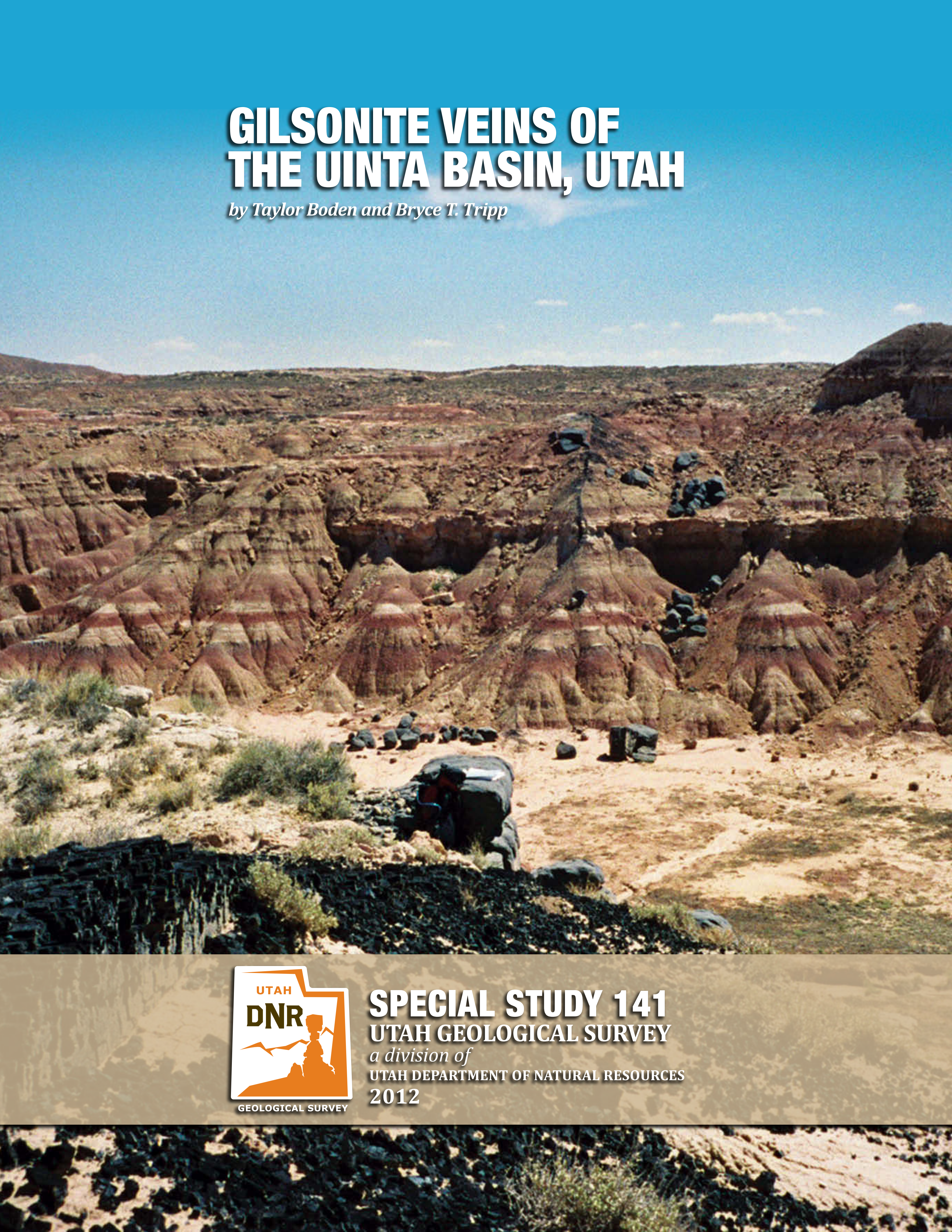
GILSONITE VEINS OF THE UINTA BASIN, UTAH

by Taylor Boden and Bryce T. Tripp



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by Taylor Boden[1] and Bryce T. Tripp[2]

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Cover photo: *Red Wash gilsonite vein cropping out in member C of the Uinta Formation in NW¼NE¼ section 19, T. 8 S., R. 23 E., Salt Lake Base Line and Meridian, Uintah County.*

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GILSONITE VEINS OF THE UINTA BASIN, UTAH

by Taylor Boden and Bryce T. Tripp

ABSTRACT

Gilsonite is a solid hydrocarbon that forms a swarm of subparallel, northwest-trending, near-vertical, laterally and vertically extensive veins in the Uinta Basin of Utah and Colorado. The Uinta Basin hosts the world's largest deposits of gilsonite and is the only place where gilsonite is economically produced in large quantities. Gilsonite is sourced from the Mahogany oil shale zone of the Green River Formation and is hosted in the Tertiary Wasatch, Green River, Uinta, and Duchesne River Formations. The veins formed in two stages associated with thermal maturation of the Mahogany oil shale. Overpressuring deep in the Uinta Basin expelled large quantities of thermal water from the reservoir rocks and hydrofractured the overlying strata. Subsequently, thick liquid gilsonite was expelled from the reservoir rocks, forcing open the existing fractures in the overlying strata. The gilsonite later solidified in these fractures, probably primarily through cooling and polymerization.

This study included examination and mapping of 59 veins, vein systems, and isolated vein outcrops totaling more than 120 miles in length. In addition, we collected 1474 Global Positioning System data points with associated attribute data, obtained field data from previous geologic mapping by the U.S. Geological Survey and U.S. Bureau of Land Management, and examined recent National Agriculture Imagery Program high-resolution color aerial photography. A total of 71 significant veins, vein systems, and vein extensions were documented in our study, having a total combined vein length of more than 170 miles.

Gilsonite is a valuable resource and has a wide variety of uses, including asphalt paving mixes and coatings; chemical components in metallurgical, adhesive, coating, binder, ink, and paint products; and uses in metal foundry and oil well drilling and well completions. Even though significant amounts of the approximately 45-million-short-ton original gilsonite resource have been mined, millions of tons of the resource still remain. This resource tends to be in the deeper parts of the veins and in thinner, more remote veins that will likely be more expensive to mine than veins mined in the past. At the recent industry production rate of 60,000 to 80,000 tons per year, gilsonite could continue to be mined in the Uinta Basin for decades.

INTRODUCTION

The Uinta Basin of northeastern Utah and northwestern Colorado (figure 1) contains vast hydrocarbon deposits. Oil, natural gas, tar sand, oil shale, coal, and solid hydrocarbons (asphaltites), including gilsonite, wurtzilite, tabbyite, and ozokerite, have a long history of exploration and/or production in the basin. The Uinta Basin is the only place where gilsonite is economically produced in large quantities, and contains the world's largest deposits. Gilsonite is remarkable for its unusual geologic origin, chemical and physical properties, and industrial uses. Also notable are the ingenuity and persistence of the gilsonite pioneers who created a new industry, and over the past 100 years have solved mining, processing, transportation, marketing, and other challenges to continue to supply this unique material to world markets.

The gilsonite veins in Utah are the largest in the world and have a long, colorful history of profitable mining. Consequently, gilsonite has been studied and described

Figure 1. *Uinta Basin location map.*

in a large body of work dating back to the 1880s. However, some ambiguity has always existed in the descriptions of the veins, especially in their locations and extent, so accurate summaries have been lacking. The goal of the Utah Geological Survey (UGS) study was to use Global Positioning System (GPS) and geographic information system technology to generate accurate maps of the gilsonite veins, collect vein attribute data, and combine these new data with existing data into an accurate, up-to-date compilation of Utah's gilsonite resource. Historical production data and an extensive bibliography were also compiled. All of the data were compiled into a map (except for isolated vein outcrops) and accompanying text, which includes detailed descriptions of the character of the gilsonite deposit for each vein, vein system, vein extension, isolated vein outcrop, and evidence of mining and prospecting.

Definitions and Gilsonite History

Gilsonite is naturally occurring hydrocarbon bitumen that occurs in dikes (veins), sills, fracture fillings, and disseminated blebs, commonly in association with oil shale and tar sand. Gilsonite has a dull, black, coal-like appearance on weathered surfaces and a shiny, black, obsidian-like appearance on fresh surfaces. Fracture surfaces vary from conchoidal to columnar (pencillated) to flaky or scaly (figure 2). Occasionally gilsonite in deep parts of some veins is in a semi-solid state. Industry once defined three major subdivisions of gilsonite based on appearance and fusing temperature: selects, seconds, and jet. Select material is very shiny, fuses from 300 to 334°F, and tends to occur in centers of veins. Seconds are somewhat duller than selects, fuse from 306 to 361°F, and tend to occur along vein margins, sometimes having columnar jointing (pencillated texture). Pencillated tex-

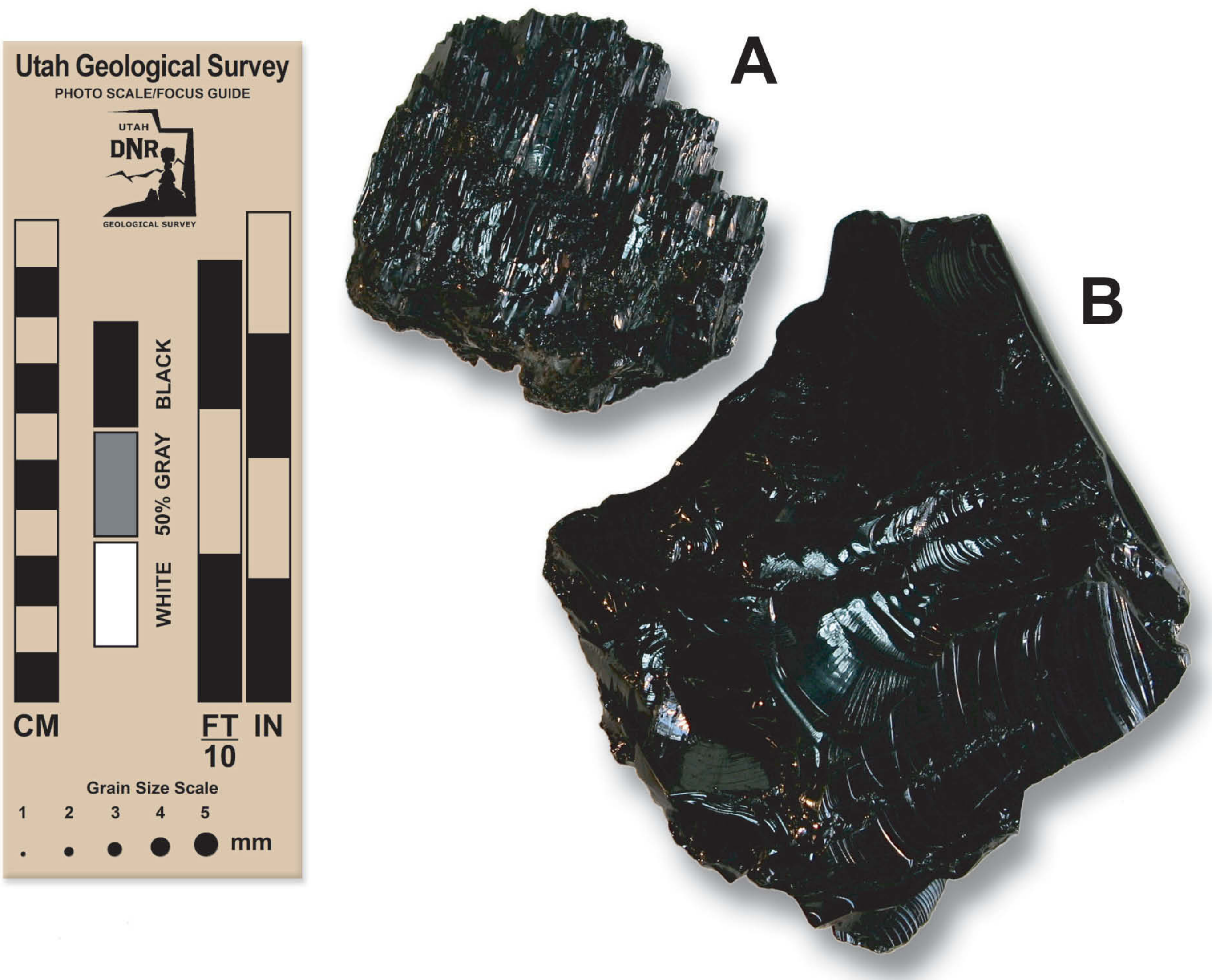

Figure 2. *Gilsonite textures:* ***A****. gilsonite showing columnar "pencillated" structure, and* ***B****. "select" gilsonite from underground workings on the Independent vein showing conchoidal fracturing.*

ture forms at right angles to vein walls and penetrates about 6 inches into the ore (Verbeek and Grout, 1993). Gilsonite in some localities also has flaky or scaly texture. A third, unusual variety, called jet gilsonite, has a brilliantly shiny surface, a bluish-black color, and fuses from 390 to 446°F (Abraham, 1960). To date, it has been found only in the Cowboy vein. Gilsonite is now classified into five ranges, according to fusing temperature, which are used in different applications and sell for different prices. Gilsonite from different veins or different parts of veins is sometimes mixed to achieve a product with a specific fusing temperature range. Physical and chemical characteristics of gilsonite (table 1) are important for differentiating it from other asphaltites and in determining possible industrial applications.

Gilsonite, named after Samuel H. Gilson, was discovered in the 1860s. Gilson was not one of the original discoverers of gilsonite, but his enthusiastic development and promotional efforts linked the material to him, and people in the region began referring to this material as gilsonite rather than using its scientific name, "uintahite" (Kretchman, 1957; Covington, 1964). The name gilsonite further solidified in common usage when an early mining company adopted and trademarked the name.

People in the late 1800s were uncertain about the exact nature of gilsonite, whether it was asphaltum, coal, or mineral wax. Samples were shipped to several scientists for examination. Wurtz (1869) described a sample in the Columbia College School of Mine's collection and noted the similarity of this material to the grahamite that is present in dikes in Ritchie County, West Virginia. Blake (1890) examined this same sample and determined it to be "uintahite," an asphaltite that he had described in an earlier scientific paper (Blake, 1885).

Gilsonite is classified as a member of the asphaltite group of hydrocarbon bitumens. These are a group of naturally occurring solid hydrocarbons that are somewhat similar in appearance, occurrence, and properties. Scientists describing these hydrocarbons have developed various classification schemes for them. Abraham (1960) developed a systematic classification scheme based on physical and chemical characteristics such as solubility, physical state (solid or liquid), fusibility, and oxygen content. Hunt (1963) slightly modified Abraham's classification system. King and others (1963) devised a classification scheme starting with the geologic origin of the hydrocarbon. Hunt (1979) combined aspects of Abraham's and King and others' classifications while deleting petroleum from the scheme and subdividing some of the hydrocarbons based on their hydrogen-to-carbon ratios (figure 3). Other proposed hydrocarbon classification systems have been published by Rogers and others (1974), Jacob (1983), Curiale (1986), and Cornelius (1987), but Hunt's (1979) classification scheme is commonly accepted and is easy to apply using basic laboratory data.

Table 1. *Physical and chemical characteristics of gilsonite.*

Characteristic	Value	Data Source
Color	black	-
Fracture	usually conchoidal, occasionally columnar to platy	-
Luster	bright	-
Streak	brown	Abraham (1960)
Hardness (Mohs scale)	2	Abraham (1960)
Specific gravity (g/cc)	1.03–1.10	Abraham (1960)
Bulk density (kg/m^3)	641	Ziegler (2008)
Solubility in CS_2 (%)	98	Abraham (1960)
Solubility in petroleum naptha (%)	10–60	Abraham (1960)
Carbon (wt %)	85–86	Abraham (1960)
Hydrogen (wt %)	8.5–10	Abraham (1960)
Sulfur (wt %)	0.22–0.53	Bell and Hunt (1963)
Nitrogen (wt %)	2.25–3.29	Bell and Hunt (1963)
Oxygen (wt %)	1.5	Wen and others (1978)
Refractive index	1.59–1.64	Bell and Hunt (1963)
H/C ratio	1.42–1.47	Bell and Hunt (1963)
Fusing (softening) point (°C) (ring and ball method)	161–230	Bell and Hunt (1963)
Moisture content (wt %)	0.5	Ziegler (2008)
Heating value (J/kg)	4.2 x 10^7	Ziegler (2008)
Specific heat (168°C)	0.52	Ziegler (2008)
Penetration (28°C)	0–3	Ziegler (2008)
Porphyrin content (wt %) (nickel complex)	0.004–0.03	McGee (1956)
Molecular weight	8,130–12,300	Dickie and Yen (1967)
Saturated hydrocarbons (wt %)	2.4–2.8	American Gilsonite (2008)
Asphaltenes (wt %)	56.7–76.2	American Gilsonite (2008)
Resins (maltenes, wt %)	21.0–26.7	American Gilsonite (2008)
Volatile matter (wt %, dry, ash-free basis)	75.2–86.5	American Gilsonite (2008)
Fixed carbon (wt %)	13.8–18.6	Hunt (1963)
Ash (wt %)	0.3–0.7	American Gilsonite (2008)
Resistivity (ohm-m)	1.9 x 10^{10}	Neel (1980)
Reflectance (% RM)	0.11–0.13	Jacob (1983)

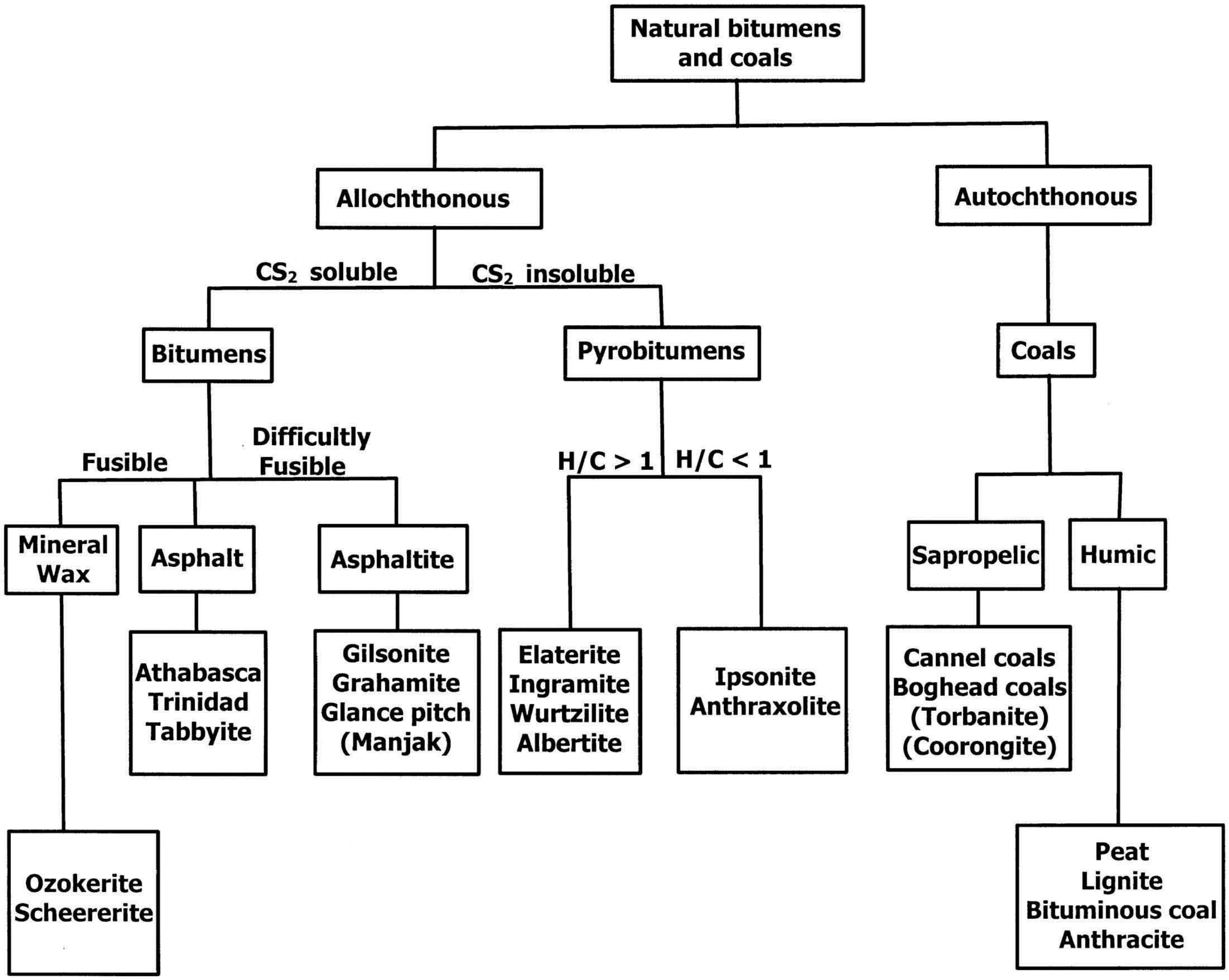

Figure 3. *Hunt's (1979) classification of natural bitumens and coals.*

Study Area

The study area (plate 1) is principally in Uintah County and to a lesser extent in Duchesne County. Gilsonite veins are exposed in the vicinity of the Green and White Rivers, south of the towns of Roosevelt and Vernal. Gilsonite forms a subparallel set of relatively straight, linearly continuous, vertical veins in a northwest-southeast-trending zone approximately 64 miles long by 30 miles wide. The landscape is moderately dissected, and typified by small mesas, low buttes, dry washes, and sparse vegetation.

