The Wasath Hingeline is a topographic expression of the eastern edge of the Basin and Range. It represents a change in structure from extension in the Great Basin to relatively undeformed rocks in the Colorado Plateau. The line is also a demarcation of a change in depositional environments from marine shelf settings in the early Paleozoic to near-shore and continental in the late Paleozoic and Mesozoic. The line also coincides with a change in seismic activity, where the Transition Zone is very active seismically in what is know as the Intermountain Seismic Belt and the Colorado Plateau is relatively inactive.

Diapiric, soft-sediment deformation is present in the Sevier Valley and Sanpete Valleys and is associated with the Jurassic Arapien Shale (Willis, 1986; Witkind, et al, 1987). The Arapien contains interbedded gypsum, salt, mudstone, sandstone, and limestone, and the gypsum and salt as well as the mudstone is susceptible to weight-loading and plastic deformation, or diapirism. The deformed strata in the vicinity of the Sevier and Sanpete Valleys are attributed to compressional tectonics, such as the Sevier orogeny thrusts and Laramide folding; extensional tectonics, such as normal faulting of the Basin and Range; and diapirism (Willis, 1986; Witkind, et al, 1987). The Arapien Shale is also the surface expression of the Sevier Valley-Sanpete Valley anticline, where the Arapien represents the axis of the structure that trends generally north on the east side of the Sevier Valley and into the southern end of the Sanpete Valley.

Map 7 shows the some of the major structural features of the planning area. Regional cross-sections are provided in Attachments 1 and 4.

Cross sections from the Geologic Map of Utah are in Attachment 1. Cross section K-L shows the structure in the Colorado Plateau from the Straight Cliffs in southern Utah across the Circle Cliffs and Waterpocket Fold, the Henry Mountains, and Paradox Basin. Cross section J-I shows the structure of the Basin and Range, the Transition Zone, and the eastern Colorado Plateau. The section in the Transition Zone in the planning areas includes the Valley Mountains, Gunnison Plateau, Sanpete Valley, and Wasatch Plateau.

3. MINERAL DEPOSITS AND ENERGY RESOURCES

The first part of this section discusses energy and mineral resources in the planning area. The second part discusses mineral exploration, development, and production. Leasable commodities are discussed first (such as coal bed methane, oil and gas, tar sands, and geothermal resources), followed by locatable minerals (such as metallics and nonmetallics), then salable minerals (such as sand and gravel, clay, and stone).

3.1 Occurrence of Energy and Mineral Resources

A. LEASABLE MINERAL DEPOSITS

1. Coal

The three major coal fields in the planning area are 1) Wasatch Plateau, 2) Emery, and 3) Henry Mountains (Map 8). The Wasatch Plateau coal field includes strata in the Blackhawk Formation of the Mesaverde Group, the Emery coal field is in the Ferron Sandstone Member of the Mancos Shale, and the Henry Mountains coal fields includes beds in the Ferron Sandstone and Muley Canyon Sandstone Members of the Mancos Shale (UGMS, 1979; Tabet, 1999). In addition, four small coal fields are located in Sanpete and Sevier Counties—Mt. Pleasant, Wales, Sterling, and Salina Canyon (Map 8). This report does not address coal resources, because coal resources are assessed in two coal reports for the Richfield planning area.

2. Coal Bed Methane

Coal bed methane gas (CBM) is considered a natural gas subject to leasing under the Mineral Leasing Act of 1920, as amended. However, as CBM is associated with coal fields and the development of a CBM field is different from a conventional gas field, CBM is addressed separately from oil and gas.

The presence of methane gas in coal seams has long been recognized from the explosions and outbursts associated with underground coal mining operations. Only recently, however, has coal been recognized as both a reservoir and source rock for this unconventional energy resource.

During the coalification process that accompanies burial, organic matter is converted into coal and methane gas is produced, along with water, carbon dioxide, nitrogen, and heavier hydrocarbon fractions (Rice, 2000). A portion of this methane becomes trapped as the coal seam is compacted and can later be extracted as an energy resource. In general, the higher the rank of the coal, the greater the potential for methane gas in the coal.

A coal seam is a dual-porosity medium that consists of a solid matrix containing micropores and a fracture system known as cleats. Methane molecules are adsorbed as a single layer to the walls of the micropores and the internal surface area is very large. This results in a large adsorption capacity for methane, which can exceed that of conventional gas reservoirs by a factor of 3 to 7 times. Methane gas is also contained in a free state or dissolved in groundwater within the cleat fractures of the coal, but this amount is small compared with the adsorbed gas.

Although primary permeability is essentially nonexistent in coal beds, the beds commonly serve as aquifers because their fracture and cleat systems are well developed and are generally fully saturated before CBM production (Tabet, et al, 1995). CBM is produced by pumping water out of the coal, thereby lowering the hydrostatic pressure, which causes methane to desorb from the coal and migrate through the coal cleats and fractures to the production well. Initially, large amounts of water are produced before methane gas can desorb and begin to flow toward the well bore. As the coal beds are de-watered, methane gas production from the well increases over time. Eventually, gas production declines as ground water production diminishes in the last stages of a well's production.

CBM is an attractive resource because much of the nation's coal deposits are known and lie at relatively shallow depths, making it relatively easy and inexpensive to drill wells. CBM accumulations also tend to be widespread and laterally extensive across basins where coal beds are present in the stratigraphic section. Accordingly, locating CBM wells to target a producing horizon is somewhat easier than for a conventional gas well that depends on a trap. In addition, CBM production does not preclude the future mining of the coal beds through conventional underground methods but appears to actually benefit future mining operations by removing the methane, which poses a health and safety hazard and contributes to greenhouse emissions (Rice, 2000). The main concern with CBM wells is gas recoverability, which is constrained primarily by cost and technology.

Despite its many advantages, CBM production poses some significant environmental issues, most notably the production of large volumes of water, particularly in the early stages of well development. Although water produced from CBM wells can be potable, it is frequently saline to hypersaline and may contain total dissolved solids (TDS) at concentrations up to 170,000 mg/L (USGS, 2000). Produced water from CBM wells can also have high concentrations of dissolved organic constituents and metals. Depending on the water quality, the produced water is disposed of as waste or used for beneficial purposes, although some treatment is often required. Disposal includes surface discharge including evaporation or injection in subsurface formations. Uses include livestock watering, irrigation, watering artificial wetlands, or water supplies.

The coal fields discussed in previous sections are potentially amenable to CBM accumulation and development. The coals of the Blackhawk Formation and the Ferron Sandstone in southeastern Sanpete County and eastern Sevier County have been studied the most for CBM gas.

The USGS has identified the Wasatch Plateau–Emery Play for CBM which underlies the Wasatch Plateau (Gautier and others, 1996) and extends into the planning area (Map 9). The Wasatch Plateau–Emery Play involves CBM gas in the Ferron Sandstone associated with the coal beds in this formation. The play as originally described by the USGS has been extended southwestward and is also referred to as the

Ferron Fairway and the Ferron Trend. Along the Ferron Trend, the total coal thickness is up to 40 feet (Tabet, et al, 1995).

West of the Ferron Trend and the Wasatch Plateau-Emery play, coal beds are present within the Ferron Sandstone and the Emery Sandstone of the Mancos Shale and Blackhawk Formation of the Mesa Verde Group. These coal beds have had limited assessment and evaluation to date (Johnson and Roberts, 2003; Schenk, et al, 2003; Tabet and Quick, 2003). The coal beds in the Ferron Sandstone in this area would be at greater depths than on the Ferron Trend, and the Emery Sandstone and Blackhawk Formation are stratigraphically above the Ferron Sandstone. The Cretaceous sandstones with assumed coal bed methane in the Ferron, Emery, and Blackhawk correspond to the boundary of the Cretaceous Sandstone play (2107), discussed in the next section.

3. Oil and Gas

Oil and gas include conventional and unconventional accumulations of hydrocarbon compounds that can include liquid, gaseous and solid forms. In addition, helium is included with oil and gas in a federal lease. Coal bed methane gas is a hydrocarbon, but was presented in the previous section. Although coal bed methane gas is included in a federal oil and gas lease, CBM is not further evaluated in this section.

In the 1995 assessment of oil and gas resources (Gautier and others, 1996), the USGS defined four provinces that encompass portions of the planning area: Eastern Great Basin (Province 19), Uinta-Piceance Basin (Province 20), Paradox Basin (Province 21), and Northern Arizona (Province 24). Each province contains plays. A play is defined as known or postulated oil and/or gas accumulations sharing similar geologic, geographic, and temporal characteristics such as source rock, migration pathways, timing, trapping mechanisms, or hydrocarbon type (Gautier and others, 1996). Plays may geographically overlap in a map view, because formations in the stratigraphic column of each play may overlap in the subsurface. Plays may be conventional where the reservoir has definite boundary limits, such as a stratigraphic or structural trap, or unconventional where the accumulation is continuous without a discrete boundary. Where a play contains known accumulations, more than one field may be included in the play. The USGS oil and gas plays that are in the planning area are shown on Map 10 and are briefly summarized in Table 3, which is based on Gautier and others (1996).

Table 3. USGS Oil and Gas Plays in the Planning Area

Play Name	Play No.	Comments
Great Basin Province		
Late Paleozoic	1902	Conventional but hypothetical play that extends into western Sevier and Sanpete Counties. Possible and stratigraphic traps in carbonate and sandstone reservoirs may be preserved within the upper Paleozoic section sealed by interbedded or overlying shale or by faults.
Sevier Frontal Zone	1907	Conventional but hypothetical structural play in western Sanpete Sevier Counties. Probable traps in thrust-imbricate duplexes, triangle zones, and anticlines of the Charleston-Nebo, Wasatch, Gunnison, and Pavant thrust systems. Potential reservoirs are primarily Triassic and Jurassic strata.
Paradox Basin Province (021)		
Buried Fault Blocks	2101	Conventional play based on the occurrence of oil accumulations in fault blocks involving pre-Pennsylvanian rocks in eastern Utah. Most of the structures are associated with the salt anticlines. In the planning area, only present in the northeast corner of Wayne County.
Porous Carbonate Buildup	2102	Conventional play consisting of stratigraphic and/or structural traps, characterized by oil and gas accumulations in mounds of algal limestone associated with organic-rich, black dolomitic shale rimming the evaporite sequences of the Paradox Formation of the Hermosa Group. Includes the giant Aneth field in southeast San Juan County. This play has limited extent in the planning area (northeast Garfield and southeast of Wayne Counties).
Fractured Interbed	2103	Unconventional, continuous play (hypothetical). Potential reservoir and source is primarily the Paradox Formation. Structural and stratigraphic traps are formed as a result of fractured shale. Present in eastern Garfield and Wayne Counties.
Salt Anticline Flank	2105	Conventional play. Structural and stratigraphic traps along the axis of the northwest flank of the Paradox basin. Potential reservoir and source rocks are primarily in the Hermosa Group but also in the Cutler Group. Present in northeast corner of Wayne County. Currently productive for gas outside the planning area.
Permo-Triassic Unconformity	2106	Conventional play involving formations above and below the unconformity, namely the White Rim Sandstone (Coconino Sandstone), Kaibab Limestone, and Moenkopi Formation. Down-dip extension of the tar sand deposits of central Utah.

