPREGNATION

Definitions

Bitumen is a general term covering a large number of high-viscosity hydrocarbons. Abraham (1945, p. 55) defined the term bitumen as follows:

> Bitumen -- a generic term, applied to native substances of variable color, hardness and volatility; composed principally of hydro-

> carbons, substantially free from oxygenated bodies; sometimes associated with mineral matter, the nonmineral constituents being fusable and largely soluble in carbon disulfide; and whose distillate fraction between 300° and 350° C. yields considerable sulphonation residue.

The term "oil-impregnated sandstone," as used in this report, refers to sandstone which contains variable amounts of oil or bitumen in its pore spaces. Tests for sulphonation residues were not made. A field classification was used to indicate the grade of oil impregnation before commercial laboratory analyses were made. Under a 10-power lens, weakly impregnated (light-gray) sandstone exhibited small particles of black hydrocarbon material on the sand grains, but little in the pore spaces. On a fresh surface, moderately impregnated medium-gray sandstone was an homogeneous dark gray, an indication that the sand grains were completely covered and pore spaces filled. Richly impregnated dark-gray to black sandstone glistened on fresh surfaces and emitted an oily odor.

Reservoir

The uppermost sandstone beds of the Douglas Creek member of the Green River Formation, which form the top of the Roan Cliffs and the northward-dip slope into the basin, are oil-impregnated in most localities. Petrographically, these sandstones should be classified as arkoses -- quartz averages 60 percent and feldspar 40 percent of the total mineral content (Wiley, 1967, p. 8-9). From a detailed study of other minerals in the oil-impregnated sandstone beds, Wiley (1967) suggests a metamorphic terrane as the source of these sediments. Most likely source is the Uncompahgre uplift to the south and southeast. Lithology and correlation of the reservoir sandstones are presented in detail in plates 1, 2 and 3, and are discussed further under "Economic Factors."

Migration and Entrapment

Regional dip in the P.R. Spring area is to the north, a situation which is assumed to have existed through all of Tertiary time. Therefore, migration of hydrocarbons has been updip toward the south. Murany (1963, p. 113) concluded:

> Migration of the oil and gas is local within the Wasatch and Green River Formations and comes from source beds from within the respective formations and is not the result of older or long-distance migrated oil. The oil and gas are entrapped in lenticular sandstones within the respective formations and apparently folding and faulting is not important.

The oil impregnating the sandstones is a hydrocarbon in a semisolid state. Since the saturated beds lie at or near the surface, it is assumed that the more volatile fractions of the original crude oil have escaped into the atmosphere, leaving more viscous material behind. Up-dip migration of hydrocarbons has been controlled structurally by the plunging axes of the anticlines shown on plate 4. In particular, the northeast limb of the Hill Creek-Winter Ridge anticline and the southwest limb of the Main Canyon anticline have funneled oil up to the topographically high area around P.R. Spring. Numerous seeps of viscous oil flow down the outcrop in this area (see pl. 5).

The steep southwest limb of the Hill Creek-Winter Ridge anticline forms a reversal of the northerly regional dip. This reversal apparently has formed a barrier that has impeded oil migration up the regional dip from the north. This probably accounts for the area barren of oil-impregnated sandstone southwest of Winter Ridge (see pls. 4 and 5). The impregnation extending up Seep Ridge, southwest from P.R. Spring (see pls. 4 and 5), most likely has escaped out the top of the synclinal "funnel" between the Hill Creek-Winter Ridge and Main Canyon anticlines and migrated up the ridge.

The P.R. Spring deposit apparently is a gigantic stratigraphic trap which has been breached by erosion in relatively recent geologic time. How long the reservoir sandstones have been exposed is not known. The quantity of oil lost possibly was as great as that which remains.

Patterns of Oil Impregnation

An oil-impregnated sandstone sample from a pit dug by Kerr McGee Co. near measured section 11, Sec. 31, T. 15 S., R. 23 E., contained 27.8 gallons of oil per ton (see table 4, sample No. 21). The upper zone of oil impregnation is 38 feet thick in this area; 76 feet of barren shale and siltstone separate it from the 12-foot-thick lower zone. The maximum overburden is 20 feet thick. With the small amount of overburden and the large amount of high-grade oil-impregnated sandstone present, a strip-mining operation appears to be feasible.

The area along Seep Ridge west of P.R. Spring is similar to the one mentioned in the previous paragraph. The area is deeply dissected; overburden ranges from 50 to 100 feet. A sample from the 18-foot-thick upper zone of saturation at measured section 5, Sec. 4, T. 16 S., R. 24 E., contained 29.6 gallons of oil per ton (see table 4, sample No. 7).

A 2-foot zone of oil impregnation in a sandstone bed exposed at the top of the Douglas Creek Member in Buck Canyon (pl. 4) is the northwesternmost saturated outcrop in the mapped area. It is overlain by lacustrine limestone, shale and marlstone typical of the Parachute Creek member of the Green River Formation. Regional dip carries the saturated bed beneath cover, and overburden increases rapidly to the north.

The same overlying Parachute Creek rock types are present where Sweetwater Creek joins Bitter Creek (see pl. 4), but saturated zones do not extend southward to Seep Ridge on McCook Ridge as they do to the west (see pls. 4 and 5). From the southernmost saturated outcrop on McCook Ridge to Seep Ridge, the sandstone beds are lower in the stratigraphic section and are not saturated.

The area east of Bitter Creek to the Colorado State line is less well-dissected, and for the most part, is capped by lacustrine marlstone, shale, and limestone typical of the Parachute Creek member. Most drainages westward into Bitter Creek contain some outcrops of the saturated sandstones. The saturation emerges in the canyon near Boulevard Ridge and crosses the ridge traversed by the Baxter Pass road. Sandstone beds south of here are too low in the stratigraphic section to contain saturation.

The drainage east into Evacuation Creek contains zones of saturation, but there are only a few thin sandstone beds; most of the units in the stratigraphic section are siltstone, marlstone, and algal limestone. The northernmost zone of saturation in the mapped area is in a 20-foot sandstone in Sec. 8, T. 12 S., R. 25 E. (see pl. 4). The top of this sandstone marks the upper contact of the Douglas Creek member in this area; the "Mahogany Ledge" unit of the Parachute Creek member caps the ridge above.

Seeps

All seeps observed in the mapped area are located on the southwestern limb of Main Canyon anticline (pl. 4). An unusual mechanism has brought the viscous oil to the surface and caused hummocky masses of tar and rock fragments to flow down the outcrop. The drainage gradient to the north is greater than the regional dip of the sediments. The groundwater, moving down through beds overlying the oil-impregnated sandstone, strikes the impermeable, immiscible oil saturation, flows down-dip on top of it, and picks up particles and droplets of oil. These, in turn, float up the dip and escape from any opening in the top of the sandstone. Escapes can occur where erosion has breached the sandstone outcrop. In such places, the groundwater and the oil particles form a water spring and a viscous oil seep. After a heavy rain, this water-drive mechanism can be seen depositing a new layer of tarry oil on top of the hummocky flow. The flows entombed vegetation in their paths and trapped flies, field mice, and birds that tried to drink the water running down the sticky mass.

ECONOMIC FACTORS

Reservoir Thickness, Porosity and Permeability

Oil-impregnated zones in the P.R. Spring deposit vary considerably in thickness over short lateral distances (plates 1, 2 and 3). Zones range in thickness from 2 to 35 feet. The lensing nature of the sandstones makes lateral correlation difficult; in the dissected southern part of the deposit area, discontinuity of the oil-impregnated sandstones across drainages further complicates correlation. In the total area studied, approximately 250 square miles are underlain by oil-impregnated sands, and there may be from one to five principal zones in a given locality.

Porosity of oil-impregnated sandstones from 33 outcrop samples averaged 30.5 percent (see table 1), the highest being 36.7 percent, the lowest 7.1 percent. Porosities of 49 core samples taken from four core holes drilled by Skyline Oil Co. range from 17 to 33.7 percent and averaged 26.6 percent (see table 2).

In many cases, permeabilities from outcrop and core samples are exceptionally high, ranging up to nearly 7,000 millidarcies. These high-permeability values result from an absence of cementation and complete saturation of all pore space with oil. It is not known whether these high permeabilities are native to the sandstone or result from dissolution of original cementation and infilling with oil. Since high permeabilities also are found in sampled intervals in cores analyzed (see table 2), it can be assumed they are not related to weathering or other surficial phenomena.

Overburden

Overburden ranges from none at the outcrop to an average of about 50 feet in the southern deposit area. Because of the extensive dissection of the deposit, outcrops extend in sinuous fashion for more than 500 miles along major drainages and innumerable minor tributaries. Overburden thickness increases to 100 to 150 feet toward the centers of drainage divides; and with basinward north dip, there is increasing cover of younger lacustrine beds in that direction. In the Sweetwater and Bitter Creek drainages and in the Evacuation Creek drainage in the extreme northeastern part of the mapped area overburden thickness ranges from 200 to 250 feet.

The beds overlying the oil-impregnated sandstones -- the overburden of the deposit -- are sandstones, siltstones, shales, and marlstones of the uppermost Douglas Creek member and of the lower portion of the Parachute Creek member of the Green River Formation. The lower 60 to 120 feet of the Parachute Creek member includes the important oil-shale zones of the Green River Formation, such as the Mahogany oil-shale bed. In the southern part of the deposit area, the oil-shale zones are absent because of erosion, or are thin and contain little kerogen. However, in the northern part of the deposit area, the Mahogany bed contains oil shale with analyzed oil yields exceeding 30 and reaching 45 gallons per ton (Cashion, 1967, pls. 3 and 5). Thickness of oil-shale zones increases markedly northward. Cashion (1967, pl. 5) shows increases in thickness and richness of oil shale (from south to north across T. 13 S., Rs. 23 and 24 E.) in the drainage of Bitter Creek to be:

15 gals/ton shale	-	45 feet increasing to 105 feet
25 gals/ton shale	-	15 feet increasing to 40 feet
30 gals/ton shale	-	15 feet increasing to 25 feet

Thus, the overburden of the oil-impregnated sandstone deposit may contain large tonnages of minable oil shale of commercial grade. Strip-mining methods could be used over much of the deposit area without encountering difficult mechanical problems. The rocks are not tenacious, bedding is generally thin, and bedding planes are persistent and well-developed. Joints, that tend to segment the bedding, are common and would facilitate stripping.

EXPLOITATION METHODS AND PROBLEMS

Some parts of the deposit are well-situated for strip-mining. Other parts, more distant from outcrops and with thicker overburden, may be suitable for in situ methods of extraction. It may be within limits of economic feasibility to drill numerous close-spaced wells for in situ recovery if oil-impregnated zones are at shallow depth.

Except for some dissected portions, terrain is not rough in the deposit area. The area is served by good, graded roads easily traversed in fair weather, and construction and maintenance of access roads would present few problems.

Climatic conditions are not difficult, although severe winter weather can be expected at times as in all parts of the Mountain West at this elevation. The area is seriously water-deficient. Small reservoirs and possible sources in the subsurface undoubtedly can support limited operations in the deposit area. The possibility of developing sufficient water supplies in the deposit area for large industrial processing operations seems remote.

The 3,500-foot drop to the south from the P.R. Spring area over the Roan and Book Cliffs into the Grand Valley presents a formidable transportation barrier. However, if mining or in situ recovery operations were carried on in the deposit area and processing took place in the valley to the south, it appears that gravity could be used to advantage should bulk raw material be transported either by pipeline or by conveyor. Processing plants in the Grand Valley would have few access, transportation, water and weather problems.

Reserves

A triangular method (Park, 1949, p. 59-61) was used to compute the total barrels of oil in place (see pl. 5). Triangles were formed with stratigraphic section locations at the apices. A total saturation thickness was computed for each corner; care was taken to exclude saturation in a sandstone less than 3 feet thick. In addition, porosity and water age figure was obtained for each of these three variables. Three readings of the total area with a planimeter average 250 square miles. In the southern portion of the area and in the deeply incised Bitter Creek and Sweetwater Creek drainages, erosion has removed the saturated sandstone beds from about 36 square miles. Consequently, about 214 square miles are underlain by saturated sandstone (see pl. 5). This figure, converted to acres, was used in the following formula (Todd, 1958, p. 795):

$$R = 7{,}758 \times A \times T \times P \times (1 - I) \times S \times F$$

The reserves, R, are equal to 7,758 (the number of barrels of stock-tank oil in an acre-foot) times the area, A (acres), times the thickness of the saturated zone, T (in feet), times the percent porosity, P, times 1 minus the percent interstitial water, I, of the sample. The last two variables in the equation were not taken into consideration for this study. The shrinkage, S, for normal liquid crude oil can be calculated by measuring the amount of gas dissolved in the oil in the reservoir at depth and subtracting the amount of gas lost when the oil is exposed to the atmosphere at the surface. The gas occupies a considerable volume in liquid crudes and it is necessary to know this loss to estimate reserves with any degree of accuracy. However, since the hydrocarbon here is in a semisolid state, little volatile gas remains. Therefore, the S factor can be taken as one (1), which will not alter the rest of the equation. The recoverable reserve factor, F, is unique to each oil field and cannot be figured from similar occurrences. Figures from pilot plants in the Athabasca tar sands show a possible 95 percent recovery, but the occurrence and geometry of the deposits are different. The method of recovery also decides the recoverable percentage. No data are available for calculating such a figure, so this factor was deleted from the equation. Consequently, the final reserve figure is an estimate of total barrels of oil in place.

A residual saturation percent pore figure was run on all the samples to indicate the percent of the porosity that contained saturation. This figure was inserted into the equation as a percentage to give a more accurate estimate of the amount of oil present.

Averages of two of the variables mentioned above were obtained from all the samples analyzed. The average porosity of 33 samples was an extremely high 30.5 percent, but these were outcrop samples subject to leaching. Skyline Oil Co. drilled four shallow core holes in the Main Canyon and McCook Ridge-Rat Hole Canyon anticlines during the summer of 1966 (see pl. 4). Analyses from these four cores showed the sandstone beds to have an average porosity of 26.6 percent. The interstitial water content averages 10.5 percent (see table 2). These averages were used, with discretion, where no analysis was available. A final average for each of the three variables from the three apices was computed for the area within the triangle. These figures were entered into the reserve equation to give a total barrels-of-oil-in-place figure for each triangular area. The totals from all 37 triangular areas then were added to give a grand total of barrels-of-oil-in-place for 214 square miles. The figure obtained, 3,700,000,000 barrels, represents oil in lenticular sandstone beds. These beds pinch out, overlap each other, and frequently lack horizontal continuity. The figure greatly exceeds the 700 million-barrel estimate (Kayler, 1966, p. 14) for the Asphalt Ridge deposit near Vernal, Utah, and the 1 billion barrel estimate for the Sunnyside, Utah, deposit, the largest known oil-impregnated sandstone deposit so far reported in the United States (Holmes, Page, and Averitt, 1948; and Holmes, 1956).

Oil

Analyses of oil (or bitumen) extracted from outcrops and cores and of oil collected from the Main Canyon oil seep, NE$\frac{1}{4}$, Sec. 5, T. 16 S., R. 24 E. (see frontispiece and pl. 4), are presented in table 3. The analyses suggest that the oil present in the upper Douglas Creek Member sandstones in the P.R. Spring deposit is a normal crude oil with typical characteristics of Uinta Basin crude oils of Tertiary age. The low percentage of sulfur is notable. Low API gravity, lack of low temperature fractions obtained in distillation and high percentage of residuum emphasizes the loss of volatiles from the breached trap. The oil appears to be an acceptable feedstock for upgrading by hydrogenation or other refining methods.

FORTRAN IV PROGRAM APPLICATION

Introduction

A computer program developed at the Kansas Geological Survey for cross-association of non-numeric sequences (Sackin, Sneath, and Merriam, 1965) was used to help correlate the lenticular stratigraphy in the study area. This program originally was developed in ALGOL 60 computer language for the Elliott 803C computer by Sackin and Sneath of the Medical Research Center, University of Leicester, England. Its purpose was to compare sequences of amino acids in protein chains and to find similarities, deletions, insertions, or inversions that are difficult to detect by visual methods. Daniel Merriam of the Kansas Geological Survey saw geological analogs of these properties and with the help of Sackin and Sneath modified the program to make the best use of geological data. Data used to test the program were from five composite surface sections of Pennsylvanian rocks in Kansas and northern Oklahoma. The Pennsylvanian section was chosen because of its cyclic nature, which this program can handle readily. With the help of this program, Merriam was able to cross-correlate the difficult cyclothem relationships with a high degree of accuracy.

Input Data

A deck of cards for the FORTRAN IV version of the cross-association program was purchased from the Kansas Geological Survey. A few minor introductory commands had to be changed in the program to make the conversion from the IBM 7040/7044 computer, for which this program was originally written, to the UNIVAC 1108.

Each unit (rock type, fossil zone, textural zone, etc.) was given a numerical designation as follows:

1 = limestone
2 = barren sandstone
3 = saturated sandstone
4 = siltstone
5 = mudstone
6 = algal limestone
7 = oil shale
8 = saturated siltstone

In this way, a lithologic columnar section becomes a column of figures by using the above numbers in place of rock types. The computer readily and rapidly compares columns and matches like numbers.

Procedure and Output Form

Using a slide step of one, the two columns are compared by sliding the first number of the longest sequence of numbers by each position in the shorter sequence and recording the number of matches and number of comparisons in the remainder of the columns. From these two figures a match/comparison ratio is figured, which indicates the best match position, or positions, for those two columns. This is all the information needed to attempt a cross-correlation, but more statistical analyses are available in this program to aid in related studies. Standard deviation, Chi-square[1/] uncorrected and Chi-square (Yates) figures are computed for each step. When the comparison has been made, the program computes a Chi-square sum and its standard deviation from the mean. At this point, the program reverses the shorter sequence and subjects it to the same sequence of steps. This reverse match process will detect any overturned sequence in a stratigraphic section. "The remaining part of the program consists of the computation of a nonprobabilistic SIMILARITY INDEX, S_L, between the two chains. It is essentially a measure of the proportion of the two chains which can be paired off as matching subsequences" (Sakin, and others, 1965, p. 13-14). This program also provides for a graphic comparison of the match points for those computers equipped with an on-line digital plotter. A graphic solution may be more useful when dealing with cyclic sediments.

Origin of Data

An east-west line of 12 stratigraphic sections was chosen along Seep Ridge for cross-correlation (see pl. 2). Since geological knowledge of an area is needed to choose the correct best match, prominent beds were walked-out in the field for control and for interpretation of the output data, because there could be more than one best match in any

1. Chi-square is the sum of the quotients obtained by dividing the square of the difference between the observed and theoretical values of a quantity by the theoretical value.

one set of data. These sections then were reduced to sequences of numbers and subjected to the cross-association program (described earlier) on the University of Utah's UNIVAC 1108 computer. The print-out data were then used to align diagrammatic representations of the sections. With the help of geological control, the proper best match for each two adjacent sections was chosen. The best computer match was not always the best geological match, but even in these cases the correlation was close.

A similar study was made of seven sections on a north-south line to show facies changes into the basin to the north (see pl. 3). The match/comparison ratios were much lower for this line, as would be expected for intertonguing units deposited in a transitional environment of facies change. The reliability of this correlation is less than the first comparison because some of the best match ratios are low and approach unrealistic probabilities of no use. This problem could have been avoided by using weighted characteristics.