Project Background

This project began as an evaluation of the gilsonite resources of the Uinta Basin for the Utah School and Institutional Trust Lands Administration (SITLA). This evaluation included compilation of existing data, as well as examination and GPS plots of most known veins. Summary reports of this work for SITLA were published by Tripp (2004), Tripp and White (2006), and Boden and Tripp (2008).

Scope

Although many good, early summary reports have been published, they lack detailed and/or accurate vein information. Reliable, detailed information about gilsonite deposits in large areas of the Uinta Basin is contained only in proprietary company files and has not been published. The lack of detailed, accurate published data is partially due to the remoteness of the gilsonite veins, poor-quality base maps at the time of some of the earlier studies, and the greater difficulty of accurately plotting more than 100 miles of veins before GPS technology was available. While some of the largest and most economically significant veins are well described in published reports, other veins containing significant resources are not well described. Therefore, for this investigation we sought to locate, accurately map, and collect data on all the gilsonite veins, especially the "lesser-known" deposits. This study fills many of the data gaps; however, we were unable to obtain access to gilsonite deposits on the Uintah and Ouray Indian Reservation, so veins located there remain inadequately described. Also, we were unable to examine deposits in the area of Fort Duchesne where the deposits have been obscured by development.

Methods

Mapping of the gilsonite veins in the study area was accomplished using recreational grade Garmin GPS equipment with horizontal accuracy of approximately 15 feet, and U.S. Geological Survey (USGS) 7.5-minute topographic quadrangle maps. National Agriculture Imagery Program (NAIP) 1 meter, high-resolution, color aerial photography of 2006 from the Utah Automated Geographic Reference Center was also used to locate and map veins. We used the gilsonite deposit maps produced by Pruitt (1961) and Cashion (1967) as initial base maps to approximately locate reported veins. The Cowboy, Independent/Tabor, Little Bonanza, Little Chepetta, Chepetta, Caldwell, Augustine, and Colorado segment of the Weaver vein locations were digitized from previous USGS mapping (Cashion, 1974, 1977, 1978, and 1986). The locations of the digitized vein traces were improved through examination of NAIP aerial photography from 2006. We used early work by Cashion (1967) for general geological information as it relates to the gilsonite deposits. To compile the geology shown on the gilsonite veins map (plate 1), we adopted the geologic map units developed during recent mapping in the Uinta Basin by Sprinkel (2007, 2009).

Previous Work

Gilsonite is a geologically interesting and economically significant resource, so it has been the subject of numerous studies and publications from the late 1800s to the present. Some of the more important publications include those of Eldridge (1901), who gave an early description of the gilsonite deposits and geologic setting. Abraham (1960), Bell and Hunt (1963), Hatcher and others (1992), Hunt (1963, 1979), Hunt and others (1954), and Monson and Parnell (1992a, 1992b) investigated origins and compositions of gilsonite deposits and various other hydrocarbons in the Uinta Basin. Verbeek and Grout (1992, 1993) studied the geometry and structural evolution of the gilsonite veins. Henderson (1957) described the refining of gilsonite by the American Gilsonite Company. Covington (1964), Kretchman (1957), Remington (1959), Tripp (2004), and Tripp and White (2006) described the history of the gilsonite industry and mining. Cashion (1967) described the geologic setting and estimated gilsonite reserves. Boden and Tripp (2008), Crawford and Pruitt (1963), Davis (1957), and Pruitt (1961) described the location, occurrence, and geologic setting of gilsonite deposits.

In the early 1980s, U.S. Bureau of Land Management (BLM) employees mapped selected gilsonite veins on the Ouray, Ouray SE, Big Pack Mtn. NW, Big Pack Mtn. NE, Archy Bench, Asphalt Wash, and Rainbow 7.5-minute topographic quadrangle maps (Peter Sokolosky, BLM, written communication, April 2, 2004). The survey appears to have focused on veins in old BLM prospecting permit application areas. Many of the veins mapped by the BLM are on the Uintah and Ouray Indian Reservation and were not visited by UGS geologists. However, UGS geologists observed some of these veins in road cuts and outcrops along the public roads that pass through the reservation. In the areas covered by both field investigations, mapping mostly agrees except for small discrepancies. Plate 1 shows the Pride of Utah, Natural Buttes, Black Gnat, Workman, Willow #2 southeast extension, Black Bridge, and southeast extensions of the Willow Creek #1 and #2 veins as mapped by the BLM, most of which are on the Uintah and Ouray Indian Reservation.

GILSONITE USES

Gilsonite has an extremely wide range of uses that have changed over time with new technology and industrial needs. Kemmerer (1934), Carey and Roberts (1949), Davis (1951a, 1951b), Kretchman (1957), and Remington (1959) give good summaries of past gilsonite uses, which include use as a component of the durable black paint used by Ford Motor Company on early Model T automobiles. Gilsonite has hundreds of uses, but they can be grouped into the following five major categories (American Gilsonite Company, 2008):

1) Asphalt paving mixes and coatings – gilsonite added to asphalt paving mixes (black top) improves pavement performance. Gilsonite can also be incorporated into solvent-based and emulsion-type pavement sealers.
2) Chemical products – gilsonite is used in metallurgy, in adhesives and coatings, as a binder in refractories, and as a binder in brake pads.
3) Metal foundry uses – gilsonite is used as an additive in molding sand mixes in iron and steel casting.
4) Inks and paints – gilsonite, added to ink and paint formulations, can save money and improve product properties.
5) Oil well drilling and well completions – gilsonite has long been used to improve characteristics of water-based, oil-based, and synthetic-based drilling mud systems.

Gilsonite is also used in low-density cementing slurry for lost circulation control. More details on these applications are provided by American Gilsonite Company (2008) and are summarized by Tripp and White (2006).

STRUCTURAL SETTING

Gilsonite veins are hosted in gently dipping Tertiary sedimentary rocks on the southern flank of the Uinta Basin. The basin is an asymmetric, intermontane basin along the northern edge of the Colorado Plateau. The Uinta Basin is bordered by the Uinta Mountains to the north, Douglas Creek arch to the east, Uncompahgre uplift to the southeast, San Rafael Swell to the southwest, and Wasatch Range to the west (figure 4). The closely related Piceance Creek Basin to the east is separated from the Uinta Basin by the north-south trending Douglas Creek arch. Structural features in the Uinta Basin and Uinta Mountains region have a development history that is long and complex, with some structures like the Uinta rift basin forming during Proterozoic time, and other structural activity possibly occurring during the Pennsylvanian-Permian ancestral Rocky Mountains uplift (Stone, 1993).

The Uinta Basin, Uinta Mountains, and associated folds were formed by west-southwest to east-northeast compression during the Cretaceous-early Tertiary Laramide orogeny (Erslev, 1993; Stone, 1993). Some fault systems that may have been formed during or were reactivated by the Laramide orogeny, were subsequently reactivated during the late Tertiary by extensional deformation producing normal-slip displacement.

Structural features within the study area include folds, faults, joints, and dikes, and are influenced by the regional structural trends exhibited throughout the Uinta Basin and Uinta Mountains. Faulting in the study area is minor in both abundance and displacement. The eastern part of the east-west-striking, normal-slip, Duchesne fault system (plate 1) occurs in the northwestern part of the study area. Other significant fault systems in the study area exist in the southwestern part trending northwest

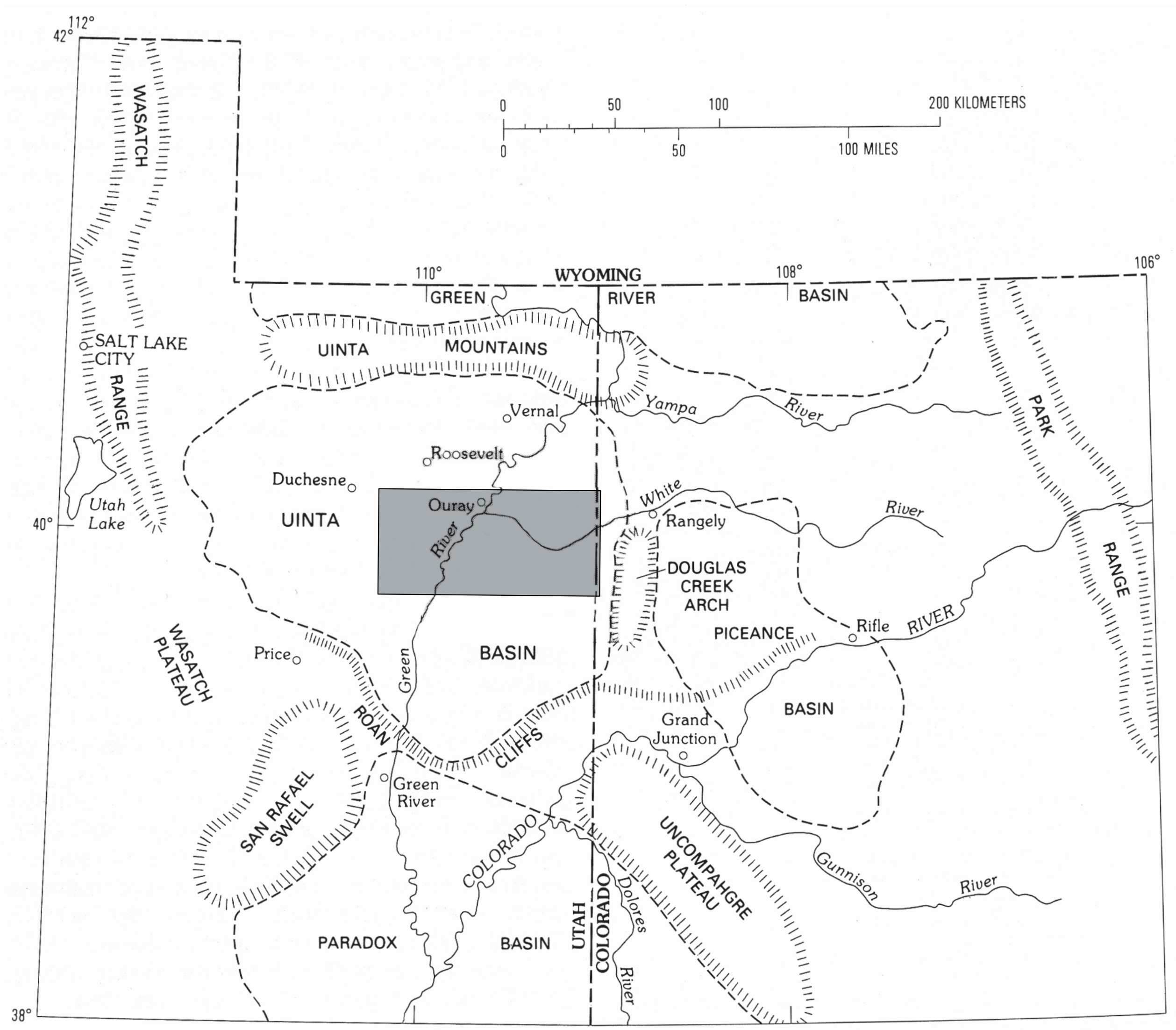

Figure 4. *Tertiary basin and uplift structures, and physiographic features in relation to study area (gray box)(modified from Cashion, 1967).*

and in the southeastern part, near the Utah-Colorado border, trending northeast. Two gilsonite veins in the Pariette Draw area, the O.K. and Original Owner, apparently postdate movement on the Duchesne fault. The O.K. vein is along the fault and trends east-west. The Original Owner vein is approximately 0.3 mile south of the O.K. and also trends east-west. Also, the Florence vein has an unusual "kink" that may be related to faulting in the area.

In addition to the fractures that host the gilsonite veins, two other significant regional fracture/joint sets are common in the Uinta Basin; they trend northwest and northeast (Verbeek and Grout, 1993). According to Verbeek and Grout (1993), the older, northwest-trending set of joints dominates the fracture network in many areas and developed during the strongest period of post-Laramide extensional deformation. These joints strike almost parallel to the gilsonite veins; however, they are not directly related to (and appear to postdate) the fractures containing gilsonite, as shown by abutting relations between vein walls and joint surfaces, and differences in orientation and physical characteristics. The younger, northeast-trending joints are most numerous where the older northwest-trending joints are least developed. The gradual regional shift of the relative abundance of one joint set over the other reflects the gradually changing stress gradients over time in the basin (Verbeek and Grout, 1993).

STRATIGRAPHIC SETTING

Gilsonite veins are hosted in the Eocene strata of the upper Wasatch, Green River, Uinta, and lower Duchesne River Formations (figure 5). The rocks comprising these formations were deposited in lacustrine and fluvial depositional environments and range in composition from chemically precipitated carbonate rocks to clastic rocks, and include minor tuffaceous rocks. Contacts between these formations are gradational, having complex intertonguing relationships and abrupt facies changes that reflect fluctuating paleo-lake (Lake Uinta) levels.

The lowest stratigraphic unit containing gilsonite veins is the Eocene Renegade Tongue of the upper Wasatch Formation. The predominantly fluvial Renegade Tongue consists of massive, irregularly bedded, brown and gray sandstone, and red and gray shale and siltstone that were deposited around the edges of Lake Uinta (Cashion, 1967). The Renegade Tongue interfingers with the primarily lacustrine Douglas Creek Member of the lower Green River Formation. Gilsonite veins in the Renegade Tongue crop out on the eastern side of the Uinta Basin near the Utah-Colorado border. The Weaver vein (in Colorado it is known as the Colorado vein) is present in the Renegade Tongue inside Colorado and is reported to pinch out farther to the southeast in Colorado and downward into shale beds in the Renegade Tongue (Cashion, 1967). The Black Dragon vein is located approximately 12 miles south of the Weaver vein and approximately 1 mile west of the Utah-Colorado border where it pinches out downward into shale beds at the contact zone between the Renegade Tongue and Douglas Creek Member.

Eocene Green River Formation lacustrine deposits host gilsonite veins in the basal Douglas Creek and upper Parachute Creek Members; however, no gilsonite is known to cross-cut the Mahogany oil shale zone contained in the Parachute Creek Member. The Douglas Creek Member consists primarily of sandstone, siltstone, and shale; algal, oolitic, and ostracodal limestone; and a few oil shale beds (Cashion, 1967). Veins below the Mahogany oil shale zone are thickest in the sandstone beds of the Douglas Creek Member and interfingering Renegade Tongue of the Wasatch Formation.

SYSTEM	SERIES	SYMBOL		FORMATION	Thickness (feet) (not to scale)	LITHOLOGY	NOTES
Tertiary	Eocene	Tdb		Brennan Basin Member of Duchesne River Formation	720–1970		Contains gilsonite deposits (Tuc through Tw)
		Tu	Tuc	Member C of Uinta Formation	200–820		
			Tub	Member B of Uinta Formation	100–900		
			Tua	Member A of Uinta Formation	0–720		
		Tgsl		Sandstone-Limestone facies of Green River Formation	200–590		
		Tgp		Parachute Creek Member of Green River Formation	0–3120		Mahogany oil shale zone
		Tgd		Douglas Creek Member of Green River Formation	0–1710		Uinta Mountains continue to uplift and erode; creation of Lake Uinta as the Uinta Basin continues to subside; contains oil shale and oil reserves
		Tg-Tw		Green River-Wasatch Formations transition zone	200–870		
		Tw		Wasatch Formation	980–3020		

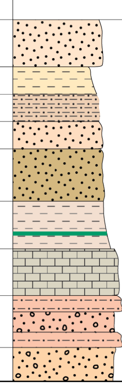

Figure 5. *Stratigraphic column of the Eocene section hosting gilsonite veins in the Uinta Basin (modified from Sprinkel, 2007, 2009).*

The Parachute Creek Member overlies and interfingers with the Douglas Creek Member and consists primarily of marlstone, oil shale, siltstone, sandstone, and tuff (Cashion, 1967). Bedding within the Parachute Creek Member is thin to laminated, even, and laterally continuous. The Mahogany oil shale zone is a sequence of rich oil shale beds within the Parachute Creek Member. The Mahogany bed is a particularly rich and laterally extensive oil shale bed in the Mahogany zone; its lateral continuity makes it a good regional marker bed (plate 1). Petrographically the oil shale is dolomitic marlstone having a high content of organic matter in the form of kerogen. All but two (Weaver and Black Dragon) of the known significant gilsonite veins are located above the Mahogany oil shale zone. Gilsonite veins that are above or beneath the Parachute Creek Member branch into veinlets and pinch out within the thin-to-laminated marlstone and oil shale beds contained in this member (Cashion, 1967). The veins can thicken in the upper beds of the Parachute Creek Member near the contact with the Uinta Formation.

Gilsonite veins in the eastern part of the basin are known to achieve their greatest thickness in the lower Uinta Formation (Pruitt, 1961; Cashion, 1967). The Eocene Uinta Formation interfingers with the underlying Parachute Creek Member and consists of marginal lacustrine deposits in the lower part, mixed fluvial and marginal lacustrine deposits in the middle part, and entirely fluvial deposits in the upper part. Marginal lacustrine deposits in the lower part consist primarily of thick, laterally continuous, medium-bedded to massive sandstone containing interbedded siltstone and thin intervals of marlstone and tuff. Fluvial beds in the middle and upper parts are composed of channel-form sandstone, variegated mudstone, and minor conglomerate that tend to be laterally discontinuous and thinner than marginal lacustrine deposits down section. Gilsonite veins commonly split, become discontinuous, and/or pinch out in the mudstone-rich upper Uinta Formation.

Rocks of the Eocene lower Duchesne River Formation are the youngest strata to host gilsonite veins. Conformability between the Uinta Formation and overlying Duchesne River Formation varies depending on location. The Duchesne River Formation consists primarily of fluvial interbedded mudstone and weakly cemented channel-form sandstone (Cashion, 1967). In the area of Fort Duchesne, Utah, the Carbon and Raven veins are located in the Brennan Basin Member of the lower Duchesne River Formation (Sprinkel, 2007) and were the first veins to be mined in the Uinta Basin (Pruitt, 1961).

Gilsonite veins can maintain their widths over extensive vertical and horizontal distances; vein continuity is related to the stratigraphy and lithology of the host formations (Pruitt, 1961; Cashion, 1967). Gilsonite veins are commonly widest in the thick, competent, laterally continuous sandstone beds of the lower Uinta Formation and also in similar beds at the top of the Green River Formation (figure 6). Continuing up section, veins tend to split and be less continuous in thinner bedded marlstone, thicker bedded mudstone and siltstone, and discontinuous channel sandstones in the middle and upper Uinta Formation. In the eastern part of the study area, gilsonite veins above the source beds are in many cases eroded down near their roots, and the remaining veins generally can be expected to split and thin with depth. Gilsonite veins exposed beneath the source beds attain their greatest thickness in the Douglas Creek Member and the interfingering Renegade Tongue and can be expected to thin both downward and upward from these units. In the central and northwestern parts of the study area, bedrock hosting gilsonite veins is generally less eroded, and the veins rooted in the Green River Formation oil shale have greater vertical extent and generally can be expected to widen with depth from exposures in the middle and upper Uinta Formation.

