DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Oil Shale Resources of the Mahogany zone in eastern Uinta Basin, Uintah County, Utah

by

John R. Dyni, John R. Donnell, Wilbur D. Grundy, William B. Cashion, Louis A. Orlowski, and Courteney Williamson

Denver, Colorado

Open-File Report 91-285

Prepared in cooperation with the U.S. Bureau of Land Management and the Utah Divsion of Land and Forestry

1991

CONTENTS

ILLUSTRATIONS

TABLES

OIL-SHALE RESOURCES OF THE MAHOGANY ZONE IN EASTERN UINTA BASIN, UINTAH COUNTY, UTAH

By

John R. Dyni, John R. Donnell, Wilbur D. Grundy, William B. Cashion, Louis A. Orlowski, and Courteney Williamson

U.S. Geological Survey
Denver, Colorado

ABSTRACT

The Mahogany oil-shale zone of the Parachute Creek Member of the Eocene Green River Formation contains an estimated 10.4 billion barrels of shale oil in strata that yield an average of 25 gallons of shale oil per ton of rock on about 87,736 acres of state lands in area of about 1,100 mi^2 in the eastern part of the Uinta Basin, Uintah County, Utah . About 1.7 billion barrels of shale oil in strata averaging 25 gallons per ton were estimated to be present on Federal oil-shale tracts Ua-Ub, an area of about 10,273 acres.

In the southwestern part of the study area, the Mahogany zone is as much as 136 ft thick but contains only 50-60 KBPA (thousands of barrels of shale oil per acre) owing to the presence of large amounts of clastic sediments that were derived from a southerly source. Northward, across the middle of the study area, the Mahogany zone thins to 60-75 ft along a line between the approximate centers of T.10 S., R.20 E., and T.12 S., R.25 E. A little south of this belt of thinner Mahogany, and parallel to it, is a poorly defined trend of richer grade oil shale that averages 100-120 KBPA. The Mahogany zone thickens again to about 130-135 ft and increases in oil yield to about 190-210 KBPA toward the depositional axis of the basin on the north side of the study area. The increase in thickness is probably the consequence of increased amounts of organic matter and syngenetic carbonate minerals that were deposited in the axial part of the basin.

The estimated error (two standard deviations) of the oil-shale resources calculated for 63 individual tracts or groups of tracts of state and Federal lands, with two exceptions, ranges from ±5.9 to ±67.6 percent, with an average error of ±28.3 percent. Tracts with the largest errors are found in the southwestern and northwestern parts of the study area where subsurface data are less reliable.

INTRODUCTION

In early 1989, the Utah Division of State Lands and Forestry and the U.S. Bureau of Land Management asked the U.S. Geological Survey to make an assessment of the oil-shale resources of selected state and Federal lands in the eastern part of the Uinta Basin, Uintah County, Utah. The work was authorized by a Memorandum of Understanding (MOU) signed by the three agencies on January 29, 1990 (appendix A-1). The work was scheduled for completion in 180 working days, or by October 17, 1990.

Memorandum of understanding

The MOU specified that the Geological Survey would make an assessment of the oil-shale resources of the Mahogany oil-shale zone of the Parachute Creek Member of the Eocene Green River Formation for state lands selected by the Division of State Lands and Forestry as well as the lands within the Federal oil-shale tracts Ua-Ub. Those intervals within the Mahogany zone that average 25 gallons or more of oil per ton (GPT) of oil-shale rock, and that are more than 10 ft thick, were to be evaluated. The Mahogany zone contains a few intervals less than 10 ft thick that average 25 or more GPT that were also included in the evaluation. Oil shale underlying and overlying the Mahogany zone was excluded from this study, as were tar sands, gilsonite, oil and gas, and coal, which are known to be present in the area.

Project personnel

The project leader was John R. Dyni. John R. Donnell and William B. Cashion were employed for parts of the investigation because of their expertise in the geology of oil-shale resources of the Green River Formation. Donnell prepared the stratigraphic cross sections showing bargraphs of shale-oil yields for selected core holes (plates 6-10) and reviewed all of the shale-oil data. Cashion prepared two stratigraphic cross sections showing the lithology of the Mahogany zone across the study area (plates 11 and 12). Wilbur D. Grundy, assisted by Louis A. Orlowski, was responsible for the geostatistical aspects of this study which include estimation of the shale-oil resources by kriging methods, preparation of the structure, isopach, and resource maps of the Mahogany zone (plates 2, 3, and 4), and writing the section on geostatistical methodology. Courteney Williamson prepared the base map of the study area (plate 1), digitized the boundaries of the evaluated tracts, and supervised the drafting of plates 2-12. The overburden map (plate 5) was adapted from Smith (1981). The report was written and reviewed by all of the authors.

The persons monitoring the work being done under the MOU were John T. Blake, Utah Division of State Lands and Forestry, Salt Lake City, Utah, Randy Heuscher, U.S. Bureau of Land Management, Salt Lake City, Utah, and John R. Dyni, U.S Geological Survey, Lakewood, Colorado.

Acknowledgments
Special thanks are due Richard B. Taylor and Gary I. Selner, U.S. Geological Survey, for helping the authors with the details and vagaries of making computer maps. Frances Gay digitized many of the geophysical logs and correlated them with the shale-oil analyses. Some of the illustrations were drafted by Carol S. Holtgrewe and George M. Garcia.

STUDY AREA

The lands originally selected for evaluation of oil shale resources include Federal oil-shale lease tracts Ua and Ub, which total 10,273 acres, and 168 tracts of state land, totaling approximately 135,000 acres, which were selected by the Utah Division of Lands and Forestry (appendices A-2 and A-3). These tracts lie in a 1,500 mi^2 area bounded by Tps. 7-13 S., Rs. 20-25 E., Uintah County, Utah and they are plotted on plate 1. Most of the tracts in Tps. 7-8 S., Rs. 20-25 E., could not be adequately evaluated for oil-shale resources for lack of core hole data, therefore, these lands (tracts 1-46 on plate 1) were omitted.

Some state lands in the southern part of the study area were excluded because the Mahogany zone is not present. Additional small parcels of nonstate lands lying within the boundaries of state lands were also eliminated. Thus, the number of state-land tracts which were evaluated for oil-shale resources was reduced to 104, totaling approximately 87,736 acres. These tracts lie within Tps. 9-13 S., Rs. 20-25 E. and the southernmost row of sections in T. 8 S., Rs. 20-25 E. The Federal oil-shale tracts Ua-Ub in the eastern part of the study area in T. 10 S., Rs. 24-25 E., which total about 10,273 acres, were also included for oil-shale evaluation. The boundary for the Federal tracts was provided by David E. Little, U.S. Bureau of Land Management, Vernal, Utah (Appendix A-4).

The study area is largely uninhabited and semiarid. The topography consists of a broad northward-sloping plateau, cut by many deep canyons and ravines, that rises from about 5,000 ft along the Green River in the northwestern part of the study area to about 7,800 feet near the southeastern corner of the study area. Most of drainage is to the north into the Green and White Rivers (plate 1). The major streams that are tributary to the Green and White Rivers are Evacuation Creek, Bitter Creek, Willow Creek, and Hill Creek. Vegetation in much of the area is sagebrush, sparse grasses, rabbitbrush, juniper, and western cedar. Access to the area is largely by gravel and dirt roads with the exception of the paved Uintah County Road 262, Utah State Highways 45 and 191, and U.S. Highway 40 in the northeastern part of the study area.

PREVIOUS INVESTIGATIONS

The geology of parts of the study area was mapped previously (figure 1). Cashion (1967) mapped the geology of the Green River Formation and associated rocks in the southeastern part of the Uinta Basin which includes the southern and eastern one-third of the study area. The geology of 12 7½-minute quadrangles has been mapped in detail by other workers. These quadrangles are Agency Draw NE (Pipiringos, 1979), Agency Draw NW (Cashion, 1984), Bates Knolls (Pipiringos, 1978), Bonanza (Cashion, 1986), Burnt Timber Canyon (Keighin, 1977a), Cooper Canyon (Keighin, 1977b), Davis Canyon (Pantea, 1987), Dragon (Scott and Pantea, 1985), Rainbow (Keighin, 1977c), Southam Canyon (Cashion, 1974), Walsh Knolls (Cashion,1978), and Weaver Ridge (Cashion, 1977) (figure 1). A map showing structure contours and overburden on the Mahogany zone in the eastern Uinta Basin, including the study area was published by Smith (1981). Trudell and others (1982, 1983) made a regional study of the oil-shale resources of the Green River Formation in the eastern Uinta Basin, which also includes the study area.

GEOLOGIC SETTING

The study area is located in the southeastern part of the large sedimentary-structural Uinta Basin in Uintah County, northeastern Utah. In the eastern part of the Uinta Basin, large resources of oil shale are found in the Parachute Creek Member of the Green River Formation. The largest part of these resources are found in the Mahogany oil-shale zone within the member.

The Mahogany oil-shale zone crops out in the southern part of the study area in canyons and arroyos. The thickness of overburden on the zone ranges from zero in the southern part of the area to about 3,600 ft in the northern part of the area (plate 5). The Mahogany zone dips to the north or north-northwest at about 150 to 175 ft per mile. Along the eastern edge of the area in Tps. 10-11 S., R. 25 E, the rocks increase abruptly in dip to as much as 1,000 ft per mile to the west along the flank of an unnamed structural nose on the Douglas Creek arch east of the study area (plate 2). The structural axis of the Uinta Basin lies north of the map area. Some northwest- and northeast-trending faults with displacements of generally less than 50 ft are found in parts of the area (not shown on plate 2).

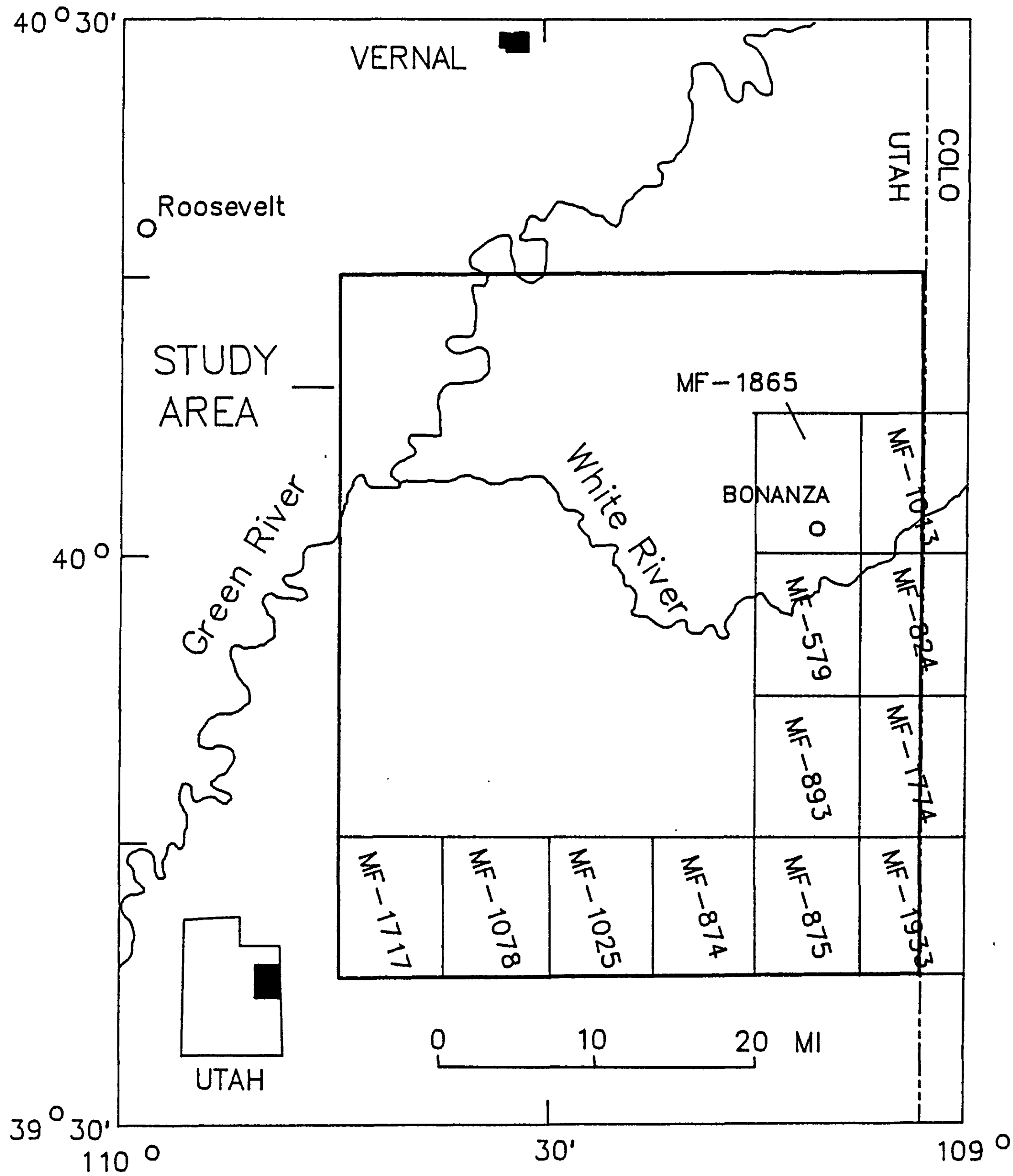


Figure 1.--Index map of the study area in eastern Uinta Basin, Utah, showing the locations of published geologic quadrangle maps in the USGS MF map series (See References for authorship of maps).

GREEN RIVER FORMATION

The Green River Formation underlies most of the study area. It crops out in the southern part of the study area and dips northward beneath younger clastic rocks of the overlying Uinta Formation of Eocene age toward the depositional axis of the Uinta Basin. A few faults with displacements of about 10 to 30 ft that form grabens have been mapped on 7½-minute quadrangle maps in the southern part of the study area. Faults with similar displacements can be expected in other parts of the study area that have not yet been mapped in detail. The overall structure of the Green River Formation is relatively simple and it probably has little or no effect on the oil-shale resources in the study area. The Green River Formation in the study area is divided into the Douglas Creek Member and the overlying Parachute Creek Member.

The Douglas Creek Member, about 1,200 to 1,900 ft thick, consists of nearshore-lacustrine rocks including sandstone, mudstone, siltstone, stromatolites, and chalky limestone that intertongue with the offshore-lacustrine oil shale and marlstone in the lower part of the Parachute Creek Member. Sandstones and siltstones of the Douglas Creek Member are commonly oil-stained on outcrops in the southern part of the study area. In places, tar sands of the Douglas Creek underlie the Mahogany zone. These rocks could be mistaken for oil shales on profiles of Fischer assay analyses of drill cores that penetrate the Douglas Creek Member.

The Parachute Creek Member contains most of the oil shale found in the Green River Formation. The member consists of brown to black oil shale, gray and yellowish-brown marlstone, thin beds of yellowish-brown siltstone, and thin layers of volcanic tuff. The member ranges from about 700 to 1,200 ft in thickness. The Mahogany oil-shale zone is a distinctive lithologic unit consisting of medium- to high-grade oil shale and kerogenous marlstone within the Parachute Creek Member. It can be identified over a large part of the Uinta Basin. In the southeast part of the study area, the Mahogany zone lies about 450 to 550 feet below the top of the Parachute Creek Member. In the southern part of the study area, the Mahogany zone is situated at or near the base of the Parachute Creen Member. The interval between the base of the Mahogany zone and the base of the Parachute Creek Member thickens northward as the Douglas Creek Member thins. Beds of oil shale that could be classified as resources are also present in the member both above and below the Mahogany zone.

Mahogany oil-shale zone

The Mahogany zone is 58 to 136 feet thick in the study area. It reaches a thickness of about 134 feet along the north side of the study area (plate 3, figure 2). This increase in thickness is attributable to deposition of organic matter and carbonate minerals in the offshore central part of the lake basin. The

Mahogany decreases southward in thickness to about 60 to 75 feet along an east-northeast-trending line between the centers of T.10 S., R.20 E., and T.12 S., R.25 E. (plate 3). South of this area, the Mahogany zone thickens again toward the southwestern corner of the study area where it reaches about 136 feet in thickness owing to influx of fine-grained clastic sediments derived from a southerly source. These clastic sediments intertongue with beds of oil shale, especially in the lower half of the Mahogany zone (plates 11 and 12).

In cores, the Mahogany zone consists of varied shades of brown to black laminated oil shale and numerous thin layers of analcimized, commonly oil-stained, tuff. Many thin beds of richer grade oil shale in the zone, which are distinguishable on shale-oil bargraphs as well as on density and sonic logs of oil and gas wells, can be traced with confidence in the subsurface throughout the study area. Disseminated pyrite and nodules and stringers of calcite are common. Sparse pods of coarsely crystalline nahcolite have been found in the unit. Ground water has dissolved some of the water-soluble nahcolite leaving open cavities in the rock. The principal mineral components found by X-ray diffraction analysis include dolomite, feldspars, quartz, calcite, illite, smectite, and some magnesian siderite and pyrite. Pyrrhotite is also found in small amounts and abelsonite is occasionally reported.

The Mahogany zone is overlain by A-groove, a unit of kerogenous marlstone about 10 to 12 ft thick that averages less than 10 gallons of shale oil per ton. The A-groove is easily recognized on shale-oil bargraphs (plates 6-10). Because of intertonguing with clastic sediments, the base of the Mahogany zone is less well defined in the study area. The contact is picked at the base of a unit of oil shale about 3 to 6 ft thick below which the rocks are dominantly marlstones or siltstones that yield only a few gallons of oil per ton. In parts of the study area, bituminous sandstones underlie the Mahogany zone. These sandstones may yield as much as 20-30 gallons of oil by Fischer assay. Tuff beds are often saturated with bitumen which contributes additional oil to the Fischer assay.

Oil-shale resources of the Mahogany zone

Variations in shale-oil values of the Mahogany zone are illustrated on cross sections AA′,BB′,CC′,DD′, and EE′ (plates 6 through 10). These cross sections show bargraphs of shale-oil analyses for selected drill holes in the study area. Several plots of digitized sonic and density logs plotted against depth for oil and gas wells are also included in those parts of the study area lacking core holes. Cross sections AA′, BB′, and CC′ are oriented west to east across the study area, cross sections DD′, EE′, and GG′ are oriented south to north, and cross section FF′ is drawn from the southwest corner of the study area to the east side of Federal tracts Ua-Ub (figure 3). The stratigraphic datum for the cross sections is the Mahogany oil-shale bed.

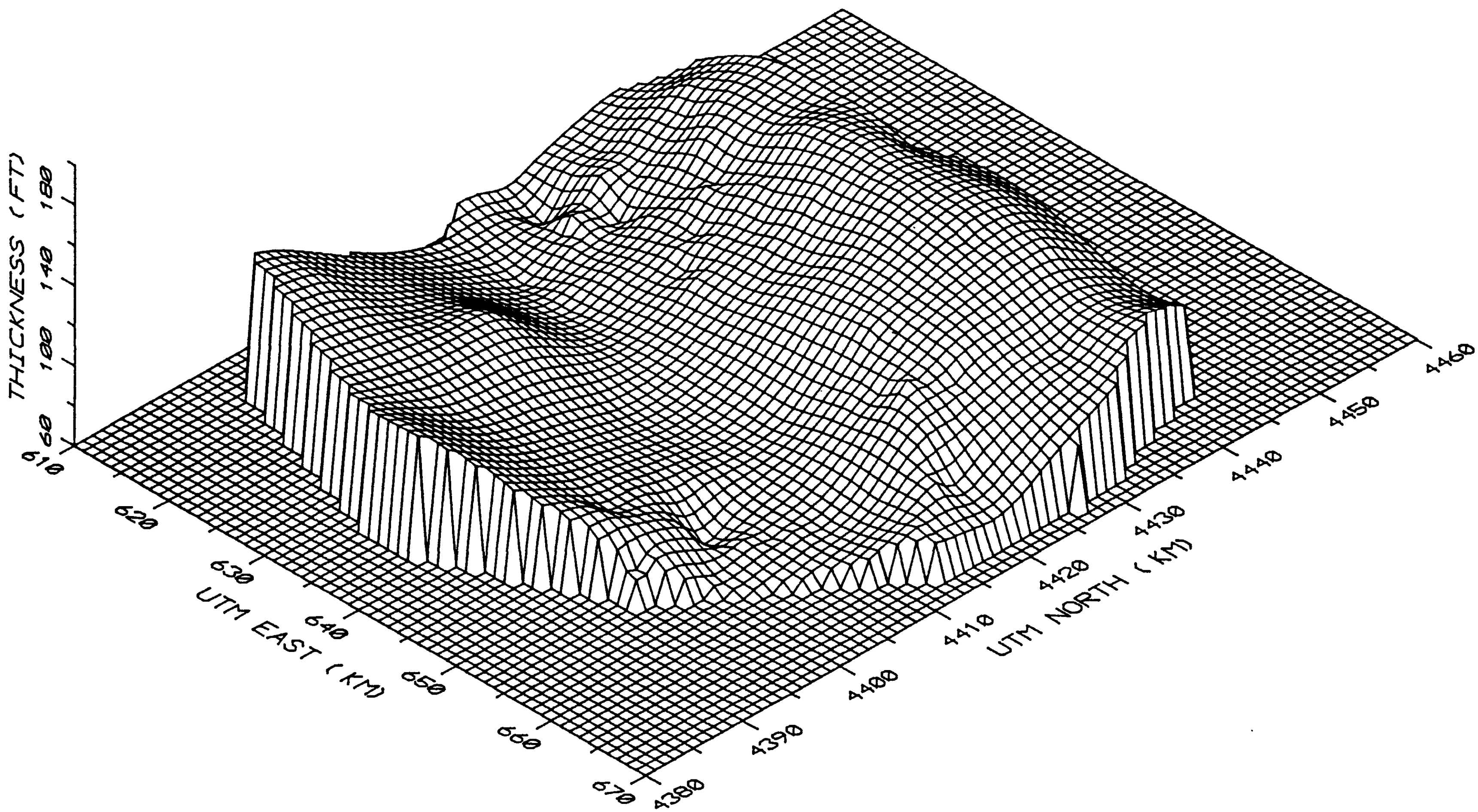


Figure 2.--Block diagram of the study area showing the thickness, in feet, of the Mahogany oil-shale zone viewed from the southeast corner of the area. The vertical skirt around the model delimits the edge of the well control.

Correlation lines are drawn on the top and bottom of the Mahogany zone and on the top and bottom of a unit of low-grade oil shale containing the Mahogany marker, a thin bed of analcimed tuff. Two additional correlation lines are shown at the top of two easily recognized beds of high-grade oil shale between the Mahogany bed and the base of the Mahogany zone. The bargraphs are equally spaced on the cross sections, rather than proportioned to distance between the drill holes, to accommodate the delineation of the thickest sequence of oil shale that averages 25 GPT.

In most of the study area, the upper 10 to 20 ft of the Mahogany zone consists of oil shale that averages about 25 GPT. Underlying this interval is a low-grade oil shale that averages approximately 10 GPT, which in turn, is underlain by a sequence of medium- to high-grade oil shale, about 25 to 65 ft in thickness, that averages about 32 GPT. The lower interval of high-grade oil shale (not specifically designated on plates 6 through 10) is the most likely sequence to be selected for mining within the Mahogany zone. The richest bed in this sequence (and in the Mahogany zone) is the Mahogany oil-shale bed, a unit of brownish black oil shale about 2 to 4 ft thick, averaging about 60 to 70 GPT. It lies about 3 to 13 ft below the top of the high-grade interval (plates 6 to 10).

For calculating the resources of the Mahogany oil-shale zone, the thickness of oil shale that averaged 25 gallons of shale oil per ton of oil shale was determined by the USGS computer program OSAP (Oil Shale Averaging Program). The program determines this thickness by averaging richer and leaner grades of oil shale until a continuous sequence of drill core that averages 25 GPT is reached. This sequence of 25 GPT oil shale is bracketed on the shale-oil bargraphs on cross sections AA′ to EE′ (plates 6 to 10).

The top of the 25 GPT sequence is commonly the top of the Mahogany zone, but in some core holes that penetrate a higher grade of oil shale, it extends upward into A-groove. Because of the variability of the grade of oil shale in the lower part of the Mahogany zone, the base of the 25 GPT sequence varies considerably from one core hole to the next On cross sections AA′-EE′, the base of the 25 GPT interval ranges from 0 to about 45 ft above the base of the Mahogany zone.