Table 3. USGS Oil and Gas Plays in the Planning Area

Play Name	Play No.	Comments
Upper Cretaceous Sandstone	2107	Conventional play. An extension of Upper Cretaceous Sandstone play (2003) in the Uintah-Piceance Basin province (020). The major producer has been the Ferron Sandstone on the Wasatch Plateau, with minor production from the Dakota Sandstone. Source rocks are the Mancos Shale and the Mesaverde Group. Predominately structural traps.
Northern Arizona Province (024)		
Late Proterozoic (Chuar-sourced) and Lower Paleozoic	2403	Hypothetical, highly speculative play. Defined on the inference that Late Proterozoic Chuar Group sourced reservoir units within itself and in superjacent Paleozoic reservoirs, primarily the Cambrian Tapeats Sandstone. Potential accumulations are associated with large Colorado Plateau structural traps. Boundaries for this play are ill-defined because so few boreholes have penetrated the Chuar; consequently, its regional occurrence and facies are poorly understood.

NOTE. The Wasatch Plateau–Emery Play (2052) for CBM in the Uinta-Piceance province (020) is discussed in the previous section.

Hydrocarbons have been produced in the planning area in Sevier County and in Sanpete County. The production in Sevier County is relatively recent with production beginning in 2004. To date, public information is limited with respect to this new discovery. Historically, gas was produced at the Joes Valley field on the Wasatch Plateau. This field was developed in the Ferron Sandstone in conventional gas reservoirs. The field is currently not producing, although proposals for additional exploration are pending.

Well records indicate shows of oil and gas from various formations in the planning area. Shows from oil and gas wells have been reported from Cambrian, Devonian, Mississippian, Pennsylvanian, Permian, and Triassic in the eastern part of the planning area. Of particular interest as potential targets are the Lynch, Elbert, Ouray, Redwall (Leadville), Molas, Paradox, Honaker Trail, Elephant Canyon, Cedar Mesa, White Rim, Kaibab, Moenkopi, Navajo, Dakota, and Mancos. Two known fields are adjacent to the planning area in the Permo-Triassic Unconformity play: Upper Valley near Escalante, primarily in the Kaibab Limestone, and Last Chance in southwest Emery County in the Moenkopi.

In the western part of the planning area, shows have been reported from the Permian, Jurassic and Cretaceous. Of particular interest as targets are the Cambrian through Mississippian carbonate rocks, Callville, Permian sandstone such as the Coconino or equivalent, Kaibab, Moenkopi, Navajo, Dakota, Ferron, Emery, and Mesa Verde. Oil is currently being produced from the Navajo Sandstone near Sigurd in the Sevier Frontal play (The Rocky Mountain Oil Journal, 2004). Past production has included gas from the Ferron Sandstone at Joes Valley in the Cretaceous Sandstone play, which is now an abandoned field.

4. Tar Sands

In the geologic literature, the term tar sand is used synonymously with bituminous sandstone, oil sands, or oil impregnated rock. Tar sands are loosely defined as any sedimentary rock impregnated with heavy, viscous crude oil that cannot be recovered by conventional techniques but rather requires an external energy source (i.e., heat) to mobilize the oil. In 1980, the U.S. Department of Energy (DOE) defined tar sands as any consolidated or unconsolidated rock material that contains hydrocarbons (bitumen) and has a high gas-free viscosity, excluding coal, oil shale, and gilsonite.

In the planning area, tar sands occur at several localities as presented by Doelling (1975), Ritzma (1979), and Campbell and Ritzma (1979). These are summarized below:

- Tar Sand Triangle—Known outcrop of oil-impregnated rocks with projected, subsurface, lateral extent, including Elaterite Basin, Red Cove, Teapot Rock, Fault Point, The Cove, and Hatch Canyon. Deposits hosted primarily in the White Rim Sandstone of the Cutler Group and secondarily in the Cedar Mesa Sandstone of the Cutler Group, Moenkopi Formation, and Shinarump Member of the Chinle Formation.
- Circle Cliffs (East Flank)—Known outcrop of oil-impregnated rocks with projected, subsurface, lateral extent. Deposit hosted in Moenkopi Formation.
- Poison Spring Canyon—Small deposit hosted in the Moenkopi Formation.
- Teasdale— Small deposit hosted in the Moenkopi Formation and Kaibab Limestone.
- Thousand Lake Mountain—Small deposit hosted in the Navajo Sandstone.

In addition, several unnamed occurrences are reported in the vicinity of the Tar Sand Triangle in the White Rim, the Circle Cliffs in the Shinarump, and Teasdale in the Moenkopi and Kaibab.

The tar sand localities are shown on Map 11. Ritzma (1979) delineated deposits of large and small extent, which in this report have been grouped as Zones 1 and 2 for deposits of large extent and Zone 3 for deposits of small extent as displayed on Map 11. Zone 1 is an area with oil-impregnated rocks or an area where impregnation is reasonably projected from a known exposure in outcrop or corehole. Zone 2 is an area probably completely underlain by impregnated rocks. Zone 3 is an area with deposits of small extent. The Tar Sand Triangle as delineated by Ritzma (1979) has been modified on Map 11 to include Poison Spring Canyon (a deposit of small extent) and several unnamed deposits to the southwest of the Triangle.

The Tar Sand Triangle includes the most significant deposits in the planning area and encompasses approximately 230 mi^2 (Doelling, 1975, p. 97). The bitumen-bearing beds are up to 300 ft in total thickness, have been estimated to contain 16 billion barrels of oil, and have a maximum overburden of 500 feet (Doelling, 1975, p. 97). The Circle Cliffs (East Flank) and related deposits are the second most important deposits, have a similar thickness to the Tar Sand Triangle, and are estimated to contain greater than 860 million barrels (Doelling, 1975, p. 97, 102). The other occurrences, such as at Teasdale and Thousand Lake Mountain, are more widely separated; thus, the confidence in continuity of deposits in the subsurface is less assured.

As stated under Land Status, BLM has defined special tar sand areas (STSA), as directed under the Combined Hydrocarbon Leasing Act. These areas are delineated as being subject to the provisions of that act. In these special leasing areas, all hydrocarbons, including tar sands and oil and gas, are subject to a combined hydrocarbon lease. Two STSAs are in the planning area—Tar Sand Triangle and Circle Cliffs (Map 11).

5. Geothermal Resources

Geothermal resources are related to the heat generated by an active earth, which in essence is a thermal engine (Blackett and Wakefield, 2002, p. 5). The thermal engine produces heat flow, which results in a thermal gradient where normally the temperature increases with depth below the surface. In geothermal regions, the thermal gradient increases more rapidly than in regions without geothermal resources. Thus, regions with geothermal resources may be indicated by high heat flow and an increase in the thermal gradient. In addition, thermal (hot) springs, Quaternary intrusive bodies and/or volcanic centers, seismicity, and hydrothermal alteration may be present and indications of regions with geothermal resources.

The western part of the Transition Zone in the planning area is characterized by high heat flow, thermal springs, seismic activity, Quaternary igneous features, and Quaternary faults (Blackett and Wakefield, 2002). Thermal springs and elevated temperatures in some wells and mine shafts are present at places in the Sanpete and Sevier Valleys and in the vicinity of Marysvale. The central part of Utah in the Transition Zone is one of the most seismically active regions in the state, as indicated by a northward-trending zone of relatively concentrated and frequent earthquakes of varying magnitudes, which is referred to as the Intermountain Seismic Belt. Earthquakes indicate active faulting, and the related faults are possible conduits for the migration of steam or heated water. Thermal springs and hydrothermal zones are surface indications of the subsurface migration of heated water. Quaternary volcanic centers may indicate relatively shallow magmatic bodies that may serve as sources for heat at relatively shallow depths.

Mabey and Budding (1987) proposed the name Sevier thermal area for southwest Utah, which includes the state's moderate and high temperature hydrothermal systems

(Wright, et al, 1990, p. 32-33; Blackett and Wakefield, 2002, p. 42). Moderate and high temperature systems are defined, respectively, as greater than 90º C (194º F) and 150º C (302º F). An area lateral extent for geothermal resources has been delineated for the Sevier and Sanpete Valleys by the Utah Geological Survey (Gurgel, 1983, Map 68). The Sevier thermal area and the area of lateral extend are shown on Map 12, and these two areas are favorable for geothermal resources.

Dr. David Blackwell (Southern Methodist University) has compiled geothermal resource data for the western U.S., based on heat flow, sediment thickness, thermal gradient and hot springs and identified areas of broad geothermal resources (Farhar and Heimiller, 2002, p. 9-10). His compilation map shows most of the western part of the planning area as being in a high development potential for geothermal resources (Farhar and Heimiller, 2002, Figure 1). Blackwell's area of high development potential larger area is more extensive than the Sevier thermal area and encompasses most of the Marysvale volcanic field.

At the south end of the Sevier Valley, two areas of hot springs are present—Monroe-Red Hill and Joseph (Map 12). In the 1970s, the Monroe-Joseph Known Geothermal Resource Area was classified on public land for the purposes of competitive leasing. However, the anticipated industry interest did not develop and the KGRA was de-classified in the early 1990s. The town of Monroe did complete gradient holes and deeper drilling at the Monroe-Red Hill springs in an assessment of the geothermal resource for direct heating. These springs are located along faults that serve as conduits for the geothermal fluids. The discharge temperatures are in the 62–82° C range at Monroe–Red Hill and 57–63° C range at Joseph (UGS, 2000b). The Monroe-Red Hill and Joseph hot springs apparently represent a mixture of thermal and non-thermal groundwater (Mabey, et al, 1987), and geothermal gradient calculations indicate a reservoir temperature of 100–160° C.

6. Oil Shale

Oil shale is a very fine-grained, dense, sedimentary rock that is rich in organic material. The organic material in these sediments can be converted into low viscous oil during thermal decomposition. In the planning area, oil shale deposits occur in the Green River Formation in Sanpete County and Sevier County (Map 11). These sediments were deposited in Eocene Lake Uinta.

Subject to Executive Order 5327, signed in 1930, part of the planning area was withdrawn for oil shale. The subject lands were withdrawn from lease or other disposal and reserved for investigation, examination, and classification. The initial executive order has been modified, in part, by subsequent Executive Orders and Public Land Orders. The prospectively valuable classification for oil shale is shown on Map 11, which coincides with the withdrawal. Limited information is available in the planning area with regard to the oil shale deposits, and the potential is not evaluated further in this report.