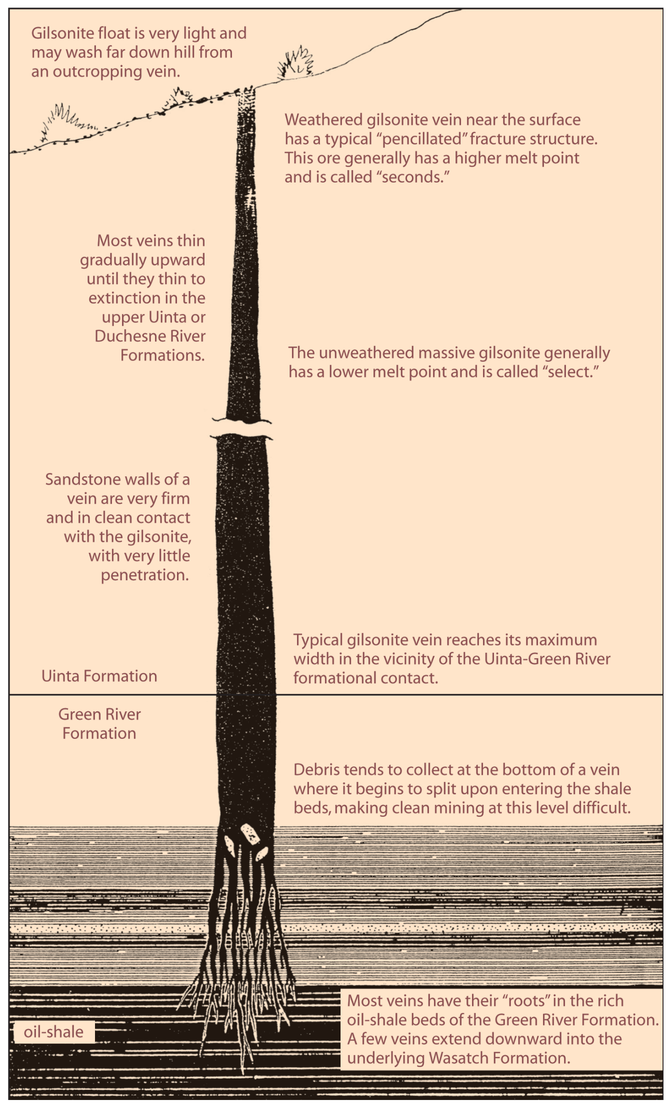

Figure 6. *Cross section of a typical gilsonite vein (from Eldridge, 1901).*

ORIGINS OF GILSONITE

Gilsonite deposits primarily form as long, essentially vertical dikes (veins) that predominantly trend northwest and can range in width from less than an inch to more than 20 feet. Gilsonite sills (figure 7) are occasionally associated with the gilsonite dikes. The continuity of the veins is impressive; they stretch in relatively long, straight ribbons across the hills of the Uinta Basin, with the longest vein system (Pride of the West–Rainbow–Black Dragon) extending more than 22 miles. The gilsonite veins are also vertically continuous, ranging from hundreds to more than 3000 feet, commonly having only small variations in width.

The source and mechanisms that may have formed the gilsonite vein deposits in the Uinta Basin have long been debated, and the theories are well summarized by Verbeek and Grout (1993). Laboratory and field evidence strongly suggests that the gilsonite was sourced from kerogen-rich oil shale beds contained in and around the Mahogany oil shale zone in the Parachute Creek Member of the Green River Formation. Mechanisms for propagating the fractures that contain gilsonite appear to involve elevated pore pressure within the hydrocarbon source beds of the Green River Formation and regional stress fields.

The processes that formed the gilsonite vein deposits in the Uinta Basin began during Eocene time when a large lake, Lake Uinta, developed within a basin formed during the Late Cretaceous–early Tertiary Laramide orogeny. Lake Uinta covered an area now containing the Uinta Basin in Utah and Piceance Creek Basin in Colorado, but varied in position, size, and water chemistry over its millions of years of existence. During middle Eocene time, the lake reached its maximum areal extent and greatest depth, extending open-lacustrine conditions over a wide region. The lake also appears to have been chemically stratified during this time, having a lower, stagnant saline layer enriched in hydrogen sulfide and devoid of free oxygen, as indicated by the preservation of organic matter and the common occurrence of pyrite in the lake-bottom sediments (Hunt and others, 1954). Large amounts of organic material (primarily algae) accumulated on the bottom of the central area of the lake, along with bedded to laminated sediments composed primarily of calcium, magnesium, and sodium carbonates precipitated out of the lake water. Later, the heat and pressure of burial changed the organic-rich sediment into the thick, kerogen-bearing oil shales of the middle and upper Green River Formation.

Hunt and others (1954) and Hunt (1963) summarized compelling evidence that supports the Mahogany oil shale

Figure 7. *Gilsonite sill (right of rock hammer) on the Rainbow vein in the lower Uinta Formation in NW¼NE¼ section 25, T. 11 S., R. 24 E., SLBLM, Uintah County.*

zone as the source of the gilsonite. Their work involved comparing physical and chemical characteristics of vein and tar sand hydrocarbons to that of soluble organic matter contained in associated rocks to identify similarities that would connect solid hydrocarbon deposits to their source rocks. With respect to gilsonite, numerous sites were sampled starting approximately 1000 feet above the base of the Green River Formation, and the organic matter was analyzed for refractive index, infrared spectra, liquid chromatography results, and elemental composition. Near Bonanza, Utah, a strong similarity was demonstrated between the oil shale in and around the Mahogany zone and the nearby Cowboy and Bonanza (Independent) gilsonite veins. Hatcher and others (1992) used gas chromatography and mass spectrometry to compare hopane, sterane, and carotenoid biomarker compositions of gilsonite, tar sand, oil, and Green River Formation oil shale in the Uinta Basin. Results of their work demonstrated a direct relationship between Green River Formation oil shale and gilsonite, tar seeps, Asphalt Ridge tar sand, and asphaltic crude oils.

Strong field evidence also supports the Mahogany oil shale zone as the source of the gilsonite. No gilsonite veins are known to cross-cut the Mahogany zone. The Black Dragon vein is located beneath the Mahogany zone and in Threemile Canyon can be traced as it thins directly below, and subsequently terminates in, the Mahogany oil shale. The Bonanza (Independent) vein is located above the Mahogany zone and is reported to split at its base into numerous veinlets as it encounters the rich oil shale of the Mahogany (Hunt and others, 1954).

Verbeek and Grout (1993) concluded that the fractures filled by gilsonite veins are large-scale hydraulic extension features that resulted from the overpressurization of pore-space fluid in the hydrocarbon-rich source beds in the Green River Formation. Early-stage, post-Laramide, regional tectonic extension is also believed to be a factor in fracture formation (Verbeek and Grout, 1993). Fractures were forcefully propagated first by formational water, which in some instances bleached wall rock, deposited limonite and calcite on vein walls, and deposited chlorite in adjacent sandstones. Subsequently, fractures were widened as viscous, liquid asphaltite was injected under high pressure and later solidified into gilsonite, probably through cooling and polymerization. The gilsonite contains authigenic quartz and barite and occasionally 1- to 3-millimeter vesicles (Monsen and Parnell, 1992b) that originally contained water or gas.

EXPLORATION TECHNIQUES

All of the veins mined today were discovered by early prospectors who located surface exposures. Many of the veins have prominent surface expressions, appearing as black, straight bands irrespective of topography, and contrasting strongly with light-colored host rocks in a sparsely vegetated terrain. Sections of the veins are, however, frequently covered by alluvium and colluvium and are generally well exposed only on ridges and in bedrock drainages, disappearing under alluvial valleys and reappearing on adjacent ridges. Where covered, veins can usually be mapped by the presence of eroded gilsonite flakes or evidence of past mining such as headframes and shafts sunk through the colluvium. The veins are generally straight and continuous, and the simple regional geology makes it easy to extrapolate between good exposures. Gilsonite is lightweight and can wash down colluvium-covered slopes, so streaks of gilsonite float (figure 8) can be offset from actual vein locations by 20 feet or more (Tripp and White, 2006).

Figure 8. *Gilsonite float eroding from the northwest segment of the Harrison vein in S½SW¼ section 29, T. 10 S., R. 23 E., SLBLM, Uintah County. Notebook is 7.5 inches long.*

In areas where alluvium or colluvium is relatively thick, the traditional exploration technique was to project the trend of a vein and then trench or sink shallow shafts to verify location and determine the extent and quality of the gilsonite. Current exploration practices include angle and vertical drilling of suspected vein extensions using a truck-mounted drill rig; such drilling is important because some past mines were abandoned because the vein pinched out at shallow depths. Before a mine is placed in operation, the shaft location typically is core drilled to various depths; additional angle drilling is generally completed at 400-foot intervals along the strike of the vein on both sides of the shaft. Typical drill intercepts are at depths of 100, 300, 600, and 800 feet. Data collected during exploration include vein width, wall-rock characteristics, and ore quality. Quality characteristics of gilsonite veins, particularly the melt point, viscosity, and ash content, can change rapidly along strike and/or with depth. This information is of paramount importance for mine planning and determining potential markets for the gilsonite (Tripp and White, 2006).

Geochemical and geophysical exploration methods for gilsonite have yielded some success, but none have become standard exploration procedures. Botbol (1961) collected soil samples along closely spaced transects across covered extensions of known veins and then concentrated and measured the gilsonite fraction in the soil. The resulting data showed that the gilsonite contents in closely spaced samples were high over the expected trends of the veins. Electrical resistivity surveys across known gilsonite veins produced sharp anomalies with peak values over the center of the veins and smaller auxiliary peaks symmetrically spaced on both sides of the veins (Hays and others, 1967). Boleneus (2007) used electrical resistivity imaging to determine the presence and extent of gilsonite at abandoned mine sites on the Cowboy vein and a proposed shaft site on the Cottonwood vein. Near the northwest end of the Cowboy vein, electrical resistivity imaging was used to estimate the reclamation needs at abandoned gilsonite mines by determining the extent of underground workings and the location of unmined gilsonite. On the southeast segment of the Cottonwood vein, electrical resistivity imaging was used to locate gilsonite at a proposed shaft site for underground mining by Lexco, which operated two shafts farther to the northwest. The Cottonwood vein survey located an approximately 30-inch-wide vein using an electrode spacing of 16.4 feet in the proposed shaft area where there was no sign of gilsonite at the surface, neither in outcrop nor evidenced from soil or rock outcrops overlying the vein (Boleneus, 2007). The relatively wide electrode spacing shows that this type of geophysical survey can be used for rapid reconnaissance of a wide area to explore for concealed gilsonite veins of minable width.

DEVELOPMENT

Mining History

Gilsonite has a long, colorful mining history, which includes early exploration and development in rugged, remote country by prospectors; development of uses and markets; competition for the resource; conflicts among Native Americans, developers, and the U.S. Government; passage of laws; consolidation of development companies; development of processing and transportation infrastructure; and competition for markets. While the history before 1938 is very interesting, we will focus on the history since then. Crawford (1957), Kretchman (1957), Remington (1959), Covington (1964), and Bender (1970) discussed the pre-1938 period of gilsonite discovery and development in detail, and their accounts have also been summarized by Tripp (2004), and Tripp and White (2006).

In 1938, The Gilson Asphaltum Company, which had acquired the dominant gilsonite position in the Uinta Basin, changed its name to Barber Asphalt Company (the predecessor of Barber Oil Company). Barber Oil Company sold part ownership in the gilsonite operation to Standard Oil of California (now ChevronTexaco Corp.) in 1948 (Lewis, 1994). The new, jointly owned company was named the American Gilsonite Company (AGC). The new company renewed efforts to make gasoline and high-purity electrode carbon from gilsonite (Kretchman, 1957). Refinery design problems were solved by 1954, but a lower cost method of transporting the gilsonite was needed to make the project economic. A 72-mile-long slurry pipeline was constructed on an abandoned railroad right-of-way to a new (in August 1957) petroleum refinery at Gilsonite, Colorado, built specifically to refine gilsonite (Kretchman, 1957). The intended market for gasoline from the refinery was western Colorado, and most of the electrode carbon was for sale to the growing aluminum smelting industry of the Pacific Northwest (Henderson, 1957). Use of gilsonite for refinery feedstock greatly expanded production. In 1957, AGC started mining gilsonite with water jet cutters to speed production and prevent gilsonite dust explosions; Kilborn (1964) described the hydraulic mining technique in detail. AGC discontinued refining gilsonite and sold the refinery in 1973. Mine production declined from about 360,000 tons per year to about 54,000 tons per year as a result. AGC re-emphasized non-fuel uses of gilsonite and within 10 years AGC's gilsonite production expanded to 91,000 tons per year (Jackson, 1985). Around 1981, AGC replaced their 30-year-old, 4500-tons-per-month mill with a new, $6 million processing plant. The new mill was designed to process 9000 tons per month of ore, be more efficient, improve product quality, and meet environmental and safety regulations (Jackson, 1985). In January 1981, Chevron bought out Barber Oil's share of the business (Jackson, 1985; Hawes, 1990). AGC has simultaneously mined ore from several mines on different veins to provide the various grades of gilsonite specified by customers. In 1983, AGC mined ore from 11 gilsonite mines near Bonanza (Shushan, 1983). In 1991, Chevron sold their gilsonite operation to Stratford Enterprises Company of Tulsa, Oklahoma (Lewis, 1994). AGC then became an independent, publicly held company until March 2008, when they were acquired by American Gilsonite Holding Company, a privately held portfolio company of Palladium Equity Partners III, L.P. (Business Wire, 2008). In 2007, AGC employed 91 people at its mines and Bonanza mill and office (U.S. Mine Safety and Health Administration, 2008).

Two smaller companies have also mined gilsonite in the recent past: Ziegler Chemical & Mineral Corporation (Ziegler) and Lexco, Inc. Ziegler was incorporated in 1944 as a New Jersey-based producer of pitches, asphalts, and resins. The company, then known as G.S. Ziegler and Company, purchased gilsonite from small independent gilsonite producers. Ziegler acquired its own gilsonite properties in 1952 from the Utah Gilsonite Company, which had been in operation since 1920. In 1953, Ziegler also purchased some of the property of the American Asphaltum Association (a company formed in 1902 by former stakeholders in The Gilson Asphaltum Company). Ziegler additionally acquired the assets of the Standard Gilsonite Company in 1962 and renamed the combined company the Ziegler Chemical & Mineral Corporation (Lewis, 1994; Ziegler, 2008). The consolidated operation's office and plant were at Little Bonanza, Utah. Ziegler typically has produced less ore than AGC, but in 1994 produced more than 50% of the gilsonite mined in the Uinta Basin (Ziegler, 2008). In 2007, an average of 15 Ziegler employees worked 26,619 hours at the mines and the Little Bonanza mill (U.S. Mine Safety and Health Administration, 2008).

Lexco, Inc. was relatively new to the gilsonite industry when it began operating in 1988. Lexco operated a processing plant southeast of Fort Duchesne, in central Uintah County, and produced gilsonite from the ITM and Cottonwood mines. As recently as 2008, Lexco operated the Cottonwood mine where the vein width averages 36 to 38 inches. At the ITM mine, the vein width averages 18 inches and was mined in sections as narrow as 14 inches. In 2007, an average of 19 Lexco employees worked 32,187 hours at the mine and mill (U.S. Mine Safety and Health

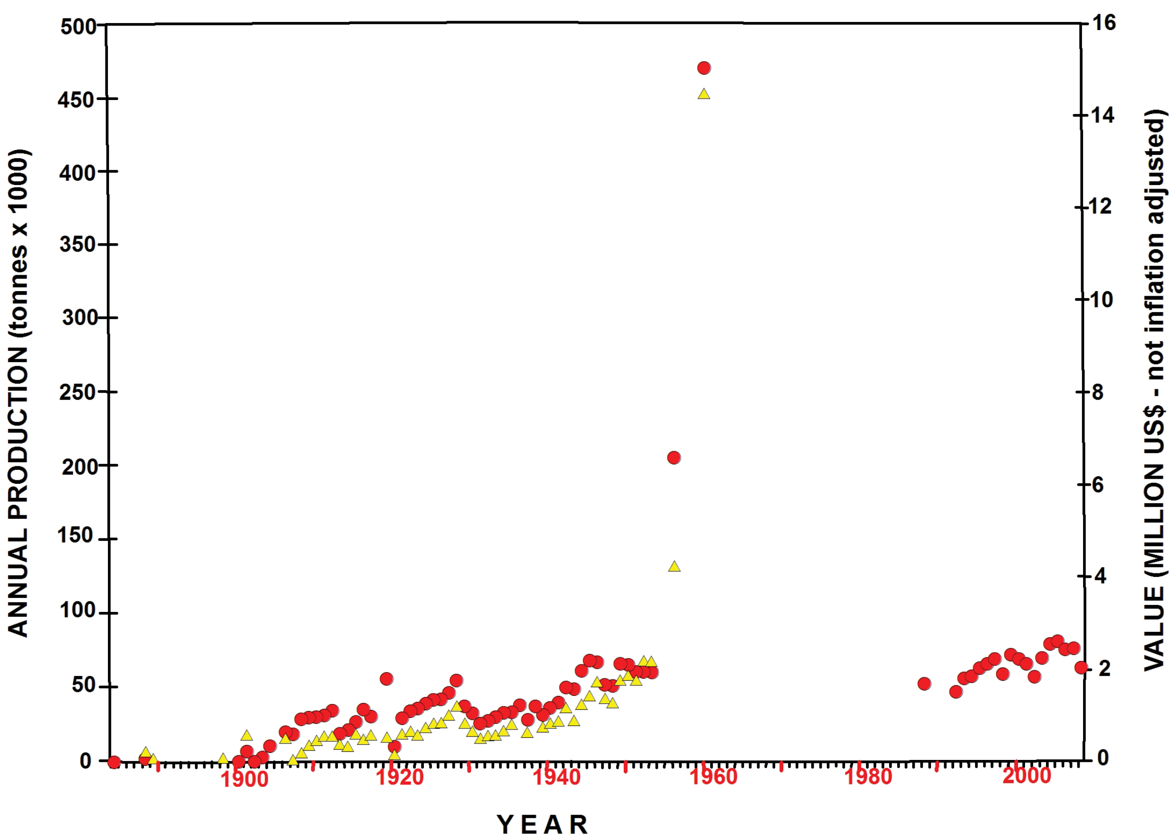

Figure 9. *Gilsonite annual production (red dots) and value (yellow triangles). Data gaps occur where production data were not preserved or where data were withheld by U.S. Bureau of Mines. Data from U.S. Bureau of Mines; Utah Division of Oil, Gas and Mining; Utah Geological Survey; Aurand (1920); Baker (1950); Carey and Roberts (1949); Cashion (1969); Covington (1964); Crawford (1957); Dennis (1930); Eldridge (1901); Garvin (1966); Kretchman (1957); Ladoo and Myers (1951); Romney (1963); Utah Mining Association (1955, 1959, 1967).*

Administration, 2008). Lexco was recently acquired by AGC and its mines and processing plant were idle as of 2010. In general, gilsonite production and value has increased gradually from 1885 to 2008 (figure 9) except for the production spike from 1957 to 1973 that was associated with operation of AGC's refinery.

Mining Methods and Transportation

Early gilsonite mining was predominantly by open-cut mining with picks, shovels, and horse-powered hoists. All the gilsonite produced today from the Uinta Basin is by underground mining methods (figure 10). Mining consists of two major phases: shafts are sunk at regular intervals along the veins, and drifts and slopes are then extended laterally from the shafts. The top 30 feet of the gilsonite is not mined for safety and reclamation reasons. The following mining method description was largely taken from Tripp and White (2006).

Mining begins with main shaft development either by hand sinking directly into the ore or by drilling the shaft with a Teton drill rig that has a large-diameter (7-foot) bit. The method selected depends on the width of the vein at the surface and at depth. Hand sinking is preferred if the vein is at least 2 feet wide at the surface because it yields salable gilsonite. Shaft drilling contaminates the gilsonite with wall rock; however, it is sometimes necessary on veins that, on outcrop, are too narrow for hand mining, but that widen at depth. On the Cowboy vein, where outcrops are generally not very wide but vein width increases with depth, the large-diameter drill is used to develop a shaft down to the depth where the vein is at least 4 feet wide. Once this width has been verified, the shaft sinking continues by hand. Drilled sections of shafts are usually about 220 feet deep. Typically, shafts developed in the ore body extend 26 feet along the length of the vein. All of the shaft-support equipment, including landings and guide rails, are installed in conjunction with hand sinking. The shaft contains three compartments; the two outside compartments contain pipes for the air lift and compressed air, and a central compartment contains a skip for miners.