Problems and Suggestions

There are methods of weighting particular characteristics with this program to obtain a more reliable ratio of cross-correlation. For example, if two barren sandstone beds have different structural characteristics, such as cross-bedding and flaggy bedding, they can be given multiple numerical notations. In this manner, it is possible to note the rock type and any of nine additional characteristics for each unit. This also would work well with different faunal assemblages in the same rock type. In some cases, the program matched a thick bed with a thin bed. This could have been avoided by having a weighted characteristic for thickness.

If cross-correlation statements are to be made with confidence, they must be based on a large quantity of accurate information. The reliability of any correlation is no better than the quality of the data taken in the field. Similarity of quality is necessary also, if cross-correlations are to be accurate.

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APPENDIX

Table 1. Outcrop sample analysis (data prepared by Core Laboratories, Inc., Denver, Colorado).

Company State of Utah Geological Survey County Uintah-Grand

Well Outcrop Samples State Utah

Location Southeastern Uinta Basin

Sample Number	No. of Measured Section[1]	Permeability in Millidarcys: Before Ext.[2]	Permeability in Millidarcys: After Ext.[2]	Porosity Percent	Residual Liquid Saturation — Oil: Percent Volume	Oil: Percent Pore[3]	Oil: Percent by Weight	Total Water Percent Pore[3]	Oil Gal. Per Ton
1	3		955	31.7		18.6		1.9	7.0
2	4-L	2,578	5,700	32.5	6.4	19.7	3.3	1.5	8.4
3	4-M		1,210	31.0		27.4		1.9	10.6
4	4-U	1,690	1,720	33.6	0.9	2.7	0.5	1.2	1.2
5	5-6L		3,180	28.8		9.7		1.4	3.6
6	5-7M		1,655	29.9		23.1		2.7	8.6
7	5-8U	10	3,120	36.7	23.2	63.2	11.7	2.5	29.6
8	6-2M	218	925	31.5	9.8	31.1	4.9	2.9	12.5
9	6-7U	98	578	31.0	11.3	37.7	6.3	1.3	15.8
10	7-2L		2,610	33.2		53.3		3.0	21.6
11	7-3		Frac Plug	35.1		11.1		1.4	5.3
12	7-6		930	30.5		15.7		2.0	6.2
13	7-8	13	Frac Plug	29.5	12.4	42.0	6.0	3.4	15.1
14	7-10U	15	1,425	29.0	10.6	36.6	5.1	2.7	13.0
15	10-4U		Frac Plug	31.0		15.8		1.6	6.5
16	11-3L		0.01	7.1		0.0		7.0	0.0
17	11-6		0.07	16.0		54.3		4.4	9.4
18	11-7M	0.8	132	27.3	14.7	53.9	6.8	3.7	17.3
19	11-9		918	24.7		38.1		3.6	10.6
20	11-10		79	24.7		12.6		4.0	3.8
21	11-11U	2.7	2,244	31.6	24.2	76.7	11.0	1.9	27.8
22	12-1L		2,980	28.9		48.1		3.5	17.0
23	12-3M		2,318	23.8		29.4		3.8	7.9
24	12-5U		128	28.8		10.1		3.5	3.8
25	15-L		928	24.6		35.8		2.4	10.6
26	15-U		10	21.5		17.2		4.6	4.3
27	16		990	26.1		31.6		1.5	9.8
28	17-L		Frac Plug	29.7		22.9		0.7	8.6
29	17-U		356	24.9		32.1		2.8	8.9
30	21	86	690	25.7	3.5	13.6	1.7	2.3	4.3
31	23-U	69	155	25.3	7.6	30.0	3.5	3.2	8.9
32	24-1L	186	215	24.3	2.6	10.7	1.2	0.8	3.1
33	24-4U		662	27.0		18.9		3.0	6.2

1. The first number in depth column is the stratigraphic section number. The second number is the sample number in that section, and L, M, U refer to the lower, middle, and upper zones of saturation within that section.
2. Permeability before and after extraction of bitumen.
3. Percent oil and percent water of total porosity.

Table 2. Analyses for Utah Geological Survey by Core Laboratories, Inc.

Company: Skyline Oil Company Formation: Green River (Eocene) County: Uintah State: Utah
Well: Sweetwater Creek Unit core holes Location: See plate 4 Core Type: DIA. CONVT. 1½"

Sample Number	Depth (Feet)	Permeability (Millidarcys)	Porosity (Percent)	Residual Saturation (Percent Pore 1/)	
				Oil	Total Water
CORE HOLE 25-32					
1	101-02	151	25.7	40.1	12.7
2	134-35	257	23.8	29.8	13.4
3	138-39	116	26.5	54.8	8.3
4	185-86	4,446	28.8	45.7	11.1
5	187-88	1,384	25.5	24.7	15.3
6	188-89	2,075	21.6	45.0	10.2
7	189-90	3,755	28.8	29.5	14.9
8	190-91	1,670	28.8	20.2	11.5
9	191-92	1,976	27.4	20.1	15.7
10	192-93	2,570	28.8	23.3	14.9
11	193-94	1,185	22.5	25.8	14.2
12	194-95	4,350	28.3	20.8	14.8
13	195-96	3,260	28.9	25.0	14.2
14	196-97	4,940	26.0	22.7	16.2
15	198-99	4,940	27.1	18.8	15.8
16	200-01	1,037	25.5	16.5	12.6
CORE HOLE 26-33					
1	91.5-92.5	295	27.9	67.4	7.9
2	119-20	257	21.0	26.7	10.5
3	120.5-21	3,360	17.0	46.0	7.1
4	212-22	3,656	30.1	88.0	9.0
5	122-23	203	22.1	41.0	10.0
6	124-25	246	23.8	43.3	13.4
7	131-32	220	29.1	80.5	9.3
8	132-33	43	24.5	40.0	9.0
9	133-34	49	24.3	36.6	9.1
10	134-35	20	22.6	24.8	14.3
11	158-59	790	21.4	36.5	11.7

Sample Number	Depth (Feet)	Permeability (Millidarcys)	Porosity (Percent)	Residual Saturation (Percent Pore 1/)	
				Oil	Total Water
CORE HOLE 24-24					
1	62-63	820	25.5	71.3	7.1
2	63-64	493	25.5	72.9	7.5
3	83-84	6,917	27.0	74.1	4.4
4	84-85	5,930	26.3	74.9	4.6
5	85-86	6,117	30.1	54.2	7.3
6	118-19	145	24.9	28.9	13.8
7	119-20	238	22.5	40.5	9.8
8	120-21	988	28.2	27.6	14.9
9	121-22	22	25.3	37.2	12.7
10	122-23	790	29.6	30.7	14.2
11	123-24	800	27.4	33.2	11.7
12	124-25	527	28.8	49.0	7.7
13	125-26	1,384	33.7	79.5	4.7
14	126-27	890	33.6	89.9	3.6
15	127-28	116	25.6	80.5	7.8
16	129-30	440	23.6	71.2	6.4
CORE HOLE 14-34					
1	82-83	1,581	31.5	58.7	10.2
2	96-97	319	26.6	77.5	8.3
3	133-34	330	25.8	43.7	12.4
4	135-36	1,778	29.4	37.1	10.9
5	223-24	2,470	28.8	60.0	7.6
6	226-27	4,940	28.7	43.5	11.2

1. Percent oil and percent water of total porosity.

Table 3. Analyses of oil or bitumen from seeps and extracted from outcrops and cores (Bureau of Mines, Laramie, Laboratory).

Sample PC-67-161

IDENTIFICATION

P.R. Springs Area
Skyline #25-32 SCU Core Hole
190-194 Feet

Utah
Uintah County
SW NE, Sec. 25
T. 14 S., R. 22 E. (SLM)

GENERAL CHARACTERISTICS

Gravity, specific 0.993
Sulfur, percent .40
Viscosity, Saybolt Universal at ______

Gravity, °API 11.0

Pour Point, °F ______
Color brownish black
Nitrogen, percent 1.08

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

Stage 1 — Distillation at atmospheric pressure ______ mm. Hg
First drop ______ °F

Fraction No.	Cut temp. °F	Percent	Sum percent	Sp. gr. 60/60°F	°API 60°F	C. I.	Refractive index n_D at 20°C	Specific dispersion	S.U. visc. 100°F	Cloud test °F
1	122	----	----	------	---		-------	-------		
2	167	----	----	------	---	---	-------	-------		
3	212	----	----	------	---	---	-------	-------		
4	257	----	----	------	---	---	-------	-------		
5	302	----	----	------	---	---	-------	-------		
6	347	----	----	------	---	---	-------	-------		
7	392	----	----	------	---	---	-------	-------		
8	437	----	----	------	---	---	-------	-------		
9	482	----	----	------	---	---	-------	-------		
10	527	----	----	------	---	---	-------	-------		
Stage 2 — Distillation continued at 40 mm. Hg										
11	392	----	----	----	---	---	-------	-------		
12	437	----	----	----	---	---	-------	-------		
13	482	----	----	----	---	---	-------	-------		
14	527	----	----	----	---	---	-------	-------		
15	572	----	----	----	---	---	-------	-------		
Residuum .	. . . .	----	----	----	---					

Carbon residue, Conradson: Residuum, ______ percent; crude, 15.2 percent.

APPROXIMATE SUMMARY

	Percent	Sp. gr.	°API	Viscosity
Light gasoline	------	------	----	
Total gasoline and naphtha	------	------	----	
Kerosine distillate	------	------	----	
Gas oil.	------	------	----	
Nonviscous lubricating distillate	------	------	----	50-100
Medium lubricating distillate	------	------	----	100-200
Viscous lubricating distillate	------	------	----	Above 200
Residuum	------	------	----	
Distillation loss	------			

Weight percents: Oil, 3.7 percent; Sand, 96.1 percent; Water, 0.0 percent; Loss, 0.2 percent.

Table 3. continued

Sample PC-67-162

IDENTIFICATION

P.R. Springs Area
Skyline #14-34 SCU Core Hole
137-141 Feet

Utah
Uintah County
SW SE, Sec. 14
T. 14 S., R. 22 E. (SLM)

GENERAL CHARACTERISTICS

Gravity, specific 1.004 Gravity, °API 9.4 Pour point, °F
Sulfur, percent .36 Color brownish black
Viscosity, Saybolt Universal at Nitrogen, percent 0.84

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

Stage 1 — Distillation at atmospheric pressure ________ mm. Hg
First drop 334 °F (stage 2)

Fraction No.	Cut temp. °F	Percent	Sum Percent	Sp. gr. 60/60°F	°API 60°F	C. I.	Refractive index n_D at 20°C	Specific dispersion	S.U. visc. 100°F	Cloud test °F
1	122	----	----	----	---		-------	-------		
2	167	----	----	----	---	---	-------	-------		
3	212	----	----	----	---	---	-------	-------		
4	257	----	----	----	---	---	-------	-------		
5	302	----	----	----	---	---	-------	-------		
6	347	----	----	----	---	---	-------	-------		
7	392	----	----	----	---	---	-------	-------		
8	437	----	----	----	---	---	-------	-------		
9	482	----	----	----	---	---	-------	-------		
10	527	----	----	----	---	---	-------	-------		

Stage 2 — Distillation continued at 40 mm. Hg

Fraction No.	Cut temp. °F	Percent	Sum Percent	Sp. gr. 60/60°F	°API 60°F	C. I.	Refractive index n_D at 20°C	Specific dispersion	S.U. visc. 100°F	Cloud test °F
11	392	3.1	3.1	0.891	27.3	---	1.48471	128.3	45	below 5
12	437	2.8	5.9	.903	25.2	55	1.49304	141.2	58	below 5
13	482	4.5	10.4	.930	20.7	64	1.50460	134.0	110	below 5
14	527	4.1	14.5	.939	19.2	66	-------	-------	420	below 5
15	572	12.5	27.0	.962	15.6	73	-------	-------	2550	below 5
Residuum	....	71.0	98.0	1.010	8.6					

Carbon residue, Conradson: Residuum, 16.9 percent; crude, 12.5 percent.

APPROXIMATE SUMMARY

	Percent	Sp. gr.	°API	Viscosity
Light gasoline	-----	-----	---	
Total gasoline and naphtha	-----	-----	---	
Kerosine distillate	-----	-----	---	
Gas oil	2.7	0.891	27.3	
Nonviscous lubricating distillate	4.7	.896-.925	26.4-21.5	50-100
Medium lubricating distillate	2.0	.925-.933	21.5-20.2	100-200
Viscous lubricating distillate	17.6	.933-.980	20.2-12.9	Above 200
Residuum	71.0	1.010	8.6	
Distillation loss	2.0			

Weight percents: Oil, 11.7 percent; Sand, 88.2 percent; Water, 0.0 percent; Loss, 0.1 percent.

Table 3. continued

Sample PC-67-163

IDENTIFICATION

P.R. Springs Area
Skyline #24-24 SCU Core Hole
79-83 Feet

Utah
Uintah County
SE SW, Sec. 24
T. 14 S., R. 22 E. (SLM)

GENERAL CHARACTERISTICS

Gravity, specific 0.995
Sulfur, percent .33
Viscosity, Saybolt Universal at ____

Gravity, °API 10.7

Pour point, °F ____
Color brownish black
Nitrogen, percent 0.88

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

Stage 1 — Distillation at atmospheric pressure ____ mm. Hg
First drop 342 °F (stage 2)

Fraction No.	Cut temp. °F	Percent	Sum percent	Sp. gr. 60/60°F	°API 60°F	C. I.	Refractive index n_D at 20°C	Specific dispersion	S.U. visc. 100°F	Cloud test °F
1	122	----	----	------	---		-------	-------		
2	167	----	----	------	---	---	-------	-------		
3	212	----	----	------	---	---	-------	-------		
4	257	----	----	------	---	---	-------	-------		
5	302	----	----	------	---	---	-------	-------		
6	347	----	----	------	---	---	-------	-------		
7	392	----	----	------	---	---	-------	-------		
8	437	----	----	------	---	---	-------	-------		
9	482	----	----	------	---	---	-------	-------		
10	527	----	----	------	---	---	-------	-------		

Stage 2 — Distillation continued at 40 mm. Hg

Fraction No.	Cut temp. °F	Percent	Sum percent	Sp. gr. 60/60°F	°API 60°F	C. I.	Refractive index n_D at 20°C	Specific dispersion	S.U. visc. 100°F	Cloud test °F
11	392	1.6	1.6	0.893	27.0	---	1.48441	112.0	45	below 5
12	437	2.2	3.8	.911	23.8	59	1.49146	132.7	55	below 5
13	482	2.9	6.7	.918	22.6	59	1.50004	134.9	85	below 5
14	527	5.6	12.3	.939	19.2	66	-------	-------	320	below 5
15	572	11.8	24.1	.948	17.8	67	-------	-------	1150	below 5
Residuum	....	74.8	98.9	1.002	9.7					

Carbon residue, Conradson: Residuum, 18.2 percent; crude, 13.7 percent.

APPROXIMATE SUMMARY

	Percent	Sp. gr.	°API	Viscosity
Light gasoline	-----	----	---	
Total gasoline and naphtha	-----	----	---	
Kerosine distillate		----	---	
Gas oil	1.8	0.894	26.8	
Nonviscous lubricating distillate	3.7	.903-.920	25.2-22.3	50-100
Medium lubricating distillate	1.8	.920-.929	22.3-20.8	100-200
Viscous lubricating distillate	16.8	.929-.954	20.8-16.8	Above 200
Residuum	74.8	1.002	9.7	
Distillation loss	1.1			

Weight percents: Oil, 10.4 percent; Sand, 89.6 percent; Water, 0.0 percent; Loss, 0.0 percent.

Table 3. continued

Sample PC-67-164

IDENTIFICATION

P.R. Springs Area
Outcrop Sample
Surface

Utah
Uintah County
SE¼ SE¼, Sec. 36
T. 15 S., R. 22 E. (SLM)

GENERAL CHARACTERISTICS

Gravity, specific 1.027
Sulfur, percent .42
Viscosity, Saybolt Universal at

Gravity, °API 6.3

Pour point, °F
Color brownish black
Nitrogen, percent 1.26

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

Stage 1 — Distillation at atmospheric pressure ______ mm. Hg
First drop 360 °F (stage 2)

Fraction No.	Cut temp. °F	Percent	Sum percent	Sp. gr. 60/60°F	°API 60° F	C. I.	Refractive index n_D at 20°C	Specific dispersion	S.U. visc. 100°F	Cloud test °F
1	122	----	----	------	---		-------	------		
2	167	----	----	------	---	---	-------	------		
3	212	----	----	------	---	---	-------	------		
4	257	----	----	------	---	---	-------	------		
5	302	----	----	------	---	---	-------	------		
6	347	----	----	------	---	---	-------	------		
7	392	----	----	------	---	---	-------	------		
8	437	----	----	------	---	---	-------	------		
9	482	----	----	------	---	---	-------	------		
10	527	----	----	------	---	---	-------	------		
Stage 2 — Distillation continued at 40 mm. Hg										
11	392	1.9	1.9	0.909	24.2	---	1.48527	114.9	43	below 5
12	437	2.0	3.9	.907	24.5	57	1.49309	124.3	52	below 5
13	482	2.3	6.2	.927	21.1	63	1.50249	138.1	87	below 5
14	527	5.7	11.9	.934	20.0	63	-------	------	185	30
15	572	8.0	19.9	.951	17.3	68	-------	------	1470	80
Residuum	....	74.1	94.0	1.021	7.1					

Carbon residue, Conradson: Residuum, 21.3 percent; crude 15.8 percent.

APPROXIMATE SUMMARY

	Percent	Sp. gr.	°API	Viscosity
Light gasoline	-----	-----	----	
Total gasoline and naphtha	-----	-----	-----	
Kerosine distillate	-----	-----	-----	
Gas oil	2.5	0.908	24.3	
Nonviscous lubricating distillate	3.0	.909-.928	24.2-21.0	50-100
Medium lubricating distillate	3.6	.928-.935	21.0-19.8	100-200
Viscous lubricating distillate	10.8	.935-.961	19.8-15.7	Above 200
Residuum	74.1	1.021	7.1	
Distillation loss	6.0			

Weight percents: Oil, 12.2 percent; Sand, 88.5 percent; Water, 0.0 percent; loss. 0.7 percent.

Table 3. continued

Sample PC-67-165

IDENTIFICATION

P.R. Springs Area
Main Canyon Oil Seep
Surface

Utah
Grand County
NE¼ NE¼, Sec. 5
T. 16 S., R. 24 E.

GENERAL CHARACTERISTICS

Gravity, specific 0.974
Sulfur, percent .34
Viscosity, Saybolt Universal at

Gravity, °API 13.8

Pour point, °F
Color brownish black
Nitrogen, percent 0.77

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

Stage 1 — Distillation at atmospheric pressure ______ mm. Hg
First drop 343 °F (stage 2)

Fraction No.	Cut temp. °F	Percent	Sum percent	Sp. gr. 60/60°F	°API 60° F	C. I.	Refractive index n_D at 20° C	Specific dispersion	S.U. visc. 100° F	Cloud test °F
1	122	----	----	------	---		-------	------		
2	167	----	----	------	---	---	-------	------		
3	212	----	----	------	---	---	-------	------		
4	257	----	----	------	---	---	-------	------		
5	302	----	----	------	---	---	-------	------		
6	347	----	----	------	---	---	-------	------		
7	392	----	----	------	---	---	-------	------		
8	437	----	----	------	---	---	-------	------		
9	482	----	----	------	---	---	-------	------		
10	527	----	----	------	---	---	-------	------		
Stage 2 — Distillation continued at 40 mm. Hg										
11	392	1.9	1.9	0.896	26.4	---	1.48662	124.8	48	below 5
12	437	2.3	4.2	.901	25.6	54	1.49348	125.9	62	below 5
13	482	3.1	7.3	.912	23.7	56	1.50105	124.1	97	below 5
14	527	3.4	10.7	.925	21.5	59			195	below 5
15	572	9.5	20.2	.936	19.7	61	-------	------	700	below 5
Residuum .	. . . .	75.8	96.0	.993	11.0					

Carbon residue, Conradson: Residuum 14.2 percent; crude 11.0 percent.