OTHER MINERAL RESOURCES IN THE STUDY AREA

Gilsonite veins are found in the eastern part of the study area near Bonanza (Cashion, 1967). Mining claims filed on the veins have modified the boundaries of some state and Federal lands in the eastern part of the study area (plate 1). Tar sands of good quality are found in the Douglas Creek Member underlying the Mahogany zone, especially in the southeastern part of the study

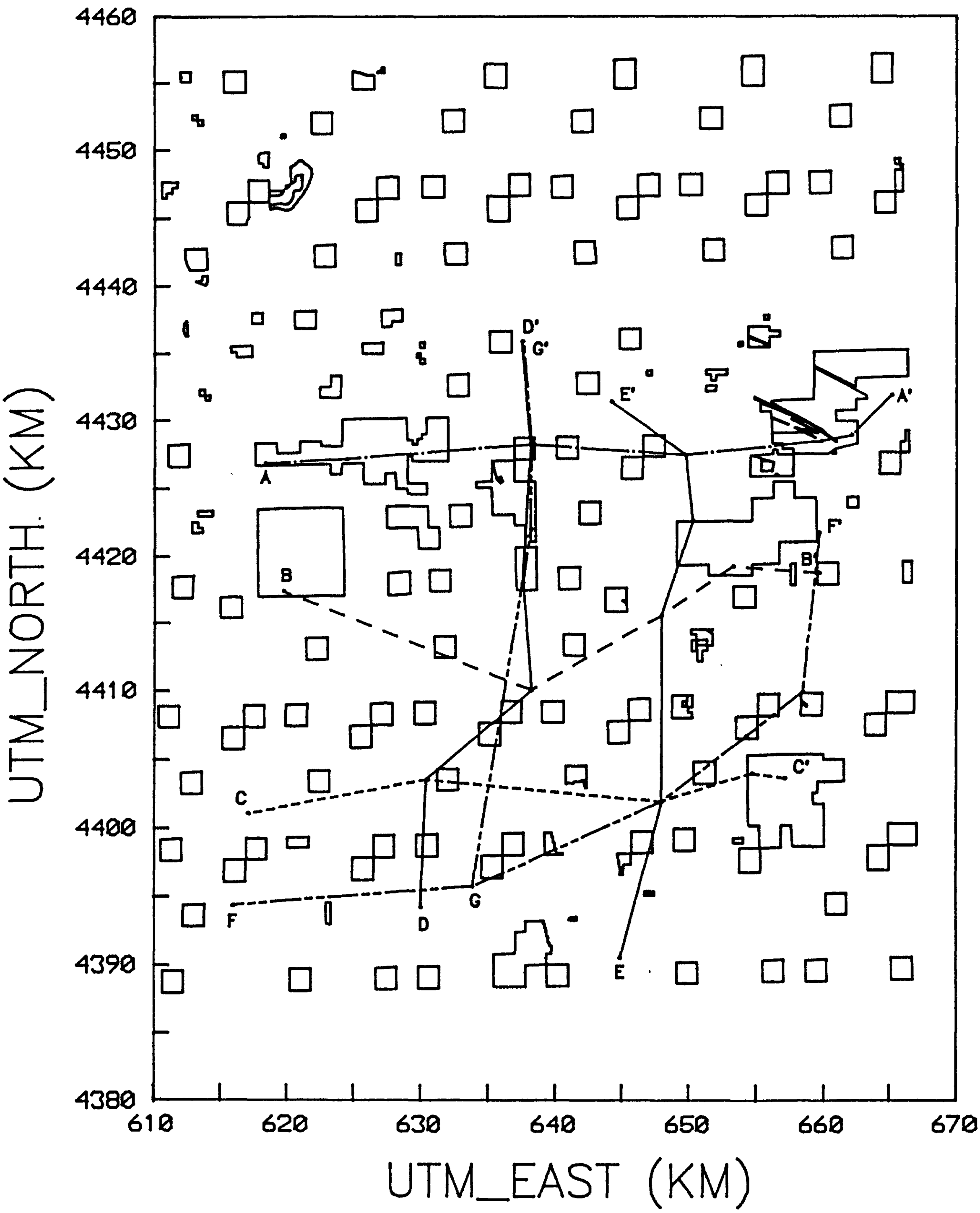


Figure 3.--Index map of the study area showing lines of sections AA' through GG' as shown on plates 6 through 12.

area. Many wells have been drilled for oil and gas in the study area and a number of oil and gas fields are present in the area.

Coal beds and probably associated methane are present in the subsurface in the Cretaceous Mesaverde Group at depths of several thousand feet. Sodium carbonate brines have been found in porous rocks in the upper part of the Parachute Creek Member and pods of nahcolite [$NaHCO_3$] have been found in the Mahogany zone.

METHODOLOGY

Base map and acreage calculations

A base map of the study area, which includes Tps. 7-13 S., Rs. 20-25 E. was prepared from 1:100,000-scale U.S. Geological Survey topographic maps, Seep Ridge and Vernal, Utah-Colorado. The boundaries of the tracts of state and Federal lands that were evaluated for oil shale were plotted on 1:24,000-scale topographic maps from Public Land Survey descriptions supplied by the Utah Division of State Lands and Forestry (appendices A-2, A-3, and A-4). The tract boundaries were digitized from the 1:24,000 scale topographic maps by latitude and longitude coordinates with the computer program GSMAP (Selner and Taylor, 1989) and plotted on the 1:100,000-scale base map of the study area (plate 1). The complex boundaries of tracts 123, 167, and 168 were drawn on 1:24,000-scale topographic maps by the Utah Division of Lands and Forestry. These maps were used for digitizing the boundaries of these tracts.

Because the Mahogany zone has been eroded from parts of the study area, it was necessary to digitize a marker bed (Mahogany oil-shale bed) in the upper part of the Mahogany zone in order to exclude lands barren of Mahogany oil shale. The Mahogany bed was digitized from 1:24,000-scale geologic quadrangle maps (figure 1). The Mahogany bed is shown only on those tracts within which the bed is exposed at the surface (plate 1).

A computer-drawn base map made by the program, GSMAP, using the digitized data, shows the selected state lands and the Federal Ua-Ub tracts, the locations of the wells used in the study, and the boundary of the Mahogany bed (plate 1). Acreages determined by GSMAP averaged about 0.2 percent larger than the acreages determined by the Public Land surveys (figure 4). The slightly larger acreages determined by GSMAP probably result from inherent limitations of computer digitizing. The errors in acreages between the two methods range from -7.7 to +7.4 percent. Errors in excess of ±2.5 percent that were found for 14 tracts may be due to inaccurate surveys. The acreage determined for Federal leases Ua-Ub (tract 90) by digitizing is 10,273, whereas, the acreage by cadastral survey is approximately 10,240. To standardize the acreages for this study, it was agreed by the USGS, the BLM, and the Utah Division of State Lands and Forestry that the acreages determined by GSMAP would be used for resource calculations. If desired, the resources could be easily recalculated using the acreages of the BLM cadastral surveys.

The tracts evaluated for oil-shale resources are numbered from 1 to 170 beginning in the northwest corner of the study area (plate 1). Six parcels of non-state lands (tracts 79, 80, 81, 88, 106, and 120) lie within state tracts. These parcels, identified on plate 1 by diagonal (NE-SW) lines, were excluded in the evaluation. Other whole and partial tracts of state lands in the southern and eastern parts of the study area (tracts 76-78, 91, 102, 123-125, 131, 134-136, 142, 146-148, 150-163, and 167) are also excluded because they do not contain Mahogany zone oil shale. These tracts are also shown by diagonal (NW-SE) ruling on plate 1.

Well data

Subsurface data from 176 holes drilled for oil shale and for oil and gas were used in this study. Estimates of the oil-shale resources of the state lands and the Federal tracts Ua and Ub, reported in 42-gallon barrels of shale oil, are based on Fischer assays of the Mahogany zone made on samples from 70 core holes. Others are based on shale-oil yields estimated from selected density and sonic geophysical logs of 24 exploratory holes drilled for oil and gas in the study area. Geophysical logs from many additional oil and gas wells were used to determine the top and base of the Mahogany zone.

The locations of drill holes used in this study are shown on plate 1. The core holes are identified by the prefix 'U' followed by a three-digit mumber and the oil and gas wells are identified by the prefix 'UT' followed by a four-digit number. The company, name, and location of 94 holes drilled for oil shale and for oil and gas, for which oil-shale resources were estimated, are listed in Table 1.

Shale-oil analyses

It is assumed that all of the drill cores were analyzed by the modified Fischer assay method as described by Stanfield and Frost (1949) and subsequently adopted by the American Society of Testing and Materials (1980). Assays from seven laboratories were utilized. These laboratories, and the number of cores that each analyzed are: the Laramie Energy Technology Center (LETC) (43); Colorado School of Mines Research Institute (16); Core Laboratories (14); Tosco Corporation (5); Dickinson Laboratory (2); Core Analytical Services (1); and Hazen Research (1). The laboratories that made the Fischer assay analyses for five of the cores is unknown.

The Colorado School of Mines Research Institute (now defunct) made the Fischer assay analyses on 16 drill cores ('P' and 'X' series) from Federal tracts Ua-Ub. These analyses gave resource values as much as 5 to 30 percent lower than values found for 9 nearby Gulf Oil Corp. core holes which were analyzed by LETC.

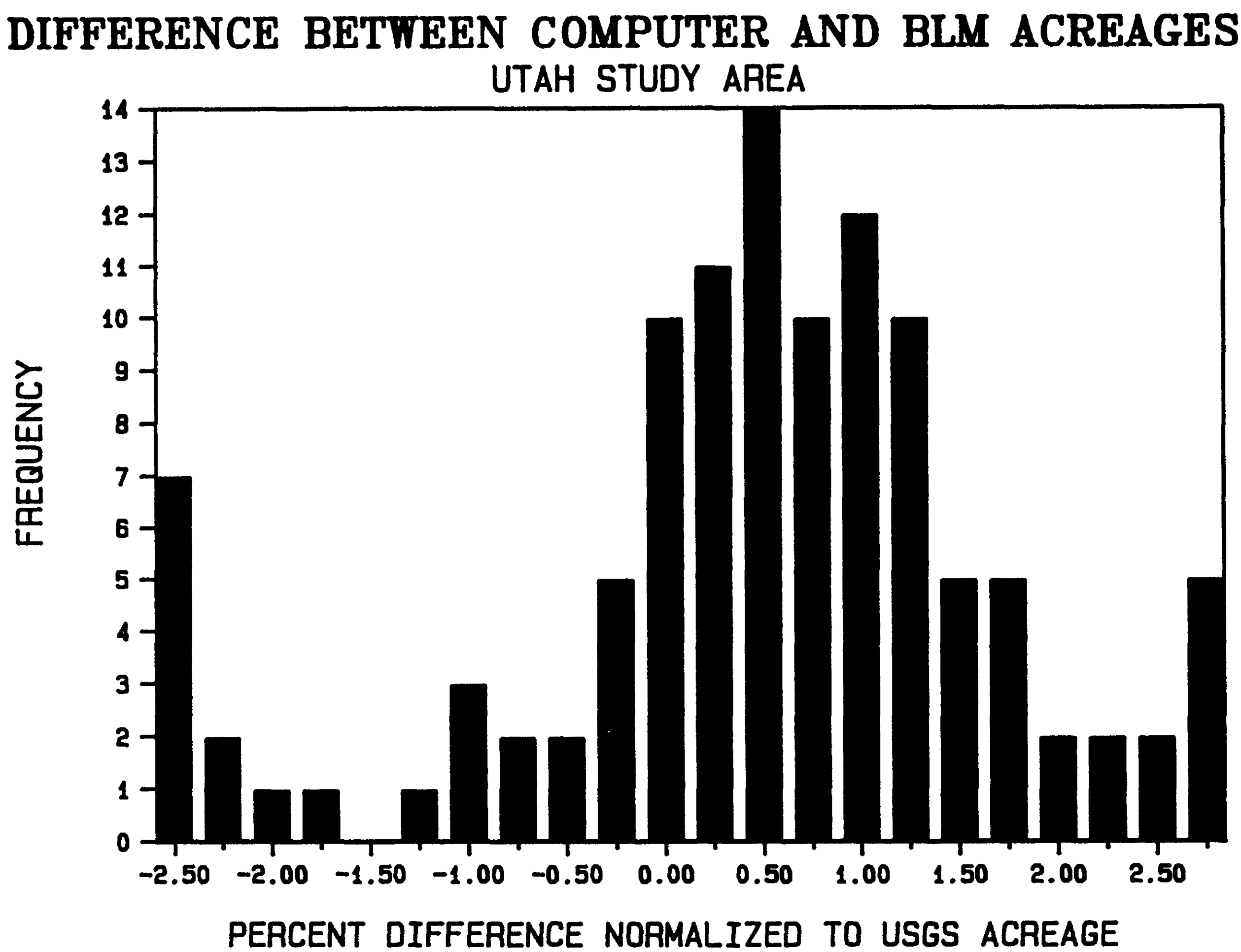


Figure 4.--Distribution of differences in acres of the tracts in the study area as measured by USGS computer program GSMAP and by USBM cadastral surveys.

Table 1.--Company, name, and location of drill holes used in estimating oil-shale resources.

Map number	Company and name of core hole	Footage from section line		Sec., Twp. Range		
	Core holes drilled for oil shale					
U020	Byllesby Inc., Windy	167 FWL	1364 FSL	24	12S	20E
U022	Byllesby Inc., Pinon	1437 FWL	523 FNL	14	13S	20E
U026	Nat'l Farmer's Union, 5	2553 FWL	739 FSL	02	12S	24E
U027	Nat'l Farmer's Union, 6	1792 FWL	1748 FSL	02	13S	24E
U029	Nat'l Farmer's Union, 9	413 FWL	2480 FNL	32	10S	25E
U030	Skyline Oil Co., Stringham 1	3238 FWL	2193 FNL	23	09S	25E
U032	Skyline Oil Co., Watson 3	143 FEL	2411 FSL	03	11S	25E
U033	Skyline Oil Co., Watson 2	264 FWL	2367 FSL	16	11S	25E
U034	Skyline Oil Co., Watson 4	1630 FEL	320 FNL	22	11S	25E
U035	General Petr. Corp., 37-4	1359 FWL	777 FSL	04	10S	25E
U036	General Petr. Corp., 42-12	15 FEL	761 FNL	12	10S	25E
U038	General Petr. Corp., 35-28	1848 FWL	2152 FSL	28	10S	25E
U039	General Petr. Corp., 18-29	551 FWL	281 FSL	29	11S	25E
U041	Brewer et al, 8-1	660 FWL	1980 FSL	08	13S	24E
U042	Brewer et al, 9-1	1980 FEL	1980 FNL	09	13S	24E
U043	West. Oil Sh. Corp., EX-1	1844 FWL	504 FSL	36	09S	20E
U044	USGS, Coyote Wash 1	2100 FEL	2175 FNL	22	09S	23E
U045	USGS, Red Wash 1	2850 FEL	2600 FNL	01	09S	22E
U046	Gulf Min. Res., Evac. Cr. 1	372 FWL	2104 FSL	13	10S	24E
U047	Gulf Min. Res., Evac. Cr. 3	2283 FEL	378 FNL	26	10S	24E
U048	Gulf Min. Res., Evac. Cr. 2	2050 FEL	1350 FSL	18	10S	25E
U049	Gulf Min. Res., Southam 1	2015 FWL	3582 FSL	22	10S	24E
U050	Gulf Min. Res., Southam 2	1134 FWL	611 FNL	34	10S	24E
U051	Gulf Min. Res., Southam 3	2382 FEL	949 FNL	29	10S	24E
U052	Gulf Min. Res., Southam 4	1705 FWL	315 FSL	17	10S	24E
U054	West. Oil Shale Corp., EX-2	1737 FWL	1291 FSL	31	10S	21E
U069	ERDA-LERC, S. Uinta Basin 1	118 FEL	349 FNL	30	12S	21E
U070	ERDA-LERC, S. Uinta Basin 2	1582 FEL	2459 FNL	35	12S	21E
U071	ERDA-LERC, S. Uinta Basin 3	804 FWL	718 FNL	17	13S	22E
U072	ERDA-LERC, S. Uinta Basin 4	1707 FEL	1734 FNL	35	13S	22E
U073	ERDA-LERC, S. Uinta Basin 5	1631 FEL	119 FSL	35	13S	22E
U074	ERDA-LERC, S. Uinta Basin 6	945 FEL	276 FNL	31	13S	22E
U076	ERDA-LERC, S. Uinta Basin 8	2079 FWL	1773 FSL	26	13S	23E
U077	ERDA-LERC, S. Uinta Basin 9	2413 FEL	2157 FNL	06	13S	24E
U078	ERDA-LERC, S. Uinta Basin 10	1807 FWL	2542 FNL	10	13S	24E

U079	ERDA-LERC, S. Unita Basin 11	2215	FEL	2474	FNL	10	13S	22E
U080	ERDA-LERC, S. Unita Basin 12	2471	FEL	1597	FSL	19	12S	24E
U081	Quintana Min. Corp., SYN-1	845	FEL	400	FNL	16	09S	25E
U082	Quintana Min. Corp., SYN-2	750	FWL	250	FSL	02	09S	25E
U083	Quintana Min. Corp., SYN-3/3A	820	FWL	435	FSL	15	09S	24E
U084	Quintana Min. Corp., SYN-4	70	FEL	295	FNL	29	09S	24E
U085	Quintana Min. Corp., SYN-5	910	FWL	345	FSL	32	09S	24E
U086	USGS, Asphalt Wash 1		?		?	07	11S	24E
U089	Arco, Evac. Cr. 1	224	FNL	135	FEL	36	10S	24E
U092	West. Oil Shale Corp., EX-3	500	FWL	200	FSL	16	09S	25E
U101	Tosco Corp., Utah St. 11-18	91	FWL	823	FNL	18	10S	22E
U102	Tosco Corp., Utah St. 1	800	FEL	660	FNL	26	09S	21E
U103	Science Appl., MC-2		?		?	19	10S	20E
U105	Tosco Corp., Utah St. 23-36	1775	FWL	2100	FSL	36	10S	22E
U110	Shell Oil Co., 14X-34	689	FWL	951	FSL	34	09S	21E
U111	Shell Oil Co., 22X-12	2313	FWL	2128	FNL	12	10S	22E
U114	DOE-LETC, Cowboy Can. 1	1498	FEL	1258	FNL	33	09S	25E
U134	Gulf Min. Res., Bonanza 2	1150	FWL	1050	FSL	22	12S	24E
U136	Gulf Min. Res., Bonanza 4	750	FWL	500	FSL	31	11S	25E
U137	Gulf Min. Res., Bonanza 5	1550	FEL	2050	FNL	13	11S	25E
U138	Gulf Min. Res., Bonanza 6A	1625	FWL	1425	FSL	34	10S	25E
U139	Gulf Min. Res., Bonanza 7	2050	FEL	1575	FSL	20	10S	25E
U140	Gulf Min. Res., Bonanza 8	1850	FWL	850	FSL	18	12S	25E
U143	Gulf Min. Res., Bonanza 11	1800	FWL	350	FSL	17	12S	25E
U144	Gulf Min. Res., Bonanza 12	1200	FEL	150	FSL	01	12S	24E
U145	Gulf Min. Res., Bonanza 13	1175	FWL	2300	FNL	15	12S	24E
U146	Gulf Min. Res., Bonanza 14	975	FWL	450	FSL	33	10S	25E
U147	Gulf Min. Res., Bonanza 15	600	FEL	525	FNL	33	10S	25E
U148	Gulf Min. Res., Bonanza 16	2400	FWL	1500	FSL	30	10S	25E
U149	Gulf Min. Res., Bonanza 19	1300	FWL	450	FNL	24	11S	25E
U150	Gulf Min. Res., Bonanza 22	1500	FWL	2440	FSL	21	10S	25E
U151	Gulf Min. Res., Bonanza 32	375	FWL	2225	FSL	20	10S	25E
U152	Gulf Min. Res., Bonanza 33	325	FWL	1225	FNL	17	12S	25E
U153	Gulf Min. Res., Bonanza 34	2100	FEL	1100	FNL	25	12S	24E
U156	Gulf Min. Res., Bonanza 37	150	FWL	1075	FSL	12	12S	24E
	Wells drilled for oil and gas							
UT0007D	Conoco, Kurip 1-27	1354	FWL	271	FNL	01	09S	20E
UT0012D	Conoco, 38-22B	1207	FEL	638	FSL	22	09S	20E
UT0013S	Conoco, 29	2110	FEL	2500	FNL	16	09S	23E
UT0015D	Conoco, 45-24B	1980	FEL	1980	FSL	24	09S	20E
UT0016D	Conoco, 24-32B	1284	FEL	1166	FNL	32	09S	20E

UT0020D	Conoco, Cesspooch 5-14	1404	FEL	799	FSL	05	09S	21E
UT0023D	CIG Exploration, 19-16-9-21	1558	FEL	1080	FSL	16	09S	21E
UT0026D	CIG Exploration, 99D-25-9	660	FWL	660	FSL	25	09S	21E
UT0032D	Belco, 35-15	660	FWL	660	FSL	15	09S	22E
UT0037D	Coastal, 80V	984	FWL	2042	FSL	34	09S	22E
UT0038D	Pacific Transmission, 23-11	2034	FWL	2031	FSL	11	09S	23E
UT0038S	do		---		---		---	
UT0045D	Mapco, 7-10F	1928	FEL	2390	FNL	10	10S	20E
UT0049D	CIG Exploration, 74-N3	1975	FEL	2070	FNL	24	10S	20E
UT0055D	CIG Exploration, 41	725	FEL	1486	FSL	12	10S	21E
UT0057D	CIG Exploration, 58-16	782	FEL	477	FSL	16	10S	21E
UT0063D	Coastal, 59	599	FEL	2144	FNL	33	10S	21E
UT0069D	Coastal,38-N2	1752	FWL	1768	FSL	13	10S	22E
UT0075D	CIG Exploration, 17	1404	FWL	1546	FNL	29	10S	22E
UT0077D	Pacific Trans., 4-5	1020	FEL	1620	FSL	05	10S	23E
UT0077S	do		---		---		---	
UT0081D	Pacific Transmission, 1-7	1571	FEL	1168	FNL	07	11S	21E
UT0082D	Diamond Shamrock, 14-8	526	FWL	620	FSL	08	11S	22E
UT0084S	Diamond Shamrock, 1-1	2006	FEL	1848	FSL	01	12S	21E
UT0086S	Gulf Energy, Gray Knoll 1	1980	FEL	2280	FSL	22	12S	21E
UT0087S	Delhi-Taylor, 1-17	2080	FEL	1851	FSL	17	12S	22E

Note: The letters D and S on the end of the map number for the oil and gas wells designates density and sonic logs, respectively, which were used to estimate shale-oil yields for these wells.

The combined data from the P and X and the Gulf core holes were found to give resource numbers that were 9 percent less for tract Ua and 5 percent less for tract Ub, than the resource determinations for these tracts made from the Gulf wells alone. The Fischer assay data for the 9 Gulf core holes were judged to be adequate for determining the oil-shale resources of the Federal tracts; therefore, the assay data for the P and X holes were not used for resource calculations for the Federal and state tracts. However, the geophysical logs of the P and X holes were used with data from other wells to prepare the thickness and structure maps of the Mahogany zone.

Lacking evidence to the contrary, the Fischer assays made by the remaining named laboratories are assumed to be unbiased and to be reproducible to within the limits of the ASTM Fischer assay method (±1 gal/ton by the same laboratory and ±2 gals/ton between laboratories on duplicate samples). However, some bias in the data reported by the different laboratories probably exists, but to what extent is unknown.

Core holes that did not penetrate the entire Mahogany zone were rejected for evaluation of oil-shale resources, with exceptions. For a few core holes that penetrated all but the lowermost few feet of the Mahogany, estimates of the shale-oil yields of the undrilled portion of the Mahogany zone were made by comparison with nearby (one or two miles) core holes. These estimated yields were added to the Fischer assay data for calculating oil-shale resources.