7. Potash and Salt

Saline deposits are loosely defined to include all minerals that have precipitated from waters of either marine or continental origin through evaporation (USGS, 1969). Saline potassium minerals, such as sylvite and carnallite, are often referred to as potash, and the most common sodium mineral is halite, which is composed of sodium chloride. Other valuable salts include potassium sulfate, sodium carbonate, sodium sulfate, and salts of magnesium, lithium, bromine, and boron. Within the planning area, salt deposits occur in the Arapien Shale in Sevier and Sanpete Valleys and in the Pennsylvanian Paradox Formation in the subsurface in the eastern part of the planning area.

Within the intensely deformed Arapien Shale of the Sevier and Sanpete Valleys, discontinuous beds and scattered pockets of red-to-white halite are common. The outcrop of the Arapien Shale is shown Map 13. Most of the salt is coarse-grained (Willis, 1986; Pratt and Callaghan, 1970; USGS, 1969). Because of the intense diapiric deformation that has affected the Arapien Shale, the orientation, distribution, and thickness of salt beds are highly variable and do not reflect the original distribution or thickness of the deposit. Outcrops of salt are discontinuous because of erosion and dissolution, and bedding planes (where visible) are usually steeply dipping. More commonly, however, salt occurs in structureless masses in the Arapien, where the erosion has left a residual red clay cover on vegetation-free slopes. Although extensive salt deposits are exposed at the surface in only a few locations, primarily in the Redmond Hills, it is assumed that they underlie extensive portions of the Sevier and Sanpete Valleys. In the

A wildcat well advanced by Phillips Petroleum near Moroni in the Sanpete Valley penetrated salt-bearing beds (Witkind, et al, 1987). Reportedly, 2,000 ft were penetrated in the subsurface by this well.

The rocks of the Pennsylvanian Paradox Formation contain 29 distinct evaporite cycles, each containing deposits of halite, sylvite, and other saline minerals (Stokes, 1986). Most of these deposits accumulated in the deepest part of the Paradox Basin, which is located to the east of the planning area in Grand and San Juan Counties. However, the Paradox Basin, which has traditionally been defined by the extent of salt deposition, extends in the subsurface into eastern Wayne and northeastern Garfield Counties. This area is shown on Map 13 as the limit of salt deposition in the Paradox Basin. In the Paradox Basin, the thickness of saline facies exceeds 1,000 ft in places (Stokes, 1986). However, within the planning area, these saline deposits are not exposed at the surface and underlie several thousand feet of Permian and Mesozoic strata in the planning area.

B. Locatable Mineral Deposits

1. Metals

Western Side of the Planning Area

Mineral deposits in the vicinity of Marysvale are associated mainly with rocks of the middle and upper Cenozoic age, which are the calc-alkine and bimodal episodes, respectively. The mineral deposits differ in the mineral assemblages depending upon the association with the two volcanic episodes. Epithermal gold mineralization is associated with the older, middle Cenozoic rocks, and gold, molybdenum, uranium, and base metal mineralization is associated with the younger, upper Cenozoic rocks (Steven, et al., 1978; Cunningham, et al, 1983; Rowley, et al, 2002).

The calc-alkaline plutons in the Tushar Mountains have associated propylitic and argillic alteration zones that contain pyrite-bearing quartz-carbonate veins (Cunningham, et al, 1984; Rowley, et al, 2002, p. 139). At the historic site of Kimberly, the Annie Laurie mine is the most significant deposit of this type. Other such deposits were worked at Deer Creek on the east side of the Tushar Mountains and at locations outside the planning area (Rowley, et al, 2002, p. 140).

Replacement alunite deposits are associated with the intracaldera, calc-alkaline plutons of the Monroe Peak caldera (Cunningham, 1984; Steven and Morris, 1987; Rowley, et al, 2002, p. 140). The overlying and adjacent volcanic rocks were intensely altered to argillic and advanced argillic zones by the plutonism and hydrothermal fluids to produce potassium- and alumina-bearing rocks (Cunningham, 1984; Steven and Morris, 1987; Rowley, et al, 2002, p. 140). Alunite deposits in the Sevier Plateau and the Antelope Range, respectively, east and northeast of Marysvale, and the Box Creek kaolinite deposit farther east of Marysvale are examples of this alteration type. The Central Intrusion is an intercaldera pluton that is large enough to be mapped in the Antelope Range (Cunningham and Steven, 1979) and formed in near-surface conditions with an interaction of hydrothermal fluids and evaporite-bearing strata, inferred to be in the subsurface. The near-surface reaction of the generated hydrogen sulfide with oxygen formed a strong acidic solution that altered the volcanic rocks, resulting in the precipitation and formation of alunite deposits. Two well-developed examples are the Whitehorse and Yellow Jacket Mines.

Uranium is the most important mineralization associated with the bimodal episode of volcanism and plutonism, and the mineralization is most prevalent in the Antelope Range in what is referred to as the Central Mining Area, northeast of Marysvale (Rowley, et al, 2002, p. 140). The principal uranium mineralization was deposited in veins that cut the Central Intrusion as well granite of the Red Hills caldera, and the primary ore mineral was pitchblende (Callaghan, 1973, p. 48).

Molybdenum is generally found with uranium increasingly in deeper zones. An association of uranium and molybdenum may be indicative of a deeper intrusive body, such as a porphyry-molybdenum disseminated deposit (Rowley, et al, 2002, p. 140). Also, the uranium, molybdenum, and hydrothermal alteration could be indicators of disseminated gold mineralization, and some exploration has occurred for epithermal gold in this area.

In the Mt. Belknap area, uranium has been found in veins associated with rhyolite dikes. However, uranium has also been associated with hydrothermal alteration of the fill material in the calderas (Steven, et al., 1978). According to the National Uranium Resource Evaluation report (Bromfield, et al, 1982), the Marysvale area has at least 60 uranium occurrences. The uranium deposits have either been deposited by the interaction of hydrothermal fluids with the host rock in the subvolcanic plutons or have been formed by the oxidation of the original rocks.

Southwest of Marysvale at Alunite Ridge and Deer Trail Mountain, respectively, alunite veins fill fractures that are up to 60 feet in width in a domed, radial fault system, and highly kaolinitized rocks are present with another distinct radial-fracture pattern (Rowley, et al, 2002, p. 140). An annular ring of base and precious metal deposits (copper, lead, gold, and silver) have been identified around the altered areas (Rowley, et al, 2002). Quartz veins containing gold and silver with minor amounts of base metals have been reported to cut the propylitized volcanic part of these rings. At the Deer Trail mine on the east side of Deer Trail Mountain, base metals form a replacement lead-zinc deposit in flat-lying carbonate rocks (manto) and precious-metal bearing veins cut the carbonate strata on the eastern side of the ring (Rowley, et al, 2002, p. 140; Beaty, et al, 1986). These deposits are associated with cupolas of stocks that are not exposed at the surface and may be the higher zones of a porphyry-type intrusion at depth (Rowley, et al, 2002, p. 140). At Bullion Canyon, lead, zinc, and copper, in addition to precious metals, are associated with veins and replacement deposits.

In addition, small deposits of iron and manganese are found in the vicinity of Marysvale. The Iron Duke magnetite mine is located 3 mi north of Marysvale on the south contact of the Central Intrusion (Cunningham and Steven, 1979; Callaghan, 1973). The magnetite occurs in irregularly shaped masses and veinlets and as disseminated grains in a contact-metamorphosed latite flow. The Iron Cap deposit is a magnetite-bearing, limonitic deposit in altered tuff breccias. Several small manganese oxide deposits occur either as small veins or as disseminations in volcanic rocks (Callaghan, 1973). These deposits are located in the Manning and Dry Creek drainages on the west slope of the Sevier Plateau. These deposits are generally associated with the bimodal episode, although the Iron Cap may be related to the calc-alkaline sequence.

The Lucky Boy mine, close to the Deer Trail mine, is an occurrence of mercury. The mercury was deposited as replacement mineralization in the Permian Toroweap Formation (Map 14).

Antimony occurs in the form of stibnite and secondary, oxidized, antimony-bearing minerals in Antimony Canyon. The canyon is located about 5 mi southeast of the town of Antimony in northwestern Garfield County (Map 14). These epigenetic stibnite deposits are hosted in limestone of the Paleocene Flagstaff Formation. Mineralization is related to the Paunsaugunt fault and also middle Tertiary igneous activity.

In the vicinity of Marysvale, placer gold has been reported on the east side of the Tushar Mountains in pediment and terrace gravels above the present-day Sevier River and in tributary streams. At the mouth of Bullion Canyon, placer gold has been recovered and is attributed to the gold-bearing veins that were eroded by the steams flowing therein. Placer gold has also been reported from other streams in the area.

In Sevier and Sanpete Counties, scattered mineral occurrences are reported and include lead-zinc, oxidized copper, mercury, and manganese. In Salina Canyon, lead-zinc mineralization is present in channel sandstone beds in the Flagstaff Formation, which unconformably overlies near-vertical beds of the Jurassic Twist Gulch Formation (Willis, 1986). In northern Sevier County and southern Sanpete County, low-grade lead-zinc mineralization is hosted in fractured calcareous sandstones, limy siltstones, and sandy limestones of the Green River, North Horn, and Crazy Hollow Formations and the Arapien Shale (Pratt and Callaghan, 1970; Witkind, et al, 1987). The manganese mineralization is associated with the Moroni Formation in northern Sanpete County.

Eastern Side of the Planning Area

During the Tertiary, numerous igneous stocks and laccoliths intruded the sedimentary strata of the Henry Mountains. As a result of rapid downcutting through the sedimentary strata, which range in age from Permian to Cretaceous, the Henry Mountains were exposed.

In the Henry Mountains, metallic occurrences are generally restricted to the stocks, contact zones, or shattered zones adjacent to the intrusions. The metallic mineralization in the Henry Mountains appears to be related to the hydrothermal process associated with the emplacement of the intrusive rocks in the area. Except for uranium and vanadium, metal production has been minimal. In general, alteration zones associated with the intrusions, hydrothermal process, and metamorphism of the

Small amounts of gold, silver, and copper have been produced from the Mt. Ellen (Bromide Basin) area. Most of these ores were from mineralized fissures. In addition, minor amounts of gold and other metals were produced from the laccoliths and igneous-sedimentary contacts as disseminated pyrite containing gold. Gold and copper mineralization in the Mt. Pennell area (Map 14) is associated with the diorite porphyry deposits.