Once the main shaft has been developed to a depth where the ore is wide enough for mining, or is at least 30 feet below the surface, a drift is started in one or both directions from the shaft. These drifts extend 500 to 700 feet from the shaft and serve as the escapeway drifts for the initial phase of mining. Once the initial drifts are complete, a small escapeway shaft is raised to the surface or is drilled if the distance from the surface down to the

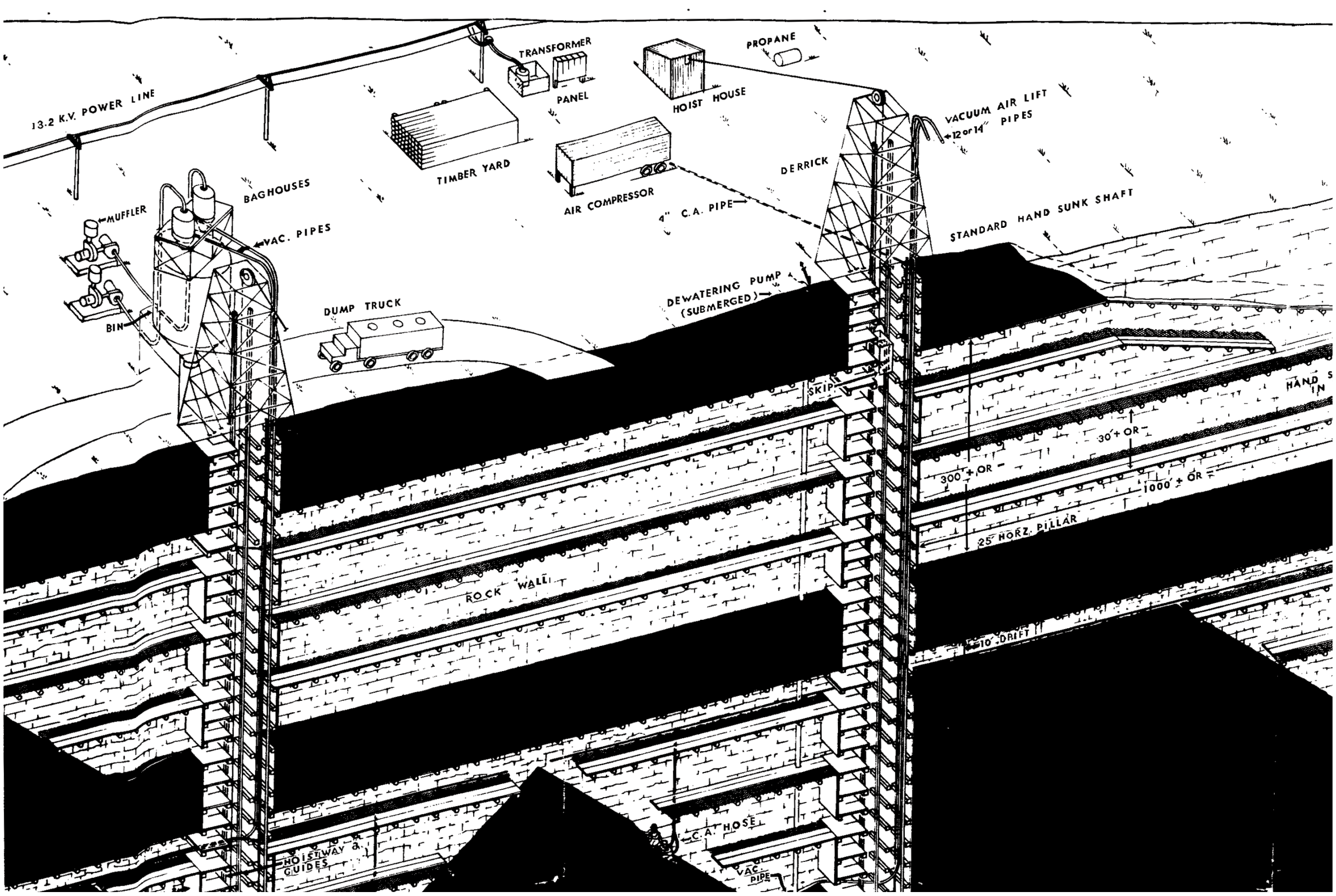

Figure 10. *Gilsonite underground mining methods (from Tripp and White, 2006, courtesy of American Gilsonite Company).*

escapeway drift is more than 50 feet. In cases where the ore width is insufficient to conduct shaft raising or sinking in the vein, an escapeway shaft is drilled to intersect the escapeway drift.

Recently, AGC changed its mining methods by sinking the main shaft to the bottom of the ore deposit and then developing the initial drifts at this lower level and extracting ore from the bottom of the mine up to the top of the mine. The major benefit of this method is reduced shaft and escapeway maintenance. Once the ore has been extracted from the lower levels, those portions of the drifts and shaft do not need to be maintained. If mining is conducted from the top of the mine to the bottom, all of the drifts and shafts must be maintained for the life of the mine.

Gilsonite slope mining is generally initiated by developing two drifts, 200 vertical feet apart, from the main shaft to the escapeway shafts. Development can take place along strike in both directions from the shaft. Once these drifts are completed, mining begins on the floor of the upper drift downward and a 45° slope is created. This slope is extended along the upper drift until the bottom of the slope reaches the lower drift. This creates a slope in the ore body, which is approximately 140 feet long. Mining progresses from the bottom of the slope, which is the lower drift, to the top of the slope, which is the upper drift. A miner using a chipping hammer cuts a 4-foot-high bench on the bottom of the slope. The miner then cuts this bench up the 45° incline to the top of the slope. As the ore is cut with the chipping hammer, it slides down the slope and is directed into the air lift that conveys the ore to the surface. In a 5-foot-wide vein, each bench mined up the slope yields 79 tons of gilsonite. These benches are mined until the slope reaches the escapeway shaft. The remaining triangle of ore is mined from the top to the bottom of the slope so that a straight face of ore is left.

The gilsonite ore usually is mined using pneumatic chipping hammers that weigh approximately 12 pounds and are equipped with 12-inch-long, hardened steel moils. Compressed air for the chipping hammers comes from a 150-horsepower air compressor on the surface via a 3-inch-diameter steel pipe down the shaft to the working face (Jackson, 1985). On occasion, permissible explosives will be used if the ore is particularly hard to mine.

Mine timbers placed on 5-foot centers provide ground support in gilsonite mines. The timbers used in the shaft and on working floors are "hitched" into holes approximately 2 inches deep and slightly larger than the diameter of the timber and are locked into these hitches with wooden wedges. With the support resting on the 2-inch-wide rock ledge of the hitch, the timber will remain in place regardless of shrinkage. Timbers that are only set to control the wall rock are not hitched, but are placed on 2 x 10 x 12-inch cap boards on each end, then wedged tightly into place.

AGC conveys the mined ore from the shaft, drift, or slope by means of an air lift system. Each system is generally equipped with three centrifugal fans, each powered by a 101-horsepower electric motor. The Sprout Waldron centrifugal fans are arranged in series and together develop a vacuum of 140 inches of water gage. The fans are connected to a 12-inch-diameter, steel, air lift pipe which is connected to a bag house and bin arrangement. The air lift pipe extends from the bag house into the mine. Depth of workings and distance between shafts is partially controlled by the capacity of the air lift system. The air lift system can efficiently transport gilsonite in 1100-foot-deep shafts having 700-foot-long drifts, but performance drops off after these distances are exceeded. The air lift system performs three additional functions: (1) it ventilates the mine, (2) it breaks the ore into smaller fragments (gilsonite fractures easily during mining and transport), and (3) it removes the small amount of water that percolates into the mine. Occasionally, large inflows of water require pumping by 50-horsepower staged pumps. While the air lift system is expensive to operate, it is a versatile and proven technology.

Additional mechanization of gilsonite mining has been limited by (1) lack of equipment designed to operate in narrow veins, (2) the highly explosive nature of gilsonite dust, which complicates use of explosives and diesel-, gas-, and electric-powered equipment, and (3) the need to prevent contamination by wall rock fragments, which favors careful hand mining of the ore. Despite these constraints, AGC has experimented with several mechanical mining systems and has recently evaluated a hydraulically powered continuous mining machine designed for narrow veins.

HEALTH ISSUES

Gilsonite is friable and mining generates large quantities of very fine, dark-brown dust, which can be explosive, but which does not represent any special respiratory risk to workers. In the early days of gilsonite mining, ventilation was often inadequate, candles were used for illumination, and explosives were sometimes used, all of which resulted in occasional, spectacular mine explosions and fires. Modern mining techniques and regulations have eliminated most of the explosions and fires. The U.S. Occupational Safety and Health Administration's Material Safety Data Sheets classify gilsonite as non-toxic, noncarcinogenic, and nonmutagenic, so no extreme safety measures are necessary. However, a respirator is recommended in heavy dust concentrations. Gilsonite is also approved for use as a coating on surfaces that contact food (Ziegler, 2008).

GILSONITE VEINS

In our field study, 59 veins, vein systems, and isolated vein outcrops were mapped and described in detail. The total combined vein length mapped was more than 120 miles. The UGS work, combined with previous mapping, identified 71 significant veins, vein systems and vein extensions having a total combined vein length of more than 170 miles. Cashion (1967) estimated the original in-place gilsonite resource of all the veins to be approximately 45 million short tons. In the following sections each vein, vein system, vein extension, isolated vein outcrop, or field investigation is summarized from field data and/or previous work by other investigators. Gilsonite veins in a particular area are generally listed north to south. Significant gilsonite veins that were located during the field study, or confirmed in the literature, are shown on plate 1 (except the Carbon and Raven veins) and summarized in table 2. All township, range, and section locations in the following text are relative to the Salt Lake Base Line and Meridian (SLBLM) unless otherwise noted.

Bonanza Area Veins

Red Wash and Little Red Wash

The Red Wash and Little Red Wash veins (figure 11; plate 1) are closely related and are located in sections 18 and 19, T. 8 S., R. 23 E., and section 13, T. 8 S., R. 22 E. We mapped the vein system for approximately 1.9 miles, from a 7-inch-wide outcrop located approximately 1 mile northwest of Red Wash at the southeast end to a 7-inch-wide outcrop located a short distance southeast of the paved road on Glen Bench at the northwest end. The vein system generally strikes N. 65° W., having a maximum width of 1.1 feet on the south vein and a maximum width of 1 foot on the north vein. Both maximum widths are located a short distance northwest of the vein system's midpoint. The veins are hosted at the surface by the mudstone and minor sandstone belonging to Sprinkel's (2007) member C of the upper Uinta Formation (plate 1). The vein system consists of two main veins less than 200 feet apart that run subparallel, and also has thinner, closely spaced, subparallel, secondary veins cropping out in places. The southernmost vein is 1.9 miles long and generally wider than the north vein, which is 1.2 miles long. The north vein begins a short distance southeast of the vein system's midpoint and continues with the south vein to the northwest termination. Both veins are locally sinuous, and pinch and swell throughout their lengths. Bitumen-impregnated sandstone outcrops (figure 10) are present along the veins at various stratigraphic levels, and one relatively thick sandstone bed appears to contain the most significant bitumen deposits. Bitumen-impregnated sandstone outcrops are black adjacent to the veins, and quickly lighten away from the veins. The black, bituminous sandstone is not widespread and is found only adjacent to the veins. The thicker sandstone unit that hosts the most significant bitumen-impregnated sandstone outcrops is, however, fairly gray and widespread but also bleached in places. The vein system is unmined and only one or two superficial prospects exist.

Cowboy (Eureka)

The Cowboy (Eureka) vein system (plate 1) contains the widest gilsonite vein in the Uinta Basin, as well as the largest single gilsonite deposit, and has supported mining operations since the late 1800s (Pruitt, 1961). Vein locations on plate 1 were derived from USGS mapping (Cashion, 1978, 1986) and our NAIP aerial-photography mapping. The vein system is located in sections 7, 8, 16, 17, 22, and 23, T. 9 S., R. 25 E., sections 1, 2, 3, 4, and 12, T. 9 S., R. 24 E., and sections 32 and 33, T. 8 S., R. 24 E. The vein system is reported to be more than 10 miles long, generally strikes from N. 60 to 70° W., has a maximum width of 22 feet, and has an estimated maximum vertical extent of 1000 feet (Pruitt, 1961; Cashion, 1967). At the southeast end, the vein system begins near the north wall of the White River canyon in the SW¼ section 23, approximately 1.3 miles west of the Utah-Colorado state line. In places, the southeast end of the vein appears to be eroded away where it intersects drainages that cut through the upper Green River Formation. Historical open-trench mining at the southeast end appears to have been shallow, which suggests the vein is splitting and pinching out as it cuts deeper into the upper Green River Formation. Nahcolite ($NaHC0_3$) dissolution cavities in the upper Green River Formation have also been filled with gilsonite at the southeast end of the vein. The Cowboy vein splits in places, having offshoots of significant width on the northwest segment. Pruitt (1961) reported that a 5- to 6-foot-wide vein called the "E.B." (extra black) vein is located parallel and approximately 100 feet to the north of the northwestern part of the Cowboy vein. Upper Green River Formation (Parachute Creek Member) and Uinta Formation sandstone and mudstone host the vein system at the surface (plate 1). The Cowboy vein system attains its greatest width in the massive sandstone in the lower part of the Uinta Formation. The base of the vein is about 150 feet above the Mahogany bed, and the upper termination is in thin mudstone and sandstone beds in the Uinta Formation (Cashion, 1967).

Independent (Bonanza), Tabor, and Little Bonanza

The Independent (Bonanza), Tabor, and Little Bonanza vein system (plate 1) contains the second-widest gilsonite vein in the Uinta Basin and has supported mining operations since the late 1800s (Pruitt, 1961). Vein locations on plate 1 were derived from USGS mapping

Table 2. *Summary of gilsonite vein attribute data.*

Vein Name	Mapped Length (mi)	Max. Surface Width (ft)	General Strike	Surface Hosting Formation	Mining	Data Source
BONANZA AREA						
Red Wash	1.9	1.1	N65°W	Uinta	No	UGS
Little Red Wash	1.2	1	N65°W	Uinta	No	UGS
Cowboy	10	22	N60-70°W	Green River - Uinta	Yes	USGS
Independent-Tabor	7.5	14	N55-62°W	Green River - Uinta	Yes	USGS
Little Bonanza	5.5	13	N68°W	Uinta	Yes	USGS
Little Chepetta	2.3	2.5	N62°W	Uinta	?	USGS
Chepetta	3	1.5	N65°W	Uinta	?	USGS
Caldwell	0.7	?	N60°W	Uinta	?	USGS
Wagon Hound	5	3.3	N63°W	Uinta	Yes	UGS
Little Emma	5	2.8	N65°W	Uinta	Yes	UGS
Augustine	0.9	2.2	N50°W	Green River	?	USGS
Weaver	2.3	2	N58°W	Lower Green River	Yes	UGS
RAINBOW AREA						
Little Butte	0.5	1.1	N60°W	Uinta	No	UGS
Rustler	0.8	1.2	N55°W	Uinta	No	UGS
Alabama	3.9	2	N50-65°W	Uinta	No	UGS
Little Alabama	0.2	0.2	N55°W	Uinta	No	UGS
Black Dragon	3.9	10	N47°W	Lower Green River	Yes	UGS
Rainbow	4.3	10	N45-55°W	Green River - Uinta	Yes	UGS
Pride of the West	13.8	7	N50-65°W	Green River - Uinta	Yes	UGS
Harrison	10.6	4	N50-65°W	Green River - Uinta	Yes	UGS
Little Asphalt Wash	0.8	2	N50-65°W	Green River - Uinta	No	UGS
Asphalt Wash	2.5	3.5	N50-60°W	Green River - Uinta	No	UGS
Snow	1.1	0.25	N67°W	Uinta	No	UGS
Saddletree	1.4	2.2	N58°W	Uinta	No	UGS
South Harrison	6.1	3.5	N58°W	Uinta	No	UGS
Little Chief	0.9	0.7	N57°W	Uinta	No	UGS
Fox	2.9	2.5	N55-65°W	Uinta	No	UGS
Kings Well	5.6	6	N55-65°W	Green River - Uinta	Yes	UGS
Neal	1.8	3	N60°W	Uinta	Yes	UGS
Bitter Water	7	3	N58-70°W	Uinta	No	UGS
Long Draw	0.6	2	N59°W	Green River - Uinta	No	UGS
Sage Brush	1.8	1	N65°W	Green River - Uinta	No	UGS
Little Antler	0.5	1	N62°W	Green River - Uinta	No	UGS
Antler	0.6	2	N58°W	Green River - Uinta	No	UGS
Little Bitter Creek #1	0.3	0.5	N56°W	Uinta	No	UGS
OURAY AREA						
Ouray	0.3	1.5	N62°W	Uinta	Yes	UGS
Little Seam	0.2	0.25	N56°W	Uinta	No	UGS
Gem	0.2	?	N46°W	Uinta	No	UGS
Little Boy	0.5	2	N45°W	Uinta	No	UGS
Cliff Dweller	0.15	0.5	N55°W	Uinta	No	UGS
Jumbo	1.8	1.1	N48-65°W	Uinta	No	UGS
Pride of Utah	6	2	N58°W	Uinta	Yes	BLM
Natural Buttes	2.2	0.7	N55°W	Uinta	No	BLM
Black Gnat	2.4	2.5	N54°W	Uinta	Yes	BLM
Workman	0.9	1.2	N53°W	Uinta	Yes	BLM
Willow #1	1.8	2.2	N50-70°W	Uinta	No	UGS
Willow #2	1.4	1.5	N63°W	Uinta	No	UGS
Willow #2 extension	1.3	1.2	N54°W	Uinta	No	BLM
Willow #3	0.5	1.8	N68°W	Uinta	No	UGS
Willow #4	0.3	0.6	N60°W	Uinta	No	UGS
Turtle Shell	0.8	1	N66°W	Uinta	No	UGS
Petroglyph	1.2	1	N56°W	Uinta	No	UGS
Antelope	0.4	0.8	N47°W	Uinta	No	UGS
Black Diamond	0.4	1.4	N56°W	Uinta	Yes	UGS
Turkey Trail Hill	1	2	N60°W	Uinta	?	UGS
Willow Creek #1	3.3	1	N50-58°W	Uinta	No	UGS
Willow Creek #2	1.2	1.8	N54°W	Uinta	No	UGS
Willow Creek extension	0.87	0.9	N57°W	Uinta	No	BLM
Black Bridge	2.2	2.5	N57-80°W	Uinta	?	BLM
Cottonwood	7	4.5	N60-70°W	Uinta	Yes	UGS
Black Cat	0.5	1	N60°W	Uinta	No	UGS
Willow Creek-Wall	3	3.5	N60°W	Uinta	Yes	UGS
Black Dog	0.4	0.6	N50°W	Uinta	No	UGS
O.K.	0.7	0.4	N80-90°W	Uinta	No	UGS
Florence	0.8	1.8	N47-80°W	Uinta	Yes	UGS
Original Owner	0.25	?	N80-90°W	Uinta	No	UGS
PARIETTE AREA						
Castle Peak-Baxter-Pariette	5	2	N30-40°W	Uinta	Yes	UGS
Gilsonite Draw	0.25	2(?)	N35°W	Uinta	?	UGS
FORT DUCHESNE AREA						
Raven	3	2	N37°W	Duchesne River	Yes	UGS
Carbon	3	4	N40°W	Duchesne River	Yes	UGS
	Total vein length = 172.4					

(Cashion, 1974, 1977, 1986) and our NAIP aerial-photography mapping. The vein system is located in sections 29, 30, 32, and 33, T. 9 S., R. 25 E., and sections 8, 15, 16, 17, 22, 23, 24, and 25, T. 9 S., R. 24 E. Upper Green River Formation (Parachute Creek Member) and Uinta Formation sandstone and mudstone host the Independent, Tabor, and Little Bonanza vein system at the surface (plate 1).

The Independent and Tabor veins are a single vein but are called by different names northwest and southeast, respectively, of the junction with the Little Bonanza vein in NW¼ section 30. The Independent/Tabor vein is reported to be more than 7.5 miles long, generally strikes from N. 55 to 62° W., has a maximum width of 14 feet, and has an estimated maximum vertical extent of 1100 feet (Cashion, 1967). The southeast end of the Tabor vein segment begins north of the White River canyon in NW¼ section 33, and contains a short split-off vein approximately 0.5 mile from the southeast end. Pruitt (1961) reported that the Independent vein segment is 6 feet wide near the junction with the Little Bonanza vein, reaches a width of 13.5 feet approximately 2 miles farther to the northwest, and then decreases to 7 or 8 feet wide 3.5 miles from the vein junction. The Little Bonanza vein is reported to be more than 5.5 miles long, generally strikes N. 68° W., has a maximum width of 13 feet and has an estimated maximum vertical extent of 1200 feet (Cashion, 1967). Pruitt (1961) reported that the Little Bonanza vein width averages 9 feet or more along its length and at the northwest end decreases to 4 feet and begins to split. All of the veins in the system are widest in the massive sandstone contained in the lower part of the Uinta Formation. The veins all pinch out down section in marlstone and oil shale above the Mahogany bed in the Parachute Creek Member, and the up-section pinch out is in thinly bedded sandstone and mudstone of the Uinta Formation (Cashion, 1967).