Although core recovery through the Mahogany zone was generally good, some core is missing because of drilling through poorly consolidated rock, or because core is ground up by the drilling bit. Missing core intervals of a few feet or less, were reported for 12 core holes. These holes are U030, U032, U035, U036, U038, U039, U102, U105, U110, U111, U146, and U148. In some instances, because the missing interval is apparently of high-grade oil shale, the oil-shale resource calculated for the core hole could be lowered somewhat if the missing interval was ignored. Therefore, oil yields for the missing intervals were estimated from Fischer assay analyses of the same sequence of oil shale in nearby core holes. The estimated oil yields were included with the Fischer assay data in resource calculations.

Errors in shale-oil analyses, or errors possibly introduced by jumbled drill core, were found for core holes U042, U079, U107, U103, and U150. In several core holes, some beds had higher than expected oil yields, but the data may be correct. Because it could not be determined whether these data are incorrect and because the effect of these "errors" on the resource calculations are probably negligible, the data were used as reported.

Most of the cores were prepared for analysis by compositing 1- to 2-ft lengths of quartered drill core; a few pounds of this material was crushed to pass an 8-mesh screen. A 100-gram sample of the crushed material was analyzed for its shale oil content by the modified Fischer assay method.

The Fischer assay data (including the estimated oil yields for missing intervals) were averaged by the program OSAP. The program determined the depths of sequences of oil shale that were more than 10 ft thick and that averaged 25 GPT. In all core holes, the thickest sequence of 25-GPT shale was found in the Mahogany zone. A few thin units of oil shale, commonly 1-5 ft thick, that average 25 or more GPT, are also present within the Mahogany zone. These units were included in the resource evaluation of the Mahogany zone.

Evaluation of density and sonic logs

Core holes drilled to evaluate oil shale in the study area are not uniformly distributed. Most of the holes are dispersed in a horseshoe-shaped pattern open to the west, whereas the central and west-central parts of the study area contain very few core holes (plate 1). To augment the core hole data, oil-shale resources were estimated from sonic and density logs of selected oil and gas wells in the study area

Many exploratory holes have been drilled for oil and gas in the northwestern part of the study area in Tps. 9-10 S., Rs. 20-23 E. On the other hand, only a few wells have been drilled for oil and gas in the central and west-central parts of the study area (plate 1). Unfortunately, the sonic log of the Mahogany zone for UT0083--a key well located in the middle of the uncored part of the study area in sec. 30, T.11 S., R.23 E.--is of doubtful value because it does not correlate well with geophysical logs of other nearby drill holes (see the digitized bargraph for this hole on plates 7 and 9). For this reason, UT0083 was not used to estimate the shale-oil resources in the study area.

Density and sonic logs of oil shale have been shown to correlate closely with Fischer assays of Green River oil shale (Bardsley and Algermissen, 1963; Tixier and Curtis, 1967; Smith, Thomas, and Trudell, 1968). Although the correlation between the geophysical logs and Fischer assays for individual wells is usually quite good, the correlation between wells is less reliable because of differences in calibration of the logging tools, changes in mineral composition, variations in porosity of the oil shale, and laboratory bias in the shale-oil analyses.

Perhaps the most significant problem is variation in porosity from sample to sample. Porosity and the organic content of the rock largely determine the character of a density or sonic log of oil shale in the Mahogany zone. If porosity remained constant, density and sonic logs would be reliable predictors of the shale-oil content, however, it appears that there is significant variation in porosity between samples within and between wells.

In a study of oil shale resources of the Green River Formation in the Piceance Creek Basin, Colorado, Habiger and Robinson (1983) have shown that porosity and oil yield can be measured with reasonably accuracy by using a suite of geophysical logs. Because their method would have required considerably more time than that allowed by the MOU, the method was not used in this study. If a sufficient number of core holes with the requisite geophysical logs are available in the study area, the technique might improve substantially the shale-oil estimates that were made from the logs.

Estimating shale-oil content from geophysical logs

Oil-shale resources were calculated for a selected group of 20 oil and gas wells using linear equations developed from plots of sonic and density logs versus shale-oil analyses of 12 of an original group of 23 core holes from the study area. The traces of the sonic and density logs were digitized on one-foot increments of depth through the Mahogany zone and extending a short distance above and below it. Vertical profiles of the digitized segments of the geophysical logs were matched with the corresponding profile of the shale-oil determinations for each core hole. The geophysical log profile was adjusted to obtain the best match with the profile of the shale-oil analyses, using about a dozen marker beds that could be readily correlated on the log and shale-oil profiles. Where sequences of missing core were encountered, the corresponding geophysical log values were eliminated. Logs that showed poor definition of beds, or that did not correlate well with the shale-oil profile were eliminated..

After adjusting the data, linear regression equations were determined for each set of log and Fischer assay data. Also reported is r^2, which is an approximation of the proportion of the variation of the amount of shale oil "explained" by the geophysical log value. These data for the group of 23 core holes is listed in Table 2. Linear regression lines for the density- and sonic-log data versus shale-oil for the core holes listed in Table 2 are plotted on figures 5 and 6, except for U061 which was omitted because of a low r^2 value of 0.47 (Table 2). The plots of the regression equations in figures 5 and 6 illustrate the relatively wide spread of data from one core hole to another.

Core holes having log-density distributions that differed widely from the majority of distributions were omitted as were those core holes that had large differences in the slope of the regression line developed for density or sonic data versus shale-oil analyses (Table 2 and figures 5 and 6). All of the coreholes that were analyzed by the Colorado School of Mines Research Institute were also eliminated because of suspected analytical errors. U155 was omitted because the well did not penetrate all of the Mahogany zone. The final number of core holes that were used in estimating resources from the density and sonic logs of the oil and gas wells is 12; these core holes are identified in Table 2.

Table 2.--Linear regression analyses of digitized density and sonic-log data versus shale-oil determinations by Fischer assay for 23 core holes.

$$Y = a + bX$$

(Y = oil yield, gpt; X = digitized log value)

Core hole	Labor-tory	No. spls	a	b	Std err of b	r^2	Std err of Y est
Density logs (apparent density, gm/cc)							
U043	LETC	117	163.396	-56.208	2.713	0.789	6.190
U044	DL	191	141.593	-55.130	1.821	0.829	5.771
U045[1]	DL	104	152.036	-59.782	2.868	0.810	5.958
U060	CSMRI	88	162.815	-64.521	3.780	0.772	7.039
U061	CSMRI	103	129.466	-47.673	5.058	0.468	8.873
U062	CSMRI	117	203.123	-80.710	4.084	0.773	6.735
U064	CSMRI	115	160.991	-59.894	4.159	0.647	8.654
U065	CSMRI	78	214.996	-83.735	4.734	0.805	7.090
U066	CSMRI	92	192.446	-71.918	4.400	0.748	7.708
U067	CSMRI	108	199.741	-71.797	3.665	0.784	5.844
U068	CSMRI	81	198.892	-76.664	4.805	0.763	7.666
U081[1]	?	89	180.869	-72.443	5.785	0.643	8.219
U082[1]	?	106	170.963	-68.303	3.033	0.830	5.087
U083[1]	?	107	199.382	-77.891	3.113	0.856	5.514
U085[1]	?	104	211.028	-76.296	3.580	0.817	6.818
U086	?	81	159.042	-59.195	4.603	0.677	10.352
U102[1]	Tosco	118	193.375	-75.346	3.244	0.823	6.843
U103[1]	Hazen	105	176.856	-68.557	2.705	0.862	4.375
U112	CL	49	194.559	-75.812	5.613	0.795	7.393
U151[1]	CL	108	204.082	-81.209	4.134	0.785	6.566
U153[1]	CL	63	201.070	-70.617	4.882	0.813	6.429
U155	CL	86	216.323	-85.056	3.610	0.869	5.394
U156	CL	45	164.564	-62.096	4.760	0.798	7.480
Sonic logs (interval transit time, microsec/ft)							
U043[1]	LETC	118	-33.860	0.5626	0.0241	0.825	5.517
U044[1]	DL	189	-34.362	0.6235	0.0211	0.823	5.899
U060	CSMRI	100	-65.503	0.7757	0.0543	0.676	8.565
U061	CSMRI	109	-45.700	0.7127	0.0642	0.535	8.622
U082	?	113	-61.851	0.6874	0.0321	0.805	5.402

U083	?	116	-40.063	0.6926	0.0309	0.815	6.356
U085	?	104	-48.195	0.7566	0.0339	0.830	6.575
U086[1]	?	81	-46.934	0.6441	0.0467	0.706	10.44
U155	CL	27	-63.749	0.8768	0.0880	0.799	3.965

-

Notes: [1]Core holes selected for estimating shale-oil resources in oil and gas wells. CL, Core Labs; CSMRI, Coloado School of Mines Research
Institute; DL, Dickinson Laboratories

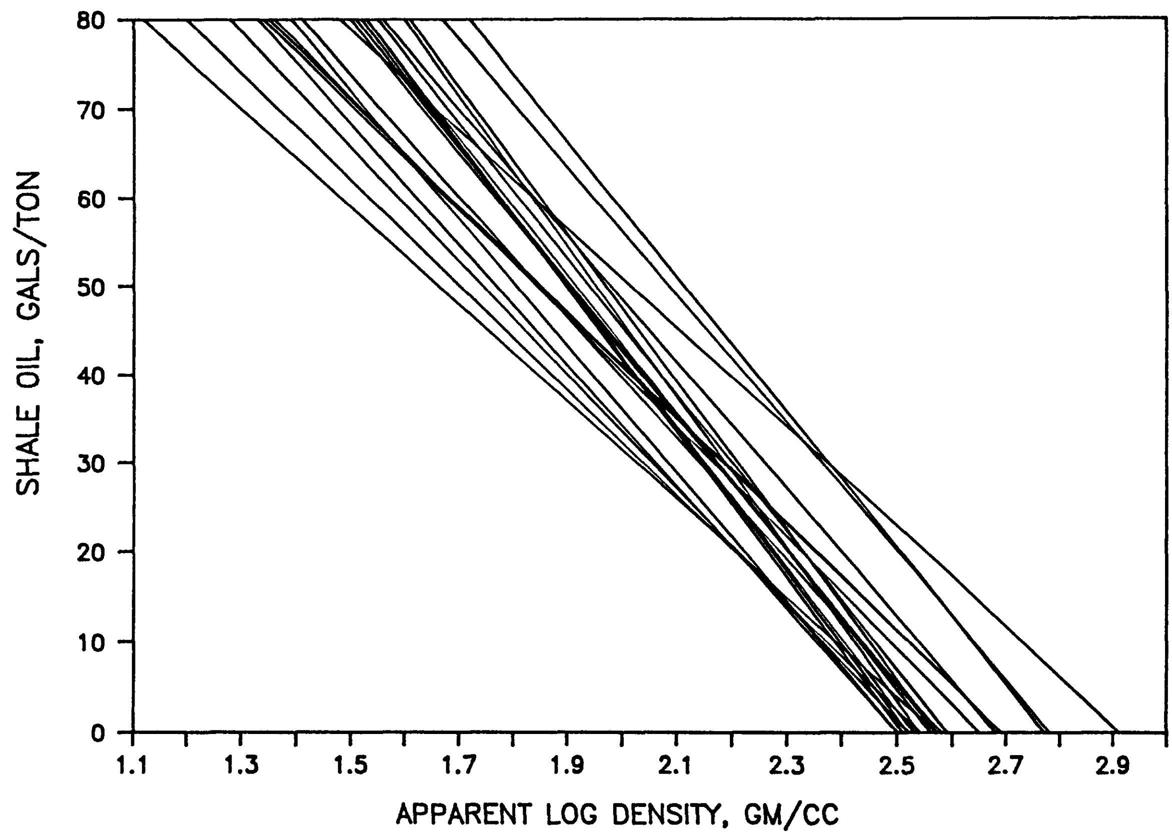


Figure 5.--Linear regression equations for cross-plots of digitized density log values versus shale-oil determinations for 22 core holes.

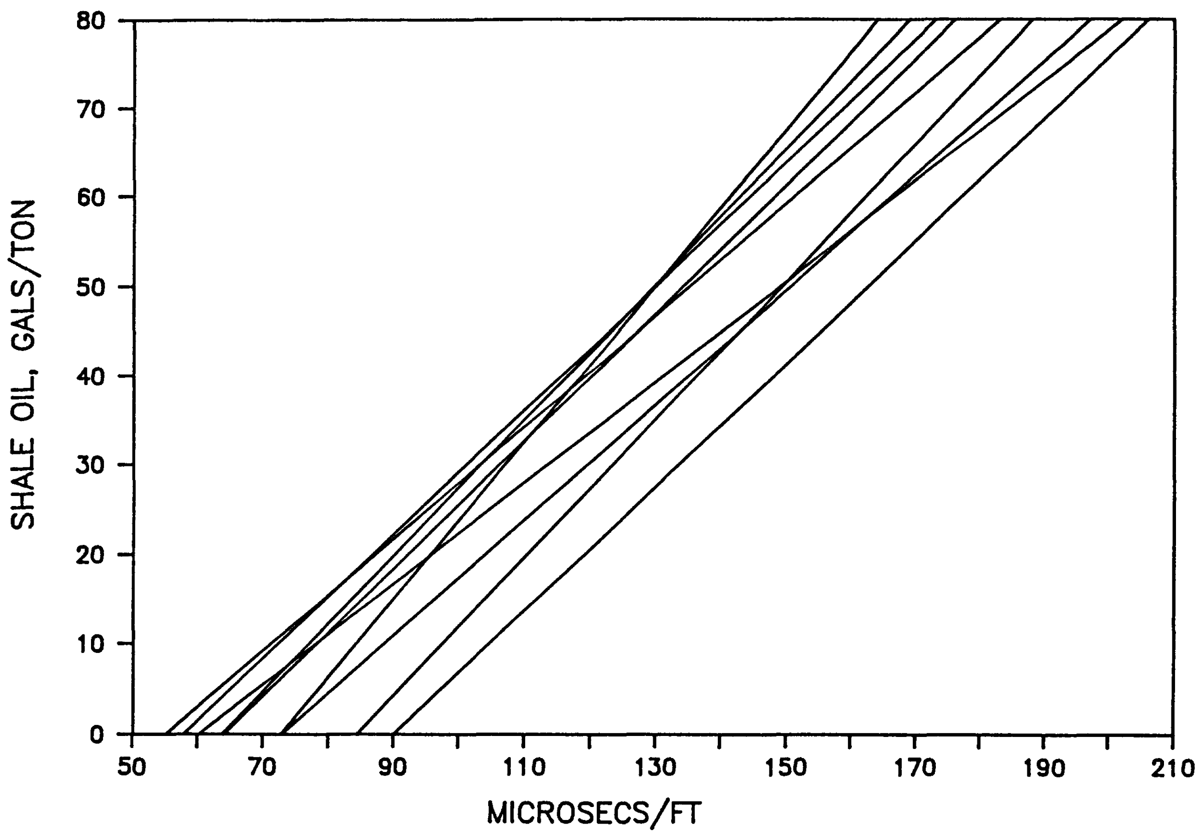


Figure 6.--Linear regression equations for cross-plots of digitized sonic log values versus shale-oil determinations for 9 core holes.

In an attempt to reduce some of the analytical and logging tool bias, the density and sonic log data were "corrected" to the average density (or sonic value) for the total number of samples in each set of density-Fischer assay and sonic-Fischer assay data. Regression analysis of the density and data sets gave the following:

Density log data (909 data-pairs from 9 core holes):

$Y = 187.59 - 73.16X$, where Y = estimated shale oil yield in GPT, and X = corrected log density (gm/cc) and $r^2 = 0.70$.

Sonic log data (772 data-pairs from 6 core holes):

$Y = -18.78 + 0.168X + 0.0024X^2$, where Y = estimated shale oil yield in GPT, and X = microsecs/ft and $r^2 = 0.78$.

A second degree polynomial regression equation was found to give a slightly better fit for the sonic data than a linear equation, whereas the linear equation for the density data was not improved by a higher order regression equation. Plots of the density and sonic log data versus shale-oil determinations are shown in figures 7 and 8. Estimates of the oil-shale resource in KBPA (thousands of barrels of oil equivalent per acre) calculated from the Fischer assay data and by using the above equations are given in Table 4. The resource estimates made by the equations range from about 79 to 205 percent of the estimates made from the Fischer assay data.

Using the equations above, estimates of shale-oil yields through the Mahogany zone from density and sonic log data were made for 20 oil and gas wells drilled in the study area (Table 3). The oil-shale resources, in KBPA, were then computed by the program OSAP for each well. These data are listed in Table 3. The estimated resources for the oil and gas wells are obviously not as reliable as the resources estimated from the core hole data. Some of the resource estimates for the oil and gas wells were omitted because of poor fit with the isoresource contours.

Most of the wells for which oil-shale reources were estimated are concentrated in the northwestern part of the study area; only a few wells are in the central and southwestern parts of the study area. Because of the wide spread in the resource estimates made from the geophysical logs of the core holes, the reource estimates for the oil and gas wells were assigned a low reliablility factor for determining oil-shale resources for the state and Federal tracts as explained in the section on kriging.

The parameters that need to be measured in order to determine the organic content of an oil shale are (1) average density of the mineral fraction, (2) the clay content and porosity, and (3) the density of fluids in the rock. The richer grades of Green River

Table 3.--Data for 90 drill holes used in resource analysis.

Hole No. (map)	Grd. Elev (ft)	Part of Mahogany zone averaging 25 GPT: Depths (ft) Top	Bottom	Thickness (ft)	Resource KBPA	Grade (GPT)	Error measure
U020	5503	141.0	240.1	41.0	72.6	25.6	-
U022	6038	113.2	222.7	29.4	52.7	26.1	-
U026	6059	153.4	217.2	63.8	108.5	25.3	-
U027	6750	92.0	154.0	57.8	98.9	25.1	-
U029	5746	603.4	692.0	88.6	152.6	25.3	-
U030	5879	445.0	521.5	76.5	133.9	25.1	-
U032	6339	374.3	452.0	73.7	126.5	25.2	-
U033	5905	356.0	429.9	73.9	125.3	25.0	-
U034	6144	350.6	407.6	57.0	99.2	25.5	-
U035	5881	373.0	469.0	83.0	145.2	25.5	-
U036	6473	134.5	217.0	70.5	127.7	26.4	-
U038	6173	360.0	444.5	76.0	132.5	25.3	-
U039	6110	281.5	344.0	55.5	96.0	25.4	-
U041	6322	39.6	116.3	58.9	102.5	25.5	-
U042	6497	57.0	129.3	54.4	95.0	25.2	-
U043	4941	2268.0	2455.0	68.7	121.3	25.4	-
U044	5087	2193.0	2320.0	122.0	211.0	25.1	-
U045	4811	2604.0	2733.0	103.0	179.4	25.1	-
U046	5292	756.0	854.0	98.4	169.2	25.1	-
U047	5433	816.0	914.9	93.4	160.6	25.1	-
U048	5435	484.2	574.0	85.8	147.9	25.0	-
U049	5242	852.0	953.0	95.0	164.0	25.2	-
U050	5432	845.0	41.0	96.0	162.6	25.0	-
U051	5334	1016.0	1116.0	100.0	169.9	25.0	-
U052	5061	928.0	1034.0	106.0	180.2	25.0	-
U054	5345	1620.0	1681.0	51.0	88.2	25.6	-
U069	5496	122.1	159.3	30.2	53.1	25.6	-
U070	5829	91.5	184.7	34.9	62.2	25.8	-
U071	6183	61.0	119.7	34.6	60.5	25.5	-
U072	6700	81.1	146.4	41.6	72.9	25.5	-
U073	6727	15.0	110.5	40.7	71.0	25.6	-
U074	6628	112.4	208.0	29.9	52.7	25.6	-
U076	6419	6.6	80.1	51.1	88.7	25.2	-
U077	6268	154.9	231.0	64.8	110.3	25.1	-
U078	6677	127.3	193.2	61.0	104.6	25.4	-
U079	6427	426.5	517.9	42.1	75.1	25.7	-
U080	6261	471.9	545.5	73.6	123.	25.0	-

U081	5890	1131.8	1240.5	91.9	160.6	25.2	-
U082	5769	1053.0	1159.0	86.0	150.6	25.1	-
U083	5366	1994.0	2113.0	109.0	188.7	25.2	-
U084	5432	1995.0	2104.0	109.0	188.1	25.1	-
U085	5604	1924.0	2034.0	110.0	189.5	25.2	-
U086	5250	549.6	624.1	67.5	113.5	25.4	-
U089	4712	635.0	722.0	80.0	139.4	25.3	-
U092	5813	995.0	1095.0	94.0	163.9	25.1	-
U101	5030	1782.0	1864.0	82.0	140.2	25.2	-
U102	4911	2275.0	2375.0	100.0	170.4	25.1	-
U103	5195	1807.0	1872.0	40.0	71.3	25.5	-
U105	5394	1372.0	1444.0	64.0	110.5	25.3	-
U110	5057	2252.0	2339.0	70.0	123.5	25.3	-
U111	5202	1817.0	1918.0	101.0	171.9	25.2	-
U114	5871	465.9	565.6	92.7	159.8	25.1	-
U134	6225	109.0	174.5	65.2	109.6	25.0	-
U136	6295	392.0	445.0	51.8	88.0	24.8	-
U137	6700	61.0	129.0	59.7	104.1	25.5	-
U138	6560	136.0	213.0	64.4	115.7	25.4	-
U139	5720	431.0	519.7	83.0	143.7	25.2	-
U140	6340	64.0	117.0	52.5	89.7	25.2	-
U143	6700	170.0	220.0	41.5	72.2	25.0	-
U144	6340	280.3	332.5	52.2	90.8	25.5	-
U145	6300	358.3	408.5	39.8	69.1	25.2	-
U146	5900	416.5	498.2	79.7	137.4	25.2	-
U147	6410	136.5	210.5	67.5	117.6	25.4	-
U148	5440	477.5	555.9	78.4	135.4	25.0	-
U149	6500	386.0	461.0	67.0	115.2	25.2	-
U150	5940	112.0	191.0	53.0	95.5	25.6	-
U151	5730	662.0	756.0	79.0	137.8	25.3	-
U152	6600	193.0	232.0	39.0	66.8	25.1	-
U153	6660	74.0	124.0	47.0	81.1	25.3	-
U155	5960	575.0	661.0	70.0	121.3	25.1	-
U156	6110	51.0	98.0	47.0	80.7	25.1	-
Wells drilled for oil and gas							
UT0007D	4678	2820.5	2923.5	86.0	150.9	25.1	648
UT0012D	4852	2413.5	2478.5	65.0	113.4	25.0	648
UT0015D	4858	2416.5	2477.5	59.0	103.1	25.3	648
UT0016D	4836	2375.5	2422.5	36.0	63.8	25.3	648
UT0020D	4694	2705.5	2803.5	84.0	146.6	25.1	648
UT0023D	4839	2485.5	2575.5	74.0	129.8	25.6	648
UT0026D	4987	2248.5	2350.5	84.0	147.4	25.2	648
UT0037D	5003	1976.5	2079.5	99.0	171.7	25.1	648
UT0038D	4990	2374.5	2499.5	104.0	180.8	25.1	648
UT0049D	5217	1878.5	1922.5	34.0	61.8	25.6	648

UT0055D	5016	1829.5	1897.5	68.0	117.6	25.2	648
UT0057D	5251	1923.5	1973.5	43.0	74.8	25.5	648
UT0063D	5419	1689.5	1754.5	51.0	89.4	25.1	648
UT0069D	5307	1742.5	1841.5	96.0	163.8	25.6	648
UT0075D	5375	1730.5	1783.5	49.0	85.5	25.1	648
UT0077D	5315	1929.5	2038.5	109.0	187.7	25.2	648
UT0081D	5552	1598.5	1636.5	23.0	41.6	25.1	648
UT0082D	5622	1491.0	1542.0	42.0	74.0	25.2	648
UT0086S	6404	1086.5	1160.5	54.0	96.2	25.1	615
UT0087S	6037	855.5	974.5	75.0	131.2	25.1	615

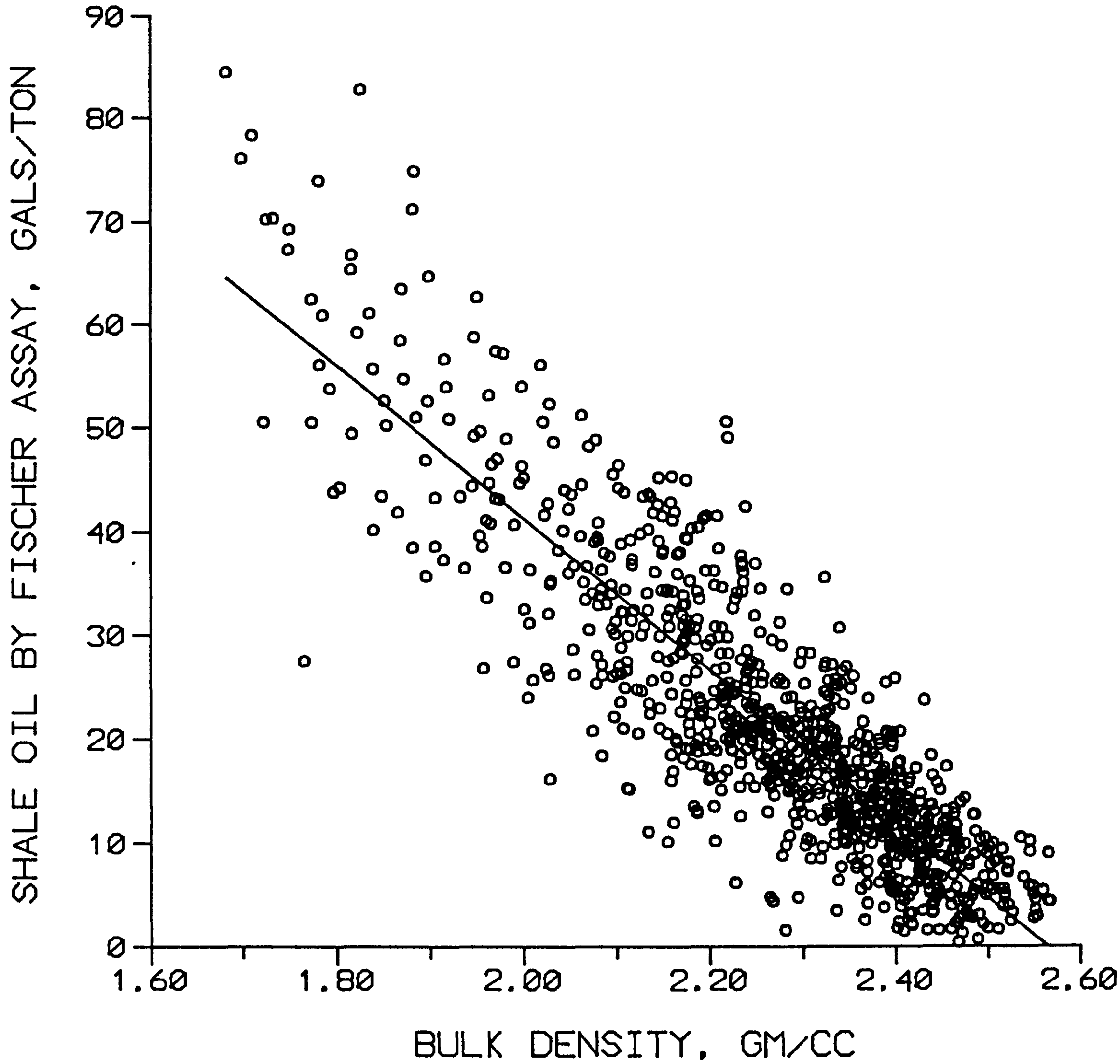


Figure 7.--Cross plot of digitized density log values versus shale-oil determinations for 909 samples from 9 core holes.