In the Henry Mountains, copper mineralization occurs in association with gold and silver in quartz-filled fissure veins, primarily on the east flank of Mt. Ellen in the Bromide Basin (Maps 14 and 16). Minor copper is also found further south on Mt. Pennell and Mt. Hillers. Ore minerals include chalcopyrite and bornite with associated pyrite and specularite (Picard, 1980). In oxidized zones, chalcopyrite is altered to malachite and azurite, and pyrite and specularite are altered to limonite and hematite. Other ore-related minerals include chrysolcolla, molybdenite, and white zeolites. In addition, laccoliths and igneous-sedimentary contacts are locally mineralized with disseminated pyrite. Gangue minerals include sericitized feldspars, chloritized hornblende, calcite, and epidote.

On Miners Mountain, just west of Capitol Reef National Park in Wayne County (Maps 14 and 16), copper mineralization is spotty, occurring as irregular veinlets and fracture fillings in the Sinbad Limestone Member of the Moenkopi Formation and the underlying Kaibab Limestone. Mineralized zones are typically lenticular, with azurite and malachite the primary ore minerals, probably formed by the oxidation of disseminated chalcopyrite and bornite (BLM, 1977). Copper often occurs in association with epigenetic tabular uranium deposits, primarily in the Jurassic Salt Wash Member of the Morrison Formation and the Triassic Moss Back Member of the Chinle Formation. Although copper mineralization is found in these sandstones throughout the Henry Mountains district in eastern Garfield County, the Teasdale, Poison Springs, and Orange Cliffs areas (Maps 14 and 16) have the most copper in the planning area. In general, however, copper is present at lower concentrations in the radioactive deposits of Garfield County compared with similar deposits in Emery and San Juan Counties. Oxidized copper minerals, such as malachite and azurite, are the predominant ore minerals, but primary chalcopyrite, chalcocite, and bornite also occur. Perhaps the best copper showing in radioactive sandstone ores is in the Cedar Point group of uranium claims on the west side of the Dirty Devil River near its junction with Poison Springs Canyon (T. 31 S., R. 14 E., sec. 19). At this location, a fluvial channel sequence in the Chinle Formation trends southwesterly and is approximately 150 ft wide and 20 ft thick. This channel has 1- to 6-in-thick malachite bands that assay up to 11 percent copper.

Sandstone-hosted epigenetic ore deposits are the dominant type of uranium occurrence in the planning area, where mineralization is strongly controlled by the texture and architecture of the fluvial channel deposits. In most epigenetic deposits, uranium is leached from low-grade source rocks and transported to the site of accumulation by oxidizing surface water and groundwater and then precipitated from solution in a reducing environment. Consequently, uranium mineralization is a post-depositional, low-temperature phenomenon that is controlled by the Eh-pH conditions of the hydrologic system. Both the Salt Wash and Moss Back Members were deposited in an aggrading fluvial environment characterized by multiple channels with low sinuosity (i.e., braided) and a high frequency of avulsion (Galloway and Hobday, 1983). Within point bar and crevasse splay channel sequences, reducing conditions were typically accompanied by the presence of carbonaceous layers, lignite, asphaltite, or woody debris that could become partially replaced by uranium minerals (Picard, 1980; Trimble and Doelling, 1978). Minor uranium mineralization is associated with tar sand deposits in the Moss Back Member of the Chinle Formation and White Rim Sandstone of the Cutler Group in the Tar Sand Triangle.

Although sandy channel, point bar, and crevasse splay sequences are the dominant uranium hosts in the Salt Wash and Moss Back Members, coarse-grained facies (i.e., containing gravels and cobbles) are less likely to support proper reducing conditions necessary for uranium deposition. This, in part, explains why the Salt Wash Member provides the dominant uranium host in eastern Garfield County—it represents a more distal channel sequence deposited by Upper Jurassic streams flowing southeasterly from highlands in western Utah (Hintze, 1988; Munts, 1990). Further to the northwest in Wayne County, the Moss Back Member becomes the dominant uranium host, where it becomes finer grained and more distal from its source.

On the basis of a National Uranium Resources Evaluation (NURE) report (Lupe, et al, 1982), the areas most likely to contain uranium are characterized by the presence of fluvial deposits of a low-energy environment, structural features that enable erosion of sediment from the top of the features downstream, preferable directional flow movement from these structures, and lacustrine mudstone beds. In general, rocks deposited in offshore marine or in marginal marine to continental environments are unfavorable for uranium deposits (Peterson et al, 1982). The Salt Wash Member of the Morrison Formation is considered the most favorable unit for uranium deposits in the planning area. The Morrison Formation crops out in many areas of the Henry Mountains area and is characterized by gently folded topography. In the planning area, these rocks are exposed primarily to the east of the Henry Mountains in Garfield County and to a lesser degree, west of the Henry Mountains in Wayne County (Maps 14 and 16).

The discovery of lode gold in the Henry Mountains was preceded by the 1883 discovery of gold placers along the banks of the Colorado River, near present-day Hite. The most important Henry Mountains' placers were located on the east side of Mt. Ellen in the fanglomerates and Holocene stream gravels on either side of Crescent Creek (Picard, 1980). Placers were found as both coarse-grained gravels on benches and mesas and in well-sorted sands on stream banks and channels (UGMS, 1966). Because of limited physical and chemical weathering associated with short, sediment-transport distances and the arid climate, coarse-grained placers are not entirely freed from their associated gangue minerals, making recovery somewhat difficult. Conversely, the black sands that accompany the fine-grained placers on the Colorado River typically contain a variety of other resistant economic minerals, including magnetite, ilmenite, chromite, garnet, barite, zircon, and platinum.

Placer gold has also been reported in Straight Creek, which drains the eastern flanks of Mt. Pennell. However, only the area along Crescent Creek has recorded commercial gold production (Picard, 1980). On the southwest flank of Mt. Hillers near Indian Springs Bench (T. 34 S., R. 11 E., sec. 17), a fluvial channel sequence has been identified in the Upper Cretaceous Ferron Sandstone Member of the Mancos Shale (Maps 14 and 16). The channel is exposed in an outcrop that extends for more than 1,500 ft, averages 3 ft in thickness, and reaches a maximum width of 100 ft (Picard, 1980). Primarily of interest because of the titanium minerals present, this deposit also contains zircon, magnetite and minor gold along with framework grains of quartz and feldspar set in a predominantly iron or hematite cement.

2. Non-Metals

Gypsum

Gypsum is formed by the evaporation of seawater and precipitation of calcium sulfate, whereby it is one of the first in a sequence of evaporite minerals to form. Calcium sulfate is originally deposited as anhydrite, but hydration by infiltrating surface and groundwater transforms it into gypsum. In the semiarid climate of Utah, hydration seldom penetrates more than 30 ft below the surface, and in many places, gypsum is mixed with anhydrite in outcrop (Willis, 1986). Gypsum frequently occurs interbedded with limestone and calcareous shales.

In the planning area, gypsum occurs in Garfield and Wayne Counties in the Carmel, Summerville, and Moenkopi Formations and in Sevier and Sanpete Counties in the Arapien Shale in the Sevier and Sanpete Valleys. Map 13 shows the outcrop the San Rafael Group in the eastern part of the planning area and the equivalent Arapien Shale in the western part of the planning area. These gypsum-bearing formations are represented by the J1 map unit of Hintze and others (2000), which includes formations that are not gypsum bearing, but for the scale of display on Map 13, represents the general location of gypsum-bearing formations in the planning area.

Thick deposits of complexly deformed calcareous mudstone, siltstone, and sandstone, along with thick beds of gypsum and salt were deposited in a Jurassic basin in central Utah, which is represented by the Arapien Shale on Map 13. The Arapien Shale is intensely deformed by diapiric and/or tectonic processes, and the total thickness of the Arapien Shale is uncertain but may exceed 13,000 ft (Witkind, et al, 1987). Individual gypsum beds average 25 feet in thickness but can be as much as 100 feet thick. As shown on Maps 6 and 13, the Arapien Shale is exposed along the east side of the Sevier Valley from Richfield in the south to the Sanpete Valley near Manti in the north. In addition to these outcrop exposures, the Arapien Shale underlies an extensive area of central Utah beneath the Sevier Valley and the Wasatch, Sevier, and Gunnison Plateaus (Witkind, et al, 1987).

In the eastern part of the planning area, gypsum is deposited in the upper part of the Carmel Formation, where it is interbedded with reddish-brown, shaly siltstone, and less commonly in upper part of the Summerville Formation as thin interbeds. These formations crop out primarily on the east and west limbs of the Henry Mountains syncline (Maps 6, 7, and 13). Both formations were deposited in tidal flat environments during the Jurassic. Most of the gypsum beds in eastern part of the planning area are impure with silt and fine-grained sand. These gypsum deposits are considered undesirable for plaster or wallboard, but are still amenable for use as a cement additive or as a soil conditioner. Overall, resource-grade gypsum beds in the Carmel Formation range from 3 to 30 ft in thickness (USGS, 1969; Doelling, 1975).

The Triassic Moenkopi Formation also hosts thin, discontinuous gypsum beds in eastern Wayne and Garfield Counties; however, they are unsuitable for mining compared with other areas in Utah (USGS, 1969). Localized beds, lenses, and nodules of gypsum also occur in the Morrison and Curtis Formations, but these are insignificant from an economic perspective as well.

The Pennsylvanian Paradox Formation in the eastern part of the planning area also contains gypsum beds. These gypsum beds are not exposed at the surface.

C. SALABLE MINERAL DEPOSITS

1. Sand and Gravel

Unconsolidated deposits of sand and gravel are widespread throughout Utah and represent a virtually inexhaustible supply of this resource. In the planning area, sand and gravel occur primarily as unconsolidated Quaternary sediments (Map 17). These materials are found in five different types of mapped units:

- Alluvium and colluvium (Qa)
- Older alluvium and colluvium (Qao), including pediment deposits
- Glacial (Qg)
- Landslides (Qls)
- Eolian (Qe)Glacial (Qg)
- Landslides (Qls)
- Eolian (Qe)

In addition, authorized sites (free use, community pits, and exclusive sales) on public land for sand and gravel and occurrences of sand and gravel from the UMOS data base are shown on Map 17. The authorized sites are from the BLM LR 2000 data base for mineral materials. The displayed free-use sites on Map 17 are for county road departments, and the displayed sites do not include authorizations for the Utah Department of Transportation or Federal Highways Administration.

Unconsolidated alluvial material has been deposited along virtually every river and stream course in the planning area and also has been deposited as terraces and as alluvial fans. In the Sevier and Sanpete Valleys, most of the alluvial material was deposited as broad, low fans that have coalesced to form extensive aprons. Although recent alluvial deposits adjacent to active stream courses can provide quality sand and gravel, particularly in the eastern part of the planning area, such deposits are often inaccessible on the floors of steep-sided canyons.

Deposits mapped as older alluvium and colluvium occur mainly as pediments. Landslide deposits are adjacent to the steeper slopes of mountain ranges. Glacial deposits are also a potential source of sand and gravel and occur mainly in the mountain ranges of the western part of the planning area on National Forest. As shown on Maps 6 and 17, eolian sands are mapped in eastern part of the planning area.