Little Chepetta, Chepetta, and Caldwell

The Little Chepetta, Chepetta, and Caldwell veins and/or systems (plate 1) are all within a mile southwest of the Independent, Tabor, and Little Bonanza vein system. Vein locations on plate 1 were derived from USGS mapping (Cashion, 1974, 1977, 1986) and our NAIP aerial-photography mapping. The veins are located in sections 29, 30, 31, and 32, T. 9 S., R. 25 E., and sections 25 and 26, T. 9 S., R. 24 E. Uinta Formation sandstone and mudstone primarily host the Little Chepetta, Chepetta, and Caldwell veins at the surface (plate 1).

The Little Chepetta vein system is located about 1000 feet southwest of the Tabor vein, extends approximately

Figure 11. *Red Wash vein and bitumen-impregnated sandstone (foreground) and Little Red Wash vein (background) cropping out in member C of the Uinta Formation in SE¼SE¼ section 13, T. 8 S., R. 22 E., SLBLM, Uintah County.*

2.3 miles along a strike of N. 62° W. (Cashion, 1974, 1986), and ranges in width from 1 to 2.5 feet over a length of 1.5 miles (Pruitt, 1961). A short subparallel vein is present a small distance north of the southeast segment of the Little Chepetta vein and may be related to it. To the northwest, the Little Chepetta vein trace disappears for a short distance and then reappears for approximately a third of a mile. The Chepetta vein system is located south of the Little Chepetta vein system and is approximately 3 miles long, generally strikes N. 65° W. (Cashion, 1974, 1986), and ranges in width from 1 to 1.5 feet over its length (Pruitt, 1961). A short subparallel vein is present a small distance north of the southeast segment of the Chepetta vein and may be related to it. The Caldwell vein is located south of the Chepetta vein system and is approximately 0.7 mile long, generally striking N. 60° W. (Cashion, 1986). Little else is known about the Caldwell vein.

Wagon Hound

The Wagon Hound vein (plate 1) is located in section 6, T. 10 S., R. 25 E., section 1, T. 10 S., R. 24 E., and sections 27, 28, 34, 35, and 36, T. 9 S., R. 24 E. We mapped the vein for approximately 5 miles, from a 1.5-foot-wide outcrop half a mile west of the White River canyon at the southeast end to a 1.4-foot-wide outcrop at the northwest end. The vein generally strikes N. 63° W. and has a maximum width of 3.3 feet, as exposed in a prospect trench 0.7 mile southeast of State Route 45. Cashion (1967) gave an estimated vertical extent of the vein of 1300 feet. Uinta Formation sandstone and mudstone host the vein at the surface; however, at the southeast end the vein terminates in beds at the top of the Parachute Creek Member of the Green River Formation (plate 1). The Wagon Hound vein consists of one main vein ranging in width from 2 to 3 feet along most of its length. The vein walls are commonly stained by iron oxide and, in places, are bitumen-impregnated. Sandstone beds hosting the vein locally contain hematite concretions, which range in size and occur within the bitumen-impregnated and iron-oxide-stained vein walls. The vein contains prospects along its entire length and appears to have been mined, via shafts and trenches, starting west of State Route 45. In 2004, the vein hosted one active mine shaft near its northwest end in NE¼SE¼ section 28, as well as several other modern, but inactive, mine shafts.

Little Emma (Uinta)

The Little Emma (Uinta) vein (plate 1) is located in sections 2 and 3, T. 10 S., R. 24 E., sections 29, 30, 32, 33, and 34, T. 9 S., R. 24 E., and section 25, T. 9 S., R. 23 E. We mapped the vein for approximately 5 miles, from an occurrence of gilsonite float chips a short distance west of the White River bridge on State Route 45 at the southeast end to an escape shaft at the northwest end. The vein generally strikes N. 65° W. and has a maximum width of 2.8 feet, as exposed in a shaft at the middle of the northwest segment of the vein. Cashion (1967) gave an estimated vertical extent of the vein of 1000 feet. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The Little Emma vein consists of one main vein having an average width of 2 feet along most of its length. The vein walls are commonly stained by iron oxide and, in places, sandstone beds contain concretions. The vein contains prospects along its entire length and appears to have been mined via shafts, both modern and historical, especially the northwest segment where numerous shafts are present.

Augustine

A gilsonite vein is reported to be located approximately 1 mile north of the Weaver vein, in sections 2, 3, and 11, T. 10 S., R. 25 E (Cashion, 1977). The area is located on the crest of a high ridge accessed by a rough, four-wheel-drive road. A brief field reconnaissance of the area resulted in the discovery of only a few small gilsonite chips as float in SE¼SE¼ section 3. A gilsonite vein probably exists in the area; however, without trenching we could not determine its exact location. A geological map of the Weaver Ridge quadrangle (Cashion, 1977) includes a vein named the Augustine (plate 1), which is mapped in the area where the float was discovered. Cashion (1977) reported the vein to be approximately 0.9 mile long, striking N. 50° W., more than 2 feet wide at its northwest end, and exposed at an elevation a few hundred feet above the Mahogany oil shale zone in the area.

Weaver

The Weaver vein (plate 1) straddles the Utah and Colorado state line (in Colorado it is referred to as the Colorado vein), and in Utah the vein is located in sections 10, 13, and 14, T. 10 S., R. 25 E. We mapped the generally N. 58° W.-striking vein for approximately 2.3 miles, from an outcrop 1.2 feet wide a short distance inside Colorado, to a short 2-foot-wide prospect trench (the vein's maximum known width in Utah) on the south side of Weaver Canyon at the northwest end. Cashion (1967) gave an estimated vertical extent of the vein of 1400 feet. The lower part of the Parachute Creek Member and the complete Douglas Creek Member of the Green River Formation host the vein at the surface in Utah and into Colorado (plate 1). In Colorado, the vein continues southeast for about another 4 miles before eventually pinching out in Wasatch Formation shale beds (Cashion, 1967). To the northwest in Weaver Canyon (SE¼ section 10), we observed the vein to abruptly terminate under thick beds of marlstone and shale in the lower Parachute Creek Member, approximately 300 feet beneath the Mahogany oil shale zone. No signs of significant mining were observed on the Weaver vein in Utah, but there are sporadic prospects along its length. However, in Colorado it was one of the first veins to be mined in the basin around 1890 (Pruitt, 1961).

Rainbow Area Veins

Little Butte

The Little Butte vein (plate 1) is located in NW¼ section 26 and NE¼ section 27, T. 10 S., R. 24 E. We mapped the vein for approximately 0.5 mile, from a 1-foot-wide outcrop at the southeast end to another 1-foot-wide outcrop at the northwest end. The vein generally strikes N. 60° W. and averages 1 foot wide along its length. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The vein appears to be present only in the upper part of a dissected butte. An attempt to follow the vein a mile to the northwest at a lower elevation was unsuccessful; the vein also does not crop out at lower elevations to the southeast. The White River oil shale mine is at the northwest end of the vein and is private land, so the northwest terminus could not be located. We observed the vein continuing across the top of the butte into the mine area. The vein shows no signs of mining or prospecting.

Rustler

The Rustler vein (plate 1) is located in SW¼SW¼ section 2, SE¼ section 3, and NW¼ section 11, T. 11 S., R. 24 E. We mapped the vein for 0.8 mile, from an occurrence of gilsonite float chips at the southeast end to an 8-inch-wide outcrop at the northwest end. The vein generally strikes N. 55° W. and has a maximum width of 1.2 feet at an outcrop near the vein's midpoint. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The vein may continue to the southeast, concealed by colluvium, but a fairly extensive search over a distance of approximately 1 mile to the southeast located only a few small gilsonite chips as float in dry washes. The Rustler vein is in a remote location having no easy access; one rough, four-wheel-drive road crosses the vein. The vein shows no signs of mining or prospecting.

Alabama

The Alabama vein (plate 1) is located in sections 35 and 36, T. 10 S., R. 23 E., and sections 4, 5, 6, and 9, T. 11 S., R. 24 E. We mapped the vein for approximately 3.9 miles, from a fracture zone containing gilsonite veinlets at the southeast end to an outcrop 2.5 inches wide at the northwest end. The vein generally strikes from N. 50 to 65° W. and has a maximum width of 2 feet, as exposed in a prospect trench near the vein's midpoint. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The vein consists primarily of one continuous vein between 0.5 and 2 feet wide having very few splits or secondary veins. The vein appears to step to the north near the midpoint, where the vein is the widest. The vein averages 1.8 feet wide over an approximately 2-mile segment, which begins at the first observed outcrop southeast of Asphalt Wash and continues southeast until a jeep trail crosses the vein in NW¼NE¼ section 9. The vein eventually thins to the southeast and northwest and subsequently disappears. No signs of significant mining were observed on the Alabama vein. However, prospect trenches are located on the widest section of the vein, beginning a short distance northwest of the vein's midpoint, and continuing for approximately 1.7 miles to the southeast.

Little Alabama

The Little Alabama vein (plate 1) is located in NW¼SW¼ section 13, T. 11 S., R. 24 E., and is about 2.5 miles southeast of, but approximately on trend with, the main Alabama vein. The vein strikes N. 55° W., was mapped for 0.2 mile, and has a maximum width of 2 inches. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). This vein is difficult to trace to the southeast or the northwest because it is mostly covered by alluvium and colluvium, and is extremely thin.

Black Dragon

The Black Dragon vein system (plate 1) is located in sections 4, 5, 9, 10, 11, and 14, T. 12 S., R. 25 E. We mapped the vein system for approximately 3.9 miles, from an occurrence of gilsonite float chips on the top of a high ridge east of Dragon Canyon at the southeast end, to a fenced, caved-in shaft or subsidence in a drainage 0.7 mile northwest of Threemile Canyon. The vein system generally strikes N. 47° W. and has a maximum width from 8 to 10 feet, as estimated at a significant mine site in Dragon Canyon (figure 12). Cashion (1967) gave an estimated maximum vertical extent of the vein of 1100 feet, extending down from the lower part of the Parachute Creek Member through the Douglas Creek Member of the Green River Formation (plate 1). We observed the vein's upper extent to abruptly thin and terminate beneath the Mahogany oil shale marker bed in Threemile Canyon. Between Dragon and Threemile Canyons, the main vein splits in many places into two closely spaced, parallel veins of significant width. The vein system pinches out to the northwest as it cuts up section into Parachute Creek Member oil shale beds, and disappears to the southeast in the Douglas Creek Member and interfingering Renegade Tongue of the Wasatch Formation. Signs of significant historical mining and prospecting activity are present along most of the Black Dragon vein system.

Rainbow

The Rainbow vein system (plate 1) is located in sections

30, 31, and 32, T. 11 S., R. 25 E, and sections 14, 15, 23, 24, and 25, T. 11 S., R. 24 E. We mapped the vein system for approximately 4.3 miles, from an isolated group of veins that crop out for approximately 0.5 mile in upper Green River Formation marlstone at the southeast end to a deep mine trench in the East Fork of Asphalt Wash, where the division between the Rainbow and the Pride of the West extensions is located in section 15. The vein system generally strikes from N. 45 to 55° W. and has a maximum width on a single vein from 8 to 10 feet. Cashion (1967) gave an estimated maximum vertical extent of the vein of 600 feet. Upper Green River Formation (Parachute Creek Member) and lower Uinta Formation sandstone and mudstone host the veins at the surface (plate 1). The Rainbow vein splits in many places and consists of a group of closely spaced, parallel veins of significant width, especially in the area of the Green River and Uinta Formation contact. Northwest of the isolated group of veins at the southeast end, approximately 0.7 mile of the vein appears to have been eroded away, exposing Mahogany oil shale beds. The southeast end of the Rainbow vein system is less than 1 mile from the northwest end of the Black Dragon vein system, and lies several hundred feet to the southwest of the projected Black Dragon vein system. Signs of significant historical mining (figure 13) and prospecting activity are present along most of the Rainbow vein system.

Pride of the West

The Pride of the West vein system (plate 1) is located in sections 6, 7, 8, 9, 15, and 16, T. 11 S., R. 24 E., sections 1 and 2, T. 11 S., R. 23 E., sections 19, 28, 29, 30, 33, 34, and 35, T. 10 S., R. 23 E., and sections 14, 15, 23, and 24, T. 10

Figure 12. *Black Dragon vein cropping out in the Douglas Creek Member of the Green River Formation in Dragon Canyon in SW¼NE¼ section 14, T. 12 S., R. 25 E., SLBLM, Uintah County.*

Figure 13. *Mined open cut on the Rainbow vein in NE¼SE¼ section 23, T. 11 S., R. 24 E., SLBLM, Uintah County.*

S., R. 22 E. We mapped the vein system for approximately 13.8 miles, from the division between the Rainbow and Pride of the West extensions at the southeast end to a 4-inch-wide outcrop at the northwest end. The vein system generally strikes from N. 50 to 65° W. and has a maximum width on a single vein of 7 feet near the southeast end of the vein. Upper Green River Formation (Parachute Creek Member) and Uinta Formation sandstone and mudstone host the veins at the surface (plate 1). The Pride of the West vein splits in many places, and at the southeast end consists of a group of closely spaced, parallel veins of significant width. From Asphalt Wash toward the northwest end, one main vein is present along with occasional thinner, secondary veins. The vein eventually thins to the northwest and disappears approximately 1 mile northwest of Bitter Creek. Signs of significant historical mining and prospecting activity are present along most of the southeast segment of the vein system, and prospects also sporadically continue for the rest of the system's length.

Harrison

The Harrison vein (plate 1) is located in sections 7, 8, 16, 17, 21, 22, 23, and 26, T. 11 S., R. 24 E., sections 1, 2, 3, and 12, T. 11 S., R. 23 E., and sections 29, 30, 32, and 33, T. 10 S., R. 23 E. We mapped the vein for approximately 10.6 miles, from a 1-foot-wide outcrop approximately 1 mile southwest of the historic Rainbow town site at the southeast end to a thin outcrop approximately 1.2 miles northwest of Saddletree Draw at the northwest end. The vein generally strikes from N. 50 to 65° W. and has a maximum width estimated at 4 feet in a deep mine trench approximately 0.8 mile southeast of a prospect in the West Fork of Asphalt Wash. Upper Green River Formation (Parachute Creek Member) and Uinta Formation sandstone and mudstone (figure 14) host the vein at the surface (plate 1). The Harrison vein consists primarily of one main vein that varies from 1 to 4 feet wide along most of its length. However, in places the main vein splits into thinner, closely spaced, parallel veins, especially toward the ends of the southeast and northwest segments. Approximately 0.7 mile northwest of Atchees Wash, the vein disappears. It reappears about 0.4 mile to the northwest on a ridge top, having stepped approximately 600 feet north of the previous trend. The vein eventually thins to the northwest and disappears approximately 1.2 miles northwest of Saddletree Draw. The vein contains prospects along most of its length. Significant historical mining and prospecting activity have occurred on the widest segments of the vein in SW¼SW¼ section 8, SE¼ section 16, and section 22.

Little Asphalt Wash

The Little Asphalt Wash vein (plate 1) is located in sections 22 and 27, T. 11 S., R. 24 E., and is approximately 900 feet northeast of, and runs subparallel to, the Asphalt Wash vein. We mapped the vein for 0.8 mile, from a sparse occurrence of gilsonite float chips at the southeast end to an occurrence of small float chips at the northwest end. The vein generally strikes from N. 50 to 65° W. and has a maximum width estimated at 2 feet on an outcrop approximately 700 feet northwest of an improved dirt road in NE¼ section 27. Upper Green River Formation (Parachute Creek Member) and lower Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The vein is mainly a single one but in places splays into veinlets cropping out in fracture zones. The Little Asphalt Wash vein also appears to be rather short and quickly disappears in both directions. The vein shows no signs of mining or prospecting.

Asphalt Wash

The Asphalt Wash vein system (plate 1) is located in sections 22, 26, 27, 35, and 36, T. 11 S., R. 24 E. This vein

Figure 14. *Harrison vein cropping out in the Uinta Formation in the West Fork of Asphalt Wash in NE¼SW¼ section 7, T. 11 S., R. 24 E., SLBLM, Uintah County.*

was previously known as the South Harrison and was renamed Asphalt Wash to avoid confusion with another more extensive South Harrison vein, which is located west of and not on trend with this vein. We mapped the vein system for approximately 2.5 miles, from a gilsonite veinlet outcrop approximately 700 feet northwest of an improved dirt road in NW¼ section 36 at the southeast end to a 4-inch-wide outcrop east of the Center Fork of Asphalt Wash at the northwest end. The vein system generally strikes from N. 50 to 60° W. and has a maximum width of 3.5 feet at the middle of the southeast segment of the southern vein. Upper Green River Formation (Parachute Creek Member) and lower Uinta Formation sandstone and mudstone host the veins at the surface (plate 1). The vein system consists of two, closely spaced, parallel veins of significant width. The southern vein is longer and generally wider than the northern vein, which crops out in the middle section of the vein system. The primary southern vein maintains a fairly consistent width of 2 to 3 feet throughout most of its length, and also contains a short split-off vein at the southeast end. Keighin (1977) reported that the vein continues to the northwest across the Center Fork of Asphalt Wash and beyond; however, we were unable to locate that extension. The vein appears to terminate to the southeast in the top of the Parachute Creek Member, where sub-inch gilsonite sills were observed in the shale beds. The vein system has been prospected sporadically along its length, but we observed no signs of significant mining.

Snow

The Snow vein (plate 1) is located in sections 2, 3, and 11, T. 11 S., R. 23 E. We mapped the vein for approximately 1.1 miles, from a 1-inch-wide outcrop at the southeast end to an occurrence of large gilsonite float chips at the northwest end in Atchees Wash. The snow vein generally strikes N. 67° W. and has a maximum width of 3 inches measured at several locations along the vein. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The vein is poorly exposed and is mostly traceable by sporadic gilsonite float and vein occurrences, but appears to be thin, having at least one other thin vein occurring a short distance to the north. The vein shows no signs of mining or prospecting.

Saddletree

The Saddletree vein (plate 1) is located in sections 4 and 5, T. 11 S., R. 23 E., and SE¼ section 31, T. 10 S., R. 23 E. We mapped the vein for approximately 1.4 miles, from a 1-foot-wide outcrop at the southeast end to an occurrence of small gilsonite float chips at the northwest end. The vein generally strikes N. 58° W. and has a maximum width of 2.2 feet at the middle of the vein, a short distance north of the improved dirt road in the West Fork of Saddletree Draw. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). Thin secondary veins and veinlets are also present. The southeast segment of the vein is fairly wide, varying between 1.4 and 2.2 feet. The vein appears to be short and quickly disappears to the northwest and southeast. No mines and only one possible prospect are present on the vein.

South Harrison

The South Harrison vein system (plate 1) is located in sections 18, 19, and 20, T. 11 S., R. 24 E., and sections 3, 4, 10, 11, 13, and 14, T. 11 S., R. 23 E. We mapped the vein system for approximately 6.1 miles, from a 1.8-foot-wide outcrop west of the Center Fork of Asphalt Wash at the southeast end to a 1.1-foot-wide outcrop a short distance east of the West Fork of Saddletree Draw at the northwest end. The vein system generally strikes N. 58° W. and has a maximum width of 3.5 feet, as exposed in a prospect between Atchees Wash and the West Fork of Saddletree Draw. Uinta Formation sandstone and mudstone primarily host the veins at the surface (plate 1). The South Harrison vein splits in many places and consists of a group of closely spaced, parallel veins, some of significant width, while others are thin secondary veins. The consistently widest section of vein is between 2 and 3.5 feet and is located in the middle of the northwest segment of the vein system. At the northwest end, the vein thins and subsequently disappears; however, at the southeast end the vein is still 1.8 feet thick where it disappears under colluvium in flatter terrain. The vein system has been prospected along most of its length, but we observed no signs of significant mining.

Little Chief

The Little Chief vein (plate 1) is located in sections 14 and 15, T. 11 S., R. 23 E. We mapped the vein for approximately 0.9 mile, from an 8-inch-wide outcrop at the southeast end to an occurrence of small gilsonite float chips a short distance east of Atchees Wash at the northwest end. The vein generally strikes N. 57° W. and has a maximum width of 8 inches exposed on the rim of a high mesa overlooking the West Fork of Asphalt Wash. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The southeast end of the vein is mostly covered by colluvium and difficult to trace. Gilsonite is fairly well exposed at the northwest end, where a thin secondary vein is also present. The vein appears to be quite short and quickly disappears in both directions. The vein shows no signs of mining or prospecting.