APPROXIMATE SUMMARY

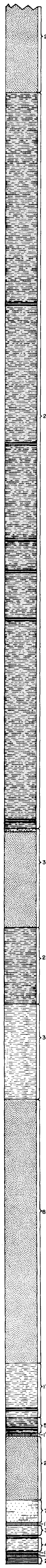
	Percent	Sp. gr.	°API	Viscosity
Light gasoline	-----	-----	----	
Total gasoline and naphtha	-----	-----	----	
Kerosine distillate	-----	-----	----	
Gas oil.	1.2	0.895	26.6	
Nonviscous lubricating distillate	4.6	.897-.913	26.3-23.5	50-100
Medium lubricating distillate	3.3	.913-.926	23.5-21.3	100-200
Viscous lubricating distillate	11.1	.926-.944	21.3-18.4	Above 200
Residuum	75.8	.993	11.0	
Distillation loss	4.0			

Table 4. Wells drilled for oil and gas in P. R. Spring deposit area.

OPERATOR	WELL NO. & NAME	LOCATION	STATUS	PRODUCING FORMATION	DATE COMPLETED OR ABANDONED	TOTAL DEPTH	DEEPEST FORMATION PENETRATED
Sinclair Oil & Gas	#1-171 Uintah-Federal	SE¼ NW¼ Section 14 T13S R22E	D & A	None	Sept. 1962	6,600 ft.	Mancos (Cretaceous)
Sinclair Oil & Gas	#1-122 Uintah-Federal	NE¼ SE¼ Section 18 T13S R22E	D & A	None	June 1962	6,500 ft.	Mancos (Cretaceous)
Woodward Oil	#1 Unit	NW¼ NW¼ Section 25 T13S R23E	D & A	None	Dec. 1954	6,095 ft.	Mancos (Cretaceous)
Skyline Oil Co.	#1 Sweetwater Creek Unit - P.M. Nielson	SW¼ NE¼ Section 26 T13S R23E	Gas (Shut-in)	Castlegate (Cretaceous)	Nov. 1960	5,852	Castlegate (Cretaceous)
Skyline Oil Co.	#26-33 Sweetwater Creek Unit	NW¼ SE¼ Section 26 T13S R23E	Core hole D & A	None	Sept. 1966	254	Green River (Eocene)
Skyline Oil Co.	#5 Sweetwater Creek Unit	NE¼ SW¼ Section 26 T13S R23E	Gas	Wasatch (Eocene)	July 1965	4,421	Mesaverde (Cretaceous)
Continental Oil	#3-A Unit	NW¼ NE¼ Section 15 T13S R24E	D & A	None	June 1952	4,177	Mesaverde (Cretaceous)
C.F. Raymond	#1 Government	NW¼ NW¼ Section 17 T14S R22E	D & A	None	Jan. 1963	8,840	Brushy Basin-Morrison (Jurassic)
Skyline Oil et. al.	#2 Sweetwater	SW¼ NE¼ Section 14 T14S R22E	D & A	None	Nov. 1962	9,421	Morrison (Jurassic)
Skyline Oil	#14-34 Sweetwater Creek Unit	SW¼ SE¼ Section 14 T14S R22E	Core hole D & A	None	Sept. 1966	244	Green River (Eocene)
Skyline Oil	#3 Sweetwater Creek Unit	SW¼ NW¼ Section 17 T14S R22E	Oil & Gas (Shut-in)	Wasatch (Eocene)	Aug. 1963	2,166	Wasatch (Eocene)
Skyline Oil	#24-24 Sweetwater Creek Unit	SE¼ SW¼ Section 24 T14S R22E	Core hole D & A	None	Sept. 1966	301	Green River (Eocene)
Skyline Oil	#25-32 Sweetwater Creek Unit	SW¼ NE¼ Section 25 T14S R22E	Core hole D & A	None	Sept. 1966	205	Green River (Eocene)
Marathon Oil Co.	#1 Two Waters Unit	NE¼ SW¼ Section 8 T14S R25E	D & A	None	Sept. 1962	7,901	Entrada (Jurassic)
Atlantic Refining Co.	#2-22 Alpine-Atlantic-Federal	SW¼ SE¼ Section 22 T15S R21E	D & A	None	Oct. 1963	5,700	Castlegate (Cretaceous)
Alpine Oil	#1 Winter Ridge	NE¼ SW¼ Section 22 T15S R21E	D & A	None	June 1962	10,060	Morrison (Jurassic)
Texaco Inc.	#2 Unit (Fence Canyon)	NE¼ SE¼ Section 26 T15S R22E	Gas	Buckhorn (K) Morrison (Jur)	Aug. 1961	8,585	Morrison (Jurassic)
Texaco Inc.	#1 Fence Canyon Unit	NE¼ SE¼ Section 36 T15S R22E	Gas	Dakota (Cretaceous)	April 1960	10,348	Granite (Precambrian)
Mountain Fuel Supply	#1 Main Canyon	NE¼ SE¼ Section 28 T15S R23E	D & A	None	Sept. 1960	9,051	Entrada (Jurassic)
Pope	#1	SE¼ NW¼ Section 35 T15S R23E	D & A	None	1900	1,000	Wasatch? (Eocene)
Texaco, Inc.	#3 Fence Canyon Unit	SW¼ SE¼ Section 33 T15½S R23E	Gas	Buckhorn (Cretaceous)	Oct. 1961	8,750	Buckhorn (Cretaceous)
Pacific Nat. Gas Exploration	#1 Cherry Canyon Unit	SE¼ SE¼ Section 2 T16S R22E	D & A	None	Dec. 1963	9,577	Morrison (Jurassic)
Sunray Mid-Continent	#4 Unit	NW¼ SE¼ Section 36 T16S R22E	D & A	None	1960	8,370	Entrada (Jurassic)
Tidewater Oil Co.	#1 Horse Point Unit	NW¼ NE¼ Section 14 T16S R23E	D & A Junked	None	Aug. 1961	3,108	Mesaverde (Cretaceous)

19

SECTION 19. Moon Ridge road to Holt's Ranch on east side of canyon
El at top of section - 7510 feet
SW NW S12-T16S-R21E



7500'

27' — Sandstone; light yellowish-brown, cross-bedded, fine grained, micaceous, limonite staining, calcareous.

231' — Mudstone; light gray, thin bedded, silty at base, calcareous;
1 foot oil shale 2 feet from base;
1 foot oil shale 65 feet from base;
1 foot oil shale 80 feet from base;
1 foot oil shale 90 feet from base;
1 foot oil shale 120 feet from base;
1 foot oil shale 164 feet from base;

31' — Sandstone; light yellowish-brown, cross-bedded and massive, fine to medium grained, calcareous, ripple marks; 1 foot bed of very tight conglomerate 10 feet from base.

24' — Mudstone; green, medium bedded, calcareous.

7200'

30' — Shale; green, thin bedded, calcareous; 1 foot oil shale 2 feet from base; 3 foot oil shale 4 feet from base.

83' — Sandstone; light brown, cross-bedded and massive, fine grained, calcareous; unit becomes medium to course grained 15 feet from base.

17' — Shale; green, thin bedded, calcareous; 1 foot oil shale 2 feet from base.

5' — Mudstone; green, medium bedded, calcareous, 1 foot oil shale 1 foot from base.

1' — Algal limestone; white.

20' — Sandstone; light gray to brown, cross-bedded and massive, very fine to fine grained, calcareous.

7' — Siltstone; light gray, thin bedded, calcareous.

1' — Algal limestone; light brown.

3' — Shale; green, thin bedded.

Oil shale; black, very thin bedded.

4' — Shale; green, thin bedded.

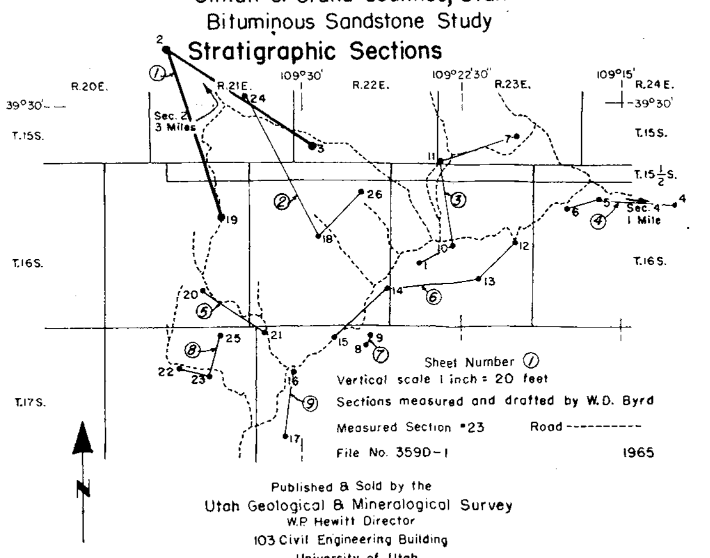
Oil shale; black, very thin bedded.

1' — Algal limestone; white

2' — Oil shale; black, very thin bedded.

ROAN CLIFF–P.R. SPRING AREA

Uintah & Grand Counties, Utah
Bituminous Sandstone Study
Stratigraphic Sections



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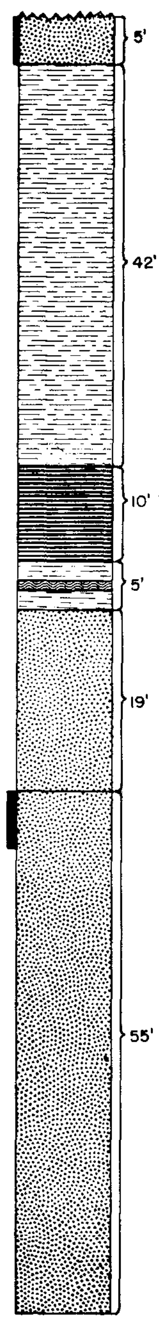
3

SECTION 3. Trapper Spring - Winter Ridge - south side of slope.
El. top of section - 6550 feet
SW NE S31-T15S-R22E



5' — Sandstone; light brown with patches of red, fine grained, subangular, micaceous, iron staining, calcareous, and porous. Slightly stained.

42' — Shale; light gray to brown, thin bedded.

6500'

10' — Oil shale; weakly saturated at bottom grading to rich at top.

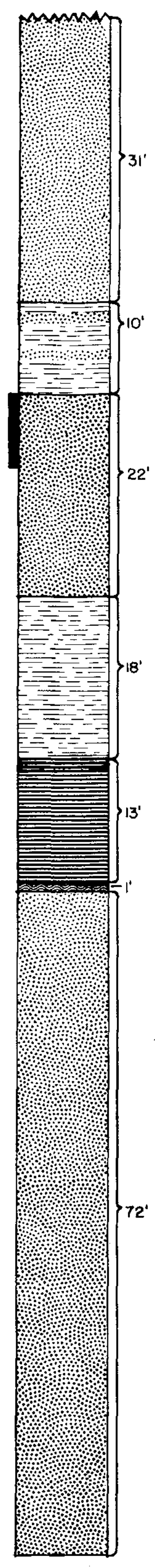
5' — Shale; light gray to brown, with algal bed.

19' — Covered; unit probably barren sandstone.

55' — Sandstone; light brown, cross-bedded, very weak saturation in last 12 feet of unit. Unit partly covered.

2

SECTION 2. Three miles northwest of Horse Point airstrip.
NWSE S5-T 15S- R 21E.
El. top of section - 6380 feet



31' — Sandstone; light brown with patches of red, cross-bedded, fine grained, subangular, iron staining, calcareous, and porous.

10' — Sandstone; light brown, fine grained, subangular, micaceous, iron staining, calcareous, medium porosity; with interbedded shales.

22' — Sandstone; light brown, cross-bedded, fine grained, subangular, micaceous, feldspars, iron staining, calcareous, highly porous. The upper 8 feet is weakly saturated.

18' — Shale; gray, weathers light brown, thin to medium bedded, iron staining.

13' — Oil shale; weathers chalky-white, thin bedded

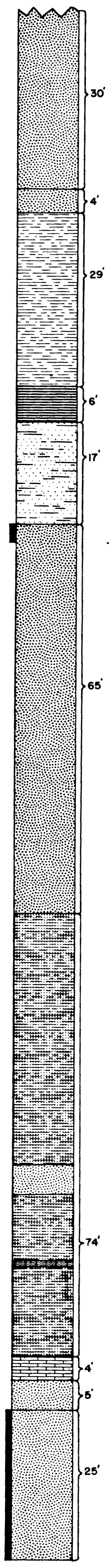
1' — Conglomerate; light yellow to white, with algal structures.

6300'

72' — Sandstone; light brown, cross-bedded, fine grained, angular to subangular grains, micaceous, feldspars, iron stained, calcareous, highly porous.

24

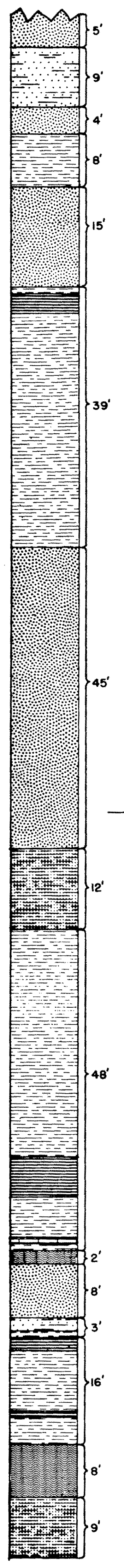
SECTION 24. East side of canyon east of Wire Fence airstrip on north end
El. at top of section - 7290 feet
NE NE S22-T15S-R21E



- 30' Sandstone; light gray, weathers light brown, massive, medium grained, micaceous, calcareous, limonite staining, poorly sorted.
- 4' Sandstone; light yellowish-brown, weathers redish-brown, flaggy, fine grained, micaceous, limonite staining, calcareous.
- 29' Shale; brown, thin bedded slightly calcareous.
- 6' Oil shale; black, thin bedded.
- 17' Siltstone; light greenish-gray, weathers medium brown; many interbeds of fine grained, thin bedded sandstone.
- 65' Sandstone; light green, weathers light redish-brown, cross-bedded, massive, very fine grained, limonite staining, calcareous, becomes fine grained toward top of unit; weak saturation 62 feet from base.
- 74' Mudstone; light greenish-gray, very slightly calcareous, thin bedded, mostly covered, becomes shaley 2 feet from base; 1 foot oil shale 15 feet from base; 5 foot sandstone lense 27 feet from base.
- 4' Oolitic limestone; medium gray, conglomeratic near top.
- 5' Sandstone; light yellowish-brown, medium bedded, very fine grained, very calcareous, fairly porous.
- 25' Sandstone; light to medium gray, cross-bedded, fine grained, micaceous, calcareous, porous, weakly saturated.

18

SECTION 18. West side of Cedar Camp Ridge two miles northwest of Cedar Camp
El. top of section - 7320 feet
SE NE S16-T16S-R22E



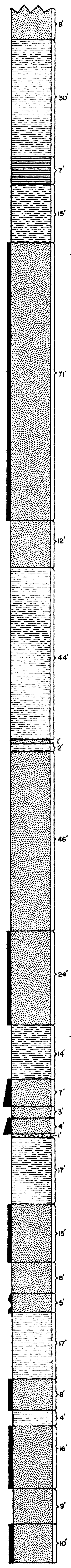
- 5' Sandstone; light brown, flaggy, very fine grained, calcareous, tight.
- 9' Siltstone; light green, weathers light brown, very thin bedded, calcareous.
- 4' Sandstone; light brown, cross-bedded, medium grained, very calcareous.
- 8' Shale; brown, thin bedded, calcareous.
- 15' Sandstone; light redish-brown, cross-bedded, flaggy to massive, micaceous, slightly calcareous, very porous.
- 39' Shale; light green, thin bedded, calcareous, 3 feet of oil shale 35 feet from base; unit partly covered.
- 45' Sandstone; light brown, cross-bedded and massive, fine to medium grained, with limonite blebs.

7200'

- 12' Mudstone; green, thick bedded; 1 foot sandstone 6 feet from base.
- 48' Shale; green, thin bedded; 1 foot oolitic limestone 1 foot from base; 6 feet of oil shale 8 feet from base.
- 2' Algal limestone; whitish-orange.
- 8' Sandstone; light yellowish-brown, flaggy, calcareous.
- 3' Siltstone; light gray, slightly calcareous.
- 16' Shale; light green, thin bedded, calcareous, 1 foot oil shale 4 feet from base; 2 foot oil shale 14 feet from base.
- 8' Algal limestone; whitish- orange.
- 9' Mudstone; green, thick bedded, very calcareous.

26

SECTION 26. Southwest side of Winter Ridge
SE SE S35-T15 1/2 S-R22E



- 8' Sandstone; light brown, cross-bedded and massive.
- 30' Shale; brown, thin bedded.
- 7' Oil shale; black to gray, very thin bedded.
- 15' Shale; brown, thin bedded.
- 71' Sandstone; light brownish-gray, massive and cross-bedded, weakly saturated.
- 12' Sandstone; light brown, massive and cross-bedded.
- 44' Shale; green, thin bedded.
- 1' Oolitic sandstone; white to orange.
- 2' Shale; light green, thin bedded.
- 46' Sandstone; light brown, cross-bedded and massive.
- 24' Sandstone; light brown to gray, massive and cross-bedded, weak to moderately saturated.

7000'

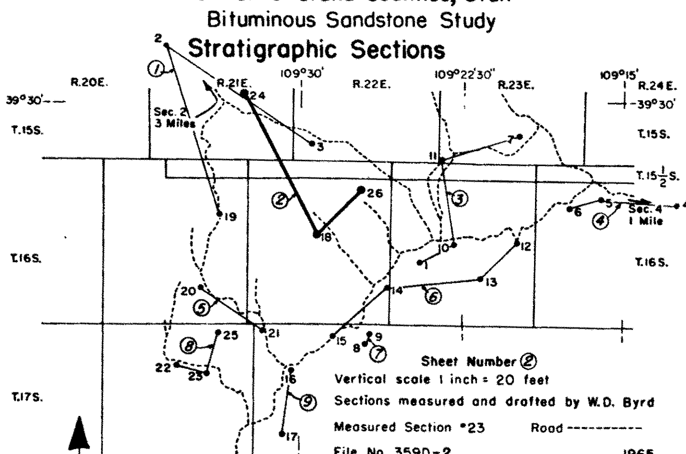
- 14' Shale; green, thin bedded.
- 7' Sandstone; light brownish-gray, cross-bedded, weak to moderately saturated.
- 3' Sandstone; light brown, cross-bedded.
- 4' Sandstone;,gray, massive, weakly to moderately saturated.
- 1' Conglomerate; calcareous matrix.
- 17' Shale; green, thin bedded.
- 15' Sandstone; light brownish-gray, massive and cross-bedded, weakly saturated.
- 8' Sandstone; light brown, massive and cross-bedded, porous.
- 5' Sandstone; light brownish-gray, irregularly saturated.
- 17' Shale; light green, thin bedded, slightly calcareous.
- 8' Sandstone; light brownish-gray, massive and cross-bedded, slightly calcareous; weakly saturated.
- 4' Interbedded sandstone and shales.
- 16' Sandstone; light brownish-gray, massive and cross-bedded, slightly calcareous; weakly saturated.
- 9' Sandstone; light brown, medium bedded, highly porous.
- 10' Sandstone; light brownish-gray, massive and cross-bedded, fine grained; weakly saturated.