Because Map 17 was derived from the Geologic Map of Utah, published at a 1:500,000 scale, many of the smaller unconsolidated Quaternary deposits do not appear on the map. For this reason, the outline of the principal modern stream and river courses in the planning area is also shown on Map 17. Also, not shown on Map 17are the sand deposits of Pleistocene Lake Bonneville exposed near the Sevier Bridge Reservoir.

In the western part of the planning area, weathered shales of the Arapien Shale and Flagstaff Formation are present generally wherever these formations crop out. The softness and friability of the material depends on the degree of weathering. The shale has been considered a sand and gravel and has been disposed as fill material, used in livestock feed lots. However, the material has been an inferior road base material or construction aggregate. The better grade material is colluvial rather than alluvial.

Talus of unconsolidated, angular clasts have been deposited at the base of steeper cliffs and have been weathered in place as colluvial material. These deposits are small, scattered and isolated and are generally not easily accessible.

In addition to the unconsolidated deposits, the Tertiary Sevier River Formation in the western portion of the planning area has been used for sand and gravel (Callaghan, 1973), and the Triassic Moenkopi Formation and the Jurassic Carmel Formation in the eastern part of the planning area have been used (Doelling, 1975).

2. Clay Including Alunite

Clay is a clast size and a class of minerals that have variable chemical composition and mineral structure. Clays are less than 0.004 millimeters in diameter and include minerals such as ilmenite, and montmorillionite. Under the federal mineral laws, clay is usually considered a salable mineral, but in certain circumstances, may be locatable or leasable. For convenience, all clays are discussed under this heading.

Clays are used for a variety of commercial and industrial purposes, including bricks, drilling and quarrying mud, sealants, liquid dyes, paints, china, ceramics, absorbents, molecular sieves, fillers, binders, cosmetics, and inert ingredients in pharmaceutical tablets. The end use of the clay is determined by its physical properties and purity. Physical properties that determine clay usage include plasticity, bonding strength, color, vitrification range, deformation with drying and heating, gelation, crystal structure and size, viscosity, and swelling capacity (USGS, 1969). The quality of bentonite largely depends on its swelling capacity. High-swelling bentonite is primarily used by the petroleum industry as a component of drilling mud and by the iron industry as a binder in casting molds and casts.

On Map 18, clay occurrences are shown as obtained from the UMOS data base. These occurrences include any reported clay as well as alunite without differentiation.

Alunite [$KAl_3(SO_4)_2OH_6$] is a hydrous sulfate of potassium and aluminum that typically occurs in hydrothermally altered volcanic rocks. It is commonly white, gray, or pink and is found as both coarsely crystalline aggregates (veins) and dense, compact earthy masses (replacements) resembling clay. In its pure form, alunite contains 11.37 percent potassium oxide, 36.92 percent alumina (19.53 percent aluminum metal), 38.66 percent sulfur trioxide, and 13.05 percent water (Callaghan, 1973). The grade of alunitic deposits vary considerably.

Most of the alunite deposits in Utah are found in the vicinity of Marysvale, where both vein- and replacement-type alunite deposits are present. As a clarification, alunite was also discussed under metals, since the hydrothermal, acid-sulfate alteration is an indicator for metallization. In this section, alunite, itself, is considered as a mineral commodity. A zone of alunite deposition is shown on Map 18. This zone includes hydrothermal alteration clays, such as alunite and kaolinite, and also includes the vein-type alunite. Principal replacement-type alunite deposits are located in the Antelope Range, north of Marysvale, and are associated with the Central Intrusion. These deposits predominately contain potassium alunite, but subordinately contain the sodium variety, natroalunite (Callaghan, 1973). As previously addressed, the vein-type alunite in the planning area is concentrated on the east side of the Tushar Mountains. This alunite zone, as shown on Map 18, has other associated alteration clays, primarily kaolinitic clay. In addition, to the zone of alunite deposits shown on Map 18, kaolinitic occurrences are found at Box Creek on the Sevier Plateau and in Mill Creek in the Tushar Mountains.

Bentonitic clays are found at Kingston Canyon and the Redmond Hills. At both of these locations, the clay is associated with volcanic rocks of the Marysvale volcanic field. The deposits are relatively small in areal extent.

Fuller's earth is found near Aurora. Fuller's earth is a hydrated aluminum silicate and is mostly likely related to the Marysvale volcanic field at this location. The known deposits are small in areal extent. In addition, in the Sevier and Sanpete Valleys, clay may be associated with the Arapien Shale.

In the eastern part of the planning area, bentonitic clays are found in the Chinle Formation and the Brushy Basin Member of the Morrison Formation (Map 18). Clay also occurs in the Dakota Sandstone and Mancos Shale, which are not shown on the map. The UMOS data base only included one clay occurrence, so these formations are shown on Map 18 as areas that may have clay minerals.

3. Stone and Industrial Minerals

Rocks, particularly granite, limestone, and sandstone, have been quarried throughout Utah for various purposes, including dimension stone, building stone, crushed rock, fieldstone, landscape rock, railroad ballast, concrete aggregate, road stone, and riprap. Limestone is also quarried for use as an acid neutralizer, coal mine dust retardant, smelting flux, flue gas scrubber, cement, sugar manufacture additive, and refractory material. Sandstone (i.e., silica) can be used as an abrasive and for glass making, filters, fluxes, chemicals, and electronics. Volcanic tuffs in Sevier and Sanpete Counties have also been quarried for use as dimension stone, crushed for lightweight aggregate in the manufacture of building block, and used as a soil amendment or as nutritional supplement for certain livestock animals, primarily poultry.

Table 4 summarizes the terminology and nomenclature for various types of stone used commonly in construction. Most of the stone quarried in Utah and in the planning area is used by the construction industry for either building stone, aggregate (crushed rock), or cement (pulverized limestone).

Table 4. Quarried Stone Nomenclature – Economic Use

Stone Name	Description
Dimension Stone	Stone that is quarried and cut in accordance with required dimensions for structural and decorative purposes. Dimension stone can be either rough or in finished form and includes blocks, sheets, and slabs.
Flagstone	A rock that splits readily into slabs suitable for paving walks and terraces.
Fieldstone	Cobbles or boulders that are used as is, split, or roughly trimmed. Commonly used to veneer walls and construct chimneys and often found in coarse alluvial deposits at the mouths of canyons. Pickup rock is a form of fieldstone.
Building Stone	A general term describing any rock that is suitable for quarrying and constructing buildings. Often used synonymously with dimension stone but may include flagstone and fieldstone.
Decorative Stone (Ornamental Stone)	Any stone that is attractively colored or banded that is used for walls, fireplaces, landscaping, and special architectural effects. Artistic patterns in some decorative stone, including limonite staining, are called picture rock.
Crushed Rock	Rock that is crushed or pulverized for construction purposes or industrial applications.

Stone quarries are found throughout Utah and are generally small-scale operations. Transportation cost is a factor in the location of quarries. Although virtually any rock material is potentially amenable for use as a construction material, limestone, sandstone, and volcanic rock are the principal materials that have been quarried in the planning area.

In the western part of the planning area, stone has been quarried from the following formations for the specified use:

- Limestone of the Green River Formation—building stone
- Sandstone of Crazy Hollow—building stone
- Limestone of the Flagstaff Formation—rock dust, kiln material, and cement manufacturing
- Tuff of the Moroni Formation—poultry feed and agricultural uses
- Tuff of the Joe Lott Tuff—building stone and crushed aggregate as a insulating block
- Tuff of the Bullion Canyon Volcanics—decorative rock (landscape, aquarium display)

The above formations are shown on Map 19. The Crazy Hollow Formation is shown as T3; the Green River Formation as T2; the Flagstaff Formation as T1; and the Moroni Formation as Tov.

Limestone in the Green River Formation in the Sanpete and Sevier Valleys is a desirable building stone and is presently being quarried. The limestone beds are white to light brown and range in thickness from a few inches to a few feet. The stone is quarried as flagstone and cut stone. Most of the commercial operations are on state or private land; however, the BLM has one authorized community pit for limestone from the Green River Formation, northeast of Gunnison.

Tuffs of the Bullion Canyon Volcanics have been quarried as decorative stone in the Antelope Range. This rock is color banded and used for decorative purposes.

The Joe Lott Tuff, which crops out in southern Sevier County, has been quarried as a building stone and tested as a lightweight aggregate. The unit is a crystal-poor, partially welded, rhyolite ash-flow tuff with dominant colors that include light gray, tan, reddish brown, and light green.

Tuffs of the Moroni Formation in Sanpete County have been prospected for agricultural uses. Sandstones in the Moroni Formation have had limited use as building stone.

Limestone of the Flagstaff Formation has been quarried for industrial purposes that include rock dust, flue-gas, desulphurization in coal-fired plants, and cement manufacturing. Past operations have been on the west side of the Wasatch Plateau in the hogback ridges, although the principle commercial operation has been on state land east of Redmond. Limestone in theValley Mountains has been prospected for desulphurization, coal-rock dusts and agricultural applications. A commercial quarry recently began production at Scipio Lake in Juab County.

In the eastern part of the planning area, stone has been quarried from following formations for the following uses:

- Sandstone of the Moenkopi Formation—building stone
- Navajo Sandstone—decorative stone

The sandstones of the Moenkopi Formation are light brown to red, range in thickness from a few inches to a few feet, and are quarried as flagstone and cut stone. Most of the operations are located on BLM land. Interesting ripple-marked, mud-cracked, and limonite-stained surfaces make this material prized for ornamental use as well. The Navajo Sandstone near Teasdale has been prospected as a decorative stone.

In addition to quarrying of stone, the public has utilized pick-up stone or field stone. This material is generally boulders or cobbles and is present in numerous locations in the planning area. The areas, which have the most use for collection, are generally close to the population centers, and the material of interest has mainly included basalt, tuff, sandstone, or limestone. The demand has been relatively low and the material is disposed in small tonnages. Although field stone is present throughout the planning area, the principle areas of interest have been in the Sevier Valley and near Loa (Map 17).

Paleozoic and Mesozoic sandstone and Quaternary eolian deposits in the eastern part of the planning area have a potential use as sources of silica. The formations of interest include the White Rim Sandstone, Wingate Sandstone, Kayenta Formation, and Navajo Sandstone. In addition, outcrop of the Navajo Sandstone near Monroe has also been evaluated as a potential source for silica. Potential uses for silica include abrasive or grit for sandblasting, glass making, foundry material, filters, fluxes, chemicals, and electronic components.

4. Humate

Humates are essentially carbonaceous shale associated with weathered coal beds. The quality of the humate increases with increasing humic acid content, which typically increases with weathering.