Fox

The Fox vein system (plate 1) is located in sections 14, 15, 16, 23, and 24, T. 11 S., R. 23 E. We mapped the vein system for approximately 2.9 miles, from a 1.3-foot-wide outcrop a short distance west of the West Fork of Asphalt

Wash at the southeast end to a 6-inch-wide outcrop a short distance east of the West Fork of Saddletree Draw at the northwest end. The vein system generally strikes from N. 55 to 65° W. and has a maximum width of 2.5 feet measured on an outcrop approximately 0.5 mile from the southeast end of the vein system. Uinta Formation sandstone and mudstone primarily host the veins at the surface (plate 1). The Fox vein splits in many places, especially east of Atchees Wash where it is composed of one main vein and several thinner, closely spaced, parallel, secondary veins. The main vein varies between 1 and 2 feet wide along most of its length until it thins and disappears to the northwest, but remains 1.3 feet wide until it disappears to the southeast. No signs of mining were observed, but sporadic prospects are found along the length of the main vein.

Kings Well

The Kings Well vein (plate 1) is located in section 4, T. 12 S., R. 24 E., sections 30, 32, and 33, T. 11 S., R. 24 E., and sections 22 and 23, T. 11 S., R. 23 E. We mapped the vein for approximately 5.6 miles, from a 1-foot-wide outcrop a short distance east of Kings Well at the southeast end to an occurrence of small gilsonite float chips a short distance east of Atchees Wash at the northwest end. The vein generally strikes from N. 55 to 65° W. and has a maximum width of 6 feet, as measured in a short open cut leading to an adit. The vein at this location (approximately 0.3 mile northwest of Kings Well) is anomalously thick compared to vein outcrops short distances in either direction that are barely half as wide. We also observed no evidence of significant mining activity. Upper Green River Formation (Parachute Creek Member) and Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The Kings Well vein locally splits into one main vein along with thinner, closely spaced, parallel, secondary veins. Approximately 1.8 miles northwest of Kings Well, the vein steps north approximately 500 feet. A few hundred feet farther to the northwest of this step, a new 2-foot-wide vein appears a short distance north of the main vein location, and crops out for about 300 feet. The main vein is traceable for 1 mile northwest of this location, and then it disappears for approximately 1.5 miles across the West Fork of Asphalt Wash, and finally reappears approaching a steep mesa slope. The vein eventually thins to the northwest and disappears just short of Atchees Wash. To the southeast it disappears in the Parachute Creek Member west of Long Draw. Prospects sporadically occur along the entire length of the vein, and two small historical mines are located in section 32, T. 11 S., R. 24 E. One is a 1.5-foot-wide mine trench that is several hundred feet long in SE¼NW¼ section 32, and the other is a shaft in a short mine trench where a 3- to 4-foot-wide vein is exposed in NW¼NW¼ section 32. The depth of mining at both sites appears to be shallow, only about 30 feet.

Neal

The Neal vein (plate 1) is located in sections 31 and 32, T. 11 S., R. 24 E. We mapped the vein for approximately 1.8 miles, from an occurrence of small gilsonite float chips about 0.7 mile west of Kings Well at the southeast end to a 1-foot-wide outcrop at the northwest end. The vein generally strikes N. 60° W. and has a maximum estimated width of 3 feet in a mine trench at the middle of the southeast segment of the vein. Lower Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The Neal vein consists of one main vein with some thinner, closely spaced, parallel, secondary veins cropping out in places. The vein steps north approximately 300 feet near the northwest end and continues for about 1200 more feet after this step before it thins and disappears. Prospects and mine trenches having shafts are present at the middle of the southeast segment of the vein in S½ section 32 where the vein is widest, averaging between 2.5 and 3 feet.

Bitter Water

The Bitter Water vein (plate 1) is located in sections 16, 17, 18, 21, 22, 26, and 27, T. 11 S., R. 23 E., and sections 11, 12, and 13, T. 11 S., R. 22 E. We mapped the vein for approximately 7 miles, from an occurrence of small gilsonite float chips a short distance west of the West Fork of Asphalt Wash at the southeast end to a 9-inch-wide outcrop a short distance east of Bitter Creek at the northwest end. The vein generally strikes from N. 58 to 70° W. and has a maximum width of 3 feet, as measured on an outcrop approximately 1.3 miles southeast of the northwest end of the vein. Uinta Formation sandstone and mudstone primarily host the vein at the surface (plate 1); however, both ends of the vein appear to be located in the uppermost beds of the Parachute Creek Member of the Green River Formation. The Bitter Water vein consists primarily of one main vein with thinner, closely spaced, parallel, secondary veins cropping out in places. At the southeast end, and especially at the northwest end of the vein, significant splitting produces vein groups that may represent the vein's termination. The vein is concealed under colluvium for 0.7 mile, from 1.3 miles northwest of the West Fork of Saddletree Draw to a steep drainage leading down to Bitter Creek, where the vein reappears. Few prospects and no mines are found along the vein; the prospects are present sporadically from 0.5 mile southeast of Atchees Wash to approximately 1 mile northwest of the West Fork of Saddletree Draw.

Long Draw

The Long Draw vein system (plate 1) is located in S½ section 10, T. 12 S., R. 24 E. We mapped the vein system for 0.6 mile, from an occurrence of gilsonite float chips at the southeast end to a 1.2-foot-wide outcrop at the northwest end. The vein system generally strikes N. 59° W. and has a maximum width of 2 feet, as measured on the northernmost vein at the middle of the system. At the surface the veins are located in the contact zone between the Green River and Uinta Formations (plate 1). The Long Draw vein system consists of two significant veins and numerous veinlets; the northernmost vein appears to be the widest. Northwest-trending fractures in gray marlstone near the southeast end of the veins are locally filled with gilsonite veinlets. To the northwest, the veins are concealed by alluvium as they disappear down the middle of a drainage that leads to the Center Fork of Asphalt Wash. To the southeast, the veins disappear in thinly bedded marlstone of the upper Parachute Creek Member of the Green River Formation. The vein system shows no signs of mining or prospecting.

Sage Brush

The Sage Brush vein (plate 1) is located in NE¼ section 18, T. 12 S., R. 24 E., and section 12, T. 12 S., R. 23 E. We mapped the vein for approximately 1.8 miles, from a 3-inch-wide outcrop at the southeast end to a 1-foot-wide outcrop at the northwest end. The vein generally strikes N. 65° W. and has a maximum width of 1 foot on an outcrop at the northwest end. The vein is exposed in the contact zone between the Green River and Uinta Formations (plate 1). The vein consists of one main vein with thinner, closely spaced, parallel, secondary veins cropping out in places. The vein is generally poorly exposed and is especially difficult to trace in the southeast, where it is mostly concealed under colluvial and alluvial deposits. The northwest segment is better exposed, but disappears in alluvium a short distance to the northwest. The vein shows no signs of mining or prospecting.

Gilsonite float chip and veinlet occurrences roughly on trend to the southeast of this vein are present in SE¼NW¼ section 17, T. 12 S., R. 24 E., and may be related to the vein, extending it about another 0.7 mile. Another unreported gilsonite vein is located in SW¼NE¼ section 18, T. 12 S., R. 24 E., approximately 1300 feet south of the southeast end of the Sage Brush vein. The 4-inch-wide vein strikes N. 30° W. and is exposed for only a few feet in a sandstone outcrop. Approximately 0.8 mile to the southeast of this vein outcrop, the Little Antler vein is on trend with it and may be related.

Antler and Little Antler

The Antler and Little Antler veins (plate 1) are located in sections 17, 20, and 21, T. 12 S., R. 24 E. The veins are separated by approximately 500 feet and are subparallel. We mapped the Antler vein for 0.6 mile, from a 1.4-foot-wide outcrop at the southeast end to an occurrence of gilsonite float chips at the northwest end. The vein generally strikes N. 58° W. and has a maximum width estimated at more than 2 feet on an outcrop a short distance southeast of an unimproved dirt road in NE¼NE¼ section 20. The Antler vein (figure 15) consists of one main vein with thinner, closely spaced, parallel, secondary veins cropping out in places. The vein maintains a width between 1 and 2 feet from a short distance northwest of where the unimproved dirt road intersects the vein to its southeast end.

We mapped the Little Antler vein for approximately 0.5 mile, from a 1-foot-wide outcrop at the southeast end (the vein's maximum known width) to an occurrence of gilsonite float chips at the northwest end. The vein generally strikes N. 62° W. and is generally poorly exposed,

Figure 15. *Outcrop on the Antler vein showing the main 1.8-foot-wide vein and an adjacent thinner (1.2 feet), parallel, secondary vein cropping out on the right side, located west of the Center Fork of Asphalt Wash in NE¼NE¼ section 20, T. 12 S., R. 24 E., SLBLM, Uintah County. Notebook is 7.5 inches long.*

traceable mainly by sporadic gilsonite float occurrences. The Antler and Little Antler veins are exposed in the contact zone between the Green River and Uinta Formations (plate 1). Both veins may continue beyond extents shown on plate 1 since they are difficult to trace due to colluvial cover. The mapped segments of the veins show no signs of mining or significant prospecting.

Little Bitter Creek #1

The Little Bitter Creek #1 vein (plate 1) is located in SW¼SW¼ section 34, and possibly in SE¼ section 33, T. 10 S., R. 22 E. We mapped one vein for a couple hundred feet up the side of a steep mesa on the west side of Bitter Creek. It has a width of 5 to 6 inches and a general strike of N. 56° W. on the steep slope. Aerial photographs suggest the vein continues a short distance farther to the northwest for a combined mapped length of approximately 0.3 mile. The vein did not appear to continue to the southeast on the east side of Bitter Creek. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). A 2- to 3-inch-wide vein is present approximately 200 feet to the north of the first one. Bitumen-impregnated sandstone occurs adjacent to both veins. The veins at this location appear to be thin, short, and show no signs of mining or prospecting. Other veins of small dimensions are likely present in northwest-trending fractures in the Bitter Creek drainage, in the area between the northwest ends of the Bitter Water and Pride of the West veins.

Ouray Area Veins

Jumbo

The Jumbo vein (plate 1) is located in sections 25, 26, and 36, T. 9 S., R. 21 E. We mapped the vein for 1.8 miles, from an occurrence of gilsonite float chips at the southeast end to an approximately 6-inch-wide outcrop a short distance south of the Uintah and Ouray Indian Reservation at the northwest end. The vein generally strikes N. 48° W. and has a maximum width of 1.1 feet, as measured at a prospect (figure 16) in the middle of the northwest segment of the vein. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The vein is poorly exposed and is mostly traceable by sporadic gilsonite float and vein occurrences, but appears to consist of one main vein having closely spaced, subparallel veinlets cropping out in places. Near the southeast end of the vein, the general strike abruptly changes to N. 65° W. and the vein appears to shift significantly eastward. The vein may continue to the northwest on the Uintah and Ouray Indian Reservation, but thins before disappearing to the southeast. The vein has been prospected sporadically along its length but shows no signs of mining.

Pruitt (1961) reported that south of Ouray, Utah, on the Uintah and Ouray Indian Reservation, the Jumbo vein lies 2 miles northeast of the Pride of Utah vein in the west half of T. 9 S., R. 21 E., and the east half of T. 9 S., R. 20 E. The report states that the vein is 5 miles long, strikes N. 67° W., and is 1 to 1.2 feet wide near the northwest end. According to Pruitt (1961) and unpublished BLM gilsonite maps from the 1980s, several short veins also exist between the Jumbo and Pride of Utah veins.

Pride of Utah

The UGS-mapped segment of the Pride of Utah vein system (plate 1) is located in N½ section 32, T. 9 S., R. 21 E. We mapped the vein for 0.6 mile, from an occurrence of gilsonite float chips a short distance west of Cottonwood Wash at the southeast end to another float occurrence at the northwest end. The vein segment generally strikes N. 47° W. and has a maximum width estimated at 2 feet in a group of closely spaced shafts that Pruitt (1961) referred to as the Anthill mine. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The vein

Figure 16. *Prospect on the Jumbo vein exposing a 1.1-foot-wide section of vein in NE¼SE¼ section 26, T. 9 S., R. 21 E., SLBLM, Uintah County.*

is poorly exposed and traceable for only a short distance in both directions, away from the exposures in the mine shafts at the Anthill site. Sparse outcrops, middle Uinta Formation stratigraphy, and the generally low topographic relief in this area make locating this gilsonite vein difficult. The vein system is reported by the BLM to continue as a group of veins for more than 5.5 miles to the northwest into the Uintah and Ouray Indian Reservation.

Antelope

The Antelope vein (plate 1) is located in SE¼ section 36, T. 9 S., R. 20 E. We mapped the vein for 0.4 mile, from an occurrence of gilsonite float chips at the southeast end to a vein fracture outcrop at the northwest end. The vein generally strikes N. 47° W. and has a maximum width of 10 inches, as measured in a prospect trench. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The vein is traceable for only a short distance away from the prospect trench; however, sporadic, small gilsonite float chips were observed in the alluvial cover for more than a mile to the southeast. A filled-in prospect shaft having a wooden collar is located on the vein a short distance south of an improved dirt road in NW¼SE¼ section 36.

Unreported Occurrences

We located a number of unreported gilsonite occurrences in and around SW¼NW¼ section 33, T. 9 S., R. 21 E. They are approximately 0.5 mile southeast of a group of shafts (Anthill mine) on the Pride of Utah vein, but do not appear to be directly related to the main vein. We mapped the N. 70° W.-striking occurrences for 0.3 mile east of Cottonwood Wash. The occurrences consist of gilsonite veinlets less than 1 inch wide in fracture zones and small patches of gilsonite float chips.

We also located two unreported gilsonite occurrences in the middle of section 2, T. 10 S., R. 21 E. They are approximately 3.1 miles southeast of a group of shafts (Anthill mine) on the Pride of Utah vein and a short distance east of a prominent butte in section 2. The occurrences consist of two isolated patches of small gilsonite float chips that are less than 1 inch in width. The two patches could not be linked to any other gilsonite deposits.

Cottonwood

The Cottonwood vein system (plate 1) is located in section 6, T. 11 S., R. 22 E., section 1, T. 11 S., R. 21 E., sections 28, 29, 30, 33, 34, and 35, T. 10 S., R. 21 E., and possibly section 24, T. 10 S., R. 20 E. We mapped the vein system for approximately 7 miles, from an occurrence of small gilsonite float chips approximately 0.7 mile east of Sand Wash at the southeast end to another occurrence of small float chips at the northwest end. The vein system generally strikes from N. 60 to 70° W. and has a maximum width of 4.5 feet, as exposed in a shaft wall approximately 0.3 mile east of Cottonwood Wash in an area having several other shafts. Uinta Formation sandstone and mudstone host the veins at the surface (plate 1). The vein system consists of two main veins of significant width with thinner, closely spaced, parallel, secondary veins cropping out in places. In SW¼ section 28, T. 10 S., R. 21 E., the vein splits into a northern and southern vein. Both veins continue southeast, sporadically cropping out toward modern mine shafts; the southernmost vein appears to host the modern mine shafts and be wider than the northern vein. Southeast of the shafts, the vein trace is concealed under alluvium and colluvium for approximately 0.6 mile, reappearing as a single vein in Sand Wash. The vein appears to thin to the northwest and eventually disappears. Near the southeast end, the vein splits into 2.2-foot and 4-inch-wide veins before disappearing a short distance farther to the southeast. The southeast end of the Cottonwood vein system and the northwest end of the Bitter Water vein are separated by approximately 4 miles but lie roughly along the same trend. We investigated the area between the southeast end of the Cottonwood vein system and the canyon rim above Bitter Creek, but were unable to locate any gilsonite on the surface. However, topographic relief in this area, northwest of the Bitter Creek drainage, is generally low and gilsonite veins in the area tend to be poorly exposed. The vein system is also reported by the BLM to continue into the Uintah and Ouray Indian Reservation, cropping out farther to the northwest as the Black Bridge vein group in the Willow Creek area. The veins have been prospected along most of their lengths and as recently as 2008 hosted two active mine shafts (operated by Lexco Inc.) on the southernmost vein in SW¼ section 35, T. 10 S., R. 21 E. Signs of significant historical mining were also observed in section 29, T. 10 S., R. 21 E., beginning from the midpoint in section 29 and continuing southeast for approximately 0.6 mile.

Black Cat

The Black Cat vein (plate 1) is located in S½SW¼ section 30, and partially in NW¼NE¼ section 31, T. 10 S., R. 21 E. We mapped the vein for approximately 0.5 mile, from an occurrence of gilsonite float chips at the southeast end to an 8-inch-wide outcrop at the northwest end. The vein generally strikes N. 60° W. and has a maximum width of 1 foot, as measured a short distance southeast of the vein's midpoint. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The Black Cat vein consists of one main vein averaging 9 inches wide that is traceable for only a short distance before it disappears in both directions. The vein shows no signs of mining or prospecting.

Willow Creek/Wall

The Willow Creek/Wall vein (plate 1) is located in section 32, T. 10 S., R. 21 E., and section 25, T. 10 S., R. 20 E. The northwest segment of the vein is called Willow Creek and the southeast segment is called Wall. We mapped the vein for approximately 3 miles, from a 2.5-foot-wide outcrop in a prospect trench a short distance west of Cottonwood Wash at the southeast end to an occurrence of gilsonite float chips at the northwest end. The vein generally strikes N. 60° W. and has a maximum width of 3.5 feet, as exposed in a prospect trench a short distance northwest of a reclaimed mine site near the northwest end of the vein. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The vein consists of one main vein having a width between 2 and 3.5 feet along most of its length. The vein trace disappears for approximately 1.5 miles in a flat to low hilly area in the middle section of the vein. The vein disappears to the northwest not far past a reclaimed mine site and disappears to the southeast in the Cottonwood Wash area. However, the BLM reports exposures of a vein group (Willow Creek extension) on the Uintah and Ouray Indian Reservation northwest of Willow Creek, and these veins are also reported to continue northwest off the reservation. The vein has been prospected along most of its exposed length, and the southeast Wall segment contains historical mine sites consisting of trenches and shafts. The reclaimed mine site (ITM mine) is located on the northwest Willow Creek segment in NE¼SW¼ section 25, T. 10 S., R. 20 E.

Ouray

The Ouray vein (plate 1) is located in NW¼ section 26, T. 4 S., R. 2 E., Uinta Base Line and Meridian (UBLM). We mapped the vein for approximately 0.3 mile, from a 6-inch-wide outcrop at the southeast end to an occurrence of gilsonite float chips at the northwest end. The vein generally strikes N. 62° W. and has a maximum width of 1.5 feet, as exposed in a prospect trench a short distance southeast of a mine shaft. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). We could only trace the vein a short distance southeast and northwest of the mine shaft located mid-vein. The historical mine site appears somewhat significant, having two cabins, a collapsed headframe, and a wooden-collared, open shaft. A small copper deposit, associated with fossilized wood, has been prospected within a mile of the vein to the southeast.

Little Seam

The Little Seam vein (plate 1) is located in NW¼NE¼ section 36, T. 4 S., R. 2 E., UBLM. We mapped the vein for approximately 0.2 mile, from a 3-inch-wide outcrop (the only gilsonite outcrop encountered on the vein) exposed in a prospect shaft wall at the southeast end to a prospect shaft at the northwest end. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The vein could only be traced a short distance and was locatable only via three prospect shafts aligned along a N. 56° W. trend. No other naturally occurring gilsonite outcrops or float occurrences were observed elsewhere along the trend of the shafts. The Little Seam vein may be related to the Ouray vein, which is located approximately on trend 1.3 miles to the northwest.

Gem

The Gem vein (plate 1) is located mostly in NW¼SW¼ section 36, T. 4 S., R. 2 E., UBLM. We mapped the vein for 0.2 mile along a N. 46° W. trend between two prospect shafts. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The vein was locatable only via two prospect shafts containing gilsonite chips. No other naturally occurring gilsonite outcrops or float occurrences were observed elsewhere along the trend of the shafts.

Little Boy

The Little Boy vein (plate 1) is located in SW¼ section 36, T. 4 S., R. 2 E., UBLM. We mapped the vein for approximately 0.5 mile, from a prospect shaft at the southeast end to a 6-inch-wide outcrop exposed in a prospect shaft wall at the northwest end. The vein generally strikes N. 45° W. and has a maximum width estimated to be 2 feet on an outcrop exposed in a prospect shaft a short distance northwest of the vein's midpoint. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The vein can be traced for only a short distance and was locatable mostly via prospect shafts; however, a few gilsonite outcrops and float chip occurrences are present along the vein trend.