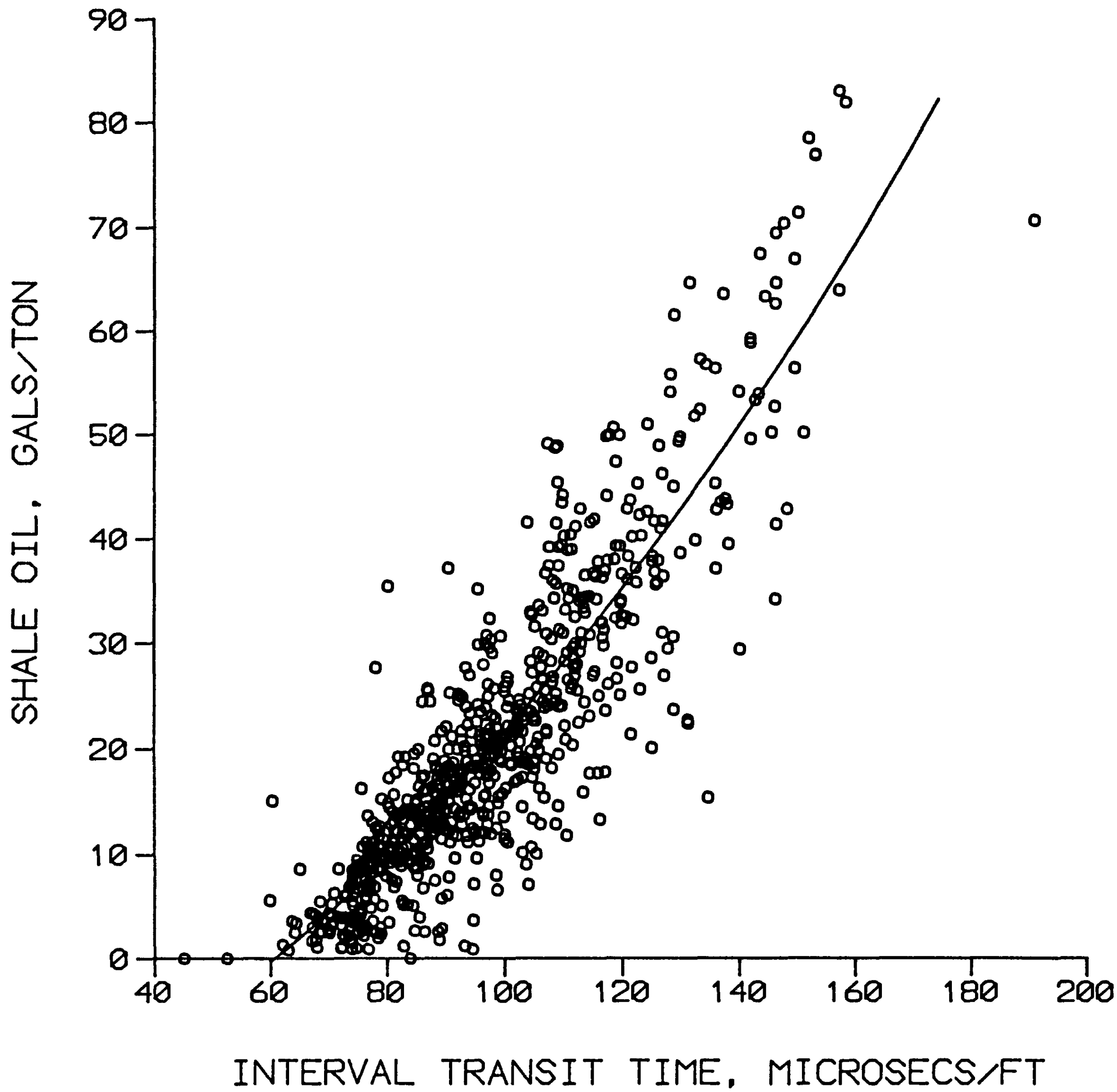


Figure 8.--Cross plot of digitized sonic log values versus shale-oil determinations for 772 samples from 7 core holes.

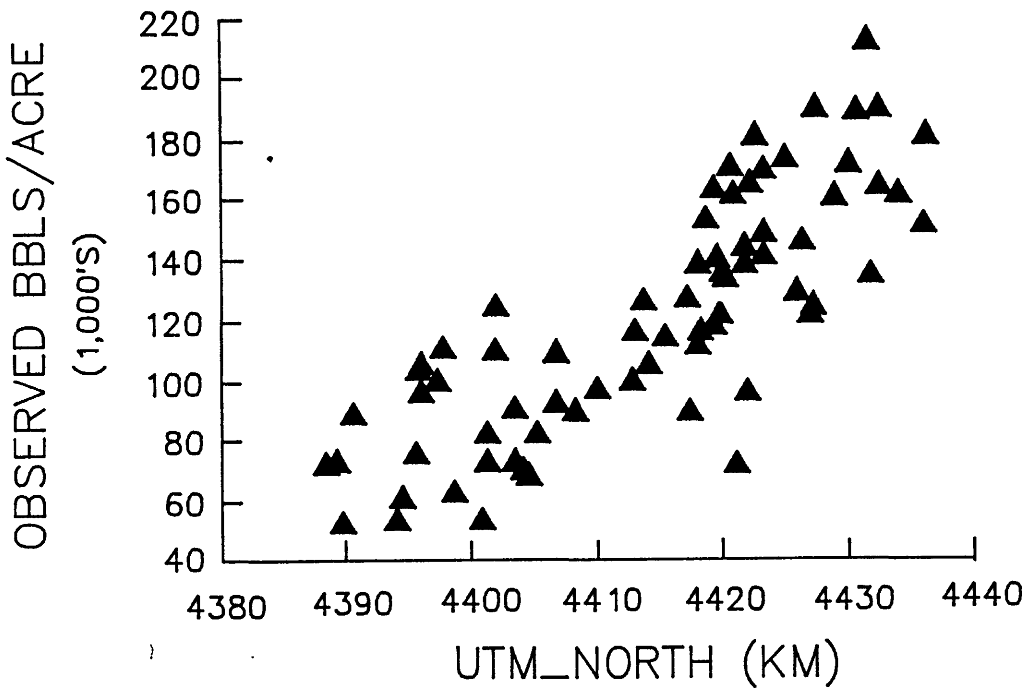


Figure 9.--Cross plot of observed barrels of shale oil per acre (1,000's) versus UTM northings (km).

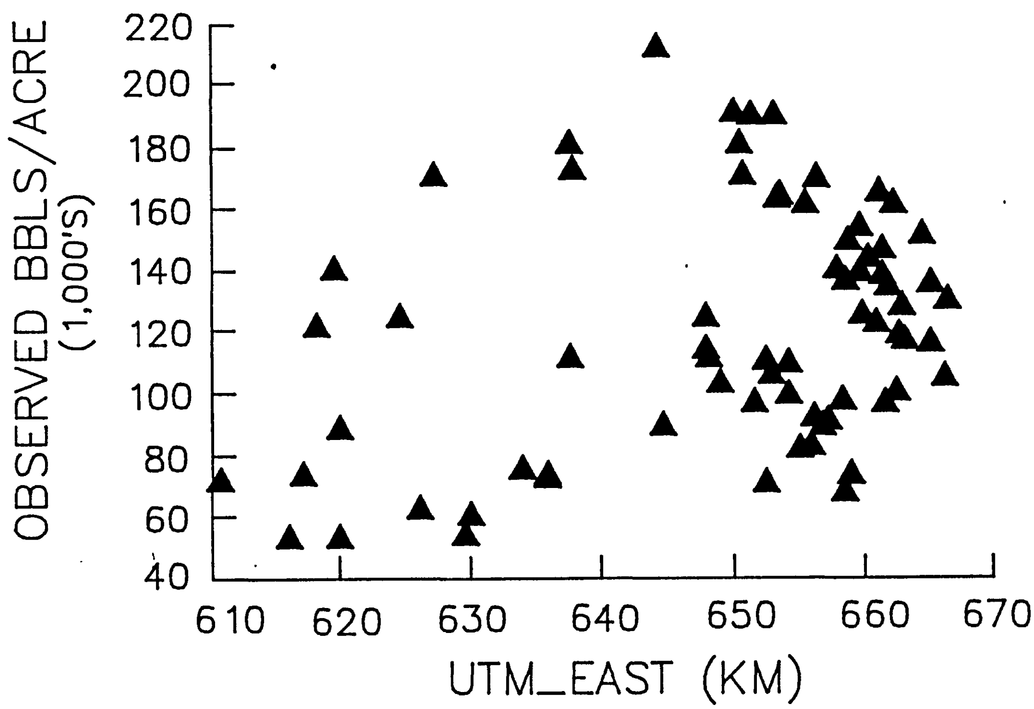


Figure 10.--Cross plot of observed barrels of oil per acre (1,000's) versus UTM eastings (km).

oil shale, such as those found in the Mahogany zone, commonly have a low clay content and contain relatively little free water. It was assumed that the composition of the organic matter and the mineral fraction of the oil shale in the Mahogany zone in the study area are essentially constant across the study area. If these assumptions are correct, one could calibrate the density or sonic log with the Fischer assay data for a core hole and extrapolate the data to nearby oil and gas wells. Unfortunately, the approach used was not totally satisfactory. The major reason for the wide spread in geophysical log versus Fischer assay data may be due to variations in porosity of the oil shale as explained by Habiger and Robinson (1983), and perhaps to a lesser extent, due to laboratory bias in analytical procedures and to differences in logging equipment.

GEOSTATISTICS

The oil-shale resources of the Mahogany zone in the selected tracts were estimated by kriging, a geostatistical technique. Geostatistics is a methodology for the analysis of spatially correlated data. It takes into account the assays from samples taken short distances apart tend to be closer in value than those from samples taken far apart (Clark, 1979).

The kriging algorithm estimates the average value of a geological variable at a point location or over an area or block of ground by assigning weights to values of surrounding samples. The weights are computed in such a way that the resulting estimate is unbiased and has a minimum variance of error. Kriging takes into consideration the following characteristics of the sample set:

1) The number of samples (e.g. drill holes) and the quality of the data for each sample,
2) the locations of the samples within the area being analyzed,
3) the distances between the samples and the block being estimated, and
4) the spatial continuity of the geological variable.

The computer software used in the resource analysis of the Mahogany zone is described by Grundy and Miesch (1987).

Data used in analysis of oil shale resources

Drill hole data used in the resource analysis are shown in Table 3. Oil and gas well numbers ending in "D" include 18 wells for which density logs were used and 2 wells ending in "S" are those for which sonic logs were used. For the resource analysis, drill hole coordinates were expressed in kilometers east and north using the Universal Transverse Mercator (UTM) coordinate system for zone 12, the central meridian of which is 111 degrees west of Greenwich. The UTM coordinates of the drill holes are not included in this report.

Columns headed "Top" and "Bottom" in Table 3 indicate the depths in feet to the top and to the bottom of that part of the Mahogany zone for which the minimums of grade and thickness discussed earlier in this report were met. The difference between top and bottom does not necessarily represent the thickness of this material, because lean zones not meeting the cut-off criteria may be interbedded with higher grade material. The column labeled "Thickness" in Table 3 gives the thickness in feet of 25 GPT oil shale only.

The column labeled "Resource" in Table 3 is the oil-shale resource calculated in KBPA by the program, OSAP. For the core holes, these values were determined from Fischer assay analyses, whereas, for the oil and gas wells, the KBPA values were estimated from the regression equations obtained by the procedures described earlier in this report. The average grade in GPT is reported in the next column. Errors of estimation are inherent in regression procedures and are usually expressed as the "standard error of the estimate." For purposes of this report, the square of the "standard error of the estimate" is called the "error measure" reported in the last column in Table 3. The usage of the error measure in geostatistics is discussed later in this report. Note that the error measure applies only to those KBPAs obtained from the regression equations.

Table 4 illustrates the methodology of determining the error measure for the density and sonic logs. The data in Table 4 are for core holes for which both Fisher assays and density logs are available. The difference between the KBPA determined from the Fischer assays and the KBPA estimated from the regression equation is the error of estimation. A calculation of the error measure was also made for the KBPA estimates obtained from sonic log data.

Variogram modeling

Seventy core holes were used to estimate the spatial correlation structure of three geological variables: thousands of barrels of shale oil per acre; thickness of oil shale meeting cutoff specifications; and depth to the top of this oil shale. As noted previously, the core holes (plate 1) fall in a horseshoe-shaped band which is open to the west for an east to west distance of about 55 km and a north to south distance of about 45 km. Along this band, the spacing of core holes is highly irregular. This areal distribution of sample locations is far from ideal for a kriging study, and was the motivation for obtaining additional information of lesser quality from the density and sonic logs. These additional sample points were not used in modeling of the spatial correlation structure, but were used to fill in gaps in sampling where core holes were not available, but yet estimates were still required.

Isoresource contours in KBPA (plate 4) were determined by a minimum curvature spline gridding routine using SURFER, a commercial mapping program developed by Golden Software. The KBPA values show a strong tendency to increase in a northerly direction and to a much lesser extent in an easterly direction. A plot of KBPA against the north UTM coordinate (figure 9), and

Table 4.--Derivation of error measure for density logs

Core hole number	KBPA by Fischer assay (A)	KBPA by regression equation (B)	KBPA error (B-A) (C)	Squared error (C^2)	B/A
U045	145.1	131.5	-13.6	184.96	1.10
U081	121.6	111.1	-10.5	110.25	1.09
U082	140.3	138.0	-2.3	5.29	1.02
U083	179.2	143.7	-35.5	1260.25	1.25
U085	163.9	158.4	-5.5	30.25	1.03
U102	146.8	159.1	12.3	151.29	0.92
U103	71.3	145.9	74.6	5565.16	0.49
U151	128.9	132.8	3.9	15.21	0.97
U153	81.1	78.4	-2.7	7.29	1.03
Averages	130.9	133.2	2.3	814.4	1.0

[Average (mean) squared error is called the "error measure".]

the east UTM coordinate (figure 10) is another way of showing this trend or "drift" in the sampled KBPA.

The hypothesis of a linear drift in the data appears reasonable, but it must be remembered that the unfavorable configuration of drill holes could possibly conceal a more complex drift, or perhaps the existence of two or more populations of assay values.

Adjusting for drift

A variogram (a plot of one-half the mean-squared difference of paired sample measurements as a function of the distance between samples) was made of the KBPA values using a lag (distance class interval) of 2.5 km (figure 11). The variogram has concave-upward (parabolic shape) curvature for the first 15 km. This phenomenon, discussed in detail by David (1977, pp 266-274), is attributed by him to the presence of a linear drift. A variogram exhibiting this parabolic curvature cannot be used in kriging, as its underlying parameters cannot be directly estimated. A method of compensating for the presence of linear drift is described below.

A trend surface of the form,

KBPA = a*UTMN_KM + b*UTME_KM + c,

was fitted to the data from the 70 core holes using the statistical technique of ordinary least-squares regression. In the above equation, the coefficients a, b, and c are the quantities to be estimated. After these coefficients are estimated, the equation is solved for KBPA using the location coordinates of each sample point. Differences between the assayed KBPA and the predicted KBPA are the "drift residuals". The equation for the linear drift for KBPA was found to be:

KBPA = 0.34*UTME_KM + 2.33*UTMN_KM - 10401.7.

The above drift equation accounts for 67.7 percent of the variability of KBPA.

A variogram is then plotted using the drift residuals (figure 12). The parabolic curvature of the variogram of KBPA has disappeared, and the values of gamma(h), are reasonably fitted by the theoretical variogram whose parameters are shown in the figure. The names of the parameters used are those typically used in geostatistics (e.g., see Journel and Huijbregts,1978 or David,1977): The "nugget" is the intersection of the variogram curve with the vertical axis. The "sill" is the point where the variogram curve becomes level. The "range" is the distance from the origin where this levelling off occurs and beyond this distance, there is no additional autocorrelation. The "C-value" is the vertical distance from the nugget to the sill, in this case, 600 - 80, or 520 KBPA squared.

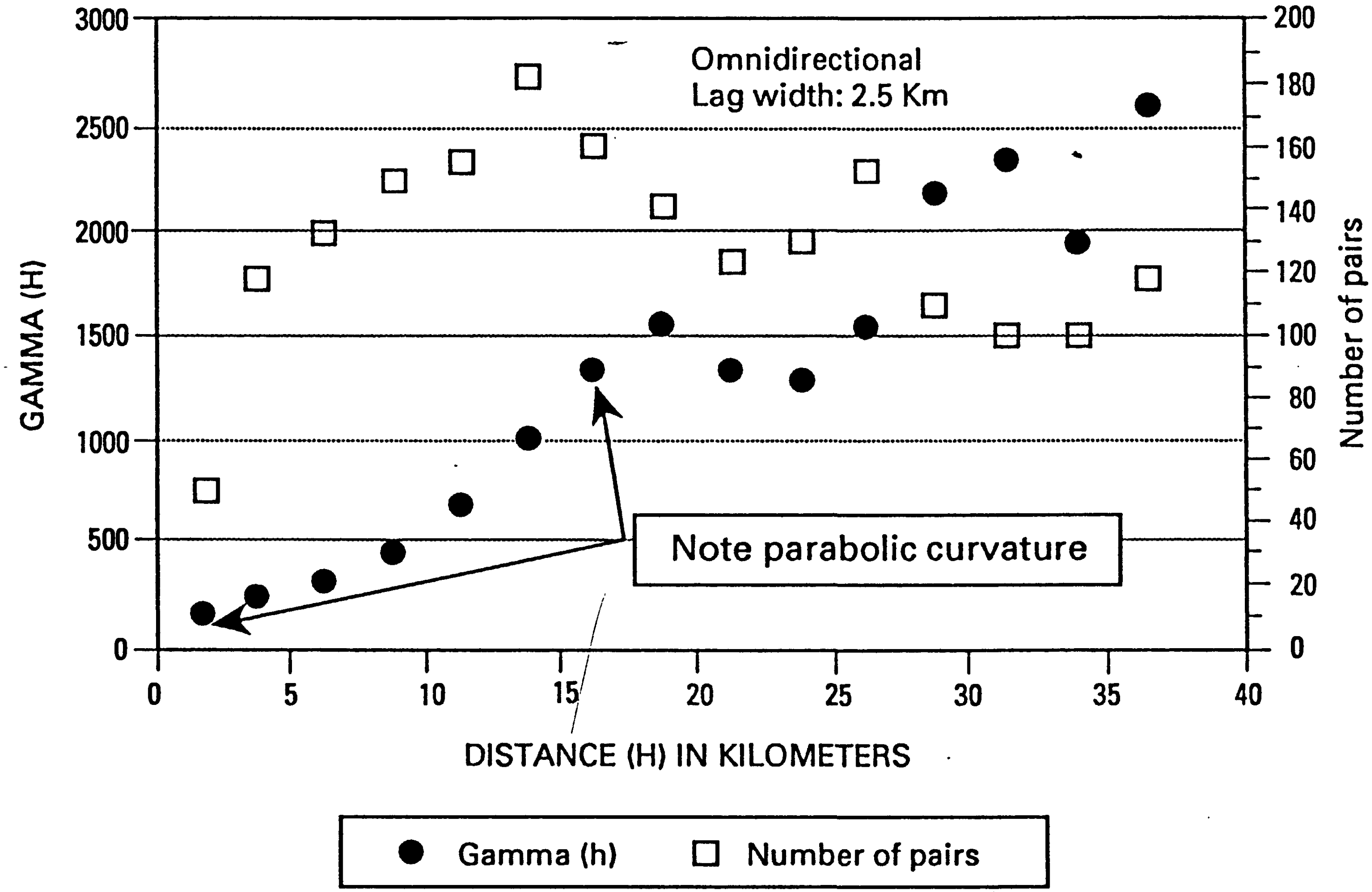


Figure 11.--Variogram of barrels of shale oil per acre (1,000's) for 71 core holes.