Most of the humate mined in Utah comes from the Coal Cliffs area of southwest Emery County, where coal-bearing strata of the Ferron Sandstone Member of the Mancos Shale (specifically the G bed) crops out. However, coal-bearing strata of the Ferron Sandstone are also exposed around the perimeter of the Henry Mountains syncline. Currently there are three active humate mines: two on BLM land and one on state land in northern Wayne County near Factory Butte.

The material is mined as a dietary colloidal mineral supplement and as a soil amendment for gardening and farming applications. Humate increases the water holding and ion exchange capacity of the soil, aids in nutrient uptake of the plant via the humic acids, and acts as a pH buffer for alkaline soils

5. Other Minerals

Oyster shell from the Dakota Formation has been used for road surfacing in Wayne County and has also been used for agricultural applications. Semiprecious gemstones are found principally in the eastern part of the planning area and include petrified wood, jasper, agate, and chalcedony in the Morrison and Chinle Formations. Alabaster and selenite are found in the Carmel Formation, and specimen-grade selenite crystals have been mined from the Carmel Formation in Cathedral Valley in northern Wayne County.

3.2 MINERAL EXPLORATION, DEVELOPMENT, AND PRODUCTION

This section discusses the history of mineral exploration, development, and production in the planning area and the economic significance of each mineral commodity. The potential for the occurrence and the likelihood of development of these resources in the next 15 years are discussed in Section 4.

A. Leasable Mineral Deposits

1. Coal Bed Methane Gas

The CBM industry is relatively young, but it shows great potential as a major energy source in the United States as production has increased rapidly over the past 5 to 10 years. Overall, CBM accounts for 7.5 percent of the total natural gas production in the United States and 30 percent in Utah, but those figures are expected to rise significantly over the next several years (USGS, 2000). The USGS conservatively estimates that more than 700 trillion cubic feet (tcf) of CBM exists in the conterminous United States and that perhaps 141 tcf are recoverable using existing technology (USGS, 2000). This estimate has risen significantly during the last few years. For example, during its 1995 assessment, USGS estimated that about 300 tcf of CBM may exist nationwide, with 50 tcf being technically recoverable.

CBM is produced in Emery and Carbon Counties with commercial production beginning in 1991, although minor production had occurred prior to that in underground coal mines. The CBM production is from the Ferron Sandstone in the Wasatch Plateau-Emery play. Overall, Carbon County was Utah's third-leading producer of natural gas in 2002 with 99 percent of this production derived from CBM wells. The Wasatch Plateau–Emery Play is rapidly becoming one of the most productive CBM areas in the United States with approximately 900 active wells producing as of December 2002.

The southwest extension of this play, the Ferron Trend, extends into the planning area; however, development of CBM has not occurred in the planning area. One test well has been drilled in the planning area. In 1994, a stratigraphic test well was spudded at T. 21 S., R. 5 E., sec. 36, and the well was subsequently plugged and abandoned.

The gas content of the Ferron coal beds may decrease southward from the Drunkards Wash Field in Carbon County (Lamarre, 2001; Utah Geological Survey, 2004); and Nuccio and Roberts (2003, p. 32) show vitrinite reflectance values of less than 0.60 at the base of the Mancos Shale in much of the eastern and southern parts of the Wasatch Plateau. Higher values are indicated for parts of the Wasatch Plateau in Sanpete County than in Sevier County. These data suggest that the potential for CBM occurrence may decrease southward into Sevier County.

2. Oil and Gas

Hydrocarbon exploration in the planning area dates back to the early 1910s. Based on well data for 2003 from HIS Energy Group (an industry service), more than 200 oil and gas wells have been drilled in the planning area (Map 10). Although the wells are displayed on a map showing the USGS-defined plays, a well shown within the boundary of a play on this map does not necessarily indicate that the well was targeting a formation in that play. As previously stated, the formations in different plays are based on formations at different positions in the stratigraphic column, and more than one play could be in a geographic area. A tabulation of the wells, including the target formations, is in Attachment 3. The wells are listed by county, and the list includes all wells regardless of land ownership.

In Wayne County, 78 wells have been drilled and targets have included the Tapeats, Lynch Dolomite, Devonian (Elbert and Ourary), Mississippian (Redwall, Leadville, Madison), Hermosa Group (Pinkerton Trail and Paradox), Cutler Group (Elephant Canyon, Cedar Mesa, and White Rim), Kaibab, Moenkopi, Shinarump, Wingate, and Mesa Verde. These targets are in the Paradox Basin, except for the Shinarump, Wingate, and Mesa Verde. Oil shows were reported in the Lynch Dolomite, Mississippian, Hermosa (including Paradox), White Rim (Coconino), Kaibab, and Moenkopi (including Sinbad), Shinarump, and Navajo. One well (A-1 USA Sorrel Butte) reported a production of 10 BOD as a test. Gas shows were reported in Tapeats, Elbert, Mississippian, Hermosa (including Pinkerton Trail and Paradox), Cutler Group (including Elephant Canyon, Cedar Mesa, and White Rim), Kaibab, and Moenkopi (including Sinbad). In one well (1-27 Tanner) 170,000 mcf of gas/day was reported from the Elbert Formation as a test.

In Garfield County, 49 wells have been drilled and targets have included the Devonian, Mississippian, Hermosa Group (Paradox), Cutler Group (White Rim and Cedar Mesa), Moenkopi (including Sinbad), Shinarump, and Wingate. Shows were reported in the Mississippian including Madison, Hermosa (Paradox and Akah), Cedar Mesa, Dakota, and Mancos (including Tununk and Ferron). The wells were drilled to targets in formations of plays of the Paradox Basin province.

In Sevier County, 28 wells have been drilled, targeting Paleozoic and Mesozoic formations. Most of the wells have been drilled into the Cretaceous Sandstone play in the northeastern part of the county. However, formations in the Sevier Frontal play have been targeted, as well as deeper formations in the Permo-Triassic Unconformity play and older formations in the Paradox Basin play. Shows have been reported in the Mississippian, Permian (Coconino and Kaibab), Triassic (Moenkopi and Shinarump), Jurassic (Navajo), and Cretaceous (Dakota). A producing field is now present, based on production from the Navajo Sandstone, as discussed below.

Of the 47 wells drilled in Sanpete County, most were targeting Cretaceous sandstones, including the Dakota, Ferron, Emery, and Star Point. Gas shows as great as 8,200 mcf/day in the Ferron and 4,000 mcf/day in the Dakota have been reported in several wells in the eastern part of the county in the Cretaceous Sandstone Play. In addition, in the Tununk Formation, 1,350 barrels of oil and 300 mcf of gas during 8 days of testing were reported in one well, and 1 barrel of oil per day in another well in the same section in Sanpete Valley.

In Piute County, 4 wells have been drilled targeting the Mississippian, Kaibab, Twin Creek, and Ferron. No hydrocarbon shows were reported in any of the wells drilled. The wells have been drilled in an igneous terrane, and the influence of heat related to the Marysvale volcanic field is uncertain. The heat source could have caused over maturation of hydrocarbons, or conversely, could have promoted maturation. Drilling of 4 wells is only a minimal testing of an area.

The Utah Department of Natural Resources, Division of Oil, Gas, and Mining (UDOGM) defines an active field as one that contains one or more active wells, which includes those with a producing, shut-in, or temporarily abandoned status.

In 2003, a new, unnamed field was discovered in Sevier County. One well is producing oil on fee land, another well has been drilled on federal land, and additional wells are under permit to be drilled in late 2004 and in 2005. Production is from the Navajo Sandstone in the Sevier Frontal play. These wells are not included in Attachment 3.

Historically, Joes Valley was a producing field in Sanpete County (Table 5). The federal land within this field is administered by the Manti-LaSal National Forest. The production was established from the Ferron Sandstone in the Cretaceous Sandstone play. All past-producing wells have been abandoned; however, there has been some recent applications and drilling for new reservoirs in this area on this play.

Producing oil and gas fields are located outside the planning area, but production is established from formations that could be potential targets in the planning area (Table 5).

Table 5. Oil and Gas Fields in or Adjacent to the Planning Area

Field Name	Status	County	Major Producing Formation(s)	2000 Production		Cumulative Production	
				Oil (bls)	Gas (mcf)	Oil (bls)	Gas (mcf)
EASTERN GREAT BASIN PROVINCE							
Sevier Frontal Play							
Unnamed	Active	Sevier	Navajo	New field with initial production in 2004.			
UINTA-PICEANCE PROVINCE							
Cretaceous Sandstone Play							
Joes Valley	Abandoned	Sanpete	Dakota and Ferron	0	0	0	3,027,183
Clear Creek	Active (17)	Carbon and Emery	Ferron Sandstone	0	406	0	114,376,742
Flat Canyon	Active (6)	Emery	Ferron and Dakota	632	264,899	15,351	9,160,240
Ferron	Active (21)	Emery	Ferron Sandstone	0	0	38,470	11,553,006
PARADOX BASIN PROVINCE							
Permo-Triassic Unconformity Play							
Upper Valley	Active (25)	Garfield	Kaibab Limestone	206,270	9,125	26,309,965	28,198
Last Chance	Active (4)	Emery	Moenkopi	0	6,600	0	7,350
Porous Carbonate Buildup Play							
Greater Aneth	Active	San Juan	Desert Creek and Ismay Zones of Paradox Formation			307,359,102	336,048,973
Fractured Interbed Play							
Bartlett Flat (Kane Springs Unit)	Active	Grand and San Juan	Cane Creek Zone of Paradox Formation			341,640	318,794
Faulted Anticline Play							
Lisbon	Active	San Juan	McCracken Sandstone of Elbert Formation			49,521,469	590,954,080

Notes:
The number in parentheses represents the number of active wells (including producing, shut-in, and temporarily abandoned).
Source: UDOGM web site (2002). Information on Sevier Frontal play from *The Rocky Mountain Oil Journal (2004)*

Two of the above-listed fields—unnamed and Joes Valley—are in the planning area. The unnamed field is in the Sevier Frontal Play and was discovered in 2003 by the drilling of the Kings Meadow Ranch 17-1 at T. 23 S., R. 1 W., sec. 17. The field is in the

Central Utah thrust belt (Moulton and Pinnell, 2004). The Joes Valley field is located at T. 15 S., R. 6 E., sec. 17 on the Wasatch Plateau in eastern Sanpete County. The field was discovered in 1956, and conventional gas was produced from the Ferron Sandstone that is complex faulted in the Joes Valley graben.

The other fields listed in Table 5 are outside of the planning area; however, these fields produce from formations that are present in the planning area. Wells drilled in the planning area have targeted these formations with reported hydrocarbon shows (Map 10; Attachment 3). The Upper Valley and the Last Chance fields are the two that are closest to the planning area. The Upper Valley produces oil from the Kaibab Limestone, while the Last Chance has producible gas in the Moenkopi Formation. Both fields are included in the Permo-Triassic Unconformity play and have anticlinal, structural traps.