Cliff Dweller

The Cliff Dweller vein (plate 1) is located mostly in SW¼SE¼ section 2, T. 5 S., R. 2 E., UBLM. We mapped the vein for approximately 800 feet, from a 6-inch-wide outcrop at the southeast end to a 6-inch-wide outcrop exposed in a prospect shaft at the northwest end. The vein generally strikes N. 55° W. and has an average width of 6 inches along its length. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The vein was locatable mostly via three small, shallow, prospect shafts (figure 17). The Ouray 7.5-minute quadrangle map shows an adit near the west bank of the Green River, on the side of a steep butte, that is on trend with the prospect shafts on top of the butte.

A prospect shaft was observed in a gully northeast of the

Cliff Dweller vein that is presumably the location of the Green River vein reported by Pruitt (1961). We did not examine the Green River vein in this field investigation, but Pruitt (1961) reported that the Cliff Dweller, Green River, and Black Butte veins are within a mile of one another and similar in strike and dimension. The prospect shaft presumably on the Green River vein is located in SE¼ section 2, T. 5 S., R. 2 E., UBLM.

Willow Group

At least four veins in the Willow Group (plate 1) are located in section 19, T. 9 S., R. 20 E, and sections 13 and 24, T. 9 S., R. 19 E. Three of the veins appear to originate from the same area in SE¼ section 13. Rocks hosting the veins belong to the Uinta Formation (plate 1) and consist of interbedded, thin to thick beds of discontinuous channel sandstone and thin- to thick-bedded mudstone. Gilsonite veins contained in these beds are discontinuous and tend to vary in width, meander, and split. The Willow Group veins are discussed from south to north.

Figure 17. *Prospect shaft on the Cliff Dweller vein. Person is standing on the northwest-trending vein located in SW¼SE¼ section 2, T. 5 S., R. 2 E., UBLM, Uintah County.*

Willow #1, the southernmost vein, may be two independent veins or one vein that has a slight bend. Colluvial cover in a flat area obscures one-third of a mile of the central area of the vein, which makes it difficult to determine whether or not it is a single vein; however, for simplicity it is discussed as a single vein. We mapped the Willow #1 vein for approximately 1.8 miles, from an occurrence of gilsonite float chips a short distance west of the Uintah and Ouray Indian Reservation boundary at the southeast end to a 2.2-foot-wide outcrop exposed in a prospect trench east of the Green River at the northwest end. The vein generally strikes from N. 50 to 70° W. and has a maximum width of 2.2 feet, as measured in a short prospect trench at the northwest end of the vein. The southeast segment of the vein meanders, contains splits, and is considerably narrower, never exceeding 8 inches. The northwest segment of the vein is straighter and wider and is explored by several short prospect trenches on a low hill, the only prospects located on the vein.

We mapped the Willow #2 vein for approximately 1.4 miles, from a 10-inch-wide outcrop a short distance west of the Uintah and Ouray Indian Reservation boundary at the southeast end to a 1.2-foot-wide outcrop at the northwest end, where it appears to intersect the Willow #1 vein to the south. The vein is sinuous, generally strikes N. 63° W., and has a maximum width of 1.5 feet near the northwest end. Secondary, thinner veins are present at the southeast end. The vein continues southeast onto the reservation and the BLM survey also shows the vein extending for over a mile onto the reservation. Two short prospect trenches occur on the middle of the northwest segment of the vein on outcrops about 1 foot wide.

We mapped the Willow #3 vein for approximately 0.5 mile, from a 5-inch-wide outcrop at the southeast end to an occurrence of gilsonite float chips next to the Uintah and Ouray Indian Reservation boundary at the northwest end. An isolated prospect trench striking N. 76° W. exposes a 2-foot-wide vein approximately 0.4 mile to the northwest and may be related to the Willow #3 vein. The Willow #3 vein generally strikes N. 68° W. and has a maximum width of 1.8 feet exposed in a short prospect trench near the northwest end. The vein appears to be short and narrow, containing one anomalous 1.8-foot-wide outcrop in a prospect trench. However, if the isolated 2-foot-wide deposit to the northwest is related to this vein, more than 0.5 mile of 2-foot-thick vein may exist under the alluvial cover that separates these two prospects.

We mapped the Willow #4 vein (the northernmost vein of the Willow group) for approximately 0.3 mile, from a

5-inch-wide outcrop at the southeast end to a 7-inch-wide outcrop next to the Uintah and Ouray Indian Reservation boundary at the northwest end. The vein generally strikes N. 60° W. and is short and narrow, appearing only on one low butte. It is possible that the isolated prospect trench containing a vein 2 feet wide, previously discussed in relation to the Willow #3 vein, may instead be related to this vein. The vein shows no other signs of mining or prospecting.

Turtle Shell

The Turtle Shell vein (plate 1) is located in N½ section 24, T. 9 S., R. 19 E. We mapped the vein for approximately 0.8 mile, from a 10-inch-wide outcrop a short distance west of Willow Creek at the southeast end to a 3-inch-wide outcrop a short distance east of the Green River at the northwest end. The vein generally strikes N. 66° W. and has a maximum width of 1 foot on an outcrop southeast of the vein's midpoint. Closely spaced, parallel veinlets are also present. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The vein appears to be short and narrow and shows no signs of mining or prospecting.

Petroglyph

The Petroglyph vein (plate 1) is located in section 30, T. 9 S., R. 20 E., and N½NE¼ section 25, T. 9 S., R. 19 E. We mapped the vein for approximately 1.2 miles, from an 8-inch-wide outcrop a third of a mile east of Willow Creek at the southeast end to an outcrop at least 6 inches wide a half mile west of Willow Creek at the northwest end. The vein generally strikes N. 56° W. and has a maximum width of 1 foot, as measured near the southeast end. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The vein consists of one main vein that averages 9 inches wide along the well-exposed southeast segment east of Willow Creek, but then becomes less exposed to the northwest where it thins and then splits just before disappearing. The vein is unmined and only one or two superficial prospects are present. The Petroglyph vein gets its name from the numerous Native American rock carvings in the area.

Black Diamond

The Black Diamond vein (plate 1) is located mostly in S½NE¼ section 36, T. 9 S., R. 19 E. We mapped the N. 56° W.-striking vein for 0.4 mile, from an occurrence of gilsonite float chips at the southeast end to a 10-inch-wide outcrop at the northwest end. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). A historical mine site (figure 18) is located on the middle segment of the vein and appears fairly significant, having an open shaft and a ruined stone building present. A 1.4-foot-wide outcrop (the vein's maximum known width) is also present at the mine site. Pruitt (1961)

Figure 18. *Black Diamond mine in SE¼NE¼ section 36, T. 9 S., R. 19 E., SLBLM, Uintah County.*

referred to the site as the "Black Diamond mine" and further reported that two short veins of about the same length are also present, and that all three are located within a 200-foot-wide zone. We were unable to locate these two veins in the area where they are reported to crop out, and an extended search to the north and south was also unsuccessful.

Turkey Trail Hill

The Turkey Trail Hill vein (plate 1) is located in N½ section 9, T. 10 S., R. 20 E. The mapped extent of the vein is approximately 1 mile, striking N. 60° W. and mostly concealed in the Willow Creek drainage. At the southeast end, a 2-foot-wide exposure (the vein's maximum known width) occurs in a collapsed shaft located next to an improved dirt road in the Willow Creek drainage, and at the northwest end a 4-inch-wide outcrop occurs just prior to the vein disappearing. Uinta Formation sandstone and mudstone host the vein at the surface (plate 1). The southeast segment of the vein is on the Uintah and Ouray Indian Reservation, so the extent could not be determined, but the northwest end appears to thin west of Willow Creek in a thick sequence of interbedded mudstone and channel sandstone in the middle Uinta Formation. Only one collapsed shaft was observed on the vein in SE¼NE¼ section 9. The Turkey Trail Hill vein may be related to the Black Diamond vein that is located approximately on trend 3 miles to the northwest.

Willow Creek #1 and #2

The Willow Creek #1 and #2 vein system (plate 1) is located in sections 7, 8, 17, and 18, T. 10 S., R. 20 E., and sections 1 and 12, T. 10 S., R. 19 E. The vein system consists of two main, subparallel veins separated by several hundred feet to the northwest but appearing to converge to the southeast; secondary, thinner split-off veins also exist in places. We mapped the Willow Creek #1 vein for 3.3 miles, from an occurrence of gilsonite float chips near the Uintah and Ouray Indian Reservation boundary at the southeast end to a 6-inch-wide outcrop near an abandoned well site at the northwest end. The vein generally strikes from N. 50 to 58° W. and has a maximum width of 1 foot, as measured on an outcrop near the northwest end.

We mapped the Willow Creek #2 vein for approximately 1.2 miles, from an occurrence of gilsonite float chips near the Uintah and Ouray Indian Reservation boundary at the southeast end to a 5-inch-wide outcrop at the northwest end. The vein generally strikes N. 54° W. and has a maximum width of 1.8 feet (the system's maximum known width) measured on an outcrop near the northwest end. Uinta Formation sandstone and mudstone host the vein system at the surface (plate 1). Both veins are poorly exposed and mostly traceable by sporadic gilsonite float and vein exposures. The vein system is reported by the BLM to continue for approximately 1 mile to the southeast in sections 16 and 21, T. 10 S., R. 20 E., on the Uintah and Ouray Indian Reservation. The veins show no signs of mining and only a few superficial prospects.

O.K., Original Owner, Black Dog, and Florence

A complex system of four veins (plate 1) is located 9 miles west of the town of Ouray in sections 26, 35, and 36, T. 4 S., R. 1 E., UBLM. Rocks hosting the veins belong to the Uinta Formation (plate 1) and consist of interbeds of some thin to thick beds of discontinuous channel sandstone, but predominantly thin- to thick-bedded mudstone. The vein system coincides with the east-west-trending Duchesne fault system (plate 1), and two of these veins are also east-west trending. The O.K. vein coincides with a fairly significant fault and was mapped for approximately 0.7 mile, striking from N. 80 to 90° W. The Original Owner vein lies approximately 0.3 mile south of the O.K. vein and was mapped for 0.25 mile, also striking from N. 80 to 90° W. The Black Dog vein is located near the west end of the O.K. vein, has a maximum width of 7 inches, and was mapped for approximately 0.4 mile, generally striking N. 50° W. These three veins appear to be relatively short and narrow, never reaching a width much greater than 0.5 foot. Copper mineralization is sporadically present in sandstone beds near the Duchesne fault and gilsonite veins in this area as well.

The Florence vein, which is located between the two east-west-striking veins, was mapped for approximately 0.8 mile. The vein generally strikes N. 47° W. in the middle and northwest segments, and at the northwest end it appears to abruptly terminate where it intersects the O.K. vein near its mapped midpoint. The Florence vein abruptly changes strike to between N. 75 and 80° W. at the southeast end where a caved shaft is present on the widest observed outcrop (1.8 feet) of the four-vein system. This vein dips very steeply (>70°) to the northeast where exposed in the shaft wall. The O.K., Original Owner, and Black Dog veins contain one or two prospects on each vein, but the Florence vein hosts the most significant prospecting and possibly some mining. The vein segment that strikes N. 47° W. averages 1 foot in width and was explored by significant trenching. The Florence vein is reported by Pruitt (1961) to continue for more than 3 miles to the southeast along the vein segment trending approximately N. 75° W. We briefly investigated outcrops that lie along this trend but could not trace the vein for more than 0.8 mile. The area where the continuation is reported to be located is mostly covered by alluvial and eolian deposits, but there are a few sporadic bedrock outcrops and the area may be worth further investigation.

Pariette Area Veins

Castle Peak, Baxter, and Pariette

The Castle Peak, Baxter, and Pariette vein system (plate 1) is located in sections 4, 5, and 9, T. 9 S., R. 17 E., and sections 19, 30, 31, and 32, T. 8 S., R. 17 E. The vein system is composed of the Castle Peak vein at the southeast, the Baxter vein in the middle area, and the Pariette vein at the northwest. We mapped the vein system for approximately 5 miles, from a prospect at the southeast end to a prospect at the northwest end. Uinta Formation sandstone and mudstone host the veins at the surface (plate 1). The Castle Peak segment generally strikes N. 40° W. and has a few outcrops about 2 feet wide exposed along its length. The Baxter segment is a broken area of gilsonite veins and veinlets in the central area of the system where the Castle Peak and Pariette veins meet. The Pariette segment generally strikes N. 30° W., and Pruitt (1961) reported that it averages 1.5 feet wide at the surface. Pruitt (1961) provided a detailed description of the vein system and its history and indicated that the vein system continues for more than 3 miles southeast of the last exposure we observed on the Castle Peak vein; however, we found no gilsonite deposits in the flat to low hilly topography that is mostly covered by alluvium. The vein system was one of the earliest gilsonite deposits to be mined in the basin, starting in 1890, and by 1960 a shaft on the Pariette vein had reached a depth of 1500 feet (Pruitt, 1961). Much of the Castle Peak, Baxter, and Pariette vein system mining disturbance has been reclaimed.

Gilsonite Draw

The Gilsonite Draw vein (plate 1) is located in NW¼NW¼ section 31, T. 9 S., R. 16 E., and SE¼SE¼ section 25, and partially in NE¼NE¼ section 36, T. 9 S., R. 15 E. We mapped the vein for 0.25 mile in Gilsonite Draw, from an occurrence of gilsonite float chips at the southeast end to a fracture zone 6 inches wide containing veinlets at the northwest end. The vein generally strikes N. 35° W. and is poorly exposed. Thinly bedded Uinta Formation marlstone, sandstone, and mudstone host the vein at the surface (plate 1). A reclaimed prospecting or mining site in the bottom of the Gilsonite Draw drainage is reported by the UGS Utah Mineral Occurrence System to have contained shafts and 2-foot-wide trenches.

Fort Duchesne Area Veins

The first reports of gilsonite in the Uinta Basin came from the Fort Duchesne area in 1869, where two veins, the Carbon and Raven, are located in the Duchesne River Formation (Pruitt, 1961). The areas where these two veins are reported to be located are mostly covered by agriculture and various other developments, and we were unable to locate any gilsonite outcrops associated with the Carbon or Raven veins. Therefore, these veins are not shown on plate 1. The following discussion of the two veins is taken from Pruitt's 1961 summary.

The Carbon vein is located in T. 2 S., R. 2 E., UBLM, crossing beneath U.S. Highway 40 near Gusher, Utah. This vein was the first gilsonite vein to be mined in the Uinta Basin, starting around 1888 by Samuel Gilson, and had a long history of production. The Carbon vein is more than 3 miles long, strikes N. 40° W., and is reported as having a maximum width of 3 to 4 feet that is maintained for 1.5 miles at the middle section of the vein. The Raven vein is located in the north half of T. 2 S., R. 1 E., UBLM, north of U.S. Highway 40 and Fort Duchesne, Utah. This vein was extensively mined, mainly from 1904 to 1939. The Raven vein is approximately 3 miles long, strikes N. 37° W., and is reported to average between 1.5 and 2 feet wide.

U.S. Bureau of Land Management Gilsonite Mapping

In the early 1980s, BLM employees conducted mapping of selected gilsonite veins on the Ouray, Ouray SE, Big Pack Mtn. NW, Big Pack Mtn. NE, Archy Bench, Asphalt Wash, and Rainbow 7.5-minute topographic quadrangles (Peter Sokolosky, BLM, written communication, April 2, 2004). The survey appears to have focused on veins in old BLM prospecting permit application areas. Many of the veins mapped by the BLM occur on the Uintah and Ouray Indian Reservation, which UGS geologists were unable to get permission to visit. UGS geologists did observe some of these veins in road cuts and outcrops along the public roads that pass through the reservation. In the areas covered by both field investigations, mapping mostly agrees except for small discrepancies. Plate 1 shows the significant veins mapped by the BLM, most of which occur on the Uintah and Ouray Indian Reservation.

Various veins and vein systems are reported by the BLM. The Pride of Utah vein system is reported in sections 14, 15, 16, 23, 24, and 25, T. 9 S., R. 20 E., and sections 29 and 30, T. 9 S., R. 21 E. The vein system is reported to be composed of several veins extending approximately 6 miles, generally strike N. 58° W., and have outcrops as wide as 2 feet. The Natural Buttes vein is reported in sections 15, 16, 22, and 23, T. 9 S., R. 20 E. The vein is reported to be approximately 2.2 miles long, strike N. 55° W., and have outcrops as wide as 8 inches. The Black Gnat vein is reported in sections 16, 21, and 22, T. 9 S., R. 20 E. The vein is reported to be approximately 2.4 miles long, strike N. 54° W., and have outcrops as wide as 2.5 feet. The Workman vein is reported in sections 17 and 20, T. 9 S., R. 20 E. The vein is reported to be approximately

0.9 mile long, strike N. 53° W., and have outcrops as wide as 14 inches. The Uintah and Ouray Indian Reservation southeast extension of the Willow #2 vein is reported in sections 20 and 29, T. 9 S., R. 20 E. This extension is reported to be approximately 1.3 miles long, generally strike N. 54° W., and have a maximum width of 1.2 feet. The Black Bridge vein group (possibly an extension of the Cottonwood vein system) is reported in sections 15, 16, 22, and 23, T. 10 S., R. 20 E. The vein group is reported to be composed of at least two veins, with the most significant vein extending approximately 2.2 miles, being variable in strike, and having a maximum width of 2.5 feet. A southeast extension of the Willow Creek #1 and #2 vein system is reported in sections 16 and 21, T. 10 S., R. 20 E. This extension is reported to be composed of two parallel, closely spaced veins less than a mile long generally striking N. 57° W., and ranging in width from 5 to 11 inches. Other veins of small dimensions are also reported to occur in the vicinity of the Black Bridge, Willow #2 southeast extension, Black Gnat, Natural Buttes, and Pride of Utah veins.

Unconfirmed Deposits

Gilsonite veins discussed in this section are veins mentioned in Pruitt's (1961) report but were not confirmed by our study. Some of the veins reported by Pruitt were not located in our field investigation. Other veins were not examined due to property access restrictions. Some reported veins are questionable because of vague location descriptions. Our inability to locate some veins reported by Pruitt does not necessarily mean they do not exist, but that they may be difficult to locate due to various factors. The gilsonite field is located in a remote and rugged region and access to some areas is difficult. Veins can be concealed by unconsolidated deposits and low topographic relief, and scarce bedrock outcrops can make locating gilsonite veins at the surface difficult. Vein width and stratigraphic location can also hinder locating veins. Narrow veins in thinly interbedded sandstone and mudstone are commonly discontinuous, meandering, and generally poorly exposed. Past maps of the gilsonite field are commonly simplified, general depictions of veins, and the veins may not have been located on accurate base maps. Other veins may exist in the Uinta Basin that were not located by this study or by any previous work. However, it is unlikely that thick veins having good surface exposures went unnoticed by early prospectors. In the gilsonite field, numerous veins of small dimensions are present near other more significant veins, or are found isolated.

A short, unnamed gilsonite vein is reported (Pruitt, 1961) to be located in section 32, T. 10 S., R. 23 E., approximately 0.3 mile southwest of the Harrison vein. During a brief field reconnaissance of the area we found only a few small gilsonite float chips. A gilsonite vein probably exists in the area, perhaps covered by alluvial and colluvial deposits.

Pruitt (1961) reported that the Little Jack vein is located north of Ouray, Utah, and east of the Duchesne River in section 20, T. 4 S., R. 3 E., UBLM. The vein is reported to be 8 to 10 inches wide, 1.5 miles long, and strike N. 70° W. We did not investigate the area due to property restrictions.

Three gilsonite veins are reported (Pruitt, 1961) in the area near the southeast end of the Cottonwood vein system in and around Sand Wash. A short unnamed vein approximately 1 mile long is reported to lie a short distance north of the Cottonwood vein in Sand Wash, in SW¼ section 36, T. 10 S., R. 21 E. We were unable to locate any gilsonite deposits in Sand Wash where the vein was reported. The Red Rock vein is reported (Pruitt, 1961) to branch off the Cottonwood vein to the southeast in section 35, T. 10 S., R. 21 E., near two modern shafts, and continue for approximately 5 miles. Jim Lekas (Lexco Inc., verbal communication, 2004), who operated the two shafts on the Cottonwood vein, stated that he was unable to find that vein. Pruitt (1961) reported that he could not confirm the existence of the vein, and that its existence was doubtful. We were also unable to locate any gilsonite deposits in Sand Wash where the Red Rock vein is reported; therefore we believe its existence is questionable. This reported branch may be a misrepresentation of the vein split that is present on the Cottonwood vein in SW¼ section 28, T. 10 S., R. 21 E. Another unnamed vein is reported (Pruitt, 1961) to be located in section 2, T. 11 S., R. 21 E., approximately 1 mile southwest of the two modern shafts on the Cottonwood vein, and is reported to be about 1.7 miles long. We were unable to locate any gilsonite deposits where it is reported to crop out. The existence of these three veins located in the area near the southeast end of the Cottonwood vein system are in doubt; however, poorly exposed bedrock and the generally low topographic relief of the area makes locating gilsonite outcrops difficult.