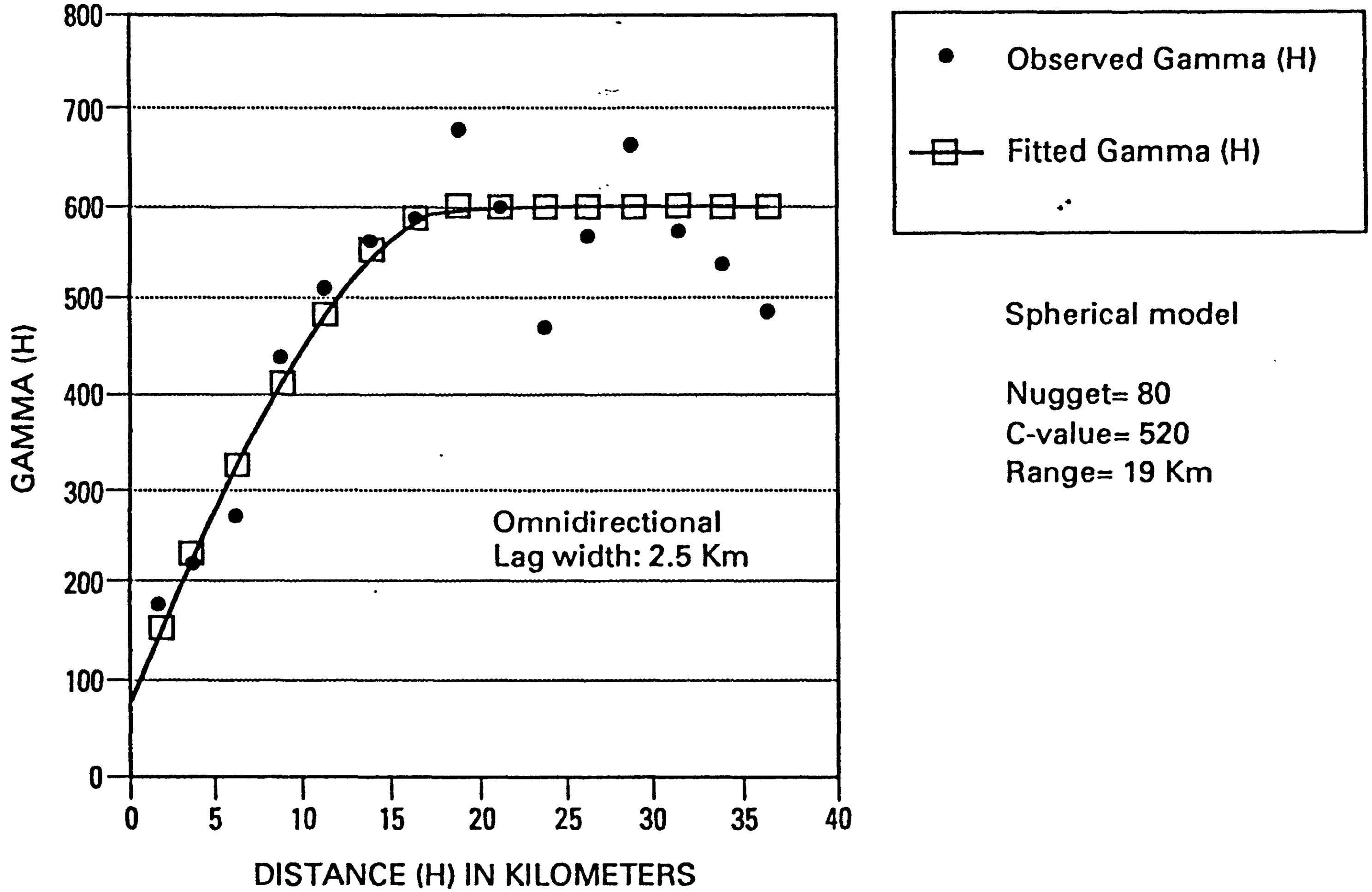


Figure 12.--Variogram of residuals derived from OLS linear drift.

Testing the validity of the fitted variogram-drift model
Kriging with compensation for drift is called "universal kriging". David (1977) and Journel and Huijbregts (1978) describe the algorithm of universal kriging used in this study. Before computing KBPA resources for the selected tracts, it is desirable to test how well the variogram of residuals and linear drift predict the values of KBPA at the actual hole locations, so that comparisons of predicted versus observed KBPA values can be used to test the acceptability of this geostatistical model. This testing procedure is called "cross-validation".

In cross-validation, one data value at a time is omitted from the 70-hole set of samples and its value is estimated from the remaining 69 data values using the universal kriging algorithm. The omitted value is then replaced into the set and a different point is removed and is similarly treated. The process is repeated until all 70 samples have been estimated.

Errors of estimation (observed value minus predicted value) are determined (table 5). For each estimated value, the kriging standard deviation is computed. This value is the standard error of estimation for the kriged estimate. Dividing the kriging error by the kriging standard deviation yields the "standardized kriging error".

Table 5.--Summary of cross-validation results for KBPA in the Mahogany zone, Uinta basin study area
N = 71

	Variable	Minimum	Maximum	Mean	Std. dev.
1.	UTM_E (Km)	610.8	666.5	649.2	14.85
2.	UTM_N (Km)	4388.0	4436.0	4414.0	13.11
3.	Observed KBPA	52.7	211.0	119.9	39.22
4.	Kriged KBPA	64.8	189.1	120.3	31.94
5.	Kriging error	-44.5	39.6	-0.4	17.13
6.	Kriging Std.Dev.	11.8	23.0	15.6	2.95
7.	Error/Krg. Std.Dev.	-3.1	2.1	-0.0	1.0

Criteria to judge acceptability of variogram/drift model

1) Mean kriging error should be close to zero.
2) Root mean square error (standard deviation of the kriging errors) should be lower than the standard deviation of the geologic variable.
3) Kriged reduced root-mean-square error (standard deviation of the standardized kriging errors) should be close to unity (i.e. in interval 1 plus or minus 2*sqrt(2/n) (Delhomme, 1976, p. 258)) where n is the number of samples in the data set.
4) The kriging errors should be independent of the kriged (estimated) values (Journel and Huijbregts, 1978, p. 495).

5) The kriging errors should be independent of their location as expressed by their x- and y-coordinates.
6) The kriged value should be positively correlated with the observed value of the geologic variable. The higher the correlation, the better, so long as the preceding criteria are met.
7) The final theoretical variogram model (either of data values or drift residuals) should closely approximate the observed variogram of the data or of the residuals.

It is desirable, although not necessary, that the kriging errors be normally distributed. If they are, the kriging variances can be used to construct confidence limits about the kriging estimates, otherwise, they cannot.

Results of cross-validation

Table 5 shows the statistics of the cross-validation of the 70 KBPA values using the variogram of figure 12 and a linear drift model. The first three criteria for goodness of fit are met. The correlation criteria are shown in Table 6 and in figures 13 and 14. The predicted KBPA values correlate well with the assayed KBPA values, but the correlation coefficient between the predicted KBPA and the kriging error (observed value minus predicted value) is 0.2. This seems a little high, but figure 14 does not give any strong indication of a correlation. No test can be made for the significance of the correlation coefficient because the kriged values are not mutually independent.

Table 6.--Correlation coefficients from cross-validations for the Mahogany oil-shale zone, Uinta basin study area

Variable	1	2	3	4	5	6	7
1	1.00						
2	0.25	1.00					
3	0.33	0.81	1.00				
4	0.29	0.84	0.90	1.00			
5	0.20	0.29	0.60	0.20	1.00		
6	-0.71	0.03	-0.08	-0.03	-0.13	1.00	
7	0.15	0.26	0.57	0.17	0.98	-0.08	1.00

Variables defined
1 = UTME_KM
2 = UTMN_KM
3 = Observed KBPA
4 = Kriged KBPA
5 = Kriging error
6 = Kriging standard deviation
7 = Kriging error/Kriging standard deviation

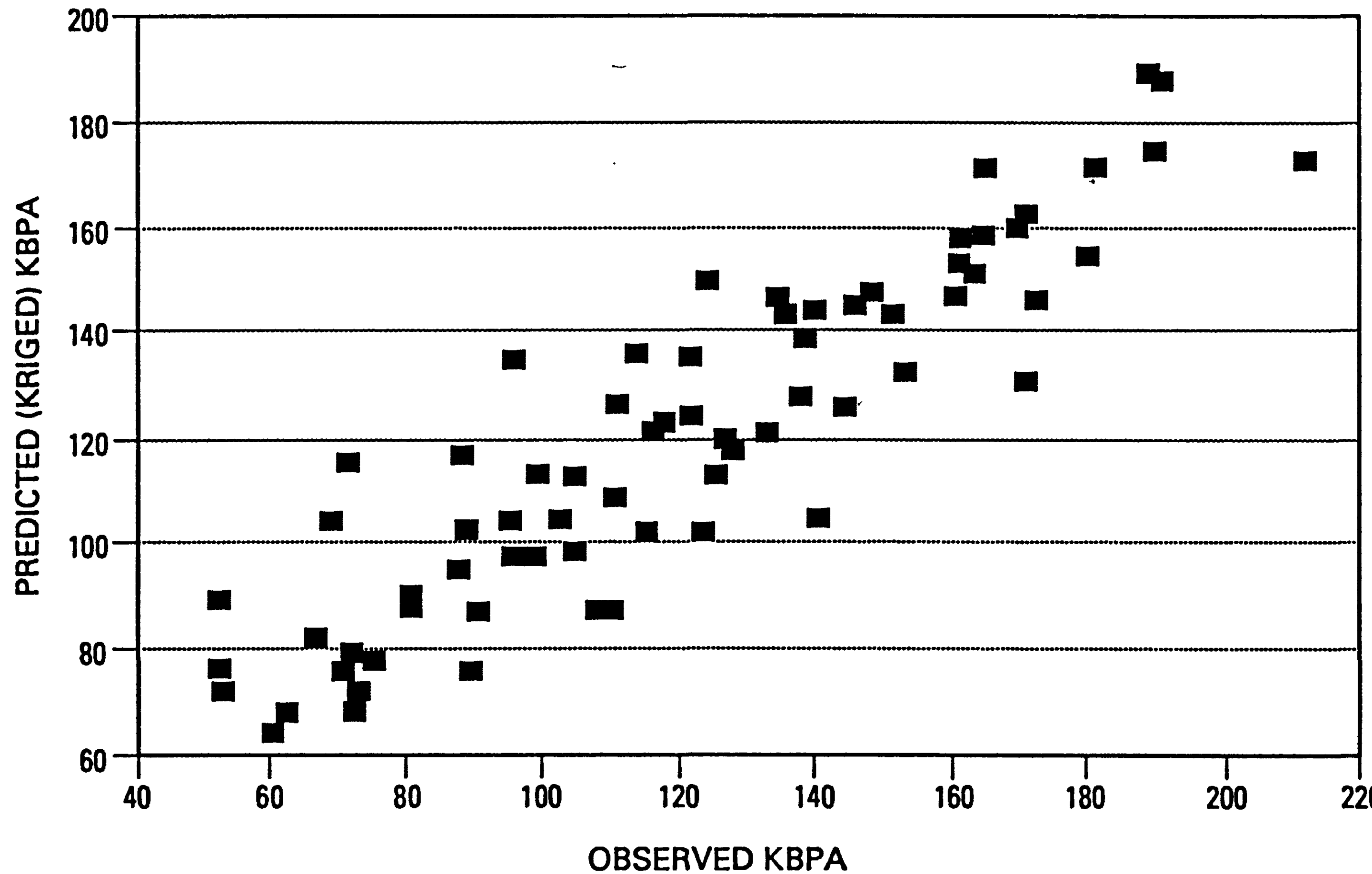


Figure 13.--Cross validation results showing observed barrels of shale oil per acre versus predicted barrels of shale oil per acre by kriging.

There is no objective test for the normality of the kriging errors. figure 15 shows a comparison of the histogram of the 70 actual kriging errors as compared with a histogram of 70 normally distributed values having the same mean and standard deviation. The histograms appear to be reasonably similar, thus, there is no good reason to reject the hypothesis that the kriging errors are normally distributed.

The results of the cross-validation test seem to validate the use of the variogram-drift model, therefore, the model was selected for use in kriging actual KBPA resource estimates of the selected tracts.

Tract-by-tract estimation of geological variables
The geological variables of thickness of and depth to the top of the 25 GPT oil shale also exhibit a linear drift and were also fitted with a variogram of residuals and a linear drift. Cross-validation results are not shown. The following summarizes the variograms of drift residuals used in this study:

Variable	Variogram type	Nugget	C_value	Range (Km)
KBPA res	Spherical	80	520	19
THICK res	Spherical	50	270	22
DEPTH res	Spherical	10000	100000	30

Kriging of resource estimates
Estimates of KBPA, thickness of the resource at the cutoff specifications, and depth of burial were made using computer program SS2DBLOK (Grundy and Miesch, 1987). Because kriging errors tend to become smaller as the size of tracts increases, some of the original individual tracts were grouped together, thereby reducing the number of tracts and groups of tracts to 63 (Tables 7 and 8, figure 16). The general rule was to group tracts that were one mile or less apart.

The variable, KBPA, was estimated using the *error measure* for the sonic and density logs from the oil and gas wells (see discussion above). Error measure allows the use of low-quality data from geophysical logs by discounting their importance in calculating resource estimates with higher-quality Fischer assay data (see Delhomme, 1976, and Karlinger and Skrivan, 1980, for discussions of the theory of error measure). This is accomplished by reducing the weights assigned to the low-quality data values, and increasing the width of the confidence limits about the estimate of the resource. Error measures were used in estimating the variable KBPA, but not thickness of overburden nor the thickness of the 25 GPT oil shale.

Estimates of the oil-shale resources in KBPA and the total barrels of shale oil for each tract or group of tracts and the 95 percent confidence limits for the total resource are given in

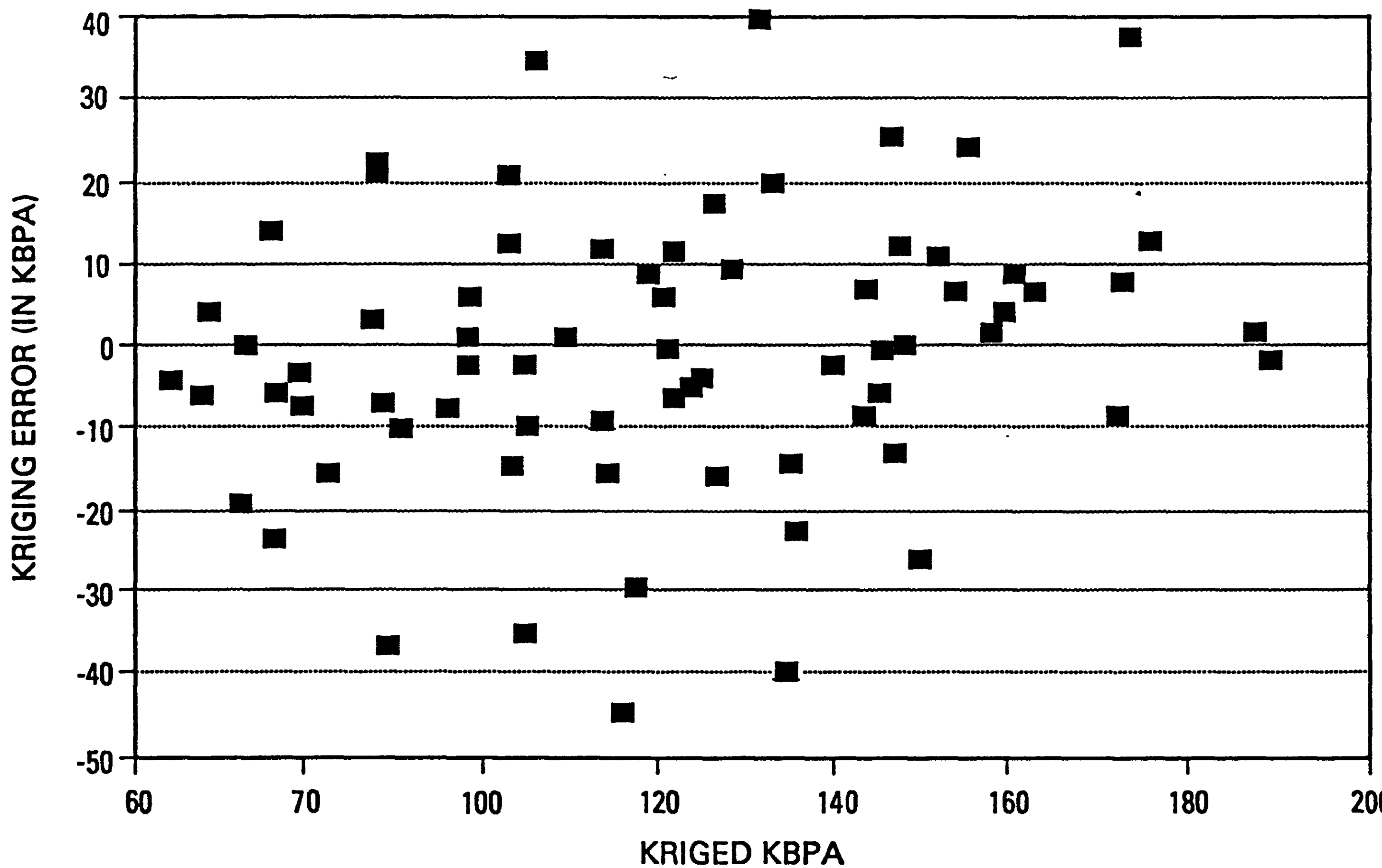


Figure 14.--Cross-validation results showing plot of shale oil in barrels per acre by kriging versus kriging error.

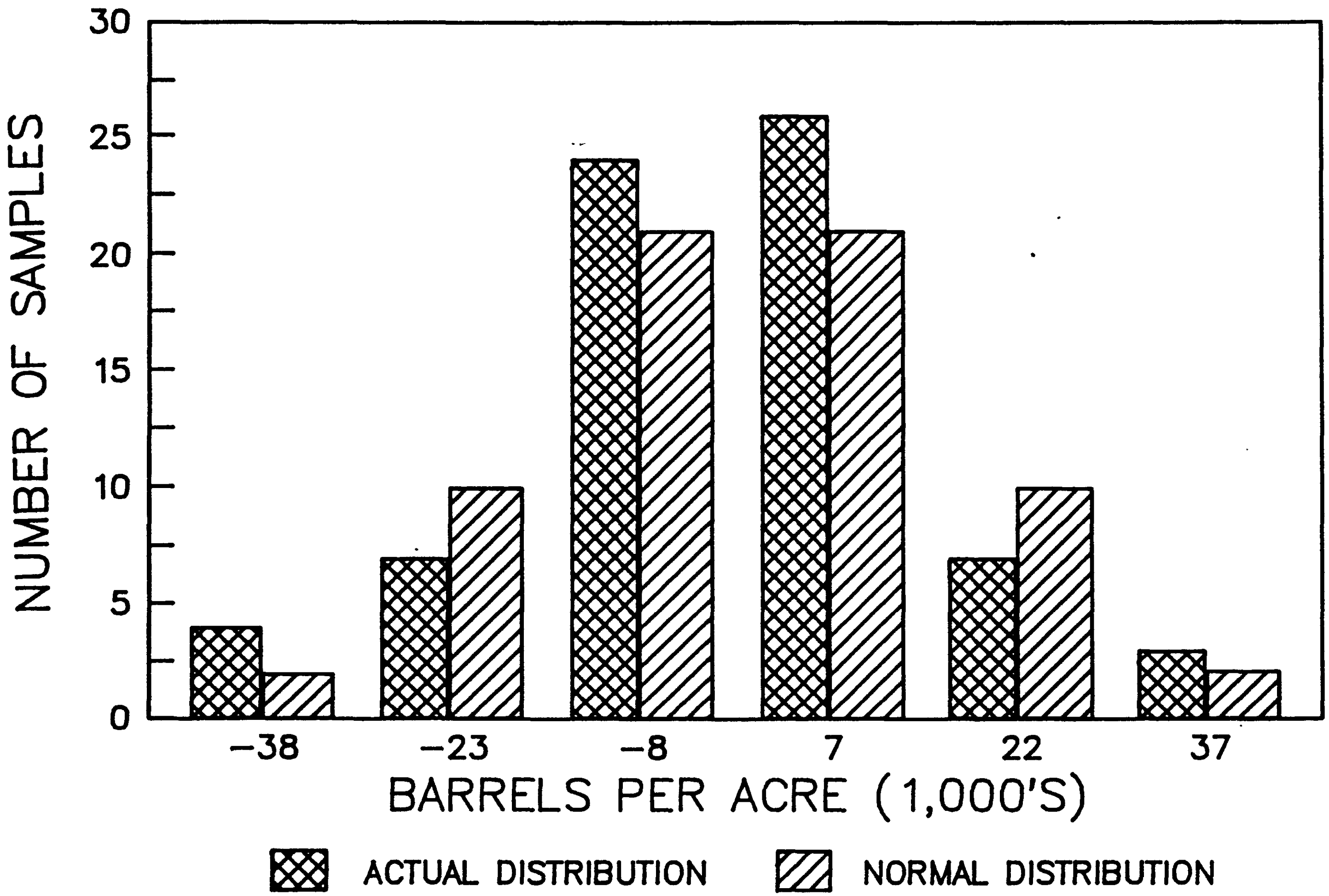


Figure 15.--Distribution of kriging errors compared with a normal distribution.

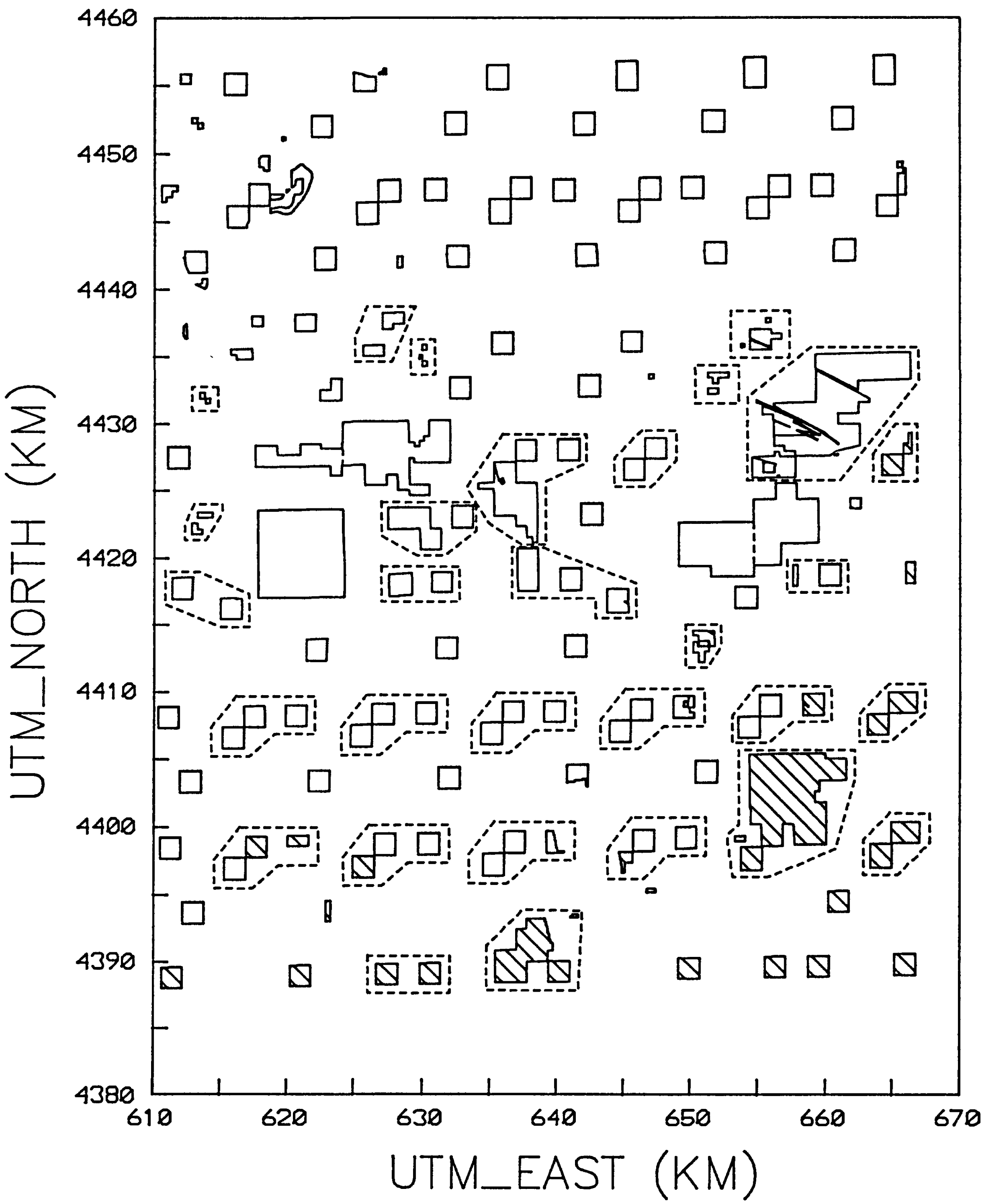


Figure 16.--Index map of the study area showing the grouping of the tracts for estimating shale-oil resources by kriging. The tracts north of 4450 km UTM_North were not evaluated and the tracts with diagonal ruling contain non-oil shale lands (see plate 1 for tract numbers and explanation).