ROAN CLIFF–P.R. SPRING AREA

Uintah & Grand Counties, Utah

Bituminous Sandstone Study

Stratigraphic Sections



Sheet Number 2

Vertical scale 1 inch = 20 feet

Sections measured and drafted by W.D. Byrd

Measured Section •23 Road ----------

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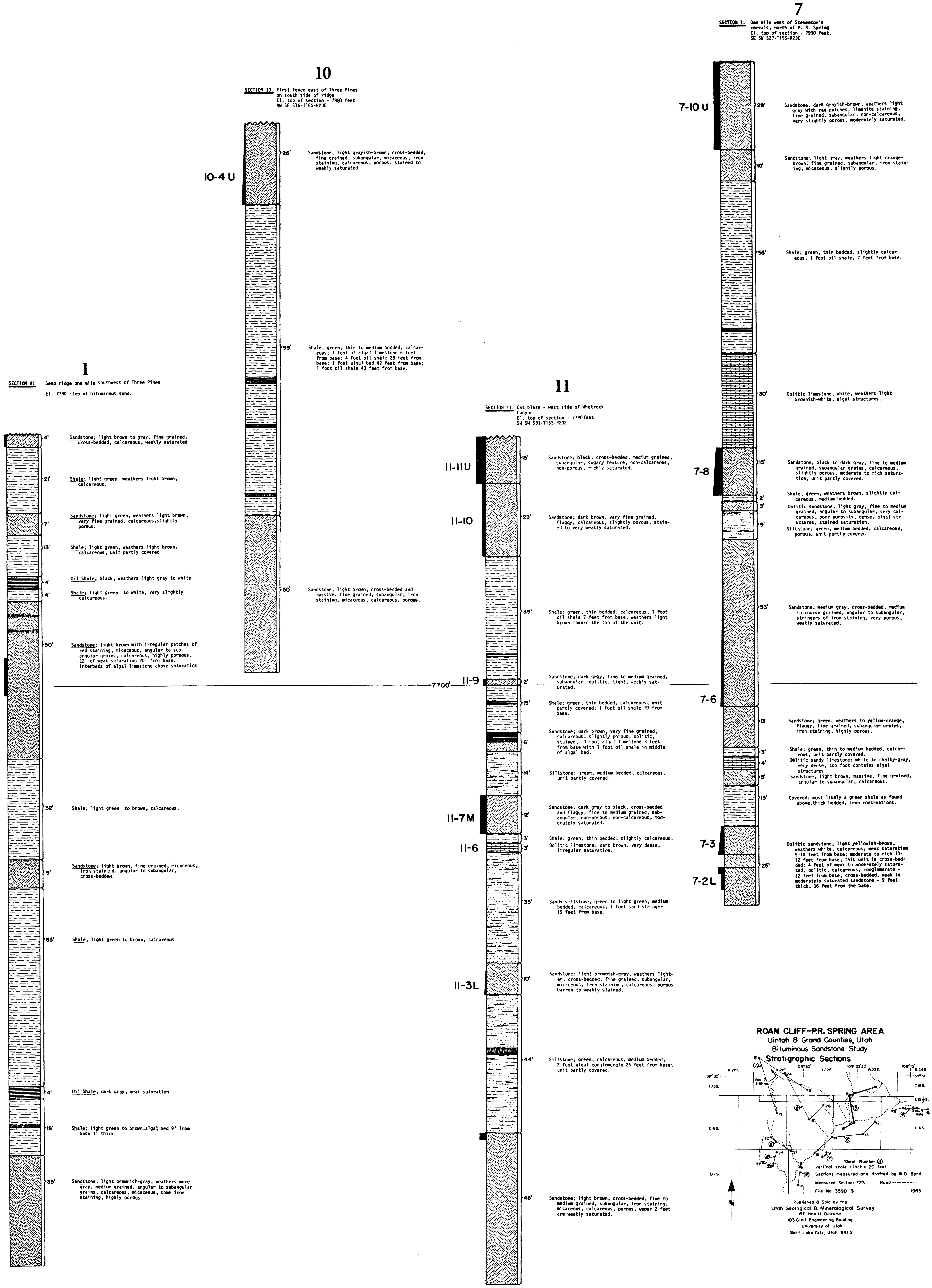
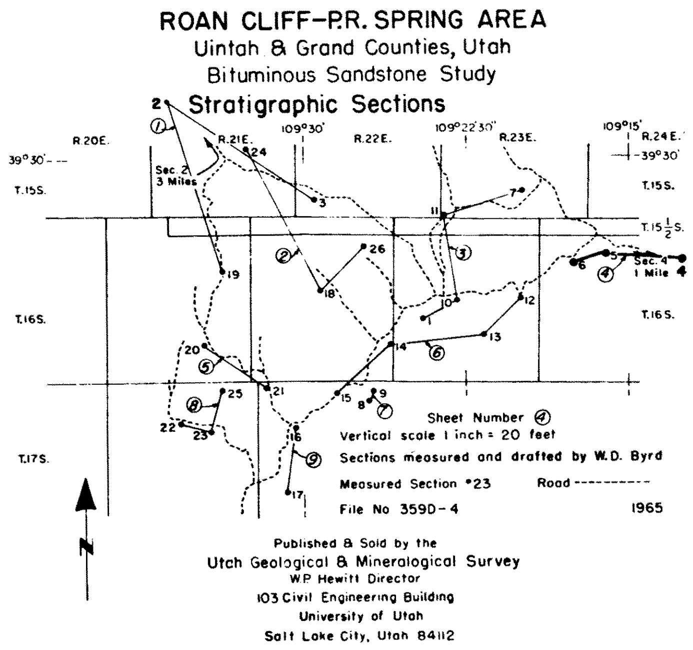
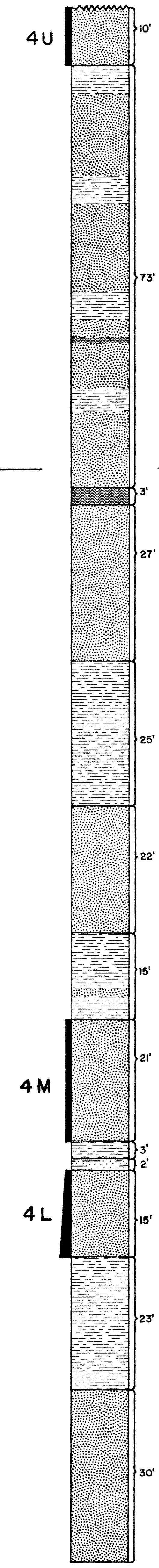




4

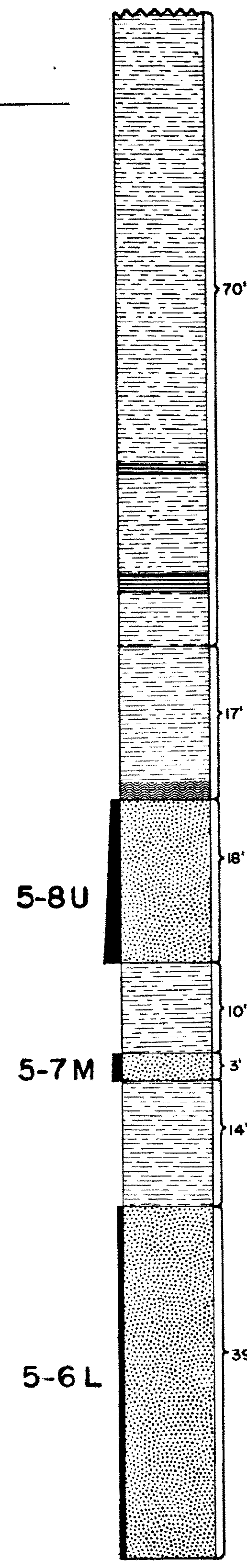
SECTION 4. Two miles southeast of P. R. Spring Junction on McCook Ridge Road.
El. 8280' at top of section
SW NE S2-T16S-R24E



- 10' — Sandstone; medium gray, very fine grained, weakly saturated.
- 73' — Interbedded sandstones and shales; an algal bed 25 feet from base mostly soil cover.
- 3' — Algal limestone; very light brown to white, limonite inclusions.
- 27' — Sandstone; light brown, weathers gray, fine grained, subangular, highly porous and friable. A bed of fossil cocina 4 feet from the base 1 foot thick, no identifiable except some fish scales; upper 20 feet covered.
- 25' — Shale; light green, thin bedded, partly covered
- 22' — Sandstone; light gray to white, weathers very light brown to white, very fine grained, calcareous, porous; oolites larger than rest of grains scattered through rock; some algal structures interbedded.
- 15' — Shale; green, thin bedded with a 1 foot interbed of sandstone 4 feet from base.
- 21' — Sandstone; light to medium gray, fine grained, cross-bedded, subangular, thin stringers of iron staining 10 feet from base, non-calcareous, highly porous and friable, weakly saturated.
- 3' — Shale; light green, very thin bedded, calcareous.
- 2' — Siltstone; light brown, calcareous, magnetite blebs oxidizing to iron staining, very hard.
- 15' — Sandstone; light gray, fine grained, subangular, micaceous, non-porous and non- calcareous. Weak to moderate saturation but saturation becomes irregular toward top. Fish scales.
- 23' — Shale; light green, thin bedded, slightly calcareous.
- 30' — Sandstone; light brown, fine grained, angular to subangular, micaceous, porous.

5

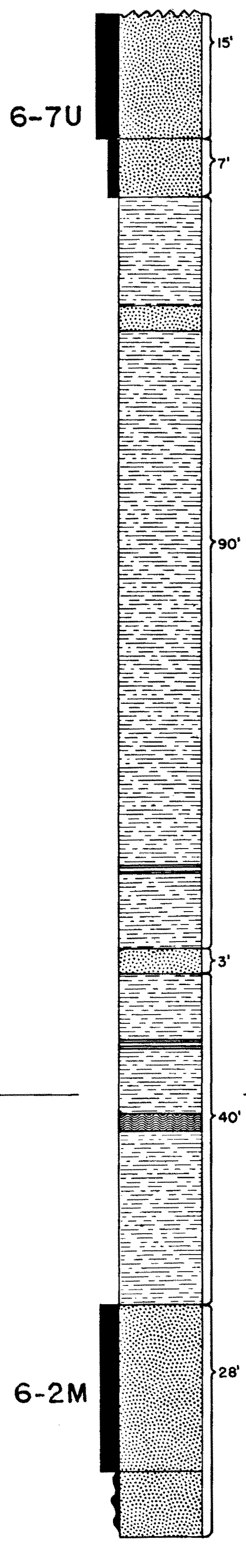
SECTION 5. One quarter mile southeast of P. R. Spring Junction on McCook Ridge Road.
El. at top of section - 8210 feet.
SW SE S4-T16S-R24E



- 70' — Shale; green, very thin bedded, calcareous, interbeds of algal limestone; 2 feet of oil shale, 6 feet from base.; Interbed of oil stained oolitic sandstone 1 foot thick, 13 feet from base of unit; 1 foot oil shale, 19 feet from base.
- 17' — Covered; most likely algal limestone- from float.
- 18' — Sandstone; dark gray to black, fine grained, subangular, highly porous, moderately saturated; saturation decreases toward the top of unit.
- 10' — Shale; green, silty at base, thin bedded, calcareous, partly covered.
- 3' — Sandstone; medium gray, seathers light brownish-gray, fine grained, subangular, calcareous, porous, limonite staining, weakly saturated.
- 14' — Shale; green, thin bedded, calcareous, partly covered.
- 39' — Sandstone; dark to medium gray, fine grained, subangular, slightly porous, weakly saturated.

6

SECTION 6. West side of ridge by airstrip west of P. R. Spring Junction
El. at top of sandstone cap - 8130 feet
NE NW S9-T16S-R24E



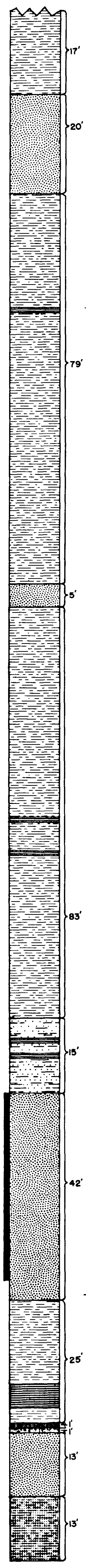
- 15' — Sandstone; black, weathers light brownish-gray, fine to medium grained, subangular grains, non-porous and non-calcareous, friable (sugary), moderate to rich saturation.
- 7' — Sandstone; light yellowish-brown, weathers with red patches on surface, flaggy, fine to medium grained, micaceous, iron staining, highly porous, non-calcareous, barren to slightly stained saturation: the unit becomes weakly saturated toward top.
- 90' — Shale; green, weathers light brown, medium bedded, calcareous, unit partly covered; 1 foot oil shale - 9 feet from base; 4 foot yellow fine-grained sandstone -74 feet from base.
- 3' — Oolitic sandstone, light brown to white, calcareous, unit becomes more silty toward top.
- 40' — Shale; green, medium bedded, slightly calcareous, with interbeds of algal limestone conglomerate - 2 feet thick, 21 feet from base, 1 foot oil shale - 31 feet from base.
- 28' — Sandstone; dark brown to black, fine grained, angular to subangular, irregular patches of red iron staining on surface, slightly calcareous, poor porosity, micaceous; 7 foot cross-bedded unit, 2 feet from base - irregularly saturated, saturation increases above the cross-bedded unit to moderately saturated.

8200'

8000'

21

SECTION 21. West side of Moon Ridge
El. at top of section - 8060 feet
NW NW S6-T17S-R22E



8000'

17' Shale; light brown, thin bedded, calcareous.

20' Sandstone; light yellowish-brown, flaggy, fine grained, very calcareous and porous.

79' Shale; green, thin bedded, calcareous; 1 foot oil shale 55 feet from base.

5' Sandstone; light yellowish-brown, flaggy, fine grained, calcareous.

83' Shale; brown, thin bedded, calcareous; 1 foot oil shale 33 feet from base; 1 foot oil shale 40 feet from base; unit partly covered.

15' Siltstone; green, thin bedded, calcareous; 1 foot oil shale 7 feet from base; 1 foot oil shale 10 feet from base.

21

42' Sandstone; light gray, massive and cross-bedded, very fine to fine grained, micaceous, calcareous, weakly saturated 4 feet from base.

7800'

25' Shale; green, thin bedded, calcareous; 5 foot oil shale 3 feet from base.

1' Algal limestone; white to light brown.

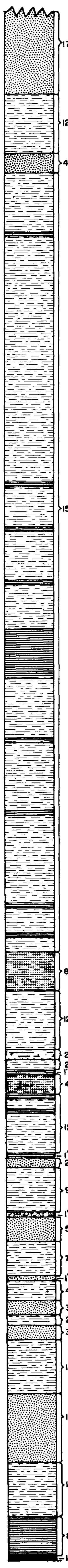
1' Conglomerate; light brownish-orange, broken algal structures make up the large pieces.

13' Sandstone; light greenish-gray, medium bedded, fine to medium grained, micaceous, calcareous, porous.

13' Mudstone; green, thin bedded, calcareous.

20

SECTION 20. South end of Moon Ridge airstrip
El. at top of section - 7800 feet
NW SW S26-T16S-R21E



17' Sandstone; light brown, massive and cross-bedded, fine to medium grained, limonite blebs, porous.

12' Shale; green, thin bedded, calcareous.

4' Sandstone; light yellowish-brown, flaggy, very fine grained, calcareous.

159' Shale; green, thin bedded, calcareous;
1 foot oil shale 3 feet from base;
1 foot oil shale 9 feet from base;
1 foot oil shale 28 feet from base;
1 foot oil shale 43 feet from base;
10 foot oil shale 56 feet from base;
1 foot oil shale 75 feet from base;
1 foot oil shale 86 feet from base;
1 foot oil shale 95 feet from base;
1 foot oil shale 146 feet from base.

8' Mudstone; light grayish-green, medium bedded, calcareous.

12' Shale; green, thin bedded calcareous.

2' Siltstone; light gray, medium bedded, biotite, very tight.

2' Shale; green, thin bedded.

1' Oil shale; black, very thin bedded.

4' Mudstone; light greenish-gray, thin bedded.

12 Shale; green, thin bedded, calcareous; 1 foot oil shale 8 feet from base; 1 foot oil shale 11 feet from base.

1' Oil shale; black, very thin bedded.

2' Sandstone; light yellowish-brown, thick bedded, fine grained, micaceous, limonite staining, calcareous.

9' Shale; green, thin bedded.

1' Conglomerate; light orange, rounded grains, calcareous matrix, extremely hard.

5' Sandstone; light brown, thick bedded, fine grained, calcareous.

7' Shale; green, thin bedded, calcareous.

1' Sandstone; light yellowish-brown, massive and cross-bedded, fine grained, micaceous, limonite blebs, calcareous.

4' Shale; green, thin bedded, calcareous.

3' Sandstone; light yellowish-brown, massive and cross-bedded, fine grained, micaceous, limonite blebs, calcareous.

2' Shale; green thin bedded, calcareous.

3' Sandstone; light greenish-brown, cross-bedded and massive, micaceous, calcareous.

11' Shale; green, thin bedded, calcareous.

14' Sandstone; light brown, massive and cross-bedded, fine grained, calcareous, fairly tight.

11' Shale; green, thin to medium bedded, calcareous.

8' Oil shale; black, thin bedded.