3. Tar Sands

The tar sand deposits in Utah are estimated to contain approximately 25 to 30 billion barrels of bitumen in place, a figure that roughly equals one-fourth of the recoverable crude oil reserves in the United States (UGS, 1996). The Tar Sand Triangle contains an estimated of 12–16 billion barrels of oil, and the Circle Cliffs (East Flank), 860 million barrels. (Ritzma, 1979).

Primarily in the 1970s, exploration wells were drilled in the Tar Sand Triangle and the Circle Cliffs in the planning area. More than two dozen wells have been drilled to targets in formations containing tar sand deposits. In 1980, the Combined Hydrocarbon Leasing Act allowed for the leasing of hydrocarbons under a combined hydrocarbon lease that included conventional oil and gas and bituminous tar sands, and existing oil and gas leases were to be converted to a combined hydrocarbon lease. However, an environmental impact statement, being prepared by the BLM and NPS, was not completed, and the price of oil dropped in the mid-1980s. Through the 1990s, interest in bituminous tar sands declined.

4. Geothermal Resources

Geothermal resources may be used to generate electricity or simply as a direct source of heat. However, because heat dissipates quickly, hot water cannot be transported far from its point of recovery without severe temperature loss. The maximum transport distance depends on the initial enthalpy of the liquid and its intended use. Although higher enthalpy fluids can be used to generate electricity, those with a lower enthalpy can only be used directly, most commonly for space heating or bathing.

Geothermal exploration wells have been drilled near the Monroe—Red Hill hot springs at the town of Monroe in the Sevier Valley in the early 1980s. A pump test was completed and was not favorable for the development of geothermal resources for direct use, because the water had low-enthalpy, the reservoir rocks had low aquifer transmissivities and production capacities, and development and maintenance costs were estimated to be uneconomic (Hulen et al, 1981). The drawdown from the pump test caused an influx of colder water into the well. However, the thermal gradient as measured in gradient holes is favorable for geothermal resources.

In the 1970s, a Known Geothermal Resource Area (KGRA) was established by the U.S. for federal leasing in the Sevier Valley and encompassed the Monroe—Red Hills springs as well as the Joseph hot springs. The KGRA was established to require competitive leasing in an area with favorable potential for development of the resource. As no competitive interest materialized, the KGRA was declassified in the early 1990s.

Development of geothermal resources in the planning area is limited to the hot springs at Monroe and at Richfield. At Monroe, spring water is used for heating a resort swimming pool. In addition, a spring at Richfield is used to heat the city's swimming pool.

In Beaver County, geothermal resources are developed for electrical production at two locations: south of Cove Fort and east of Milford. Power facilities have utilized the resource for commercial power production. These two plants are located along fault-bounded ranges in the Sevier thermal area of the eastern Basin and Range.

5. Salt

In 2001, saline evaporite minerals were the largest contributor to the value of industrial minerals production in Utah, with a combined value of approximately $172 million (UDOGM, 2002). By far, most of this production has come from surface brines and shallow subsurface deposits at the Great Salt Lake in northern Utah.

Salt mining has a long history in the Sevier Valley, dating back to 1879; it was the first mineral resource produced in the valley. Salt has been prospected at several locations in the Arapien Shale in the Sevier and Sanpete Valleys, but there is only one mine now operating, which is RCS Salt.

The RCS salt mine is located near Redmond at T. 20 N., R. 1 W., sec. 25, and is operated by Redmond Minerals, Inc. (Map 13). The RCS mine is the only current salt-producing mine besides those on the Great Salt Lake (UGS, 2002). At the RCS mine, it is difficult to estimate salt reserves because of the irregular and contorted nature of the deposits. The salt-bearing strata in the Redmond Hills are estimated to be at least 1,000 feet thick based on a well completed by Chevron USA (Willis, 1986). Although salt exposures in the Arapien Shale are sporadic at the surface, they are thought to underlie extensive portions of the Sevier and Sanpete Valleys.

As previously stated, the Paradox Basin is mapped in the subsurface, based on salt-bearing formations, in the eastern part of the planning area. East of the planning area, potash minerals are mined from the Paradox Formation at the Cane Creek Mine in Grand County. There are no known current or historic saline mines in the portion of the Paradox Basin in the planning area (UGS, 1996). This is because evaporite deposits rapidly thin west of the Green and Colorado Rivers, and overburden thickens under Permian and Triassic sedimentary cover. The extent of the subsurface salt deposits, which are part of the Paradox Basin in the planning area, are shown on Map 13.

B. Locatable Minerals

1. Metals

Historically, metallic resources that have been prospected and/or developed include uranium, gold, lead, zinc, copper, mercury, antimony, iron, and manganese. In the western part of the planning area, exploration and development has been largely focused on the igneous terrane of the Marysvale volcanic field, especially in the Tushar Mountains and the Antelope Range. In the eastern part of the planning area, gold and copper exploration has been focused on the igneous rocks of the Henry Mountains, proper, and the intruded sedimentary strata. Uranium exploration and development in the eastern part of the planning area has been focused on Mesozoic sedimentary formations in the Colorado Plateau. Vanadium and other radioactive minerals are associated with the uranium mineralization in many deposits, and in the eastern part of the planning area, copper is also deposited with the uranium. Although metal exploration and development has a long and rich history, production is small compared with overall state totals, and few mines are currently active. In Piute County, a late-1800s gold and silver boom spawned the creation of towns such as Marysvale, Bullion, and Kimberly and later growth was spurred by the development of lead, zinc, alunite, and uranium resources. Mining districts are shown on Map 14, and mineral occurrences for selected metals are shown on Maps 15 and 16.

Western Part of the Planning Area

Historically, mining districts were established to regulate mining within prospecting areas. In the vicinity of Marysvale within the planning area, five mining districts were established in the Tushar Mountains, which are: 1) Mt. Baldy, 2) Ohio, 3) Gold Mountain (also known as Kimberly or Gold Hill), 4) Henry (also known as Central), and 5) Gordon. Near Antimony, the Coyote district (also known as the Antimony district) was also established. These historic mining districts are shown on Map 14. Mining districts, in addition to the regulatory aspect, were often established on similar styles of mineralization. Callaghan (1973) provides an account of the mineralization and the development of mines within each mining district. Most historic mines in this region were underground workings.

The largest historic mines in the Marysvale volcanic field were the Annie Laurie mine in the Gold Mountain district, the Deer Trail in the Mt. Baldy district, and the VCA in the Henry district. The Annie Laurie Mine and the Deer Trail Mine account for most of the historic precious metal production in this region, and the VCA mine was the principle one for uranium. The Deer Trail has also been the principle producer of base metals.

The Annie Laurie mine at T. 27 S., R. 5 W., sec. 11, was developed on gold mineralization associated with the calc-alkaline igneous episode of the Bullion Canyon Volcanics. All developed ore was in the oxidized horizon of the ore body, where volcanic rocks are cut by a quartz vein that is up to 20 feet in width. The Annie Laurie cyanide processing mill was built in 1899 and worked continuously until 1908. Production was intermittent from 1908 until 1917, the mine was closed from 1917 until 1931, and production resumed in 1931 and continued until 1937 at less than the capacity of the mill. Maximum production came in 1902 when 78,946 tons of ore were processed, yielding 23,306 oz of gold and 69,223 oz of silver, for an average gold grade of 0.3 oz/ton (Callaghan, 1973). Total production is estimated at 127,000 oz of gold and 458,500 oz of silver during the historical operating life of the mine from the 1880s to the 1930s (Steven and Morris, 1984; Shubat, et al, 1991). Adjacent to the Annie Laurie was the Sevier mine which had less production in a similar ore body.

The Deer Trail Mine at T. 28 S., R. 4 W., secs. 11 and 12, was developed on oxidized ore for gold and replacement mineralization in limestone (a manto) for lead, zinc, and gold. The mineralization is associated with the bimodal episode of the Mt. Belknap Volcanics. The ore body was discovered in 1878 (Callaghan, 1973, p. 45-47), and mining has been sporadic as is typical of most historical mines in this region. In the early years, development was mainly on weathered sulfide ores with production of gold, silver and lead. In 1945, a tunnel was driven into the deeper part of the ore body, and production included lead, zinc, gold, silver, and copper. The ore is hosted as replacement in the Toroweap Formation and in the fractured Coconino Sandstone, and the ore body is described as up 4,000 feet in length averaging 100 feet in width (Callaghan, 1973, p. 45). Mining ceased at Deer Trail in 1971 with the closure of the Tooele lead smelter and the Midvale Mill. This mine has historically been the largest metal producer in the Marysvale region (Callaghan, 1973, p. 45), and the Deer Trail mine produced about 250,000 tons of ore containing about 146,124 oz of gold, 135,500 lbs of silver, 8,500 tons of lead, 395 tons of zinc, and and 1.3 million lbs of copper (Steven, et al, 1984). In 1971, developed ore (remaining in-place reserves) was estimated at 16,000 tons and ore resources at 64,000 tons (Callaghan, 1973, p. 46).

Unico in the 1990s re-opened the Deer Trail mine with exploration for additional reserves and constructed a new mill (UGS, 2002). In 2001, high-grade ore was being worked in an underground level averaging 1.66 oz/ton of gold, 181 oz/ton of silver, 14.4 percent lead, 8.4 percent zinc, and 8.7 percent copper. Development plans include mining additional levels of the mine. The mill reportedly has a production rate of 70 tons/day (UGS, 2002). The Deer Trail is currently the only metal mine under development in the Marysvale region (UGS, 1999a,b).

The VCA mine was actually a vertical shaft that was driven to connect several existing mines, such as the Prospector and Freedom No. 2, and for additional development. The shaft was at T. 26 S., R. 4 W., sec. 26. The most important uranium production was mined from a group of veins in an area that is approximately 3,000 feet long and 1,500 feet wide. Mineralization is related to the bimodal sequence of the Marysvale volcanic field, and the ore was hosted mainly in quartz monzonite and secondarily in granite and an overlying rhyolite (Callaghan, 1973, p. 49; Rowley and others, 2002, p. 140). Production in the Henry district started in the mid-1940s lasted into the mid-1960s, and as of 1967, total uranium production was 275,000 tons averaging 0.20 percent U_3O_8 (Callaghan, 1973, p. 48; Rowley, et al, 2002, p. 140).

Numerous prospects and mines were worked and/or developed on various mineralization styles in the historic mining districts in the vicinity of Marysvale, primarily in the Tushar Mountains and the Antelope Range. Callaghan (1973) described the historical mines by mining district, deposit type, and produced mineral, which is summarized briefly in Table 6. Metal associations were generally: quartz-carbonate veins with gold and silver were worked in the Gold Mountain district; lead-zinc-copper veins in the Ohio and Mt. Baldy districts; lead-zinc and quicksilver (mercury) replacement deposits in the Mt. Baldy district; uranium veins and disseminated deposits in the Henry district; iron deposits in the Henry district; and antimony deposits in the Coyote district. However, the metallization and alteration in this region are considerably more complex than the above statement represents.