Table 7. "Acres" lists the acreages of individual tracts and groups of tracts which were computed from the digitized boundaries of the tracts. "Shale oil" is the estimated resource in thousands of barrels for each tract or group of tracts and it is calculated as the product of "Acres" and "KBPA". The lower 0.025 percent confidence limit of "Shale oil" is obtained by

LOWER LIMIT = ACRES*(KBPA-2*KBPA_SD),

and the upper 0.975 percent confidence limit by

UPPER LIMIT = ACRES*(KBPA+2*KBPA_SD).

The last column in Table 7 gives the upper and lower limits in percent of the total resource.

Examination of Table 7 shows that for tracts 150 and 154, the lower confidence limit is negative. This occurs because the kriging standard deviation is relatively high (20 KPBA or more) compared to the KBPA estimated for the tract. In such cases where the confidence limits are negative, the reliability of the estimated KBPA is indeterminate.

Comparison of the kriged KBPA values on a tract-by-tract basis in Table 7 with the iso-resource contours of KBPA in plate 4 show some disagreement because the contour map was prepared using a minimum curvature spline gridding technique. Unlike kriging, this technique is unable to incorporate errors of measurement in the results. The minor discrepancies between the contour map and the tract values are attributed to this fact.

Kriging of thickness and depth

The thickness and depth to top of the 25 GPT oil-shale resource were estimated using the variogram models listed above with a linear drift. The results of the analysis are presented in Table 8. Two tracts had negative depths. These tracts are partially dissected by erosion (plate 1) and it is evident that the depth to the top of the 25 GPT interval is not very great. The variogram/drift model used for estimating depth is not reliable in near-outcrop areas nor in areas of high relief, such as along the White and Green Rivers, where actual measurements of the depth of overburden are sparse. For this reason, plate 5 was used to supplement the overburden thicknesses listed in Table 8. Where the thickness of overburden which was determined by the variogram model differed by more than about 100 ft from the overburden contours shown on plate 5 for a given tract, the overburden thickness estimated from plate 5 was substituted in Table 8.

Table 7.--Estimates of shale oil resources with 95 percent confidence limits for state tracts and Federal tracts Ua-Ub in the Uinta Basin study area.

				Shale oil (1,000's bbls)			
					Confidence limits		
Tract(s)	Acres	KBPA[1]	Krig. vari.[2]	Total[3]	Lower limit	Upper limit	±Pct
State Lands							
47	55	146	2418	8,100	2,600	13,500	67.6
48	284	148	382	42,000	30,900	53,100	26.4
49	164	159	463	26,000	18,900	33,000	27.2
50	485	161	416	78,300	58,500	98,100	25.2
51,52	727	166	346	120,700	93,600	147,700	22.4
53,55	113	172	319	19,400	15,300	23,400	21.0
56	633	179	145	113,300	98,100	128,600	13.4
57	626	190	277	119,000	98,100	139,800	17.6
58-61	749	183	270	136,800	112,200	161,400	18.0
62,63	78	126	369	9,800	6,800	12,900	30.3
64	480	147	207	70,400	56,600	84,200	19.7
65	641	177	251	113,300	93,100	133,600	17.9
66	644	196	148	126,500	110,800	142,200	12.4
67	41	197	213	8,100	6,900	9,300	15.0
68,69	283	190	116	53,700	47,600	59,800	11.4
70	658	97	276	64,000	42,100	85,800	34.2
71 (West)	2,363	123	68	289,600	250,500	328,600	13.5
71 (East)	7,252	153	59	1,108,900	997,200	1,220,600	10.1
72,73,87	4,449	170	67	755,200	682,700	827,800	9.6
74,75	1,283	188	137	241,200	211,100	271,200	12.5
76,77	314	133	92	41,900	35,800	47,900	14.5
82,83	244	83	172	20,200	13,800	26,600	31.7
84	10,420	93	89	965,800	769,500	1,162,000	20.3
85,86	2,499	133	78	332,000	287,700	376,200	13.3
89	649	161	215	104,600	85,500	123,600	18.2
91	121	127	102	15,500	13,000	17,900	16.0
92,93	1,266	76	209	96,700	60,000	133,300	37.9
94,95	1,322	107	207	141,100	103,000	179,200	27.0
96-98	2,630	122	81	320,800	273,500	368,200	14.7
99	644	142	128	91,400	76,800	105,900	15.9
100,101	801	137	24	110,000	102,200	117,800	7.1
103	643	84	295	54,000	31,900	76,100	40.9
104	646	95	336	61,100	37,400	84,800	38.7
105	648	100	281	64,900	43,200	86,600	33.5

107,170	546	119	178	64,700	50,200	79,300	22.5
108	617	77	511	47,300	19,400	75,100	59.0
109,110,165	1,913	109,110,165		1,913	78 274	149,800	86,500
111-113	1,933	89	314	171,200	102,600	239,700	40.1
114-116	1,915	95	311	181,400	113,800	249,000	37.2
117-119	1,853	103	207	191,200	138,000	244,500	27.8
121-123	1,838	97	31	177,600	157,200	198,100	11.5
125	276	98	233	27,000	18,600	35,400	31.2
126	637	72	345	45,900	22,200	69,600	51.6
127	642	74	210	47,300	28,700	65,900	39.3
128	646	94	328	60,400	37,000	83,800	38.8
129	483	104	353	50,400	32,200	68,500	36.1
130	643	94	75	60,100	49,000	71,300	18.5
131,145,146	5,967	84	17	498,600	449,600	547,600	9.8
132	642	63	363	40,100	15,700	64,600	61.0
133-135	1,441	58	106	83,700	54,000	113,400	35.5
136-138	1,581	70	93	110,600	80,100	141,100	27.5
139-141	1,561	92	192	143,200	99,900	186,400	30.2
142-144	1,528	111	70	169,200	143,700	194,700	15.1
149	635	52	258	33,000	12,600	53,300	61.9
150	123	51	3933	6,200	(-9,200)	21,700	248.7
153	150	81	459	12,100	5,7000	18,500	53.1
154	639	42	543	27,000	(-2,800)	56,800	110.5
155	550	42	398	23,100	1,100	45,000	95.1
156,157	576	55	100	31,800	20,300	43,300	36.2
162	2,321	78	95	181,200	135,900	226,400	25.0
166-169	11,226	163	35	1,834,500	1,701,900	1,967,100	7.2
	------			----------			
Subtotal	87,736			10,392,900			
Federal lands							
90 (Ua)	5,123	165	24	845,600	795,800	895,400	5.9
90 (Ub)	5,150	158	21	812,500	764,900	860,100	5.9
	------			---------			
Subtotal	10,273			1,658,100			
Grand total	98,009			12,051,000			

[1] 1,000's of barrels of shale oil per acre.
[2] Kriging variance.
[3] Total barrels of shale oil per tract(s).

Table 8.--Thickness and depth of burial of 25 GPT oil-shale resources on state and Federal tracts.

Tracts(s)	Center of tract UTM_E (Km)	Center of tract UTM_N (Km)	Thickness of 25 GPT shale (Feet)	Thickness of 25 GPT shale (SD)[2]	Depth to 25 GPT shale (Feet)	Depth to 25 GPT shale (SD)[2]
47	612.363	4436.862	83	32	2867	596
48	616.642	4435.222	88	8	2747	120
49	617.696	4437.667	95	8	2874	133
50	621.307	4437.531	95	9	2811	141
51-52	627.094	4436.695	97	10	2647	167
53-55	629.952	4435.022	100	11	2527	175
56	635.887	4435.970	101	8	2545	127
57	645.526	4436.122	79	8	2500[1]	---
58-61	655.235	4436.406	96	11	1822	171
62-63	613.788	4431.896	70	9	2561	142
64	623.334	4432.404	77	5	2502	82
65	632.726	4432.697	104	10	2364	154
66	642.372	4432.865	102	7	2400[1]	---
67	646.986	4433.542	88	8	2300[1]	---
68-69	651.858	4433.261	101	7	1970	112
70	611.845	4427.379	48	6	2312	97
71A	621.052	4427.371	69	5	2243	78
71B	627.847	4427.975	89	4	2161	---
72-73,87	637.596	4425.542	103	4	1700[1]	---
74-75	646.507	4427.319	112	7	1829	117
76-77	665.542	4427.383	76	7	200[1]	---
82-83	613.510	4422.629	46	8	1929	127
84	620.965	4420.278	52	4	1794	57
85-86	630.372	4422.591	73	5	1812	82
89	642.559	4423.215	104	8	1578	135
90A (Ua)	652.006	4420.748	97	4	907	53
90B (Ub)	656.853	4422.588	92	3	724	50
91	662.265	4424.057	74	7	100[1]	---
92-93	613.968	4416.899	39	9	1400[1]	---
94-95	629.833	4418.069	56	6	1624	101
96-98	640.421	4418.255	74	6	1268	90
99	654.093	4416.975	83	8	1100[1]	---
100-101	659.877	4418.690	79	3	518	53
103	622.169	4413.048	44	9	1407	145
104	631.786	4413.210	49	8	1500[1]	---
105	641.356	4413.374	58	10	1400[1]	---
107,170	650.907	4413.634	69	9	540	141
108	611.107	4408.030	39	14	1100[1]	---

109-110,165	618.069	4407.630	41	10	930	158
111-113	627.651	4407.778	47	9	1250[1]	---
114-116	637.246	4407.948	51	7	700[1]	---
117-119	646.773	4408.080	58	9	567	140
121-123	656.344	4408.423	56	4	293	60
125	665.676	4409.462	56	10	100[1]	---
126	612.781	4403.238	38	12	1200[1]	---
127	622.341	4403.380	42	8	1200[1]	---
128	631.959	4403.547	56	8	1200[1]	---
129	641.526	4403.917	58	11	612	172
130	651.136	4404.046	55	6	317	93
131,145-146	656.627	4402.519	49	3	111	45
132	611.276	4398.381	34	13	500[1]	---
133-135	617.244	4397.798	33	7	200[1]	---
136-138	628.325	4398.499	42	6	300[1]	---
139-141	636.724	4398.097	53	9	472	136
142-144	647.645	4398.833	64	6	350[1]	---
149	612.965	4393.571	29	11	600[1]	---
150	623.083	4393.853	30	42	150[1]	---
153	660.669	4394.762	46	14	100[1]	---
154	611.433	4388.686	24	16	150[1]	---
155	620.878	4388.940	24	13	100[1]	---
156-157	630.453	4389.110	31	7	100[1]	---
162	637.435	4390.949	45	7	100[1]	---
166-169	660.076	4431.182	94	4	1012	63

[1] Thickness of overburden estimated from plate 5.
[2] SD, two standard deviations

EVALUATION OF OIL-SHALE RESOURCES

Oil shales of the Green River Formation tend to form continuous beds of broad areal extent. This is especially true for the Mahogany zone which marks the largest expansion of the ancient Eocene lake that covered parts of northwest Colorado and northeast Utah. Individual units of oil shale within the Mahogany zone--for example, the Mahogany oil-shale bed--can be traced in the subsurface for many miles across the Piceance Creek Basin in northwest Colorado, to the southwestern part of the Uinta Basin, Utah. Changes in thickness and grade of oil shale, tend to be gradual through the offshore lacustrine parts of the lake and more abrupt toward the basin margins where nearshore landward-derived clastic sediments intermingle with the offshore lacustrine organic and clayey carbonate sediments.

Variations in the grade of Green River oil shale are attributable largely to the effects of dilution of the organic matter with clastic sediments derived from streams entering the lake at different points around the margins of the lake basin. Turbidity currents originating from inflowing streams and storm events can carry fine-grained clastic sediments (silts and clays) well out into the basin. The grade of the oil shale is also influenced by deposition of syngenetic minerals, especially carbonates such as dolomite and calcite as well as evaporite minerals such as nahcolite; these minerals also dilute the organic content of the oil shale. Because of the broad expanse of the lake and low gradient of the depositional surfaces of the lake bottom, these processes tended to operate over considerable distances, so that lateral lithologic changes tended to be gradual. Intertonguing of basin-margin clastics and organic-rich offshore lacustrine sediments persist laterally for relatively long distances. In the southern part of the study area toward the shoreward part of the Eocene lake, interlayered silts and carbonate muds accumulated on these broad low-gradient surfaces that received little, if any, sands. These sediments, now indurated, form a sequence of intertonguing siltstone, marlstone, and oil shale comprising the Mahogany oil-shale zone. Such laterally persistent beds of oil shale and associated rocks permit the assessment of oil-shale resources with a greater level of confidence than would be possible for other types of fossil fuels, such as coal.

Relation between thickness and grade of oil shale

Figure 17 is a three-dimensional model of plate 4 which shows isoresource contours in KBPA for the study area. Overall, the oil-shale resource increases from a low of about 50-55 KBPA in the southwest corner of the study area northward toward the westward-trending depositional axis for the Mahogany zone which lies along the northern edge of the study area. Along the depositional axis, the Mahogany zone thickens to about 130-135 feet and the oil-shale resource increases to about 190-210 KBPA. In this area the thickening of the Mahogany zone is attributable

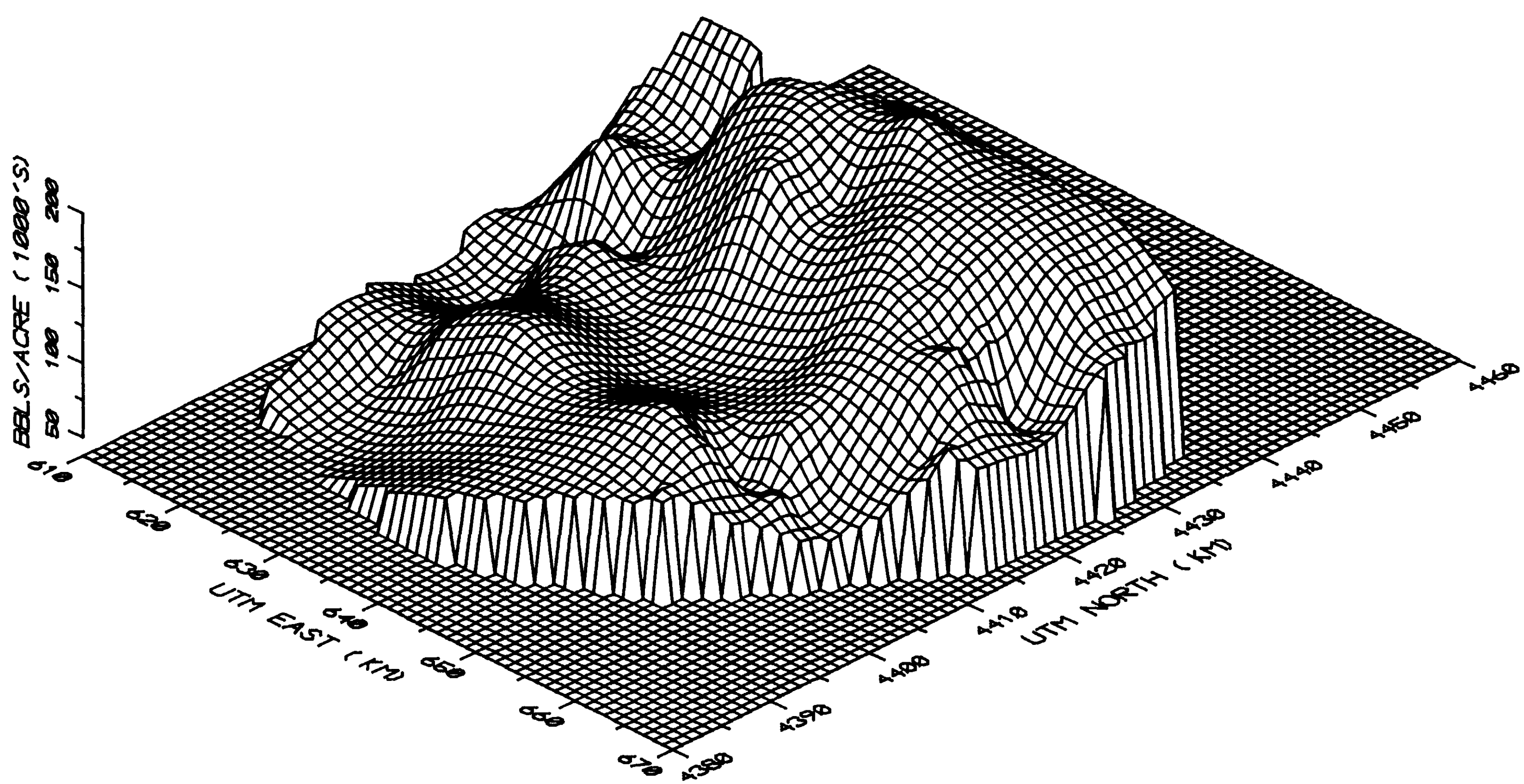


Figure 17.--Block diagram of the shale-oil resources in the study area. Vertical axis is in 1,000's of barrels of shale oil per acre. The vertical skirt delimits the area of well control in the study area. View to northwest.

to increased amounts of organic matter and syngenetic carbonate minerals that were deposited in the axial portion of the Eocene lake.

A well defined belt of minimum thickness of the Mahogany zone of about 60-75 feet trends westnorthwest to eastsoutheast across the middle of the study area (plate 3). This belt of thinned Mahogany coincides with a rather poorly defined trend of reduced oil-shale resources ranging from about 90 to 100 KBPA (plate 4 and figure 17). As the thickness of the Mahogany increases to about 135-140 feet toward the southwest corner of the study area, the oil-shale resource decreases to a minimum of about 50-55 KBPA owing to increased amounts of clastic sediments that intertongue with and dilute the organic fraction of the oil shale. The irregular surface of the resource model in the northwest part of the study area probably reflects the poorer quality of shale-oil estimates calculated for the oil and gas wells from the density and sonic logs, rather than real variations in the oil-shale resource.

A west-northwest to east-southeast trend of richer grade oil shale that reaches 100 to 124 KBPA is suggested by the iso-resource contours (plate 4) and the block diagram (figure 17) in the south-central part of the study area just south of the zone of minimum thickness of the Mahogany zone, mainly in T.12 S., Rs. 22-24 W. Additional core drilling would be needed to better define this trend, especially toward the west side of the study area where few exploratory bore holes for oil shale or for oil and gas have been drilled.

The sum of the oil-shale resources on the evaluated tracts of state lands in the study area is 10.4×10^9 barrels of oil , whereas, the oil-shale resources on Federal tracts Ua-Ub total 1.66×10^9 barrels of oil. The Federal tracts have been previously estimated to contain about 1.42×10^9 barrels of shale oil for oil shale averaging 24 GPT (Carnahan and Moulton, 1975, p. 18). However, the estimate by Carnahan and Moulton may be somewhat conservative because they included the Fischer assays for the P and X series holes in their analysis.

Estimated error of resources

As expected, the smallest estimated errors for the kriged oil-shale resource (<20 percent) for each tract or group of tracts are found in those parts of the study area where core-hole density is the highest (Table 7). The resource estimates with the largest error (>40 percent) are found for tracts in the southwest and northwest parts of the study area where the core-hole density is low. The smallest errors were found for the Federal tracts Ua-Ub (±5.9%) and state tracts 100 and 101 (±7.1%), 166-169 (±7.2%), 72,73,87 (±9.6%), and 131,145,146 (±9.8%).

RECOMMENDATIONS

An analysis of cross-plots of geophysical logs should be made to see if the estimates of shale-oil yields for oil and gas wells in the Uinta Basin study area can be improved. This work would require additional digitization of geophysical logs, evaluation of log suites available for core holes and oil and gas wells in the study area, and testing of the cross-plot method. The method was successfully used for an evaluation of oil-shale resources in an area in the Piceance Creek Basin, Colorado, where a high correlation between log estimates and Fischer assay was found ($r^2 = 0.88$).

The study area should be evaluated for oil-shale resources on a township by township basis. This work would provide oil-shale resource data for Federal lands at a relatively low cost because the state lands have been evaluated in this report. The work would require digitizing township boundaries and the Mahogany oil-shale bed from 1:24,000-scale topographic and geologic maps and analysis of the resources by kriging.

Several additional core holes to test the oil shale resources in Tps. 10-11 S., Rs. 21-23 E. are recommended. Shale-oil analyses of the Mahogany oil-shale zone in this area could significantly increase the confidence level of the resource estimates in an area where subsurface information is sparse.

REFERENCES

American Society for Testing and Materials, 1980, Standard method for oil from oil shale (resource evaluation by the USBM Fischer assay procedure): Annual Book of ASTM Standards, Part 25, Designation D 3904-80, p. 513-525.

Bardsley, S.R., and Algermissen, S.T., 1963, Evaluating oil shale by log analysis: Journal of Petroleum Technology, vol. 15, p. 81-84.

Carnahan, E.R., and Moulton, W.W., 1975, White River Shale Project, Geologic exploration program report: The Cleveland-Cliffs Iron Company unpublished report, approx. 228 p.

Cashion, W.B., 1967, Geology and fuel resources of the Green River Formation, southern Uinta Basin, Utah and Colorado: U.S. Geological Survey Professional Paper 548, 48 p.

Cashion, W.B., 1974, Preliminary geologic map of the Southam Canyon quadrangle, Uintah County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-579.

Cashion, W.B., 1977, Geologic map of the Weaver Ridge quadrangle, Uintah County, Utah, and Rio Blanco County, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-824.

Cashion, W.B., 1978, Geologic map of the Walsh Knolls quadrangle, Uintah County, Utah and Rio Blanco County, Colorado: U.S. Geological Survey Miscellaneous Field Investigations Map MF-1013.

Cashion, W.B., 1984, Geologic map of the Agency Draw NW quadrangle, Uintah County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1717.

Cashion, W.B., 1986, Geologic map of the Bonanza quadrangle, Uintah County, Utah: U.S. Geological Survey Miscellaneous Field Investigations Map MF-1865.

Clark, Isobel, 1979, Practical Geostatistics: Applied Science Publishers, Ltd., London, UK (Reprinted 1982) 129p.

David, M., 1977, Geostatistical ore reserve estimation: Elsevier Scientific Publishing Company, Amsterdam, 364 p.

Delhomme, J.P., 1976, Kriging in the hydrosciences: Advances in Water Resources, vol. 1, p.251-266.

Grundy, W.D., and Miesch, A.T., 1987, Brief descriptions of STATPAC and related statistical programs for the IBM personal computer: U.S. Geological Survey Open-File Report 87-411-A, 34 p.

Habiger, Rob, and Robinson, R.H., 1983, Using a multiple log approach to evaluate Green River oil shale in the Piceance Creek Basin *in* Sixteenth Oil Shale Symposium Proceedings: Colorado School of Mines, Golden, p. 45-67.

Journel, A.G., and Huijbregts, Ch. J., 1978, Mining geostatistics: Academic Press, New York, 600 p.

Karlinger, M.R. and Skrivan, J.A., 1980, Kriging analysis of mean annual precipitation, Powder River Basin, Montana and Wyoming: U.S. Geological Survey WRI 80-50, 29p.

Keighin, C.W., 1977a, Preliminary geologic map of the Burnt Timber Canyon quadrangle, Uintah County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-875.

Keighin, C.W., 1977b, Preliminary geologic map of the Cooper Canyon quadrangle, Uintah County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-874.

Keighin, C.W., 1977c, Preliminary geologic map of the Rainbow quadrangle, Uintah County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-893.

Pantea, M.P., 1987, Preliminary geologic map of the Davis Canyon quadrangle, Uintah County, Utah, and Garfield and Rio Blanco

Counties, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-1933.

Pipiringos, G.N., 1978, Preliminary geologic map of the Bates Knolls quadrangle, Uintah County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1025.

Pipiringos, G.N., 1979, Preliminary geologic map of the Agency Draw NE quadrangle, Uintah County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1078.

Scott, R.W., Jr., and Pantea, M.P., 1985, Preliminary geologic map of the Dragon quadrangle, Uintah County, Utah and Rio Blanco County, Colodado: U.S. Geological Survey Miscellaneous Field Studies Map MF-1774.

Selner, G.I., and Taylor, R.B., 1991, GSMAP system, version 7.0: graphics programs and related utility programs for the IBM PC and compatible microcomputers to assist compilation and publication of geologic maps and illustrations using geodetic or cartesian coordinates: U.S. Geological Survey Open-File Report 91-1, 151 p.