1' Algal limestone; light orangish-white;

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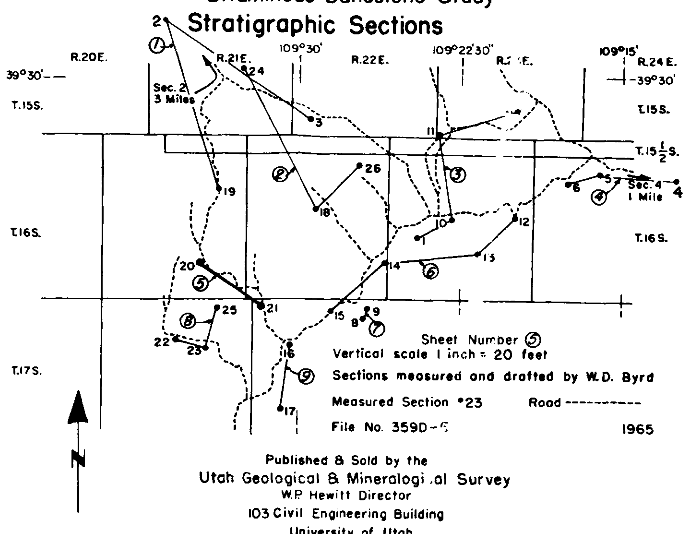
Stratigraphic Sections



Sheet Number ⑤
Vertical scale 1 inch = 20 feet
Sections measured and drafted by W.D. Byrd
Measured Section •23
Road - - - - - - - - -
File No. 3590-5
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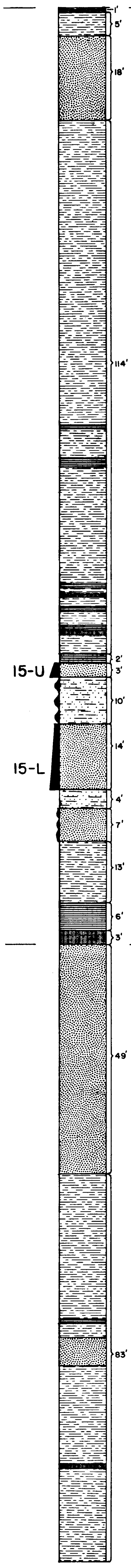
8200'

8000'

15

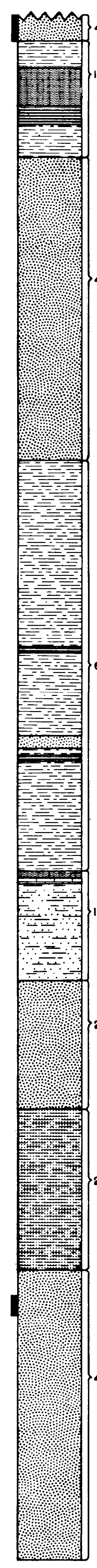
SECTION 15. One and one half miles west of Holt's corral on south side of ridge.
El. at top of section - 8200 feet
NE SW S3-T17S-R22E



- 1' Algal limestone; orange to chalky white.
- 5' Shale; light brown, thin bedded.
- 18' Covered; soil and float of barren flaggy medium grained sandstone.
- 114' Shale; green, thin bedded; 1 foot algal limestone 4 feet from base; 1 foot oil shale 5 feet from base; 1 foot oil shale 9 feet from base; 1 foot algal limestone 12 feet from base; 1 foot oil shale 14 feet from base; 2 foot oil shale 40 feet from base; 1 foot oil shale 48 feet from base; unit partly covered.
- 2' Oil shale.
- 3' Sandstone; medium brown, fine grained; weak to moderately saturated.
- 10' Siltstone; medium brown, thin bedded, cal careous; some weakly saturated stringers.
- 14' Sandstone; dark gray, massive and cross-bedded, fine grained, micaceous and calcareous; weak to moderately saturated.
- 4' Siltstone; light greenish-brown, thin bedded, micaceous, calcareous.
- 7' Sandstone; medium gray, cross-bedded and massive, fine grained, micaceous and slightly calcareous; irregular saturation.
- 13' Shale; green, thin bedded, calcareous.
- 6' Oil shale; very thin bedded.
- 3' Algal limestone; light orangish-white.
- 49' Sandstone; light greenish-brown, massive and cross-bedded, fine grained, with parts covered.
- 83' Shale; light green; 1 foot oolitic algal limestone 20 feet from base; 6 foot sandstone 42 feet from base; 1 foot oil shale 61 feet from base. Unit partly covered.

14

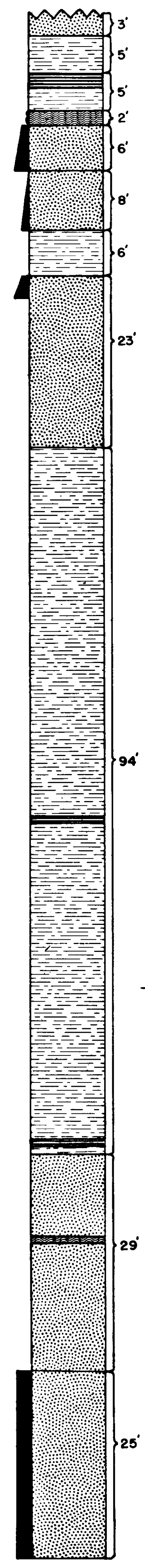
SECTION 14. Ohe half mile southeast of Cedar Camp on south side of ridge
El. at top of section - 7950 feet
SE NE S25-T16S-R22E



- 4' Sandstone; light gray, cross-bedded, fine grained to medium grained, iron staining.
- 18' Shale; light green, very thin bedded; 3 foot oil shale 5 feet from base; 6 foot algal limestone on top of oil shale.
- 47' Sandstone; light yellowish-brown, flaggy, fine grained, slightly calcareous and porous.
- 64' Shale; light green to brown; 1 foot oil shale 17 feet from base; 2 foot sand lense 19 feet from base; 1 foot oil shale 34 feet from base.
- 17' Siltstone; green, medium bedded; 1 foot of oolitic limestone with 1 foot of algal limestone on top of it, 15 feet from base.
- 20' Sandstone; light brown, cross-bedded and massive, medium grained, subangular, limonite blebs, calcareous.
- 25' Mudstone; light green, medium bedded, calcareous, unit partly covered.
- 45' Sandstone; light brown, fine to medium grained, cross-bedded and massive; 3 feet of weak saturation 38 feet from the base.

13

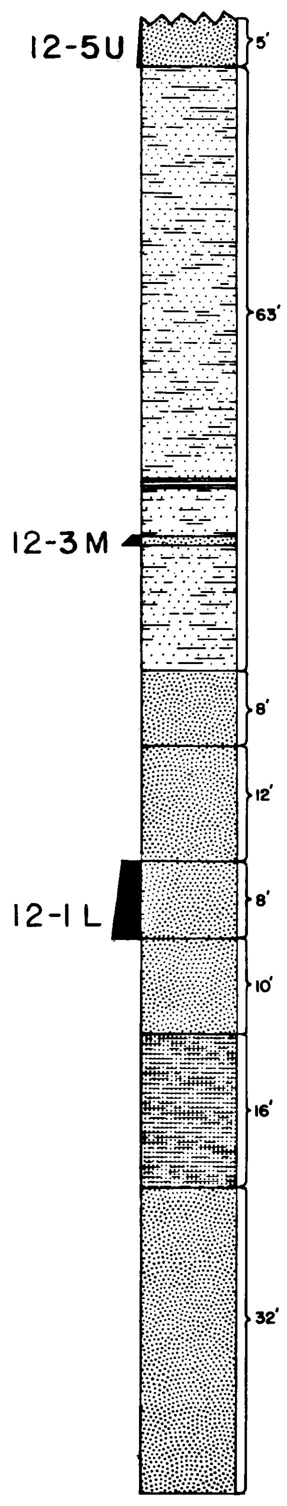
SECTION 13. Long point west of Tidewater Horse Point well, south side of Seep Ridge
El. top of section - 8130 feet
NE NE S27-T16S-R23E



- 3' Sandstone; light grayish-white, thin bedded, very fine grained.
- 5' Shale; light to medium brown, very thin bedded, very non-resistant, unit partly covered.
- 5' Shale; green thin bedded, calcareous; upper 2 feet are oil shale.
- 2' Algal limestone; light to medium gray, irregularly saturated.
- 6' Sandstone; light to medium gray, cross-bedded, massive, fine to medium grained, very calcareous, porous; weak to moderately saturated.
- 8' Sandstone; medium brown, weathers light yellowish-brown, flaggy, very fine to fine grained calcareous, irregularly stained to weakly saturated.
- 6' Shale; green thin bedded, calcareous, partly covered.
- 23' Sandstone; light greenish-brown, weathers light brown, cross-bedded, fine to medium grained, poorly sorted, micaceous, iron staining, calcareous and porous; last 3 feet weak to moderately saturated.
- 94' Shale; green, slightly calcareous; 1 foot oil shale 1 foot from base; 1 foot oil shale 44 feet from base.
- 29' Sandstone; green, very fine grained, calcareous, 6 foot algal bed with oolites 17 feet from base; unit partly covered.
- 25' Sandstone; medium gray, cross-bedded, medium grained, subangular, well weathered feldspar grains a little larger than quartz, micaceous; moderately saturated.

12

SECTION 12. One mile east of Tidewater Horse Point well
El. top of section - 8190 feet
SE NW S13-T16S-R23E



- 5' Sandstone; light yellowish-brown, weathers lighter, flaggy, fine grained, iron staining, stained near top of unit.
- 63' Siltstone; white to light gray, very thin bedded, very fine grained, non-calcareous; 1 foot moderate to weakly saturated conglomeratic sandstone 13 feet from base; 1 foot oil shale 19 feet from base, unit partly covered above oil shale.
- 8' Sandstone; white to light brown, weathers light gray to white, thick bedded, fine to medium grained, very calcareous in places, medium porosity, conglomeratic in places; top foot is very oolitic.
- 12' Sandstone; white to gray, flaggy, thin bedded, ripple marks and mud cracks.
- 8' Sandstone; black, cross-bedded, medium grained, subangular, micaceous, calcareous, non-porous, moderate to richly saturated.
- 10' Sandstone; light green, weathers light yellow-brown, fine grained subangular, calcareous, unit partly covered.
- 16' Mudstone; green non-calcareous, medium bedded.
- 32' Sandstone; light brown, weathers light grayish-brown, cross-bedded, fine to medium grained, angular to subangular.

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Bituminous Sandstone Study
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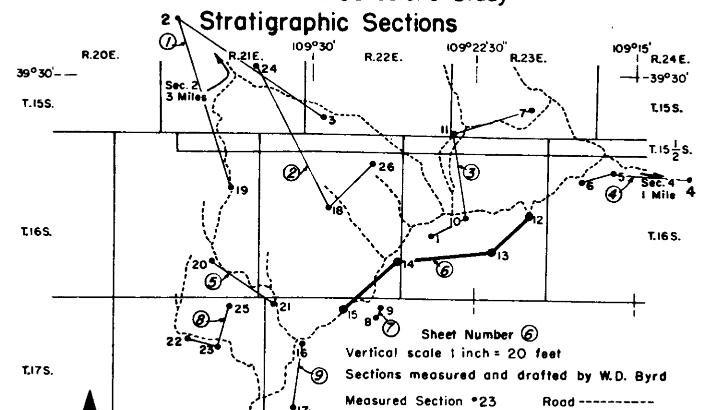

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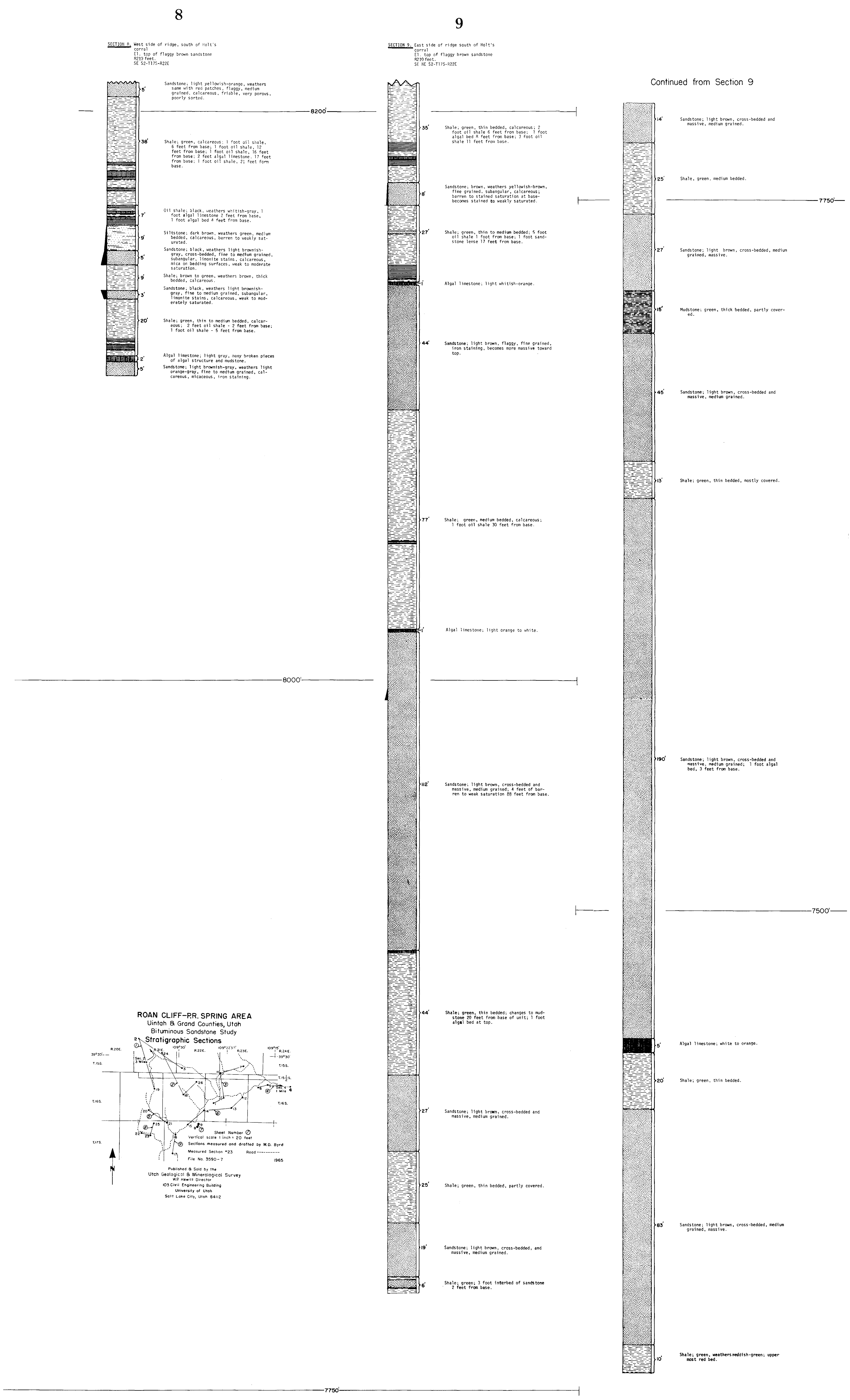
8
SECTION 8. West side of ridge, south of Holt's corral
El. top of flaggy brown sandstone 8210 feet.
SE S2-T17S-R22E
5' Sandstone; light yellowish-orange, weathers same with red patches, flaggy, medium grained, calcareous, friable, very porous, poorly sorted.
38' Shale; green, calcareous; 1 foot oil shale, 6 feet from base; 1 foot oil shale, 12 feet from base; 1 foot oil shale, 16 feet from base; 2 feet algal limestone, 17 feet from base; 1 foot oil shale, 21 feet form base.
7' Oil shale; black, weathers whitish-gray, 1 foot algal limestone 2 feet from base, 1 foot algal bed 4 feet from base.
9' Siltstone; dark brown, weathers green, medium bedded, calcareous, barren to weakly saturated.
5' Sandstone; black, weathers light brownish-gray, cross-bedded, fine to medium grained, subangular, limonite stains, calcareous, mica on bedding surfaces, weak to moderate saturation.
9' Shale; brown to green, weathers brown, thick bedded, calcareous.
3' Sandstone; black, weathers light brownish-gray, fine to medium grained, subangular, limonite stains, calcareous, weak to moderately saturated.
20' Shale; green, thin to medium bedded, calcareous; 2 feet oil shale - 2 feet from base; 1 foot oil shale - 5 feet from base.
2' Algal limestone; light gray, many broken pieces of algal structure and mudstone.
5' Sandstone; light brownish-gray, weathers light orange-gray, fine to medium grained, calcareous, micaceous, iron staining.
8200'
9
SECTION 9. East side of ridge south of Holt's corral
El. top of flaggy brown sandstone 8210 feet.
SE NE S2-T17S-R22E
35' Shale; green, thin bedded, calcareous; 2 foot oil shale 6 feet from base; 1 foot algal bed 8 feet from base; 3 foot oil shale 11 feet from base.
8' Sandstone; brown, weathers yellowish-brown, fine grained, subangular, calcareous; barren to stained saturation at base-becomes stained to weakly saturated.
27' Shale; green, thin to medium bedded; 5 foot oil shale 1 foot from base; 1 foot sandstone lense 17 feet from base.
1' Algal limestone; light whitish-orange.
44' Sandstone; light brown, flaggy, fine grained, iron staining, becomes more massive toward top.
77' Shale; green, medium bedded, calcareous; 1 foot oil shale 30 feet from base.
1' Algal limestone; light orange to white.
8000'
112' Sandstone; light brown, cross-bedded and massive, medium grained; 4 feet of barren to weak saturation 88 feet from base.
44' Shale; green, thin bedded; changes to mudstone 20 feet from base of unit; 1 foot algal bed at top.
27' Sandstone; light brown, cross-bedded and massive, medium grained.
25' Shale; green, thin bedded, partly covered.
19' Sandstone; light brown, cross-bedded, and massive, medium grained.
6' Shale; green; 3 foot interbed of sandstone 2 feet from base.
7750'
Continued from Section 9
14' Sandstone; light brown, cross-bedded and massive, medium grained.
25' Shale, green, medium bedded.
7750'
27' Sandstone; light brown, cross-bedded, medium grained, massive.
15' Mudstone; green, thick bedded, partly covered.
45' Sandstone; light brown, cross-bedded and massive, medium grained.
13' Shale; green, thin bedded, mostly covered.
190' Sandstone; light brown, cross-bedded and massive, medium grained; 1 foot algal bed, 3 feet from base.
7500'
5' Algal limestone; white to orange.
20' Shale; green, thin bedded.
83' Sandstone; light brown, cross-bedded, medium grained, massive.
10' Shale; green, weathers reddish-green; upper most red bed.
ROAN CLIFF-P.R. SPRING AREA
Uintah & Grand Counties, Utah
Bituminous Sandstone Study
Stratigraphic Sections
Sheet Number 7
Vertical scale 1 inch = 20 feet
Sections measured and drafted by W.D. Byrd
Measured Section •23   Road ----------
File No. 3590-7
1965
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Salt Lake City, Utah 84112

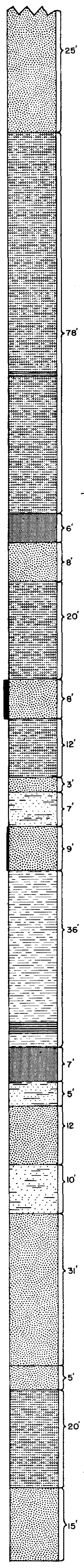
22

SECTION 22. West side of Steer Ridge near Pacific Natural Gas Segundo #1
El. at top of section - 8350 feet
NW SE S9-T17S-R21E

- 65' Shale; light brown, thin bedded, unit mostly covered; 55 feet from base float from a weakly saturated sandstone.
- 35' Sandstone; light yellowish-brown, flaggy, fine grained; unit mostly covered.
- 40' Shale; light green, thin bedded, calcareous, unit partly covered.
- 13' Sandstone; light brown, flaggy, very fine grained, calcareous.
- 22' Shale; green, thin bedded, calcareous.
- 10' Sandstone; light yellowish-brown, flaggy, fine grained, calcareous.
- 102' Shale; green, thin bedded, calcareous; 1 foot oil shale 2 feet from base; 2 foot sandstone 4 feet from base; 2 foot sandstone 39 feet from base; 1 foot algal limestone 41 feet from base; 1 foot algal limestone 59 feet from base;
- 17' Sandstone; light yellowish-brown, flaggy, fine grained, micaceous, limonite staining, calcareous, porous, ripple marks.
- 74' Shale; green, thin bedded, calcareous; 1 foot oil shale 33 feet from base; 1 foot oil shale 73 feet from base.
- 1' Algal limestone; whitish-orange.
- 3' Mudstone; green, thin bedded.
- 2' Sandstone; yellowish-brown, cross-bedded and massive, fine grained, micaceous, limonite staining, calcareous and porous.
- 32' Shale; dark greenish-brown, thin bedded, calcareous.
- 45' Sandstone; light yellowish-brown, massive and cross-bedded, medium grained, micaceous, calcareous and porous, friable; weak saturation starts 32 feet from base.
- 32' Mudstone; light greenish-brown, thin bedded, calcareous.
- 8' Oil shale; black, very thin bedded.
- 4' Algal limestone; dolomitic.
- 1' Siltstone; light brown, weathers with green siliceous rind.
- 2' Conglomerate; light brown, siliceous pebbles with a calcareous matrix.
- 29' Sandstone; light yellowish-brown, flaggy, cross-bedded, very fine grained, very micaceous, limonite blebs.
- 7' Mudstone; green, thin bedded.