Pruitt (1961) reported that the Canyon vein is located in section 26, T. 4 S., R. 2 E., UBLM, and that it is on trend with the Little Seam vein to the southeast and perhaps is part of the same vein. The vein is also reported to be 1.5 feet wide and strike N. 55° W. However, we were unable to locate any gilsonite deposits in the area where the vein is reported.

The Black Butte vein is reported (Pruitt, 1961) to be located in section 11, T. 5 S., R. 2 E., UBLM. We did not investigate the area, but believe the vein likely exists somewhere north of its reported location. We base this presumption on the existence of the Cliff Dweller and Green River veins that are located within a mile to the northeast of the reported location.

We investigated an area that may be the site of the April vein, which contained some small gilsonite chips and bitumen-impregnated sandstone outcrops. The area is in NW¼SE¼ section 22, T. 8 S., R. 17 E., where two northwest-trending shaft symbols appear on the Pariette Draw SW 7.5-minute quadrangle map. However, we did not observe any shafts or significant gilsonite deposits, and the surrounding area is now mostly covered by agriculture. The area where the April vein is reported (Pruitt, 1961) is approximately 1 mile southwest of the shaft symbols and 2 miles northeast of the Pariette mine. The vein is also reported striking parallel to the Pariette vein for 3000 feet. We briefly investigated the reported vein location area and were unsuccessful in locating any gilsonite deposits.

CONCLUSION

Gilsonite, a member of the asphaltite group of hydrocarbon bitumens, forms a swarm of subparallel, northwest-trending, near-vertical, laterally and vertically extensive veins in the Uinta Basin of Utah and Colorado. Gilsonite is sourced from the Mahogany oil shale zone in the Parachute Creek Member of the Green River Formation. Mechanisms for propagating the fractures that contain gilsonite appear to involve elevated pore pressure within the hydrocarbon source beds of the Green River Formation and regional stress fields. In this study we mapped and described in detail 59 veins, vein systems, and isolated vein outcrops, having a total combined vein length of over 120 miles. This report documents a total of 71 significant veins, vein systems, and vein extensions that were mapped by the UGS or previous investigators, having a total combined vein length of over 170 miles.

Gilsonite veins in the study area occur in Eocene Green River Formation lacustrine deposits and Uinta Formation marginal lacustrine and fluvial deposits. All but two (Weaver and Black Dragon) of the known significant veins are located above the Mahogany oil shale zone, and no gilsonite veins are known to cross-cut the Mahogany oil shale zone contained in the Parachute Creek Member of the Green River Formation. Gilsonite veins above the source beds in the eastern part of the study area are commonly eroded down near their roots, and the remaining veins generally can be expected to split and thin with depth. Gilsonite veins exposed beneath the source beds attain their greatest thickness in the Douglas Creek Member of the Green River Formation and the interfingering Renegade Tongue of the Wasatch Formation, and can be expected to thin both downward and upward from these units. Bedrock hosting gilsonite veins in the central and northwestern parts of the study area is generally less eroded, and the veins rooted in the Green River Formation oil shale have greater vertical extent and generally can be expected to widen with depth from exposures in the middle and upper Uinta Formation.

The continuity of the veins can be impressive in some areas of the study area, having veins stretching in relatively long, straight ribbons across the hills of the Uinta Basin, and the longest vein system (Pride of the West-Rainbow-Black Dragon) extending more than 22 miles. The gilsonite veins can also be vertically continuous, ranging from hundreds to more than 3000 feet, commonly having only small variations in width. However, veins can be difficult to locate in some areas of the study area due to concealment by unconsolidated deposits, low topographic relief, and vein width and stratigraphic location. Narrow veins in thinly interbedded sandstone and mudstone are commonly discontinuous, meandering, and generally poorly exposed. Many of the veins in the study area appear to lie roughly along the same trend as other veins, but lack exposed gilsonite at the surface in extensive areas between the veins. All but two (O.K. and Original Owner) of the known significant gilsonite veins trend northwest; the two veins trend east-west and coinciding with the Duchesne fault system.

Gilsonite is a geologically interesting and economically significant resource, having an extremely wide range of uses that have changed over time with new technology and industrial needs. Gilsonite has a long, colorful mining history dating back to the late 1800s, and all of the veins mined today were discovered by early prospectors who located surface exposures. The original in-place gilsonite resource of all the veins is estimated by Cashion (1967) to be approximately 45 million short tons. The remaining resources tend to be in the deeper parts of the veins and in thinner, more remote veins that will likely be more expensive to mine.

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APPENDIX
Annual production and value of gilsonite produced in the Uinta Basin

Much of the data in table A1 was compiled from the mineral yearbooks of the U.S. Bureau of Mines (USBM, 1953–1970) (later published by the U.S. Geological Survey). Mineral yearbook data became less valuable in the mid-1950s because the federal government started withholding data to protect company confidentiality (indicated by a "W" in the "QUANT." or "VALUE" data field). The Utah Division of Oil, Gas, and Mining (DOGM) started to collect and report production data in the late 1980s. DOGM collects production data from all mines that it regulates; these data were incorporated into this compilation for the years 1989 through 2009. Unfortunately, companies do not report valuation to DOGM. The Utah Geological Survey also collects production data through a questionnaire sent to mine operators; these data were used in the compilation for the years 1993 through 2009. Miscellaneous additional sources of data are noted in the "DATA SOURCE" column and are listed in a reference list at the end of this appendix.

Most of the Uinta Basin gilsonite production has been by Utah, although Colorado produced a substantial quantity early in the history of the gilsonite industry. Two companies have dominated gilsonite production over the past 50 years: American Gilsonite Co. and G.S. Zeigler and Co. American Gilsonite has produced continuously since it was organized in 1946 and its predecessor companies produced for decades earlier. G.S. Zeigler (now Zeigler Chemicals and Minerals) purchased some of the smaller gilsonite producers in the early 1950s and has produced gilsonite continuously since. American Gilsonite typically produces more gilsonite per year than Zeigler. Lexco began producing gilsonite around 1989 and produced a small amount continuously until being acquired by American Gilsonite in 2009.

***Table A1.** Annual production and value of gilsonite produced in the Uinta Basin.*

YEAR	QUANT. (st)	VALUE ($)	DATA SOURCE	NOTES
1885	-	-	2	Small quantity produced and marketed.
1886	-	-	-	-
1887	-	-	-	-
1888	-	-	-	-
1889	2100	252,000	9	From January to September, 1500 st was shipped by Gilsonite Manufacturing Co. Gilson Asphaltum Co. produced another 600 st. The gilsonite sold for $120/st.
1890	-	-	-	-
1891	-	-	-	-
1892	-	-	-	-
1893	-	-	-	-
1894	-	-	-	-
1895	-	-	-	-
1896	-	-	-	-
1897	-	-	-	-
1898	-	-	-	-
1899	>2000	>100,000	8	More than 2000 st of gilsonite shipped from the "Strip"; average price was $50/st. Production and hauling costs were $21/st.
1900	-	-	-	-
1901	-	-	11	Cost of mining and shipping material to St. Louis was $25/st. Price in Chicago and St. Louis was $40-50/st.
1902	7000	~602,000	13	7000 st of gilsonite sold in Chicago at $72/st in carloads or $100/st in 2-ton lots.
1903	-	-	13	Sold for $50/st f.o.b. railroad at Price, Ut.; company production costs were $20/st. Wages paid were $4 per 12-hour day.
1904	2978	-	15	-
1905	10,916	-	6, 15	Price of gilsonite in St. Louis was about $50/st of which $20/st was transportation costs.
1906	-	-	8	Freight rates on the Uintah Railroad were raised from $8 to $10/st.
1907	20,285	531,965	8, 16	Miners wages were $3 per 8-hr day.
1908	18,533	61,824	6, 16	Freight charge from Dragon, Utah to New York was $22.35/st.
1909	28,669	218,186	16	-
1910	29,832	372,900	16	-
1911	30,236	486,114	16	-
1912	31,478	573,069	16	-
1913	35,055	576,949	6	Includes gilsonite, wurtzilite, and grahamite.
1914	19,148	405,966	6, 16	Includes gilsonite, wurtzilite, and grahamite.
1915	21,157	352,257	6, 16	USBM reported that 1916 production was 27% more than 1915 and 1915 price was $13.11/st. Carey and Roberts (1949) reported 20,559 st worth $275,252 which included gilsonite and wurtzilite.
1916	26,870	626,640	6, 16	-
1917	35,468	511,803	6, 16	USBM reported that production was 32% greater than 1916 and was valued at $14.43/st. Carey and Roberts (1949) reported 35,049 st worth $532,989 which included gilsonite and wurtzilite.
1918	30,848	606,639	1, 6, 16	Aurand (1920) reported 31,072 st produced worth $663,257 from five producers.
1919				
1920	56,204	548,776	6, 16	-
1921	10,066	178,224	6, 16	-
1922	29,693	622,107	6, 10, 16	-
1923	34,425	681,622	6, 10, 16	Average price was $28.00/st.
1924	35,907	603,620	6, 10, 16	-
1925	39,520	767,900	6, 10, 16	-
1926	42,190	863,840	6, 10, 16	USBM noted that values may be inflated by some companies reporting a delivered value rather than at mine/railhead.
1927	42,580	876,820	6, 10, 16	USBM noted that values may be inflated by some companies reporting a delivered value rather than at mine/railhead.
1928	47,023	1,037,679	6, 10, 16	USBM noted that values may be inflated by some companies reporting a delivered value rather than at mine/railhead. Dennis (1930) wrote that the average price f.o.b. mine was $22.07/st. Selects quality ore at

				Mack, Colorado was worth \$30–\$33/st.
1929	54,987	1,235,920	6, 15	Romney (1963) reported that this production is only for Uintah Co. Value was not totally based on f.o.b. price; f.o.b price was \$14.50–\$28.00/st. Carey and Roberts (1949) reported that the largest producers in 1929 were Gilson Asphaltum Co., Utah Gilsonite Co., Raven Mining Co. of Utah, Diamond Gilsonite Co., and the American Asphalt Association.
1930	37,684	863,197	6, 16	Dennis (1930) wrote that in January 1930, the Rainbow mine shipped 125 st daily which was about 80% of the total production from this area. About 20% of the gilsonite was shipped to foreign countries. Roughly 50% of the gilsonite was low-grade material used for roofing paper and other uses. Average price was \$22.91/st.
1931	32,763	674,102	6, 16	-
1932	25,955	525,266	6, 17	Drop in production due to reduced activity in manufacturing of paint, rubber, and insulated wire.
1933	28,029	577,716	6, 17	-
1934	30,355	599,739	6, 17	Increased production over 1933 due to greater paint demand and activity in the electrical industry.
1935	33,277	696,601	6, 17	-
1936	33,694	833,966	17	Higher prices due to increased demands for paint, varnish, and electrical fitting manufacture.
1937	38,038	973,007	6, 17	-
1938	28,574	649,724	6, 17	Ten percent increase in railroad freight rates and decreased demand for varnish and ink reduced domestic demand. Higher steamship rates and exchange difficulties reduced exports.
1939	37,289	1,053,142	6, 14, 17	Carey and Roberts (1949) reported, "Demand for better grades \$28.24/st during first part of year."
1940	31,930	770,711	6, 14, 17	Carey and Roberts (1949) reported, "Exports dropped off—Germany blockaded—f.o.b. \$24.14/ton."
1941	36,407	851,623	6, 14, 17	Price at mine was \$23.39/st.
1942	40,041	909, 311	6, 14, 17, 20	-
1943	50,466	1,188,485	6, 14, 17	\$23.56/st.
1944	49,051	915,480	6, 14, 17	\$18.73/st f.o.b.
1945	61,273	1,250,546	6, 14, 17	\$20.41/st f.o.b.
1946	68,407	1,440,229	6, 14, 17	All production was from Utah. Barber Asphalt Corp. sold half of its gilsonite business to Standard Oil of California (Chevron) and the two formed a joint partnership named the American Gilsonite Co.
1947	67,165	1,746,228	6, 14, 17	-
1948	52,122	1,390,713	6, 14, 17	-
1949	51,462	1,303,584	6, 17	From 1908 to 1949 prices fluctuated between \$20 and \$40/st f.o.b. at Craig, Colorado.
1950	66,186	1,774,330	12, 17	Garvin (1966) reported combined asphalt and gilsonite production of 66,186 st worth \$1,779,815.
1951	65,521	1,895,374	15, 17, 19	Production for Duchesne and Uintah Counties combined.
1952	60,740	1,779,815	17, 19	Production for Duchesne and Uintah Counties combined.
1953	60,505	2,184,328	17, 19	Production for Duchesne and Uintah Counties combined.
1954	60,500	2,184,000	17, 19	-
1955	W	W	19	American Gilsonite Co. was the largest producer, with mines and a plant at Bonanza. Several of the smaller operations were purchased a few years earlier by G.S. Ziegler & Co. Ziegler had a processing plant in Provo. Duchesne County's Castle Peak gilsonite district was active in 1955.
1956	W	W	20	-
1957	206,041	4,259,120	13, 17, 20	Price of gilsonite at the railhead is about \$35/st. Miners earned about \$20 for an 8-hour day.
1958	-	-	-	-
1959	-	-	20	Ziegler began construction of its processing plant in Uintah County (Little Bonanza?).
1960	-	-	-	-
1961	470,000	14,500,000	7, 15, 17	Gilsonite production was lumped by USBM into the native asphalt category but almost all was due to gilsonite. Two companies operated, American and Ziegler. Cashion (1964) reported that gilsonite production in 1961 was 422,294 st valued at \$9,916,000.
1962	-	-	-	-
1963	-	-	-	-
1964	W	W	17, 21	Value of production increased 22% from 1963. Active operators included American Gilsonite Company, Ziegler Chemical and Minerals Corp., Standard Gilsonite Company, Arthur Boren, and Alva L. Hatch.
1965	W	W	17, 21	Gilsonite production decreased 13% from 1964. American, Ziegler, and Standard operated mines in Uintah County. Ziegler also operated the Castle Peak mine in Duchesne County. Standard Gilsonite Co. became a division of Mesa Petroleum Co. on September 10, 1965.
1966	W	W	17	Gilsonite production decreased 24% from 1965. American, Ziegler, and Standard operated mines in Uintah County. Ziegler also operated the Castle Peak mine in Duchesne County.
1967	W	W	17	Gilsonite production from five mines in Uintah and Duchesne Counties was down 10%. The Castle Peak

				mine in Duchesne County was closed after 30 years of production. Standard Gilsonite mined gilsonite in Duchesne County, processed it at a plant south of Myton, and made intermittent shipments. Other operators making occasional shipments include Arthur Boren and Alva L. Hatch.
1968	W	W	17	Yearbook contains no notes.
1969	W	W	17	Total output from the three gilsonite-producing companies was slightly higher than that of the previous year.
1970	W	W	17	Output from three gilsonite-producing companies rose 14% in tonnage and 12% in value in 1970.
1971	W	W	17	Total output from three gilsonite-producing companies fell 23% in tonnage and 19% in value
1972	W	W	17	Output from two gilsonite-producing companies dropped 15% but value rose 12% as a result of a higher unit value.
1973	W	W	17	Output from two gilsonite-producing companies fell 69% in quantity and 53% in value from that in 1972. The Fruita, CO, plant of American Gilsonite was sold in December 1973.
1974	W	W	17	Output from two gilsonite-producing companies rose 23% in quantity and as a result of increased unit price, value was more than triple that of 1973.
1975	W	W	17	Two companies produced gilsonite from properties in Uintah Co. Total production was 19% less than that during 1974 but as a result of higher average price for the product, total value was 2% greater.
1976	W	W	17	Output from the state's two gilsonite-producing properties increased 9% in quantity but decreased 12% in value as a result of lower average prices for this commodity.
1977	W	W	-	-
1978	W	W	17	Gilsonite was produced by American Gilsonite Co. at Bonanza in Uintah County, Utah, and by Ziegler Chemical and Minerals Corp. in Weber County. By mid-1979 American Gilsonite completed construction of its $5.3 million consolidated processing plant at Bonanza.
1979	W	W	17	1978 and 1979 yearbook reports were combined.
1980	W	W	-	-
1981	W	W	-	Chevron bought out Barber Oil's half ownership of American Gilsonite Co.
1982	W	W	17	American Gilsonite is listed as the principal producer.
1983	W	W	-	-
1984	W	W	-	-
1985	W	W	-	-
1986	W	W	-	-
1987	W	W	-	-
1988	W	W	17	American Gilsonite Co. and Ziegler Chemical and Minerals Corp. were listed as the two main producers. Lexco enters the gilsonite business.
1989	52,873	W	17	American Gilsonite Co. and Ziegler Chemical and Minerals Corp. were listed as the two producers. USBM withheld data but production is contained in DOGM files
1990	W	W	-	-
1991	W	W	-	Chevron sold American Gilsonite Co. to Stratford Enterprises Co. of Tulsa, OK.
1992	W	W	17	American Gilsonite Co. and Ziegler Chemical and Minerals Corp. were listed as the two principal producers.
1993	47,124	W	3	-
1994	56,257	W	4	-
1995	57,819	W	5	-
1996	62,925	W	18	Producers in decreasing order: American Gilsonite Co. (Bonanza mine), Ziegler Chemical and Minerals Corp. (Zeigler mine), and Lexco (Lexco mine).
1997	66,032	W	18	Producers in decreasing order: American Gilsonite Co. (Bonanza mine), Ziegler Chemical and Minerals Corp. (Zeigler mine), and Lexco (Lexco mine).
1998	69,172	W	18	Producers in decreasing order: American Gilsonite Co. (Bonanza mine), Ziegler Chemical and Minerals Corp. (Zeigler and Tom Taylor mines), and Lexco (Cottonwood mine).
1999	59,000	W	18	Producers in decreasing order: American Gilsonite Co. (Bonanza mine), Ziegler Chemical and Minerals Corp. (Zeigler and Tom Taylor mines), and Lexco (Cottonwood mine).
2000	72,300	W	18	Producers in decreasing order: American Gilsonite Co. (Bonanza mine), Ziegler Chemical and Minerals Corp. (Zeigler and Tom Taylor mines), and Lexco (Cottonwood mine).
2001	69,450	W	18	Producers in decreasing order: American Gilsonite Co. (Bonanza mine), Ziegler Chemical and Minerals Corp. (Cowboy, Neal State, and Hardaway mines), and Lexco (Cottonwood mine).
2002	65,648	W	18	Producers in decreasing order: American Gilsonite Co., Ziegler Chemical and Minerals Corp., and Lexco.
2003	56,943	W	18	Producers in decreasing order: American Gilsonite Co., Ziegler Chemical and Minerals Corp., and Lexco.

2004	70,000	W	18	Producers in decreasing order: American Gilsonite Co., Ziegler Chemical and Minerals Corp., and Lexco. Lexco production not included in quantity.
2005	79,300	W	18	Producers in decreasing order: American Gilsonite Co., Ziegler Chemical and Minerals Corp., and Lexco.
2006	81,200	W	18	Producers in decreasing order: American Gilsonite Co., Ziegler Chemical and Minerals Corp., and Lexco.
2007	75,853	W	18	Producers in decreasing order: American Gilsonite Co., Lexco, and Ziegler Chemical and Minerals Corp.
2008	76,600	W	18	Producers in decreasing order: American Gilsonite Co., Lexco, and Ziegler Chemical and Minerals Corp. Lexco portion of production estimated. Palladium Equity Partners bought American Gilsonite Co. in March.
2009	63,500	W	18	Lexco portion of production estimated. Lexco is acquired by American Gilsonite.

Abbreviations: f.o.b., free on board; st, short tons; W, withheld.

Notes: values not inflation adjusted; free on board (f.o.b.) is an International Chamber of Commerce term to indicate the price of a commodity when all transportation, insurance, and other costs have been settled and it has been loaded onto the deck of a ship (technically the term should have been f.o.r.—free on rail—for gilsonite transportation); the title and risk pass to the buyer at this point.

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