Smith, J.W., Thomas, H.E., and Trudell, L.G., 1968, Geologic factors affecting density logs in oil shale *in* Society of Professional Well Log Analysts Logging Symposium, 9th Annual, New Orleans, Transactions, Texas Society of Professional Well Log Analysts, p. P1-P17.

Smith, M.C., 1981, Structure contours and overburden on the top of the Mahogany bed, Green River Formation, eastern part of the Uinta Basin, Uintah, Duchesne, and Carbon Counties, Utah, and Rio Blanco County, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-1311.

Stanfield, K.E., and Frost, I.C., 1949, Method of assaying oil shale by a modified Fischer retort: U.S. Bureau of Mines Report of Investigations 4477, 13 p.

Tixier, M.P., and Curtis, M.R., 1967, Oil shale yield prdicted brom well logs: Proceedings, Seventh World Petroleum Congress, Mexico City, vol. 3, p. 713-715.

Trudell, L.G., Mason, G.M., Smith, J.W., and Beard, T.N., 1982, UTah's principal oil shale resources in the Uinta Basin *in* 15th Oil Shale Symposium Proceedings, Colorado School of Mines, Golden, p. 38-49.

Trudell, L.G., Smith, J.W., Beard, T.N., and Mason, G.M., 1983, Primary oil-shale resources of the Green River Formation in the eastern Uinta basin, Utah: U.S. Department of Energy Laramie Energy Technology Center, Report no. DOE/LC/RI-82-4, 58 p.

APPENDIX A

1. Memorandum of Understanding between the U.S. Bureau of Land Management, the State of Utah, and the Geological Survey.

2. Letter by John T. Blake, Utah Division of State Lands and Forestry, dated June 29, 1989, listing the state lands to be evaluated by the USGS for oil-shale resources.

3. Letter by J.R. Dyni, U.S. Geological Survey, dated March 31, 1990, listing corrections to acreages for five tracts of state lands in the list provided by Blake above.

4. Letter by David E. Little, U.S. Bureau of Land Management, dated June 28, 1989, listing Federal lands within Federal oil-shale leases Ua and Ub, Uintah County, Utah, to be evaluated for oil-shale resources by the USGS.

MEMORANDUM OF UNDERSTANDING

AMONG THE

UTAH STATE BUREAU OF LAND MANAGEMENT

THE

UTAH DIVISION OF STATE LANDS AND FORESTRY

AND THE

UNITED STATES GEOLOGICAL SURVEY

CONCERNING EVALUATION OF OIL SHALE RESOURCES

THIS MEMORANDUM OF UNDERSTANDING, hereinafter referred to as the MOU, is entered into among the Bureau of Land Management, hereinafter called the BLM; the Utah Division of State Lands and Forestry, hereinafter called the State; and the United States Geological Survey, hereinafter called the USGS.

A. PURPOSE

On December 22, 1987, Congress passed legislation (Public Law 100-202; 101-Stat 1329-216) authorizing the Secretary of the Interior, through the State Director Utah BLM, to negotiate with officials from the State of Utah and to take any action necessary under the Federal Land Policy and Management Act and other applicable laws to consummate an exchange of Federal lands and improvements thereon identified as tracts Ua and U-b, for State lands of equal value if the Secretary determines that such an exchange is in the public interest. Subsequent meetings between Utah BLM and State officials identified problems with adequacy of resource data necessary to evaluate State offered lands as compared to available data on Federal tracts Ua and U-b. The BLM and State agreed that USGS, as an objective third party having considerable expertise in oil shale resource evaluation, would be asked to conduct an evaluation of lands within a specific study area to provide information concerning data adequacy and associated confidence levels of resource estimates for lands within the study area.

The purpose of this MOU is to provide details as to the work to be conducted by USGS, the specific products to be provided, support to be provided by BLM and the State, timeframe in which the work is to be completed, and the cost of completing the evaluation.

B. INTRODUCTION

At the request of the Utah State Office of the BLM, the USGS was asked to prepare a proposal to determine oil shale resources in an area of approximately 1,400 square miles in the eastern part of the Uinta Basin, Utah, and to determine the degree of reliability of resource estimates for the area. The study would be used by BLM and the State of Utah in support of a proposed land exchange of state lands for Federal oil shale tracts Ua and U-b.

The USGS proposal was transmitted to BLM in a letter dated February 3, 1989, and with some minor modification provided the basis for the evaluation to be performed as detailed in this MOU. This MOU will become effective upon signature by appropriate representatives of the three agencies which are parties to the MOU.

C. AREA OF STUDY

The area of study includes a rectangular area that includes approximately Townships 7 to 13 South, Ranges 20 to 25 East (Salt Lake Meridian) in the eastern part of the Uinta Basin, Uintah County, Utah. The area is approximately 40 miles long in a north-south direction, and approximately 33 miles wide in an east-west direction.

The Federal Ua-Ub lands are in the eastern part of the study area and include a block of 10,240 acres in parts of Township 10 South, Ranges 24 and 25 East. As many as 27 core holes have been drilled on and near the lands and many samples have been analyzed by Fischer assay. Therefore, reasonably accurate estimates of the oil shale resources of the Ua-Ub lands can be made. Only part of the geologic data are on file with the USGS. However, the information is available through the BLM.

The State lands, mostly in tracts of approximately 640 acres (sections), or smaller, are scattered throughout the study area. Many of the state tracts lie to the south and southwest of the Ua-Ub tracts. Few of these tracts have been core drilled for oil shale evaluation. The state lands to be evaluated for oil shale are shown on the map accompanying this MOU.

For most State lands, oil shale resource estimates must be interpolated from scattered core holes and from oil and gas test wells that were drilled up to several miles away from individual tracts. In some cases it will be necessary to make resource estimates indirectly from density and sonic logs of oil and gas wells. It will be important to determine the degree of reliability that can be placed on resource estimates developed from widely spaced data points with many of the data points having only sonic and density logs as an indicator of resource quantity and quality versus core holes with Fischer assays.

D. OBJECTIVES AND PLAN OF STUDY

The objectives of this evaluation are (a) to evaluate the oil shale resources of state and Federal lands in the study area, (b) to estimate the degree of reliability of the resource data that are determined indirectly from geophysical logs in those areas for which Fischer assay data are lacking, and (c) to determine the level of confidence or the relative reliability for the resource estimates made for the state and Federal lands in the study area.

An outline of the work to be accomplished follows:

1. Prepare a series of detailed stratigraphic sections of the Mahogany zone in the study area based on histograms of shale-oil yields from Fischer assay data and from estimates of oil yields made from geophysical logs. Stratigraphic correlation lines of key beds in the Mahogany zone shall be

shown. Oil shale above and below the Mahogany zone will not be evaluated. Only those sequences of oil shale within the Mahogany zone that are more than 10 feet thick and that average more than 10 gallons per ton will be evaluated.

2. Prepare two stratigraphic cross sections drawn approximately from north to south and east to west through the study area to show significant lithologic details of the Mahogany zone that may affect the shale oil content of the zone. Those features (i.e., vuggy zones and nahcolite) which may affect the reliability of density and sonic logs shall be investigated with respect to their influence on shale-oil estimates made from these logs.

3. Determine the quantitative relationship between density/sonic logs and Fischer assays for a selected group of core holes in the study area and to estimate the degree of reliability of calculating shale-oil yields from geophysical logs for wells for which Fischer assay data are lacking.

4. Prepare variograms for (a) coreholes within the study area for which Fischer assays are available and for (b) wells for which shale-oil yields are estimated from geophysical logs.

5. Prepare resource data for Federal Tracts U-a and U-b and for each of the tracts of state lands in the study area giving (a) the total tons of oil shale per tract, (b) total barrels of oil equivalent (BOE) on each tract, and (c) average grade of oil shale for each tract. An attempt shall be made to determine to confidence limits of items 5(a) and 5(b), and if this is not possible, the relative degree of reliability of these data shall be made.

6. Prepare isopleth maps of the study area showing thickness, grade, and shale-oil resources.

7. The above stratigraphic sections, isopleth maps, oil shale resource estimates, and estimation of the degree of reliability of calculating shale-oil yields from geophysical logs, and also copies of shale-oil yield bar graphs of all of the coreholes and wells used in this study and of all semivariograms prepared in this study shall be included in an administrative report to the BLM and the State of Utah, explaining and discussing the procedures and methodologies used by USGS in evaluation of the data.

E. BLM AND STATE RESPONSIBILITIES

1. BLM will provide clerical assistance through input of Fischer assay data into Lotus 1-2-3 files which can then be input into the USGS system.

2. BLM will provide usable copies of assay data for core holes on tracts Ua/U-b.

3. The State will provide a map showing the state lands in the study area to be evaluated for oil shale and lithologic and geophysical logs for drill holes within the study area for which they have the information and as requested by USGS.

F. TIMEFRAME AND COST

USGS agrees to provide the information specified in Section D within 180 working days of the effective date of this MOU or within 180 working days of the date upon which data, as designated in paragraph E, is provided, whichever date is later.

USGS agrees to provide the information specified in Section D at a total cost of $46,410 determined as follows:

Hardware and software	$ 4,755
Materials and logs	500
Salaries (USGS personnel)	27,553
18% agency overhead	7,202
Subtotal	$40,010
Consultants	6,400
Total	$46,410

G. PERSONNEL AND METHOD OF PAYMENT

The personnel to be designated as point of contact within the State of Utah, BLM, and the USGS and the method of payment for this study will be provided in a separate letter between the three agencies.

H. AMENDMENTS

Amendments to this MOU may be proposed at any time by any party to the MOU and shall become effective upon written approval by all parties to the agreement.

IN WITNESS WHEREOF, the parties have set their hands and seals as of the date herein written.

STATE OF UTAH

Date: 8·31·87

[signature]
Director
Division of State Lands and Forestry

BUREAU OF LAND MANAGEMENT

Date: 8-31-89

[signature]
Utah State Director

U.S. GEOLOGICAL SURVEY

JUN 28 1989

Date:

[signature]
for Gary W. Hill
Chief, Office of Energy & Marine Geology

DEPARTMENT OF NATURAL RESOURCES
DIVISION OF STATE LANDS AND FORESTRY

Norman H. Bangerter
Governor
Dee C. Hansen
Executive Director
Patrick D. Spurgin
Division Director

355 West North Temple
3 Triad Center, Suite 400
Salt Lake City, Utah 84180-1204
801-538-5508

June 29, 1989

John Dyni
United States Geological Survey
Box 25046
Mail Stop MS 939
Denver Federal Center
Denver, CO 80225

Dear Jack:

RE: White River Land Exchange Study Area

Enclosed please find a revised list of State of Utah Oil Shale lands. The revised list contains expanded descriptions for sections containing lot numbers where less than the entire section is State land. It also lists acreages assigned to each tract of land by BLM cadastral surveys.

Under separate mailing I am sending you selected topographic quadrangles upon which I have drawn lot locations around gilsonite veins and Colorado River meanders. This may be helpful to you in interpreting the lands list.

Please contact me if I may be of further assistance.

Sincerely yours,

JOHN T. BLAKE
MINERAL RESOURCES SPECIALIST

JTB/dd
Enclosures

cc: Randy Heuscher, BLM State Office
Bryce Trip, UGMS

State Oil Shale Lands in Uintah Co. Utah
T7 - 13S, R20 - 25E, SLB&M.
(White River Land Exchange Study Area)

		Acreage
T7S, R20E, SLB&M.		
Sec. 2:	All	642.88 acres
Sec. 4:	Lot 3, SE¼NW¼, and beg at the SW cor of the SW¼NW¼ of said sec.; th N 1262 ft.; E 396 ft.; N 220 ft.; W 396 ft.; N 1158 ft., m/l, to the NW cor of Lot 4 of said Sec. 4; th E 80 rods, m/l, to the NE cor of aforesaid Lot 4; th S 160 rods; W 80 rods to the pob. containing 158.88 acres, m/l.	158.88 acres
Sec. 16:	NW¼NE¼ (40.00 ac.), SE¼NE¼ (40.00 ac.)	80.00 acres
Sec. 24:	Lot 6 (38.54 ac.), SE¼SE¼ (40.00 ac.)	78.54 acres
Sec. 25:	Lot 1 (39.33 ac.), Lot 6 (27.79 ac.), NE¼NE¼ (40.00 ac.)	107.03 acres
Sec. 32:	NW¼NE¼ (40.00 ac.), NW¼ (160.00 ac.), NW¼SW¼ (40.00 ac.)	240.00 acres
Sec. 36:	All	640.00 acres
T7S, R21E, SLB&M.		
Sec. 1:	Lots 3 (38.76 ac.), 5 (8.28 ac.)	47.04 acres
Sec. 2:	Lots 4, 5, 6, 7, 8, SW¼NW¼ (40.00 ac.), S½, (320.00 ac.)	*Unavailable
Sec. 16:	All	640.00 acres
Sec. 19:	NW¼NE¼	40.00 acres
Sec. 29:	Lots 5 (19.00 ac.), 6 (30.00 ac.), 7 (32.00 ac.), 8 (9.10 ac.), 10 (29.00 ac.), 11 (37.30 ac.), 12 (13.00 ac.), 13 (40.00 ac.), 14 (19.00 ac.), N½SW¼ (80.00 ac.), NW¼SE¼ (40.00 ac.)	348.40 acres
Sec. 31:	Lots 5 (6.27 ac.), 6 (5.40 ac.), 7 (32.00 ac.), 8 (36.90 ac.), 9 (0.80 ac.)	81.37 acres
Sec. 32:	Lots 1 (39.00 ac.), 2 (11.23 ac.), 3 (29.00 ac.), 6 (4.55 ac.), 7 (37.25 ac.), 8 (22.80 ac.), 9 (46.20 ac.)	190.03 acres
Sec. 36:	All	640.00 acres
T7S, R22E, SLB&M.		
Sec. 2:	All	736.04 acres
Sec. 16:	All	640.00 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres
T7S, R23E, SLB&M.		
Sec. 2:	All	883.36 acres
Sec. 16:	All	640.00 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres

T7S, R24E, SLB&M.

Sec. 2:	All	884.40 acres
Sec. 16:	All	640.00 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres

T7S, R25E, SLB&M.

Sec. 2:	All	882.02 acres
Sec. 16:	All	640.00 acres
Sec. 25:	NW¼SW¼ (40.00 ac.), Lot 4 (24.32 ac.)	64.32 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	257.76 acres

T8S, R20E, SLB&M.

Sec. 2:	Lots 1 (40.27 ac.), 2 (40.47 ac.), 3 (40.68 ac.), 4 (40.88 ac.), 5 (36.76 ac.), 6 (20.10 ac.), S½N½ (160.00 ac.), SW¼ (160.00 ac.), W½SE¼ (80.00 ac.)	619.16 acres
Sec. 16:	Lots 3 (38.00 ac.), 4 (28.50 ac.), 5 (10.40 ac.), E½ (320.00 ac.), E½W½ (160.00 ac.), NW¼NW¼ (40.00 ac.)	597.00 acres
Sec. 21:	Lots 3 (31.00 ac.), 4 (10.08 ac.), 5 (13.54 ac.)	54.62 acres
Sec. 32:	Lots 1, 2, 3	*Unavailable
Sec. 36:	NW¼	160.00 acres

T8S, R21E, SLB&M.

Sec. 2:	All	640.00 acres
Sec. 5:	Lot 3	15.72 acres
Sec. 6:	Lots 1, 2, 3, 4, 5	*Unavailable
Sec. 13:	E½SE¼	80.00 acres
Sec. 16:	All	640.00 acres
Sec. 32:	N½ (320.00 ac.), N½S½ (160.00 ac.)	480.00 acres
Sec. 36:	N½ (320.00 ac.), N½SW¼ (80.00 ac.)	400.00 acres

T8S, R22E, SLB&M.

Sec. 2:	All	722.20 acres
Sec. 16:	All	640.00 acres

T8S, R23E, SLB&M.

Sec. 2:	All	638.16 acres
Sec. 16:	All	640.00 acres

T8S, R24E, SLB&M.

Sec. 2:	All	639.84 acres
Sec. 16:	All	640.00 acres
Sec. 35:	NE¼SE¼	40.00 acres

T8S, R25E, SLB&M.

Sec. 2:	All	638.04 acres
Sec. 16:	All	640.00 acres

T9S, R20E, SLB&M.		
Sec. 2:	N½SW¼ (80.00 ac.), SE¼SW¼ (40.00 ac.), SE¼ (160.00 ac.)	280.00 acres
Sec. 16:	NW¼SE¼ (40.00 ac.), SE¼SE¼ (40.00 ac.)	80.00 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres
T9S, R21E, SLB&M.		
Sec. 2:	S½	320.00 acres
Sec. 16:	NE¼ (160.00 ac.), S½ (320.00 ac.)	480.00 acres
Sec. 25:	All	640.00 acres
Sec. 26:	All	640.00 acres
Sec. 27:	All	640.00 acres
Sec. 31:	Lots 3 (50.47 ac.), 4 (50.47 ac.), 5 (14.52 ac.), 6 (50.70 ac.), 7 (49.99 ac.), 8 (49.27 ac.), NE¼SW¼ (40.00 ac.), N½SE¼ (80.00 ac.)	385.42 acres
Sec. 32:	All	668.80 acres
Sec. 33:	Lots 1 (44.06 ac.), 2 (44.47 ac.), 3 (44.88 ac.), 4 (45.29 ac.), S½N½ (160.00 ac.), N½S½ (160.00 ac.)	498.70 acres
Sec. 34:	All	652.09 acres
Sec. 35:	All	642.82 acres
Sec. 36:	All	639.20 acres
T9S, R22E, SLB&M.		
Sec. 2:	All	634.40 acres
Sec. 6:	NE¼SE¼	40.00 acres
Sec. 7:	NW¼NE¼ (40.00 ac.), SE¼NE¼ (40.00 ac.)	80.00 acres
Sec. 16:	All	640.00 acres
Sec. 29:	All	640.00 acres
Sec. 30:	SE¼SE¼	40.00 acres
Sec. 31:	Lots 1 (27.98 ac.), 2 (28.02 ac.), 3 (28.06 ac.), E½ (320.00 ac.), SE¼NW¼ (40.00 ac.), E½SW¼ (80.00 ac.)	524.06 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres
T9S, R23E, SLB&M.		
Sec. 2:	All	624.60 acres
Sec. 13:	NE¼NW¼	40.00 acres
Sec. 16:	All	640.00 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres
T9S, R24E, SLB&M.		
Sec. 1:	S½NW¼	80.00 acres
Sec. 2:	Lots 1 (36.34 ac.), 2 (36.35 ac.), 3 (36.35 ac.), 4 (36.36 ac.), 5 (45.13 ac.), 6 (25.30 ac.), 7 (20.86 ac.), 8 (37.51 ac.), 9 (55.50 ac.), 10 (14.60 ac.), 11 (32.63 ac.), 12 (49.54 ac.), S½NE¼ (80.00 ac.), SE¼NW¼ (40.00 ac.), SW¼SW¼ (40.00 ac.)	586.47 acres
Sec. 3:	SW¼SE¼	40.00 acres

Sec. 16:	N½N½ (160.00 ac.), SE¼NW¼ (40.00 ac.), S½SW¼ (80.00 ac.)	280.00 acres
Sec. 23:	Lots 4 (23.54 ac.), 7 (16.41 ac.), 8 (20.24 ac.), 9 (15.96 ac.), 11 (38.72 ac.), SW¼SE¼ (40.00 ac.)	154.87 acres
Sec. 24:	Lots 1 (44.59 ac.), 2 (25.18 ac.), 3 (13.44 ac.), 4 (10.10 ac.), 5 (24.88 ac.), 6 (39.32 ac.), 7 (4.54 ac.), 8 (5.69 ac.), 9 (21.51 ac.), N½SE¼ (80.00 ac.)	269.25 acres
Sec. 25:	Lots 1 (5.93 ac.), 2 (5.20 ac.), 3 (40.50 ac.), 4 (39.73 ac.), 5 (46.60 ac.), 6 (23.78 ac.), 7 (24.13 ac.), 8 (42.10), 9 (37.50 ac.), 10 (38.70 ac.), 11 (27.91 ac.), 12 (45.89 ac.), NW¼SW¼ (40.00 ac.), S½S½ (160.00 ac.)	577.97 acres
Sec. 36:	N½ (320.00 ac.), SW¼SW¼ (40.00 ac.), N½SE¼ (80.00 ac.)	440.00 acres

<u>T9S, R25E, SLB&M.</u>

Sec. 8:	Lots 1 (33.81 ac.), 2 (0.87 ac.), S½N½ (160.00 ac.), E½SW¼ (80.00 ac.), NW¼SW¼ (40.00 ac.), SE¼ (160.00 ac.)	474.68 acres
Sec. 9:	S½N½ (160.00 ac.), S½ (320.00 ac.)	480.00 acres
Sec. 10:	S½N½ (160.00 ac.), S½ (320.00 ac.)	480.00 acres
Sec. 11:	S½N½ (160.00 ac.), S½ (320.00 ac.)	480.00 acres
Sec. 12:	Lots 2 (28.92 ac.), 3 (29.07 ac.), 4 (29.09 ac.), SW¼NW¼ (40.00 ac.), W½SW¼ (80.00 ac.)	207.08 acres
Sec. 13:	Lots 1 (29.16 ac.), 2 (29.20 ac.), W½NW¼ (80.00 ac.)	138.36 acres
Sec. 14:	N½	320.00 acres
Sec. 15:	N½	320.00 acres
Sec. 16:	Lots 1 (43.77 ac.), 2 (21.55 ac.), 3 (41.93 ac.), 4 (27.72 ac.), 5 (48.04 ac.), 6 (30.93 ac.), 7 (25.86 ac.), NE¼ (160.00 ac.), E½NW¼ (80.00 ac.), NW¼NW¼ (40.00 ac.), SW¼SW¼ (40.00 ac.), NE¼SE¼ (40.00 ac.)	592.80 acres
Sec. 17:	Lots 1 (36.38 ac.), 2 (16.68 ac.), 3 (34.16 ac.), 4 (53.89 ac.), 5 (44.19 ac.), 6 (18.85 ac.), NE¼NE¼ (40.00 ac.), SW¼NW¼ (40.00 ac.), S½ (320.00 ac.)	604.15 acres
Sec. 19:	S½	320.00 acres
Sec. 20:	All	640.00 acres
Sec. 21:	Lot 1 (38.59 ac.), NW¼NE¼ (40.00 ac.), S½NE¼ (80.00 ac.), NW¼ (160.00 ac.), S½ (320.00 ac.)	638.59 acres
Sec. 22:	Lots 2 (20.73 ac.), 3 (37.34 ac.), SW¼NW¼ (40.00 ac.)	98.07 acres
Sec. 28:	S½	320.00 acres
Sec. 29:	Lots 1 (42.47 ac.), 2 (24.58 ac.), 3 (0.50 ac.), 4 (30.27 ac.), N½ (320.00 ac.), NE¼SW¼ (40.00 ac.), SE¼ (160.00 ac.)	617.80 acres
Sec. 30:	Lots 1 (49.78 ac.), 2 (27.04 ac.), 3 (23.79 ac.), 4 (30.01 ac.), 5 (32.35 ac.), 6 (16.09 ac.), 7 (26.25 ac.), 8 (29.23 ac.), 9 (38.22 ac.), 10 (42.44 ac.), 11 (30.91 ac.), 12 (10.78 ac.), 13 (35.38 ac.), 14 (16.89 ac.), N½NE¼ (80.00 ac.), SE¼NE¼ (40.00 ac.)	529.16 acres

Sec. 31:	Lots 1 (24.43 ac.), 2 (29.57 ac.), 3 (48.17 ac.), SW¼NE¼ (40.00 ac.), NW¼ (160.00 ac.), S½ (320.00 ac.)	622.17 acres
Sec. 32:	Lots 1 (47.72 ac.), 2 (30.41 ac.), 3 (35.58 ac.), 4 (36.04 ac.), 5 (38.69 ac.), 6 (49.21 ac.), 7 (21.76 ac.), 8 (10.61 ac.), 9 (37.58 ac.), 10 (4.64 ac.), SE¼NW¼ (40.00 ac.), SW¼ (160.00 ac.), N½SE¼ (80.00 ac.)	592.34 acres
Sec. 33:	Lots 1 (39.00 ac.), 2 (40.47 ac.), 3 (33.82 ac.), 4 (27.15 ac.), 5 (20.49 ac.), NW¼NW¼ (40.00 ac.), E½NW¼ (80.00 ac.), NE¼ (160 ac.)	440.93 acres
Sec. 36:	Lots 1 (29.34 ac.), 2 (29.93 ac.), 3 (30.52 ac.), 4 (31.11 ac.), W½SW¼ (80.00 ac.)	200.90 acres

T10S, R20E, SLB&M.