23

SECTION 23. West side of Steer Ridge
El. at top of section - 8300 feet
NW NW S14-T17S-R21E



- 25' Sandstone; light orange, weathers light brownish-orange, massive and cross-bedded, fine grained and friable, micaceous, iron staining, calcareous, porous.
- 78' Mudstone; brown, thin bedded, slightly calcareous; 1 foot oil shale 28 feet from base; unit partly covered.

8200'

- 6' Algal limestone; light brown to white.
- 8' Sandstone; light yellowish-brown, massive and cross-bedded, fine to medium grained, poorly sorted, limonite blebs, calcareous, porous.
- 20' Mudstone; light green, thin bedded, calcareous.
- 8' Sandstone; light to medium gray, weathers light brownish-gray, medium to coarse grained, subangular to sub-rounded, micaceous, weakly saturated.

23

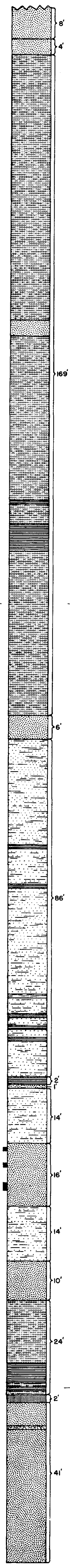
- 12' Mudstone; green, thin bedded, calcareous.
- 3' Sandstone; light orange-brown, weathers light brown, massive and cross-bedded, fine grained, calcareous, porous.
- 7' Siltstone; light brown, thin bedded, very calcareous.
- 9' Sandstone; light gray, weathers light brownish-gray, massive and cross-bedded, fine to medium grained, porous, stained saturation.
- 36' Shale; light brown, weathers light greenish-gray, thin bedded; 2 feet of oil shale 3 feet from base; becomes silty above 20 feet.
- 7' Algal limestone; light orange-brown to white, mostly broken algal structures.
- 5' Siltstone; green, thin bedded, slightly calcareous, non-resistant.
- 12 Sandstone; light yellowish-brown, massive and cross-bedded, fine grained, micaceous, calcareous and porous.
- 10' Siltstone; green, thin bedded, slightly calcareous, non-resistant.
- 31' Sandstone; light gray, massive and cross-bedded, medium grained, subangular, limonite blebs, calcareous.
- 5' Sandstone; light greenish-gray, massive and cross-bedded, very fine grained, limonite blebs, calcareous.
- 20' Mudstone; light greenish-gray, thin bedded, calcareous; oil shale zone 2 feet thick at base.

8000'

- 15' Sandstone; light yellowish-brown to gray, massive and cross-bedded, fine to medium grained, subangular, calcareous, porous.

25

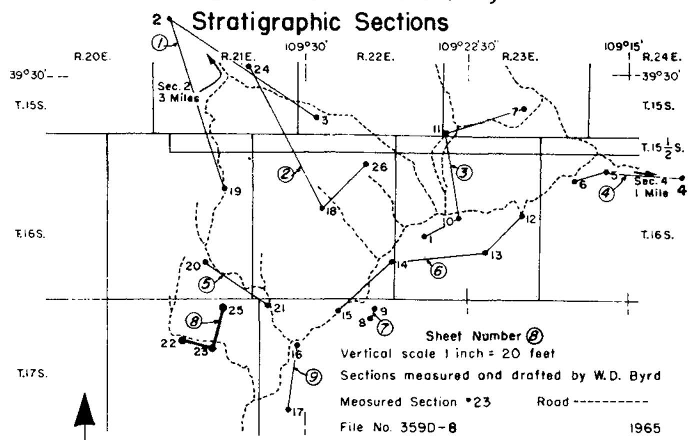
SECTION 25. North end of eastern airstrip on Steer Ridge on east side of strip
El. at top of section - 8350 feet



- 8' Sandstone; light gray, weathers light brownish-gray, cross-bedded, medium grained, subangular, limonite staining, non-calcareous, very porous.
- 4' Sandstone; light yellowish-brown, thin bedded, fine grained, limonite blebs, slightly calcareous and porous.
- 169' Mudstone; light green to white, calcareous; 7 foot oil shale 42 feet from base; 1 foot oil shale 54 feet from base; 4 foot sandstone 97 feet from base; becomes shaley above 150 feet from base.
- 6' Sandstone; light yellow, thin bedded, very fine grained, micaceous, calcareous and porous.
- 86' Siltstone; green, thin bedded, calcareous; 1 foot oil shale 9 feet from base; 1 foot oil shale 12 feet from base; 1 foot algal limestone 15 feet from base; 1 foot tuff? 20 feet from base; 1 foot oil shale 48 feet from base; 1 foot oil shale 58 feet from base.
- 2' Oil shale; black, very thin bedded.
- 1' Sandstone; light gray, weathers light orange, fine to medium grained, poorly sorted subangular grains, some reworked siltstone at base.
- 14' Siltstone; green, thin bedded, calcareous.
- 16' Sandstone; light yellowish-orange, weathers light brown, medium bedded, fine grained, micaceous, limonite staining, ripple marks; some bituminous staining 4 feet from base; 1 foot of weak saturation 10 feet from base; 1 foot of weak saturation 14 feet from base.
- 14' Siltstone; light green, thin bedded, calcareous, porous.
- 10' Sandstone; light yellowish-gray, thin to medium bedded, very fine grained, micaceous, calcareous and porous.
- 24' Mudstone; light gray, weathers white, thin bedded; 1 foot oil shale 1 foot from base; 5 feet of oil shale 3 feet from base.
- 2' Algal limestone; white.
- 41' Sandstone; light yellowish-gray, medium bedded, fine to medium grained, subangular, poorly sorted, very friable, micaceous, limonite staining, calcareous and porous; 1 foot of conglomerate with broken algal structures 34 feet from base.

ROAN CLIFF–P.R. SPRING AREA

Uintah & Grand Counties, Utah
Bituminous Sandstone Study
Stratigraphic Sections



Sheet Number 8
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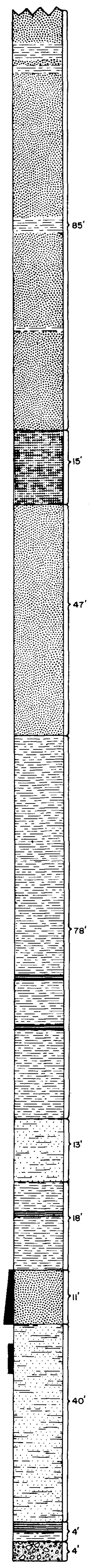
17

SECTION 17. West side of Westwater Point
near Steer Ridge turnoff
El. at top of section - 8690 feet
NW SW S29-T17S-R22E



85' Sandstone; light brown, thin bedded to flaggy micaceous; interbedded shales; unit is poorly exposed.

15' Mudstone; green, medium bedded; unit partly covered.

47' Sandstone; light brown, cross-bedded and massive, micaceous, limonite blebs, very porous.

78' Shale; green to brown, thin bedded, calcareous; 1 foot oil shale 18 feet from base; 1 foot oil shale 28 feet from base; unit partly covered.

8500'

13' Siltstone; light whitish-green, calcareous.

18' Shale; green to brown, thin bedded, pencil parting, calcareous; 1 foot oil shale 11 feet from base.

11' Sandstone, black, cross-bedded and massive, fine to medium grained, micaceous, non-calcareous and non-porous; weak to moderately saturated.

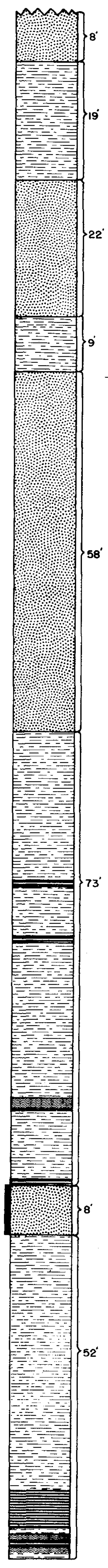
40' Siltstone; light green, medium bedded, calcareous; 6 feet of weak saturation 30 feet from base; unit partly covered.

4' Shale, green, thin bedded, slightly calcareous, 2 foot oil shale 2 feet from base; interbeds of algal structures.

4' Conglomerate; light whitish-brown, calcareous, algal structures.

16

SECTION 16. South side of Seep Ridge near, Moon Ridge turnoff
El. at top of section - 8360 feet
NW NE S17-T17S-R22E



8' Sandstone; red to redish-brown, flaggy, non-calcareous.

19' Shale; light brown, thin bedded.

22' Sahdstone; light brown, fine grained, micaceous and some iron staining, slightly calcareous, barren.

9' Shale; green, thin bedded, calcareous.

8300'

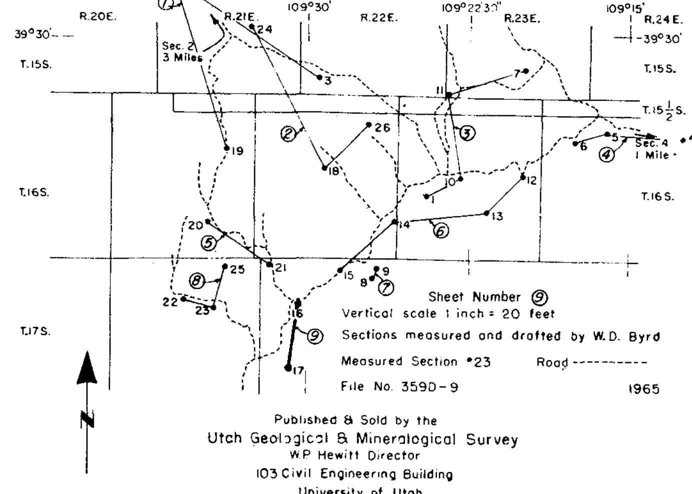
58' Sandstone; light brown, massive, cross-bedded, fine grained, calcareous, porous, iron staining.

73' Shale; green, thin bedded; 1 foot oil shale; 1 foot oil shale 10 feet from base; 2 foot algal limestone 12 feet from base; 1 foot oil shale 39 feet from base; 1 foot oil shale 48 feet from base; unit partly covered.

8' Sandstone; medium gray, weathers light brownish-gray, fine grained, micaceous, weakly calcareous; weakly saturated.

52' Shale; green, thin bedded; 1 foot algal limestone 1 foot from base; 1 foot oil shale 2 feet from base; 1 foot algal limestone 3 feet from base; 6 feet of oil shale 5 feet from base; unit becomes brown and silty toward the top.

ROAN CLIFF–P.R. SPRING AREA
Uintah & Grand Counties, Utah
Bituminous Sandstone Study
Stratigraphic Sections



Sheet Number ⑨
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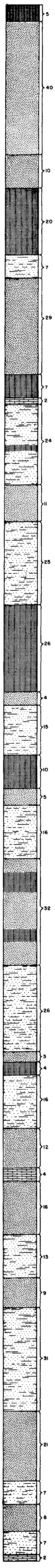
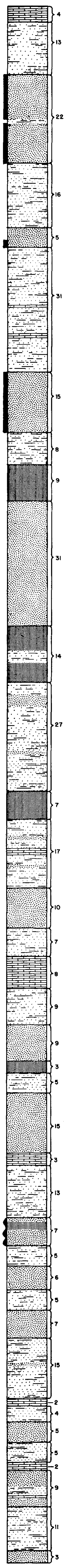
Section 30
SE ¼ Sec. 34, T 15 S, R 21 E
Section 33
SE ¼ Sec. 34, T 14 S, R 22 E
Section 27
SE ¼ Sec. 32, T 15 S, R 23 E
Section 28
SW ¼ NE ¼ Sec. 7, T 16 S, R 24 E

Section 32
SE ¼ Sec. 11, T 14 S, R 24 E



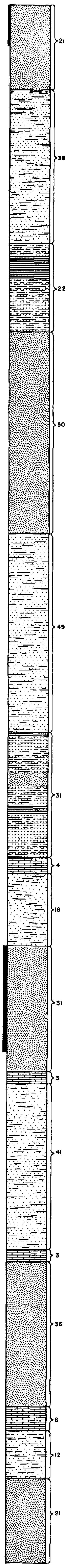
- 5 — Algal limestone; light brown, weathers light orange-brown, oolitic and ostracodal, very large silicified algal heads.
- 40 — Sandstone; light gray, massive, cross-bedded, medium grained, micaceous, calcareous, very porous and permeable.
- 10 — Sandstone; light brown, flaggy, fine grained, calcareous, very porous and permeable.
- 20 — Algal limestone; light brown, weathers light orange-brown, oolitic and ostracodal, very large silicified algal heads.
- 7 — Siltstone; light green, thin bedded, calcareous.
- 29 — Sandstone; light brown, massive, cross-bedded, fine to medium grained, micaceous, very calcareous, very porous and permeable.
- 7 — Algal limestone; light brown, weathers light orange-brown, oolitic and ostracodal, very large silicified algal heads.
- 2 — Oolitic limestone; white, weathers light grange, medium bedded.
- 24 — Siltstone; light green, thin bedded, calcareous, 2 feet of algal limestone 10 feet from base.
- 11 — Sandstone; light brown, massive, cross-bedded, medium grained, micaceous, very calcareous, very porous and permeable.
- 25 — Siltstone; light green, thin bedded, calcareous.
- 26 — Algal limestone; light brown, weathers light brown-orange, oolitic and ostracodal, very large algal heads.
- 4 — Sandstone; light gray, massive, cross-bedded, medium grained, micaceous, calcareous, very porous and permeable.
- 15 — Siltstone; light green, thin bedded, calcareous.
- 10 — Algal limestone; light brownish-white, weathers light brown to light orange, oolitic and ostracodal, very large algal heads.
- 5 — Sandstone; light brown, massive, cross-bedded, fine to medium grained, micaceous, very calcareous, very porous and permeable.
- 16 — Siltstone; light green, thick bedded, calcareous.
- 32 — Sandstone; light brown, massive, cross-bedded, fine to medium grained, micaceous, very calcareous, very porous and permeable, 4 feet of algal limestone 7 feet from base, 6 feet of algal limestone 22 feet from base.
- 26 — Siltstone; light green, thick bedded, calcareous.
- 3 — Sandstone; light brown, massive, cross-bedded, fine to medium grained, micaceous, very calcareous, very porous and permeable.
- 4 — Algal limestone; white, weathers light orange, massive, recrystallized, silicified, oolitic and ostracodal.
- 16 — Siltstone; light green, thick bedded, calcareous.
- 12 — Sandstone; light brown, massive, cross-bedded, fine to medium grained, micaceous, very calcareous, very porous and permeable.
- 4 — Limestone; white, weathers light orange, oolitic and ostracodal, fragmental, fairly permeable.
- 16 — Sandstone; light brown, massive, cross-bedded, fine to medium grained, micaceous, very calcareous, very porous and permeable.
- 13 — Siltstone; light green, thick bedded, calcareous.
- 9 — Sandstone; light yellow-brown, massive, cross-bedded, fine to medium grained, micaceous, very calcareous, very porous and permeable.
- 31 — Siltstone; light green, thick bedded, calcareous.
- 21 — Sandstone; light brownish-yellow, massive, cross-bedded, fine to medium grained, micaceous, very calcareous, very porous and permeable.
- 7 — Siltstone; light green, thick bedded, calcareous.
- 8 — Sandstone; light brownish-yellow, massive, cross-bedded, fine to medium grained, micaceous, very calcareous, very porous and permeable.
- 7 — Siltstone; light green, thick bedded, calcareous.
- 2 — Sandy limestone; light brownish-gray, medium bedded, a few ostracods.

Section 37
SE ¼ Sec. 25, T 14 S, R 23 E



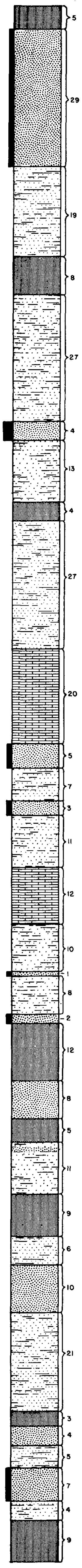
- 4 — Oolitic, ostracodal limestone; light gray, massive, weakly saturated.
- 13 — Siltstone; light green, thin bedded, calcareous, slope former, some covered.
- 22 — Sandstone; medium gray, massive, cross-bedded, fine grained, micaceous, calcareous, weakly saturated, 1 foot of siltstone 10 feet from base.
- 16 — Siltstone; light green, thin bedded, calcareous, slope former.
- 5 — Sandstone; light brown, flaggy, fine grained, micaceous, calcareous, lower 2 feet are weakly saturated.
- 31 — Siltstone; light green, thin bedded, calcareous, 2 feet of oolitic, ostracodal limestone 8 feet from base, 1 foot of oolitic, ostracodal limestone 16 feet from base.
- 15 — Sandstone; medium gray, massive, cross-bedded, fine to medium grained, micaceous, calcareous, irregular to weakly saturated.
- 8 — Siltstone; light green, thin bedded, calcareous, slope former.
- 9 — Oolitic, ostracodal, algal limestone; white, massive, porous and permeable.
- 31 — Sandstone; light brown, massive, cross-bedded, fine grained, micaceous, calcareous.
- 14 — Oolitic, ostracodal, algal limestone; white, massive, 3 feet of siltstone 5 feet from base.
- 27 — Siltstone; light green, thin bedded, calcareous, 1 foot of sandstone 9 feet from base, 3 feet of sandstone 21 feet from base.
- 7 — Oolitic, ostracodal, algal limestone; white, massive.
- 17 — Siltstone; light green, thin bedded, calcareous, 1 foot of sandstone 5 feet from base, 2 feet of oolitic, ostracodal limestone 8 feet from base, 1 foot of sandstone 12 feet from base.
- 10 — Sandstone; light brown, massive, cross-bedded, fine grained, micaceous, calcareous.
- 7 — Siltstone; light green, thin bedded, calcareous.
- 8 — Oolitic, ostracodal, algal limestone; white, massive.
- 9 — Siltstone; light green, thin bedded, calcareous.
- 9 — Sandstone; light brown, massive, cross-bedded, fine grained, micaceous, calcareous.
- 3 — Algal limestone; white, weathers light orange, massive.
- 5 — Siltstone; light green, thin bedded, calcareous.
- 15 — Sandstone; light brown, massive, cross-bedded, fine grained, micaceous, calcareous.
- 3 — Oolitic, ostracodal limestone; white, weathers light orange, massive.
- 13 — Siltstone; light green, thin bedded, calcareous.
- 7 — Sandstone; light gray to brown, massive, cross-bedded, fine grained, micaceous, calcareous, irregularly saturated, 2 feet of algal limestone 4 feet from base.
- 5 — Siltstone; light green, thin bedded, calcareous.
- 6 — Sandstone; light brown, massive, cross-bedded, fine grained, micaceous, calcareous.
- 5 — Siltstone; light green, thin bedded, calcareous.
- 7 — Sandstone; light brown, massive, cross-bedded, fine grained, micaceous, calcareous.
- 15 — Siltstone; light green, thin bedded, calcareous, 1 foot of sandstone 8 feet from base.
- 2 — Limestone; light gray, massive, medium crystalline, porous and permeable.
- 4 — Siltstone; light green, thin bedded, calcareous.
- 5 — Sandstone; light brown, massive, cross-bedded, fine grained, micaceous, calcareous.
- 5 — Siltstone; light green, thin bedded, calcareous.
- 2 — Limestone; white, weathers light brown, medium crystalline, some oolites, porous and permeable.
- 9 — Sandstone; light brown, massive, cross-bedded, fine grained, micaceous, calcareous, 1 foot of oolitic, ostracodal limestone 2 feet from base, 2 feet of light green siltstone 4 feet from base.
- 11 — Siltstone; light green, thin bedded, calcareous.
- 3 — Sandstone; light brown, massive, cross-bedded, fine grained, micaceous, very calcareous.