Sec. 13:	All	640.00 acres
Sec. 16:	N½NE¼ (80.00 ac.), NE¼NW¼ (40.00 ac.), NW¼SW¼ (40.00 ac.), S½SW¼ (80.00 ac.)	240.00 acres
Sec. 24:	All	640.00 acres
Sec. 25:	All	640.00 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres

T10S, R21E, SLB&M.

Sec. 1:	Lots 1 (42.52 ac.), 2 (42.72 ac.), 3 (42.92 ac.), 4 (43.12 ac.), S½N½ (160.00 ac.), SE¼ (160.00 ac.)	491.28 acres
Sec. 2:	All	649.92 acres
Sec. 4:	Lots 1 (42.28 ac.), 2 (42.28 ac.), S½NE¼ (80.00 ac.)	164.56 acres
Sec. 12:	N½NE¼	80.00 acres
Sec. 13:	All	640.00 acres
Sec. 16:	All	640.00 acres
Sec. 17:	All	640.00 acres
Sec. 18:	All	641.36 acres
Sec. 19:	All	643.50 acres
Sec. 20:	All	640.00 acres
Sec. 21:	All	640.00 acres
Sec. 28:	All	640.00 acres
Sec. 29:	All	640.00 acres
Sec. 30:	All	643.84 acres
Sec. 31:	All	643.12 acres
Sec. 32:	All	640.00 acres
Sec. 33:	All	640.00 acres
Sec. 36:	All	640.00 acres

T10S, R22E, SLB&M.

Sec. 2:	Lots 1 (40.77 ac.), 2 (40.70 ac.), 3 (40.64 ac.), 4 (40.57 ac.), 5 (39.92 ac.), 6 (16.03 ac.), 7 (15.45 ac.), 8 (39.92 ac.), S½N½ (160.00 ac.), N½S½ (160.00 ac.), SE¼SE¼ (40.00 ac.)	634.00 acres
Sec. 7:	Lots 1 (27.19 ac.), 2 (27.03 ac.), NE¼ (160.00 ac.), E½NW¼ (80.00 ac.)	294.22 acres
Sec. 10:	N½NE¼ (80.00 ac.), NE¼NW¼ (40.00 ac.)	120.00 acres

Sec. 11:	Lot 1 (34.49 ac.), NE¼ (160.00 ac.), NW¼NW¼ (40.00 ac.), S½NW¼ (80.00 ac.), S½ (320.00 ac.)	634.49 acres
Sec. 12:	All	640.00 acres
Sec. 13:	All	640.00 acres
Sec. 14:	N½	320.00 acres
Sec. 16:	All	640.00 acres
Sec. 18:	All	585.76 acres
Sec. 19:	E½	320.00 acres
Sec. 20:	W½	320.00 acres
Sec. 24:	NE¼ (160.00 ac.), NE¼SE¼ (40.00 ac.)	200.00 acres
Sec. 25:	All	640.00 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres

<u>T10S, R23E, SLB&M.</u>

Sec. 2:	All	642.32 acres
Sec. 16:	All	640.00 acres
Sec. 32:	All	640.00 acres

<u>T10S, R24E, SLB&M.</u>

Sec. 1:	Lots 1 (40.62 ac.), 2 (40.61 ac.), 3 (40.61 ac.), 4 (40.63 ac.), 5 (38.86 ac.), S½NE¼ (80.00 ac.), SE¼NW¼ (40.00 ac.), N½SW¼ (80.00 ac.), W½SW¼SW¼ (20.00 ac.), W½E½SW¼SW¼ (10.00 ac.), E½NE¼SW¼SW¼ (5.00 ac.), SE¼SW¼ (40.00 ac.), SE¼ (160.00 ac.)	636.30 acres
Sec. 2:	Lots 1 (40.61 ac.), 2 (40.62 ac.), 3 (40.62 ac.), 4 (40.63 ac.), 6 (6.58 ac.), S½NW¼ (80.00 ac.), SW¼ (160.00 ac.), S½SE¼ (80.00 ac.)	489.06 acres
Sec. 36:	E½E½	160.00 acres

<u>T10S, R25E, SLB&M.</u>

Sec. 2:	All	642.12 acres
Sec. 16:	NE¼	160.00 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	303.80 acres

<u>T11S, R20E, SLB&M.</u>

Sec. 2:	All	639.50 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres

<u>T11S, R21E, SLB&M.</u>

Sec. 16:	All	640.00 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres

<u>T11S, R22E, SLB&M.</u>

Sec. 16:	All	640.00 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres

T11S, R23E, SLB&M.		
Sec. 2:	Lots 1 (18.11 ac.), 2 (18.17 ac.), 3 (18.23 ac.), 4 (18.23 ac.), 5 (40.00 ac.), 6 (40.00 ac.), 7 (40.00 ac.), 8 (40.00 ac.), 9 (38.60 ac.), 10 (32.81 ac.), SW¼NE¼ (40.00 ac.), S½NW¼ (80.00 ac.), SW¼ (160 ac.), NW¼SE¼ (40.00 ac.), S½SE¼ (80.00 ac.)	704.15 acres
Sec. 16:	All	640.00 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres
T11S, R24E, SLB&M.		
Sec. 2:	All	639.76 acres
Sec. 16:	Lots 1 (29.20 ac.), 2 (37.72 ac.), S½NE¼ (80.00 ac.), N½NW¼ (80.00 ac.), SE¼NW¼ (40.00 ac.), W½SW¼ (80.00 ac.), SE¼SW¼ (40.00 ac.), NE¼SE¼ (40.00 ac.), SW¼SE¼ (40.00 ac.)	466.92 acres
Sec. 21:	E½NW¼	80.00 acres
Sec. 32:	N½NE¼ (80.00 ac.), SE¼NE¼ (40.00 ac.), W½ (320.00 ac.), NW¼SE¼ (40.00 ac.), S½SE¼ (80.00 ac.)	560.00 acres
Sec. 36:	All	640.00 acres
T11S, R25E, SLB&M.		
Sec. 32:	Lots 7 (40.00 ac.), 8 (26.82 ac.), 9 (40.00 ac.), 10 (40.00 ac.), 11 (36.75 ac.), 12 (30.54 ac.), 13 (40.00 ac.), NE¼ (160.00 ac.), NE¼NW¼ (40.00 ac.), E½SE¼ (80.00 ac.), S½SW¼ (80.00 ac.),	614.11 acres
Sec. 36:	All	863.40 acres
T12S, R20E, SLB&M.		
Sec. 2:	All	639.92 acres
Sec. 16:	All	640.00 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres
T12S, R21E, SLB&M.		
Sec. 2:	All	640.28 acres
Sec. 16:	All	640.00 acres
Sec. 32:	N½	320.00 acres
Sec. 36:	All	640.00 acres
T12S, R22E, SLB&M.		
Sec. 2:	All	640.24 acres
Sec. 16:	All	640.00 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres
T12S, R23E, SLB&M.		
Sec. 2:	All	638.84 acres
Sec. 16:	N½ (320.00 ac.), N½NE¼SW¼ (20.00 ac.), N½S½NE¼SW¼ (10.00 ac.), S½SW¼NE¼SW¼ (5.00 ac.), NW¼SW¼ (40.00 ac.), NW¼NW¼SW¼SW¼ (2.5 ac.), N½N½SE¼ (40.00 ac.), SE¼NE¼SE¼ (10.00 ac.), N½SW¼NW¼SE¼ (5.00 ac.), NW¼SE¼NW¼SE¼ (2.5 ac.), E½E½SE¼SE¼ (10.00 ac.), W½NE¼SE¼SE¼ (5.00 ac.), NW¼SE¼SE¼SE¼ (2.5 ac.)	472.50 acres

Sec. 32:	W½W½ (160.00 ac.), W½W½NE¼NW¼ (10.00 ac.), SE¼SW¼NE¼NW¼ (5.00 ac.), W½SE¼NW¼ (20.00 ac.), SW¼SE¼SE¼NW¼ (2.5 ac.), W½NE¼SW¼ (20.00 ac.), W½E½NE¼SW¼ (10.00 ac.), SE¼SW¼ (40.00 ac.), S½S½SW¼SE¼ (10.00 ac.), SW¼SW¼SE¼SE¼ (2.5 ac.)	280.00 acres
Sec. 36:	All	640.00 acres

<u>T12S, R24E, SLB&M.</u>

Sec. 2:	All	640.16 acres
Sec. 11:	S½SE¼	80.00 acres
Sec. 12:	S½S½	160.00 acres
Sec. 13:	All	640.00 acres
Sec. 14:	E½	320.00 acres
Sec. 16:	All	640.00 acres
Sec. 23:	E½	320.00 acres
Sec. 24:	All	640.00 acres
Sec. 25:	All	640.00 acres
Sec. 26:	E½	320.00 acres
Sec. 32:	All	640.00 acres
Sec. 34:	NE¼SE¼	40.00 acres
Sec. 35:	NW¼SW¼	40.00 acres
Sec. 36:	All	640.00 acres

<u>T12S, R25E, SLB&M.</u>

Sec. 2:	All	640.20 acres
Sec. 7:	S½S½	160.00 acres
Sec. 8:	S½S½	160.00 acres
Sec. 16:	All	640 ~~340.00~~ acres
Sec. 17:	All	640 ~~340.00~~ acres
Sec. 18:	All	640 ~~340.00~~ acres
Sec. 19:	All	640 ~~340.00~~ acres
Sec. 20:	W½ (320.00 ac.), W½NE¼ (80 ~~120.00~~ ac.)	400 ~~480.00~~ acres
Sec. 29:	All	640.00 acres
Sec. 30:	All	640.00 acres
Sec. 31:	E½	320.00 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	866.88 acres

<u>T13S, R20E, SLB&M.</u>

Sec. 2:	All	641.04 acres
Sec. 16:	All	640.00 acres
Sec. 32:	All	640.00 acres

<u>T13S, R21E, SLB&M.</u>

Sec. 2:	All	642.36 acres
Sec. 16:	E½E½	160.00 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres

T13S, R22E, SLB&M.

Sec. 2:	All	640.88 acres
Sec. 24:	SE¼	160.00 acres
Sec. 25:	NE¼ (160.00 ac.), S½ (320.00 ac.)	480.00 acres
Sec. 26:	SE¼	160.00 acres
Sec. 32:	All	640.00 acres
Sec. 35:	E½	320.00 acres
Sec. 36:	All	640.00 acres

T13S, R23E, SLB&M.

Sec. 2:	Lots 1 (37.33 ac.), 2 (37.59 ac.), 5 (8.82 ac.), 6 (1.93 ac.), S½NE¼ (80.00 ac.), SE¼NE¼NW¼ (10.00 ac.), NE¼SE¼NW¼ (10.00 ac.), E½SE¼SE¼NW¼ (5.00 ac.), E½W½SE¼SE¼NW¼ (2.5 ac.), E½E½E½SW¼ (20.00 ac.), E½W½NE¼NE¼SW¼ (2.5 ac.), W½W½SE¼ (40.00 ac.)	255.65 acres
Sec. 12:	S½SE¼	80.00 acres
Sec. 16:	SW¼SE¼SW¼ (10.00 ac.), W½SE¼SE¼SW¼ (5.00 ac.), SE¼SW¼SW¼ (10.00 ac.), S½SW¼SW¼SW¼ (5.00 ac.)	30.00 acres
Sec. 19:	Lots 1 (36.75 ac.), 2 (36.85 ac.), 3 (16.95 ac.), 4 (37.05 ac.), E½W½ (160.00 ac.), W½NE¼NE¼ (20.00 ac.), W½SE¼NE¼NE¼ (5.00 ac.), W½NE¼ (80.00 ac.), W½SE¼NE¼ (20.00 ac.), W½E½SE¼NE¼ (10.00 ac.), E½SE¼SE¼NE¼ (5.00 ac.), SE¼ (160 ac.)	607.60 acres
Sec. 20:	SW¼SW¼NW¼SW¼ (2.5 ac.), W½W½SW¼SW¼ (10.00 ac.)	12.50 acres
Sec. 29:	W½NW¼NW¼ (20.00 ac.), SE¼NW¼NW¼ (10.00 ac.), SW¼NW¼ (40.00 ac.)	70.00 acres
Sec. 30:	All	628.68 acres
Sec. 32:	All	640.00 acres

T13S, R24E, SLB&M.

Sec. 2:	All	696.80 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres

T13S, R25E, SLB&M.

Sec. 2:	All	711.16 acres
Sec. 16:	All	640.00 acres
Sec. 32:	All	640.00 acres
Sec. 36:	All	640.00 acres

* Boundaries of these lots are uncertain due to changes in meander line. Resurveying and clarification of State's title may be needed in these areas.

United States Department of the Interior

TAKE PRIDE IN AMERICA

GEOLOGICAL SURVEY
BOX 25046 M.S. 939
DENVER FEDERAL CENTER
DENVER, COLORADO 80225
Office of Energy and Marine Geology
Branch of Sedimentary Processes

IN REPLY REFER TO:

March 31, 1990

Mr. John T. Blake
Utah State Lands and Forestry
355 West North Temple
3 Triad Center, Suite 400
Salt Lake City, Utah 84180-1204

Dear John:

We have completed our computer map showing the state lands in the study area in eastern Uinta Basin. The acreages have been computed for all of the tracts. I have compiled these acreages with those from the cadastral surveys in your letter of June 29, 1989. Please note the following corrections to your list:

T12S, R25E	Your acreage	Corrected acreage
Sec. 16, all.	340.00	640.00
Sec. 17, all.	340.00	640.00
Sec. 18, all.	340.00	640.00
Sec. 19, all.	340.00	640.00
Sec. 20, W½,W½NE¼	480.00	400.00

I am assuming that the number of acres for each of the above sections is 640. Would you confirm my corrected acreages and let me know if this assumption is correct.

A copy of your map showing the tracts of state lands which we have numbered in rows from west to east across the map is being mailed to you under separate cover. Tracts 162-170 are out of sequence because of plotting problems; these tracts are found in the following townships:

Tract no.	Township
162	T13S,R22-23E
163	T13S,T23E
164	T7S,R20E
165	T11S,R20E
166	T9-10S,R24E
167	T9S,R24E
168	T9S,R24E
169	T9S,R25E

170 T11S,R24E

Included with the map is a plastic overlay which shows the grouping of state lands that we would like to use for our resource evaluation. Dave Grundy believes that this arrangement will give more accurate estimates of the oil-shale resources computer program. Please review the overlay and let me know if this plan is satisfactory with you.

Enclosed is a summary of the computed and surveyed acreages. Note that the difference in the sums of these two sets of acreages (excluding tracts for which you considered the acreages to be unreliable) is 549.38 acres, an error (based on our acreage) of 0.41 percent. This seems fairly good, although an enclosed figure shows that the computed acreages are generally somewhat higher than the surveyed acreages. I suspect this is due to operator error. The chances seem considerably greater of digitizing a corner of a tract outside of the tract rather than within it. Thus, the computed acreage would tend to be a trifle higher than the surveyed acreage, asssuming that the surveyed acreage is correct.

Differences in acreages for individual tracts range from -26.05 to +35.18 percent relative to our computed numbers. Those tracts that differ by more than about 3 or 4 percent in size (about 10 tracts) should be reviewed with Randy. I assume that we shall use our computed acreages for those tracts which you labeled as unreliable (tracts 3,21,47). From our viewpoint, it doesn't make much difference which set of numbers you use, but I suspect that for those tracts that differ by more than about 3 percent, our numbers will be closer to the true size of the tract. Let me know what you and Randy decide.

Sincerely yours,

John R. Dyni, Geologist

cc: Randy Heuscher, BLM

United States Department of the Interior

BUREAU OF LAND MANAGEMENT
VERNAL DISTRICT OFFICE
170 SOUTH 500 EAST
VERNAL, UTAH 84078

TAKE PRIDE IN AMERICA

IN REPLY REFER TO:
3900
UT08438

June 28, 1989

Mr. John R. Dyni
U.S. Geological Survey
Box 25046, MS 939
Denver Federal Center
Denver, CO 80225

Dear Mr. Dyni:

The materials included are those you requested in your telephone conversation of June 24, 1989, with Tim Ingwell of this office. The materials include both the legal description and map portrayal of oil shale tracts Ua and Ub. Should you have further questions, contact Howard Cleavinger or Tim Ingwell of this office at (801) 789-1362.

Sincerely,

David E. Little
District Manager

Enclosure

From memo from Little 6/28/89

Tract Ua is leased by:

- Phillips Petroleum Company
  324 Frank Phillips Building
  Bartlesville, Oklahoma 74004

- Sunoco Energy Development Company
  12700 Park Central Place
  Dallas, Texas 75251

Tract Ub is leased by:

- Sohio Shale Oil Company
  1100 Beneficial Life Tower
  36 South State
  Salt Lake City, Utah 84111

1.4.2 TRACTS Ua AND Ub

Maps and more detailed descriptions of Tracts Ua and Ub are found in Section 2 of this DDP and in the supporting document, Final Environmental Baseline Report (Ref. 1-2), and project annual reports (Ref. 1-8).

1.4.2.1 Location and Description

Tracts Ua and Ub lie immediately south of the White River in the eastern part of the Uinta Basin in a remote part of northeastern Utah. Tract Ua lease is in the county of Uintah, Utah and contains 5,120,000 acres, more or less. It includes:

T. 10 S., R. 24 E., SLM, Utah
Sec. 19, E½
Sec. 20, All
Sec. 21, All
Sec. 22, All
Sec. 27, All
Sec. 28, All
Sec. 29, All
Sec. 30, E½
Sec. 33, N½
Sec. 34, N½

Tract Ub lease is in the county of Uintah, Utah and contains 5,120.00 acres, more or less. It includes:

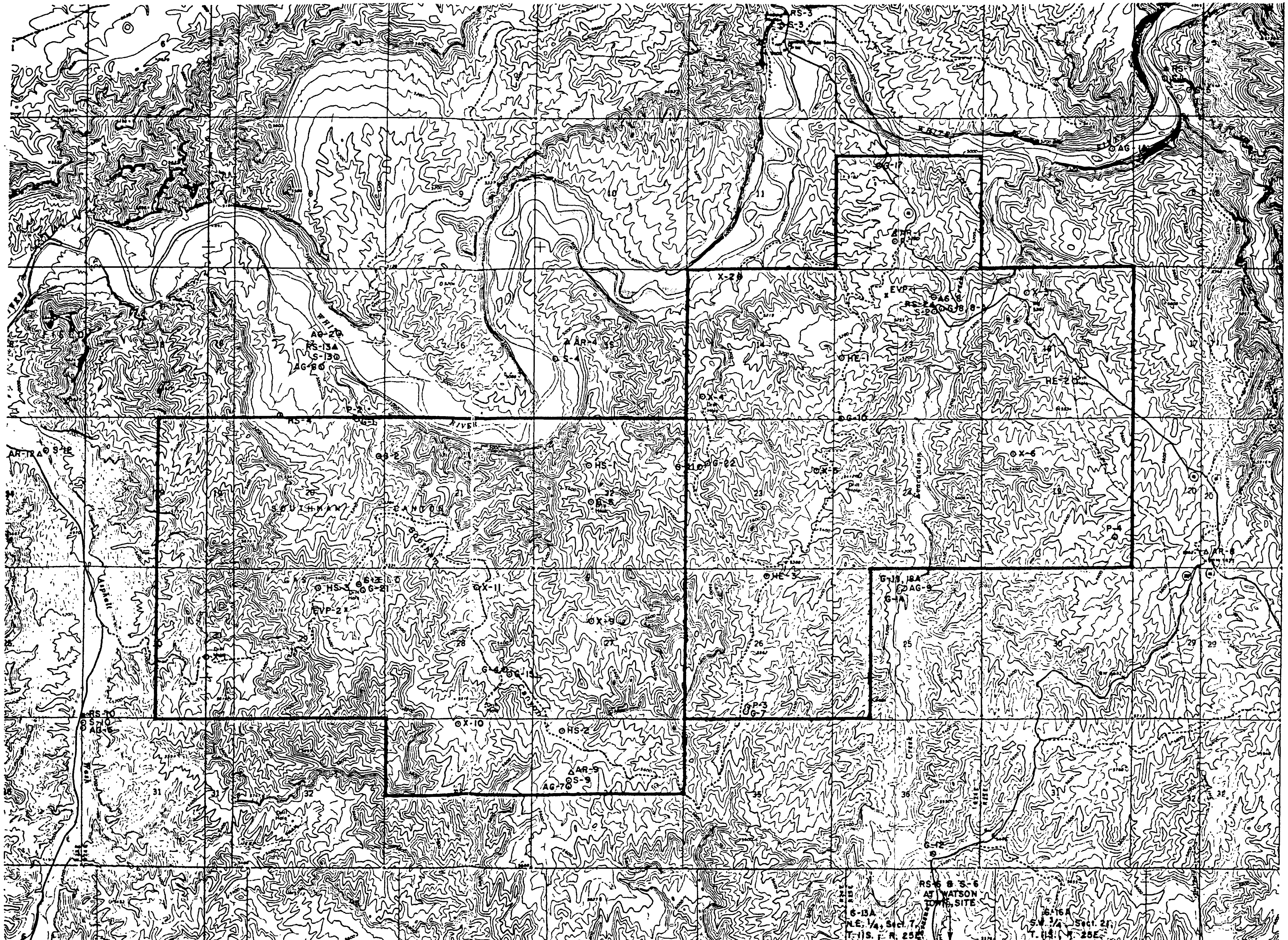
T. 10 S., R. 24 E., SLM, Utah
Sec. 12, S½, S½N½
Sec. 13, All
Sec. 14, All
Sec. 23, All
Sec. 24, All
Sec. 25, W½W½
Sec. 26, All

T. 10 S., R. 25 E., SLM, Utah
Sec. 18, All
Sec. 19, All

A map showing the location of the two tracts is presented in Figure 1.4-1. The nearest community is Bonanza, about 10 miles away, with a population of approximately 20; the nearest town in Utah having a full range of services is Vernal, population approximately 8,000; and the nearest town in western Colorado is Rangely, about 30 miles away. Vernal is served by U.S. Route 40 and Bonanza by Utah Route 45. From Bonanza, the tracts and the proposed process areas can be reached by dirt roads that are not a part of the state system.

The only major perennial stream in the area is the White River, whose valley occupies a narrow strip about 800 feet wide at the northern edge of Tracts Ua and Ub. Southam Canyon, a slightly meandering drainage, extends northwestward across Tract Ua and joins the White River just outside the tract. The canyon of Evacuation Creek trends northward across the central part of Tract Ub. West of Evacuation Creek, the terrain is more rugged and is characterized by ledges and cliffs along the canyon walls and numerous buttes along the drainage divides. Ground cover in both tracts is sparse, consisting mostly of shrubs. Surface elevations within the tracts range from 4,900 feet at the White River to approximately 5,960 feet in the south-central part of Tract Ua. The greatest altitude difference in a short distance is about 450 feet in 1/2 mile in the south-central part of Tract Ua.

91-285



LEGEND

⊙ S	SURFACE WATER MONITORING STATION
⊙ P	PILOT TEST HOLE (WATER)
⊙ G	GROUND WATER MONITORING STATION
⊙ HE	EXISTING GEOLOGIC CORE HOLE, EVACUATION
⊙ HS	EXISTING GEOLOGIC CORE HOLE, SOUTHAM
⊙ X	EXPLORATION GEOLOGIC CORE HOLE
⊙ AG	ALLUVIAL WELL (WATER)
△ AR	PRECIPITATION, AUTO (WATER)
▲ RS	PRECIPITATION, STORAGE (WATER)
× EVP	EVAPORATION PAN (WATER)

UTAH

N

1 0 1

SCALE IN MILES

vtn

WATER AND GEOLOGIC RESOURCES BASELINE MONITORING STATIONS

II-3

FIGURE II-1