Section 29
SW ¼ Sec. 12, T 16 S, R 22 E



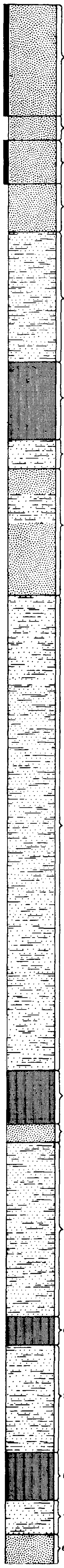
- 21 — Sandstone; light gray, weathers with light orange-brown rind, flaggy, fine to medium bedded, some clay, limonite, becomes coarser grained and very weakly saturated 10 feet from the top.
- 38 — Siltstone; light green to brown, thin platy bedding, calcareous, slope former.
- 22 — Mudstone; light greenish-gray, thin platy bedding, calcareous, 6 feet of oil shale 13 feet from base.
- 50 — Sandstone; light brown, cross-bedded, massive, very fine grained, micaceous, calcareous.
- 49 — Siltstone; light green to brown, thin platy bedding, calcareous, slope former.
- 31 — Mudstone; light greenish-gray, thin platy bedding, calcareous. 2 feet of oil shale 12 feet from base 3 feet of sandstone 19 feet from base 1 foot of oil shale 30 feet from base
- 4 — Oolitic limestone; orange to gray, ostracods and algal structures.
- 18 — Siltstone; light green, thin bedded, calcareous.
- 31 — Sandstone; light brown at base and gray above 5 feet, cross-bedded and massive, fine to medium grained, sub-angular, weakly saturated above 5 feet.
- 3 — Silty limestone; light brown, weathers light orange-brown, ostracods and oolites.
- 41 — Siltstone; light green, thin bedded, slightly calcareous, slope former.
- 3 — Limestone; light gray, massive and dense.
- 36 — Sandstone; light brown, cross-bedded, massive, fine to medium grained, micaceous, limonite, slightly calcareous, very porous.
- 6 — Limestone; light gray, massive, some silt, ostracods and oolites.
- 12 — Siltstone; light green, some fine sand grains, calcareous, slope former.
- 21 — Sandstone; light brown, massive and cross-bedded, fine grained, sub-angular, very permeable and slightly calcareous.

Section 36
NE ¼ Sec. 21, T 13 S. R 24 E



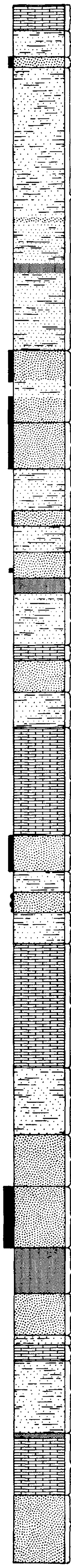
- 5 — Oolitic, ostracodal, algal limestone; dark gray, weathers light orange, weakly saturated.
- 29 — Sandstone; dark gray, massive, cross-bedded, fine grained, micaceous, calcareous, weakly saturated.
- 19 — Siltstone; light green, thin bedded, calcareous.
- 8 — Algal limestone; white, weathers light orange, massive.
- 27 — Siltstone; light green, thin bedded, calcareous.
- 4 — Sandstone; dark gray, massive, cross-bedded, medium grained, micaceous, calcareous, weak to moderate saturation.
- 13 — Siltstone; light green, thin bedded, calcareous.
- 4 — Algal limestone; dark gray, weathers light orange, massive, weakly saturated.
- 27 — Siltstone; light green, thin bedded, calcareous.
- 20 — Oolitic, ostracodal limestone; dark gray, weathers light orange, massive, weakly saturated.
- 5 — Sandstone; light gray, massive cross-bedded, fine grained, micaceous, calcareous, weakly saturated.
- 7 — Siltstone; light green, thin bedded, calcareous.
- 3 — Sandstone; medium gray, massive, cross-bedded, fine grained, micaceous, calcareous, weakly saturated.
- 11 — Siltstone; light green, thin bedded, calcareous.
- 12 — Oolitic, ostracodal limestone; light gray, weathers light orange, some thin algal layers.
- 10 — Siltstone; green, thin bedded, calcareous.
- 1 — Sandstone; dark gray, massive, cross-bedded, fine grained, micaceous, calcareous, weakly saturated.
- 8 — Siltstone; green to brown, thin bedded, calcareous, slope former.
- 2 — Sandstone; dark gray, massive, cross-bedded, fine grained, micaceous, calcareous, weakly saturated.
- 12 — Algal limestone; dark gray, weathers light orange, massive, oolitic-ostracodal matrix between heads is saturated.
- 8 — Sandstone; light gray to white, massive, cross-bedded, fine grained, micaceous, very calcareous.
- 5 — Algal limestone; white, weathers light orange, massive, large silicified algal heads, oolitic-ostracodal matrix between heads is weakly saturated.
- 11 — Siltstone; light green, thin bedded, calcareous, slope former, 1 foot of sandstone 9 feet from base.
- 9 — Algal limestone; white, weathers light orange to white, massive, oolitic and ostracodal.
- 6 — Siltstone; light green, thin bedded, calcareous, 1 foot of sandstone 3 feet from base.
- 10 — Sandstone; light brown, massive, cross-bedded, fine to medium grained, micaceous, calcareous.
- 21 — Siltstone; light green, thin bedded, calcareous.
- 3 — Oolitic, algal limestone; dark gray, weathers light orange, massive, some ostracods.
- 4 — Sandstone; light brown, massive, cross-bedded, fine grained, micaceous, limonitic, calcareous.
- 5 — Siltstone; light green, thin bedded, calcareous.
- 7 — Sandstone; dark gray, massive, cross-bedded, fine grained, micaceous, very calcareous, weakly saturated.
- 4 — Siltstone; light green, thin bedded, slightly calcareous.
- 9 — Oolitic, ostracodal, algal limestone; dark gray, weathers white, massive, weakly saturated.

Section 38
NE ¼ Sec. 4, T 13 S, R 25 E



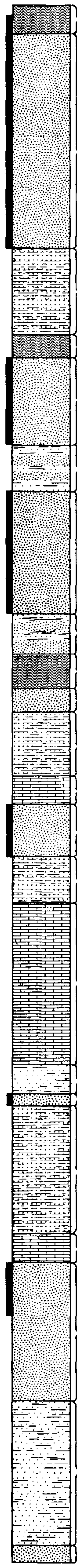
- 23 — Sandstone; medium gray, cross-bedded, fine to medium grained, micaceous, slightly calcareous and permeable, weakly saturated.
- 5 — Sandstone; light yellowish-brown, very fine grained, very permeable and friable.
- 9 — Sandstone; medium gray, flaggy, fine grained, micaceous, slightly calcareous, slightly permeable, weakly saturated.
- 10 — Sandstone; light brown, very fine grained, very permeable and friable.
- 27 — Siltstone; light green, thin bedded, calcareous.
- 16 — Algal limestone; white, weathers white to light orange, massive.
- 6 — Siltstone; light green, thin bedded, calcareous, slope former.
- 26 — Sandstone; light brown, massive, cross-bedded, fine grained, micaceous, slightly calcareous, friable, very permeable, 6 feet of siltstone 15 feet from base.
- 98 — Siltstone; light green, thin bedded, calcareous, slope former.
- 11 — Algal limestone; white, weathers light gray to white, massive, upper 9 feet have oolites and ostracods with patches of weak saturation.
- 4 — Sandstone; light brown, massive, friable, fine grained, micaceous, calcareous, very permeable.
- 36 — Siltstone; light green, thin bedded, calcareous, slope former.
- 8 — Algal limestone; white, weathers light orange to white, massive, some oolites and ostracods with irregular saturation.
- 22 — Siltstone; light green, thin bedded, calcareous, slope former.
- 10 — Algal limestone; white, weathers light orange, massive, a few oolites and ostracods, patches of irregular saturation.
- 7 — Siltstone; light green, thin bedded, calcareous, slope former.
- 6 — Sandstone; light brown, massive, cross-bedded, fine grained, micaceous, calcareous, very permeable and friable.

Section 34
NE ¼ Sec. 2, T 14 S, R 23 E



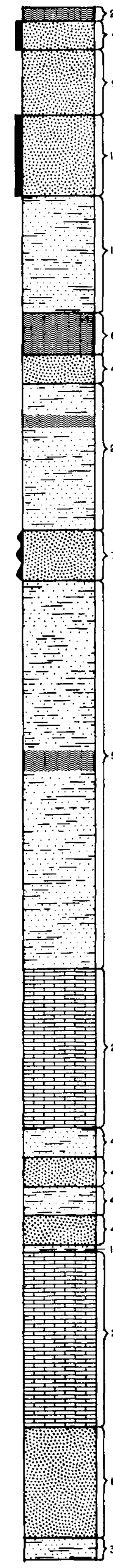
- 5 — Ostracodal limestone; medium gray, massive, weakly saturated.
- 5 — Siltstone; light green, thin bedded, calcareous.
- 2 — Sandstone; gray to dark gray, massive, cross-bedded, medium grained, micaceous, calcareous, weakly saturated.
- 55 — Siltstone; light green, thin bedded, calcareous, 2 feet of algal limestone 15 feet from base, 1 foot of sandstone 25 feet from base very weakly saturated.
- 14 — Sandstone; light gray, flaggy, very fine grained, calcareous, ostracodal, very weakly saturated, 3 feet of siltstone 5 feet from base.
- 9 — Sandstone; light gray, massive, cross-bedded, very fine grained, micaceous, calcareous, weakly saturated.
- 8 — Siltstone; light green, thin bedded, calcareous, satin spar stringers.
- 3 — Sandstone; light gray, massive, cross-bedded, very fine grained, micaceous, calcareous, very weakly saturated.
- 5 — Siltstone; light green, thin bedded, calcareous.
- 5 — Sandstone; light brown, thin bedded, very fine grained, calcareous, poor porosity and permeability, 1 foot of weak saturation 2 feet from base of unit.
- 3 — Algal limestone; dark gray, weathers light orange, large silicified algal heads with weak saturation.
- 10 — Siltstone; light green, thin bedded, calcareous.
- 3 — Limestone; light gray to white, very dense, massive, top 1 foot is algal limestone with ostracods.
- 6 — Sandstone; light brown, massive, cross-bedded, fine to medium grained, calcareous, porous and permeable.
- 7 — Siltstone; light green, thin bedded, calcareous.
- 21 — Ostracodal limestone; white, weathers light orange, massive, 2 feet of oolitic limestone with very weak saturation 3 feet from base.
- 7 — Sandstone; gray, massive, cross-bedded, fine grained, micaceous, calcareous, weakly saturated.
- 4 — Siltstone; light green, thin bedded, calcareous.
- 4 — Sandstone; light gray to brown, massive, cross-bedded, fine grained, micaceous, calcareous, very weak irregular saturation.
- 6 — Siltstone; light green, thin bedded, calcareous.
- 24 — Oolitic limestone; gray to dark gray, massive, silty, ostracodal.
- 13 — Siltstone; light green, thin bedded, calcareous.
- 10 — Sandstone; light brown, massive, cross-bedded, fine to medium grained, calcareous, porous and permeable.
- 12 — Sandstone; dark gray to black, weathers light gray, massive, cross-bedded, medium grained, slightly calcareous, moderately saturated.
- 9 — Algal limestone; light orange-brown, medium crystalline, massive, much of the matrix is oolites and ostracods.
- 8 — Sandstone; light brown, thin bedded, very fine grained, calcareous, poor porosity and permeability.
- 2 — Siltstone; green to brown, thin bedded, calcareous.
- 3 — Silty limestone; light gray, weathers light brown, medium bedded, coarsely crystalline, fossil fragments.
- 14 — Siltstone; green to brown, thin bedded, calcareous, mud cracks.
- 12 — Oolitic limestone; white, medium bedded, becomes ostracodal above 2 feet from base, 1 foot of algal limestone on top.
- 13 — Sandstone; light brownish-gray, massive, cross-bedded, fine to medium grained, calcareous, porous and permeable.

Section 31
NW ¼ Sec. 27, T 13 S, R 23 E

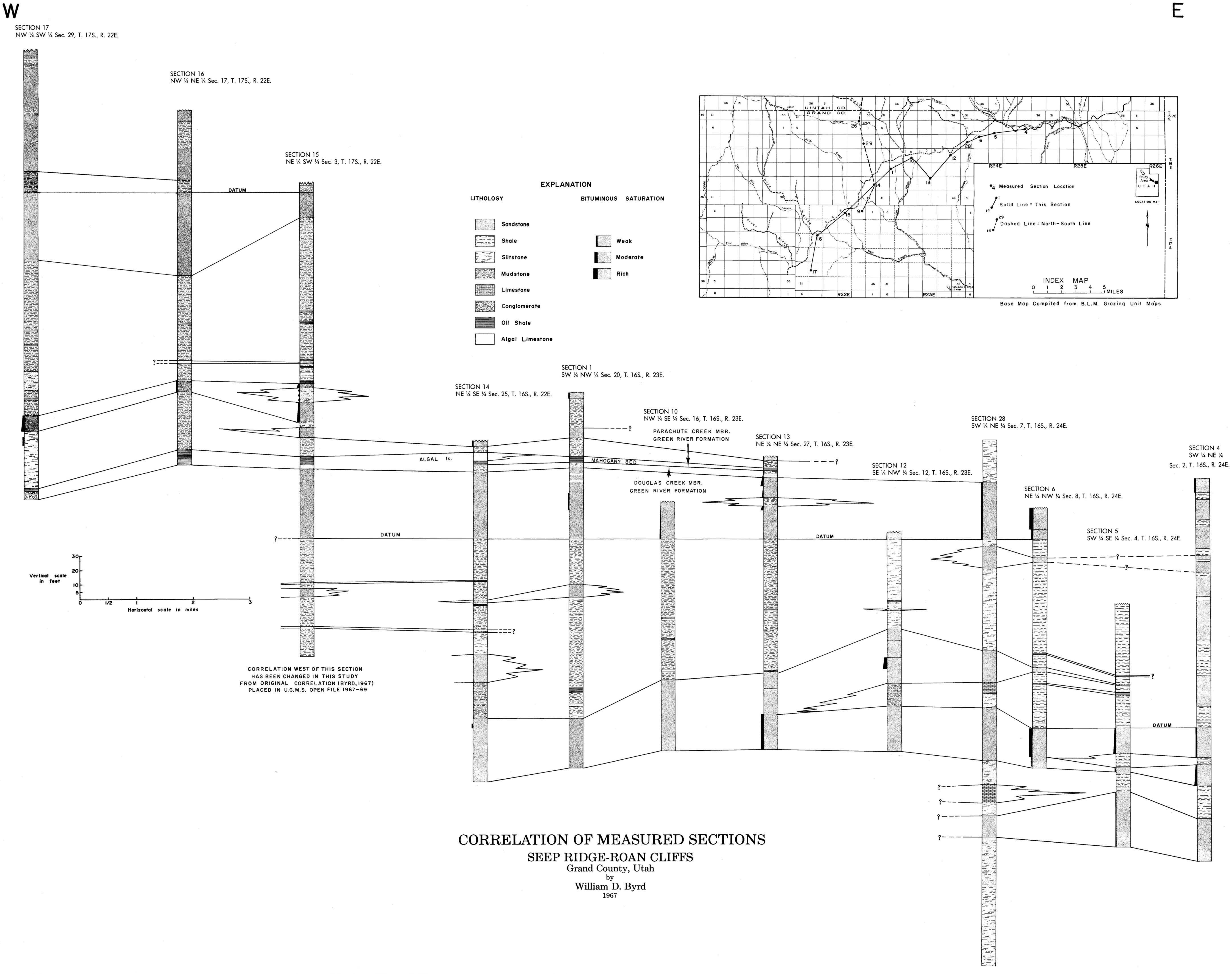


- 5 — Algal limestone; dark gray, massive, oolitic, lower 3 feet are weakly saturated.
- 37 — Sandstone; light gray, massive, cross-bedded, fine grained, micaceous, calcareous, weakly saturated.
- 15 — Mudstone; light green, thin bedded.
- 4 — Algal limestone; light orange, very dense.
- 15 — Sandstone; light gray, massive, cross-bedded, fine to medium grained, sub-angular, calcareous, weakly saturated.
- 8 — Interbedded sandstone and siltstone; 50% sandstone; thin bedded, very fine grained, calcareous. 50% siltstone; light green, thin bedded, calcareous.
- 21 — Sandstone; medium gray, massive, cross-bedded, fine to medium grained, sub-angular, micaceous, slightly calcareous, weakly saturated.
- 7 — Interbedded sandstones and mudstones; thin units, (1 foot maximum).
- 6 — Algal limestone; light orange, 4 to 5 foot algal heads, very dense.
- 4 — Sandstone; light gray, thin to medium bedded, medium grained, sub-angular, micaceous, slightly calcareous, porous.
- 12 — Mudstone; light green, thin bedded.
- 4 — Limestone; white to light orange, oolitic, ostracodal, large pebbles at base of unit, irregularly saturated in some places.
- 9 — Sandstone; medium gray, cross-bedded, medium grained, sub-angular, micaceous, slightly calcareous, weakly saturated.
- 8 — Mudstone; light green, thin bedded.
- 28 — Limestone; chalky-white, oolitic and ostracodal, top 8 feet are weakly saturated.
- 5 — Siltstone; light green, thin bedded, calcareous, slope former.
- 2 — Sandstone; light gray, massive, cross-bedded, fine to medium grained, sub-angular, limonite, micaceous, calcareous, weakly saturated.
- 22 — Mudstone; green, thin bedded, slope former.
- 5 — Oolitic limestone; light orange to white, ostracods.
- 24 — Sandstone; light brown, massive, cross-bedded, medium grained, slightly calcareous, oolitic, very permeable, ostracods, becomes weakly saturated 15 feet from base.
- 25 — Siltstone; light green, thin bedded, calcareous.
- 3 — Sandstone; light green, massive, fine grained, sub-angular, calcareous, fossil fragmental.

Section 35
C Sec. 12, T 13 S, R 23 E



- 2 — Algal limestone; dark gray, massive, ostracodal, weakly saturated.
- 4 — Sandstone; dark gray, flaggy, fine grained, micaceous, calcareous, weakly saturated.
- 9 — Sandy siltstone; light brown, thin bedded, calcareous.
- 11 — Sandstone; medium gray, massive, cross-bedded, fine grained, micaceous, limonite, calcareous, weakly saturated.
- 16 — Siltstone; light green, thin bedded.
- 6 — Algal limestone; white to dark gray, weathers white, large silicified algal heads, with weakly saturated ostracodal matrix.
- 4 — Sandstone; light brown, massive, cross-bedded, very fine grained, micaceous, calcareous, porous and permeable.
- 20 — Siltstone; light green, thin bedded, 2 feet of algal limestone with large algal heads 14 feet from base.
- 7 — Sandstone; light gray to light brown, massive, cross-bedded, fine grained, micaceous, very calcareous, irregular saturation.
- 53 — Siltstone; light green, thin bedded, 3 feet of algal limestone with large algal heads 27 feet from base.
- 22 — Oolitic limestone; white, weathers light orange to white, large oolites, ostracodal, some thin algal layers.
- 4 — Siltstone; light green, thin bedded.
- 4 — Sandstone; light gray, weathers light brownish-gray, massive, cross-bedded, medium grained, poor sorting and rounding, micaceous, calcareous, porous and permeable.
- 4 — Siltstone; light green, thin bedded.
- 4 — Sandstone; light gray, weathers light brownish-gray, massive, cross-bedded, medium grained, poor sorting and rounding, micaceous, calcareous, porous and permeable.
- 1 — Siltstone; light green, thin bedded.
- 24 — Oolitic limestone; white, weathers light orange to white, large oolites, ostracodal, some thin algal layers.
- 15 — Sandstone; light brown, massive, cross-bedded, medium grained, micaceous, very calcareous, porous and permeable, fossil fragments at base, poorly sorted, larger grained toward top of unit.
- 3 — Siltstone; light green, thin bedded, calcareous, satin spar stringers.



CORRELATION OF MEASURED SECTIONS

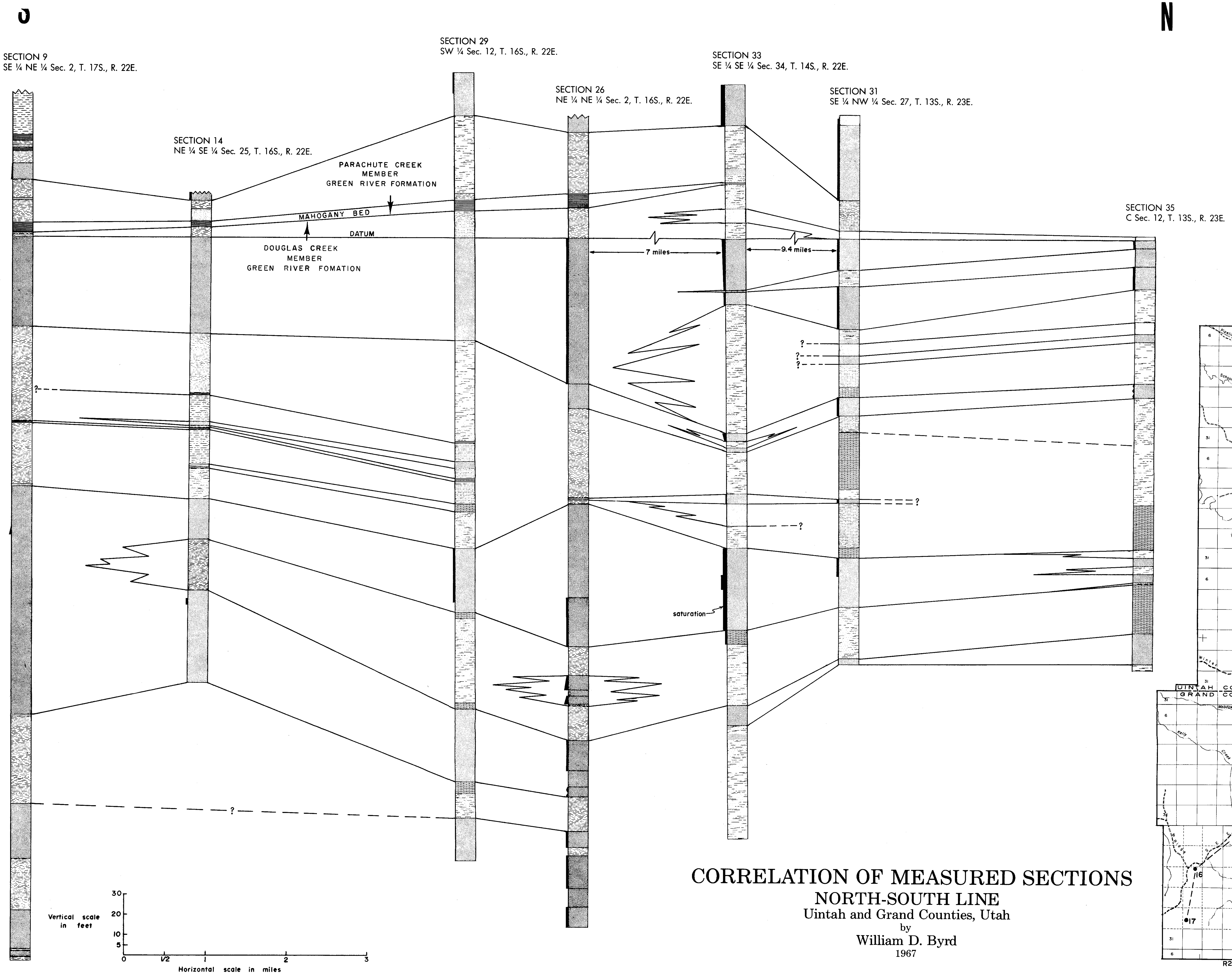
SEEP RIDGE-ROAN CLIFFS

Grand County, Utah

by

William D. Byrd

1967



CORRELATION OF MEASURED SECTIONS
NORTH-SOUTH LINE
Uintah and Grand Counties, Utah

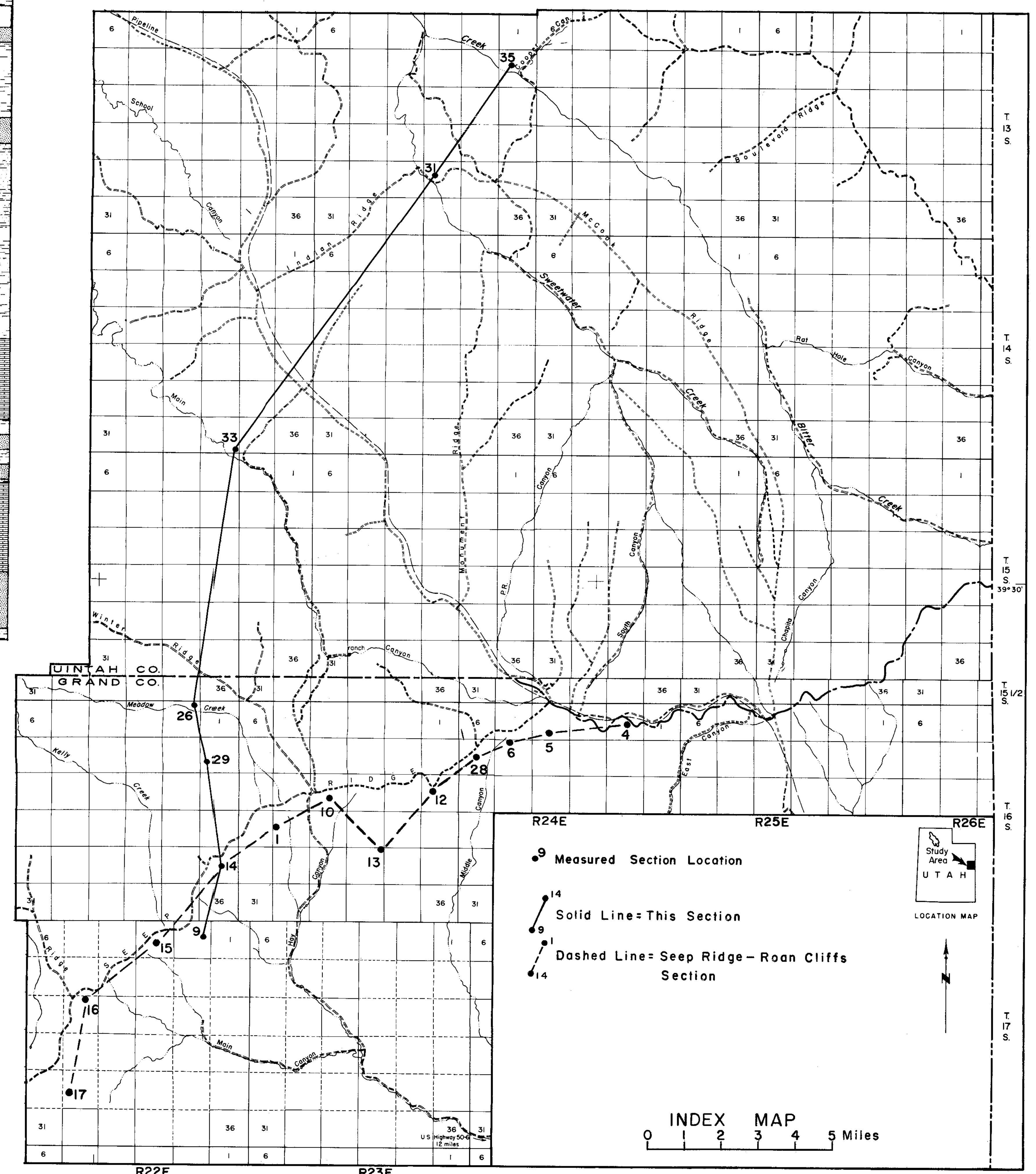
by

William D. Byrd

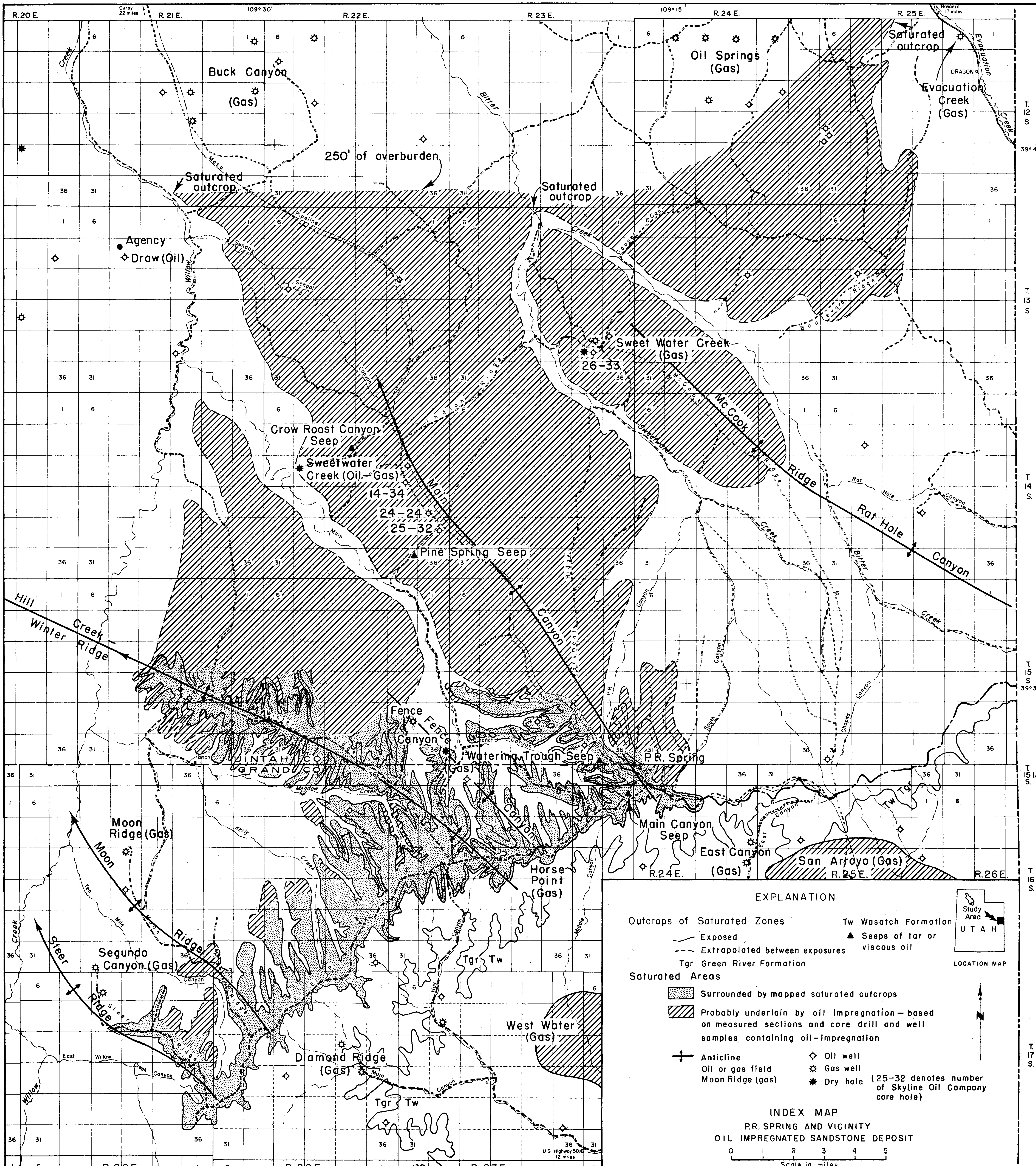
1967

EXPLANATION

LITHOLOGY	BITUMINOUS SATURATION
Sandstone	
Shale	Weak
Siltstone	Moderate
Mudstone	Rich
Limestone	
Conglomerate	
Oil Shale	
Algal Limestone	

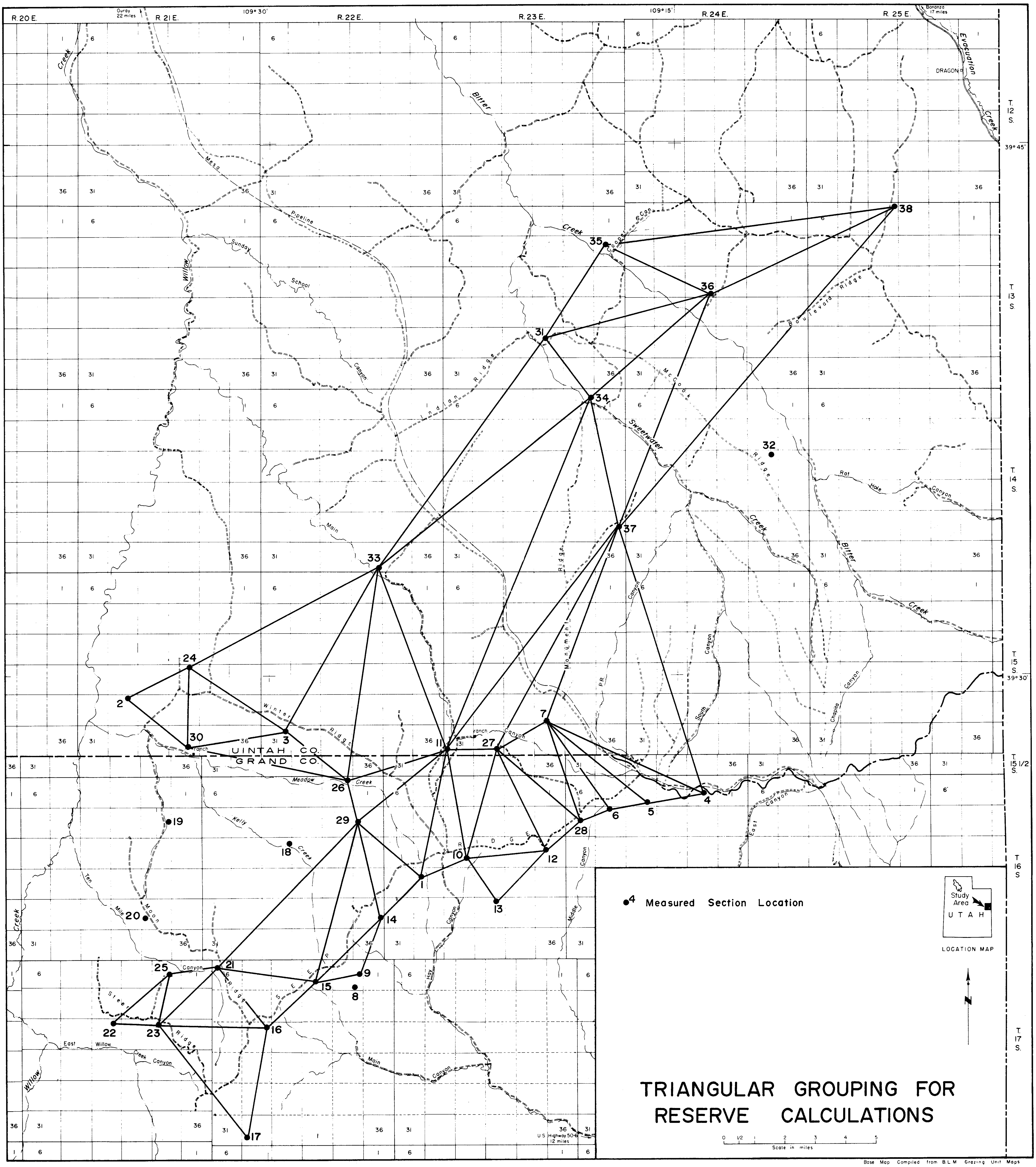


Base Map Compiled from B.L.M. Grazing Unit Maps



Base Map Compiled from B.L.M. Grazing Unit Maps


MAP OF SOUTHERN PART OF
P.R. SPRING
OIL-IMPREGNATED SANDSTONE DEPOSIT
Uintah & Grand Counties, Utah
PUBLISHED AND SOLD BY THE
UTAH GEOLOGICAL AND MINERALOGICAL SURVEY
W. P. HEWITT, DIRECTOR.
103 CIVIL ENGINEERING BUILDING
UNIVERSITY OF UTAH
SALT LAKE CITY, UTAH 84112
EXPLANATION
State Land
County Line
Indian Reservation
"Graded" Road
Unimproved Road
Stream or Drainage
Drainage Reservoir
Bituminous Sandstone Outcrop
Inferred Bituminous Sandstone Outcrop
Mapping not completed
Measured Section with Analysis
Measured Section
Saturation / Thickness VW / 10
Gas Test Wells GSI PGW P-A
Bench Mark
Spring
Adit
Fence
Ranch
Pipeline
VISUAL SATURATION ESTIMATE X
VR Very Rich
R Rich
M Moderate
W Weak
VW Very Weak
SATURATION INDEX
0 1 2 Miles
Scale
Drafted by J. W. Gwynn 1965
N
UTAH
STUDY AREA
GSI – Gas Shut in, PGW – Producing Gas Well, P-A – Plugged & Abandoned
UINTAH COUNTY
GRAND COUNTY
UINTAH OURAY INDIAN RESERVATION
SAN ARROYO GAS FIELD
Base compiled from Soil Conservation Service mosaics and survey plots.
FIELD WORK by J. W. GWYNN & W. D. BYRD – SUMMER 1965
ASSISTED by H. SUEKAWA & Wm WHITE


TRIANGULAR GROUPING FOR RESERVE CALCULATIONS
Measured Section Location
LOCATION MAP
Study Area
UTAH
Scale in miles
Base Map Compiled from B.L.M. Grazing Unit Maps
R. 20 E.
R. 21 E.
R. 22 E.
R. 23 E.
R. 24 E.
R. 25 E.
T. 12 S.
T. 13 S.
T. 14 S.
T. 15 S.
T. 15 1/2 S.
T. 16 S.
T. 17 S.
109° 30'
109° 15'
39° 45'
39° 30'
UINTAH CO.
GRAND CO.
Ouray 22 miles
Bonanza 17 miles
DRAGON
Evacuation Creek
Bitter Creek
Willow Creek
Sweetwater
Main Canyon
Winter Ridge
Meadow Creek
Kelly Creek
Ten Mile
Moon
East Willow Creek Canyon
Boulevard Ridge
Rat Hole Canyon
Monument Ridge
Indian Ridge
Sunday School Canyon
Pipeline
U.S. Highway 50-6 12 miles