As displayed in Table 6, metal deposits that have been historically worked in this region include precious metals (gold and silver), base metals (lead, zinc, and copper) radioactive metals (uranium), antimony, and iron. Manganese prospects are also reported in the Marysvale region, but are not listed in the table. In addition, one mercury prospect is known near the Deer Trail mine in the Mt. Baldy district. As previously stated, molybdenum is associated with the uranium deposits. This discussion is not intended to be a complete description of all mineral associations in a volcanic field which involves complex sequences of volcanism and plutonism of different ages and multiple stages of mineralization. In this report, the age of mineralization has been omitted, as the intent of this report is to describe the types of minerals that could be present.

Table 6. Historical Metal Mines and Prospects in the Marysvale Region

Mine Name	District	Deposit Type	Associated Metal and Comment
Deer Trail	Mt. Baldy	Lead-Zinc Replacement	Gold, silver, lead, zinc, and copper. Largest metal producer.
Annie Laurie	Gold Mountain	Quartz-Carbonate Vein	Gold and silver. Second-largest metal producer.
Sevier	Gold Mountain	Quartz-Carbonate Vein	Adjacent vein to the Annie Laurie. Gold and silver.
Butler & Beck	Gold Mountain	Quartz-Carbonate Vein	Gold and silver.
Wedge	Ohio	Quartz-Carbonate Vein	Gold and silver.
Bully Boy	Ohio	Lead-Zinc-Copper Vein	Silver, gold, lead, and copper. Largest mine of this type.
Copper Belt	Ohio	Lead-Zinc-Copper Vein	Gold.
Cascade	Ohio	Lead-Zinc-Copper Vein	Silver, gold, lead, and copper.
Shamrock	Ohio	Lead-Zinc-Copper Vein	Silver, gold, lead, copper, and zinc.
Glen Erie	Ohio	Lead-Zinc-Copper Vein	Gold and copper carbonate minerals.
Great Western	Ohio	Lead-Zinc-Copper Vein	Gold, silver, lead, copper, and zinc.
Iris	Ohio	Lead-Zinc-Copper Vein	Gold, silver, lead, and copper.
Tate	Ohio	Lead-Zinc-Copper Vein	No known production.
Clyde	Mt. Baldy	Lead-Zinc-Copper Vein	Copper, silver, and gold.
Crystal	Mt. Baldy	Lead-Zinc-Copper Vein	Lead, gold, and silver.
Park	Mt. Baldy	Lead-Zinc-Copper Vein	No records.
Monte del Rey	Mt. Baldy	Lead-Zinc-Copper Vein	Lead, zinc, gold and silver.
Trinity	Henry	Lead-Zinc-Copper Vein	Tunnel only; no mine development
Royal Purple	Henry	Quartz-Carbonate Vein	Gold. No production recorded.
Numerous mines	Henry	Uranium veins	Uranium (primarily pitchblende) and dissociation products. VCA shaft and other developments.
Iron Duke	Henry	Irregular masses	Iron (magnetite)
Iron Cap	Henry	Silicified breccia	Iron (limonitic)
Emma and Mammoth	Coyote	Mineralized sedimentary strata	Antimony (stibnite) and arsenic minerals.

Source: Callaghan (1973)

On the perimeter of the Marysvale volcanic field at Salina Canyon, east of the town of Salina, at T. 21 S., R. 1 E., sec. 33, lead and zinc are hosted in gently dipping beds of the Flagstaff Formation that unconformably overlie sandstone of the Twist Gulch (Willis, 1986; Butler, et al, 1920). The Lead Hill mine historically produced more than 100 tons of low-grade ore. The mine has been abandoned for years. Other similar prospects are known along the fronts of the mountain ranges or plateaus in similar stratigraphic and structural settings in Sevier and Sanpete Counties. Production has been minimal. These prospects are summarized in Table 7.

Table 7. Historical Lead and Zinc Mines and Prospects in the Vicinity of the Sevier and Sanpete Valleys

Mine or Prospect	Location	Comments
Lead Hill	T. 21 S., R. 1 E., sec. 33	Lead-zinc deposited in sandstones at an angular unconformity. More than 100 tons produced historically, now abandoned.
Redmond	T. 21 S., R.1 E., secs. 4, 5	Produced zinc intermittently from about 1917 to 1950
Santobar	T. 17 S., R. 2 E., sec. 4	Lead and zinc mineralization; worked in the 1960s
Lost Josephine	T. 18 S., R.1 E., sec. 19	Hosted in calcareous siltstones of the Arapien Shale
Gunnison Prospects	West of Gunnison	Several pits in the Crazy Hollow Formation
Fayette Prospects	T. 19 S., R. 1 E., sec. 18, 23	Two prospect pits east of Fayette
Bighorn Prospect	T. 18 S., R. 5 E., sec. 36	Hosted by the North Horn Formation on the Wasatch Plateau.
Lewis Claims	T. 18 S., R. 1 E., sec. 20	In either the North Horn or Price River Formation

Eastern Part of the Planning Area

The Henry Mountain area has five mining districts: 1) East Henry Mountains, 2) South Henry Mountains (also known as Little Rockies), 3) Orange Cliffs, 4) Poison Springs, and 5) Teasdale.

The largest uranium-producing region in the Henry Mountains is in Garfield County, which includes the East Henry and South Henry areas (Maps 14, 15, and 16). The Henry Mountains district is roughly defined by the area west of the Dirty Devil River and east of the Henry Mountains. The Upper Jurassic Morrison Formation is the principal ore host in the Henry Mountains district, specifically the Salt Wash Member, followed in importance by the Brushy Basin Member (Picard, 1980; Williams et al, 1971). This area has accounted for approximately 77 percent of the total uranium production from Garfield County (approximately 44,000 tons of ore, 352,000 pounds of uranium oxide, and 1 million pounds of vanadium pentoxide), about 85 percent of which came from the Morrison Formation (Doelling, 1975).

The East Henry Mountains area extends along the Morrison outcrop belt from Mt. Hillers northward to the Wayne-Garfield county line. In this area, the Salt Wash Member crops out in two narrow bands that are exposed on either side of the East Henry Mountains syncline, with the intervening Brushy Basin Member cropping out along the fold axis (Doelling, 1975). All of the important deposits occur on the gently dipping east limb of the syncline, approximately 100–150 feet above the Salt Wash–Summerville contact. The Trachyte area in the East Henry Mountains is the most significant uranium-producing area, accounting for approximately 50 percent of the total Garfield County uranium production (Doelling, 1975). Deposits tend to be lenticular with clusters of ore pods (“trash pockets”) averaging 50 feet in length. The largest deposit at John Hill is more than 400 feet long. In the East Henry area, vanadium/uranium ratios average 5:1 but vary significantly, from 134:1 to 1:30 (Doelling, 1975). Ore grade averages 0.33 percent uranium oxide and 1.48 percent vanadium pentoxide. In general, mines were small and adits only penetrated a few hundred feet behind the outcrop face.

The South Henry Mountains area continues south of Mt. Hillers and west of Mt. Holmes and Mt. Ellsworth for a distance of approximately 12 mi along the outcrop belt of the Salt Wash Member. Together, Mt. Holmes and Mt. Ellsworth are called the Little Rockies, and the South Henry Mountains uranium mining area is sometimes referred to as the Little Rockies area. Overall, the South Henry Mountains area has accounted for approximately 27 percent of Garfield County's total uranium production (or about 123,500 pounds of uranium oxide). Individual deposits are high grade, averaging 0.90 percent uranium oxide and 1.62 percent vanadium pentoxide. As in the East Henry area, mining did not generally advance more than a few hundred feet from the outcrop face, where radioactive anomalies are easily detected with counters. Principal mineralized areas are south of Mt. Hillers to near the Ticaboo area. The Orange Cliffs area in northeast Garfield County is roughly defined by the Colorado River on the east and the Dirty Devil River on the west (Maps 14, 15, and 16). Together, these areas have accounted for only about 1 percent of Garfield County's total uranium production (Doelling, 1975). The principal ore host is the Moss Back (also known as Shinarump Conglomerate) Member of the Chinle Formation, but individual deposits are widely scattered. Ore mineralization tends to be of the copper-uranium type, although no copper production has been reported.

The Teasdale area includes scattered uranium deposits along the Waterpocket fold in south-central Wayne County. Although most of these deposits are hosted by the Salt Wash Member along outcrop bands in the vicinity of Notom, some are present in the Moss Back Member within the boundary of Capitol Reef National Park. Overall, these deposits are a direct northward extension of the uranium deposits in the Circle Cliffs (east flank) and Southern Teasdale anticline areas, which are located just outside the planning area in east-central Garfield County. Because of their location on the west side of the Henry Mountains, these deposits are more appropriately included in the Circle Cliffs–Teasdale district but are discussed here as a matter of convenience. Production data are not available for the Teasdale area. In addition to the previously described uranium mining areas, several unnamed, minor uranium occurrences exist in central Wayne County (Maps 14, 15, and 16).

From 1948 through 1970, Garfield County was Utah's fourth-leading producer of uranium-vanadium ore behind San Juan, Emery, and Grand Counties, producing about 61,175 tons of ore containing 467,195 lbs of uranium oxide (0.4 percent) along with 1,491,933 lbs of vanadium pentoxide (1.66 percent) (Chenoweth, 1990). The high point in production came in 1956, when 6,900 pounds of ore were mined in Garfield County.

Although placer gold has been prospected throughout the streams and washes that drain the Henry Mountains, only the fanglomerates and the modern stream sediments along Crescent Creek on the east side of Mt. Ellen have seen commercial production (Maps 14, 15, and 16). Production statistics for placer deposits in other creeks and washes in the Henry Mountains region are not available. One of the biggest obstacles to placer mining in the Henry Mountains region is obtaining an adequate supply of water for operations. Crescent Creek generally flows only during peak spring runoff and dries out in late June to early July, which forces operations to become seasonal over most of their lifetime. Although water can be obtained from other sources (i.e., groundwater or trucked in), this venture becomes very expensive and is not economically feasible. Crescent Creek drains the Bromide Basin on Mt. Ellen, where most of the lode gold in the Henry Mountains was mined. The most productive placer areas were located in T. 31 S., R. 11 E., sec. 30 eastward for about 5 mi to the benches above the cliffs of the Salt Wash Member (Maps 14, 15, and 16). Placer mining in Crescent Creek reportedly began around 1902 and continued intermittently until the 1940s (Picard, 1980). Although mining interest was renewed in the 1970s with the dramatic increase in the price of gold, commercial mining from Crescent Creek that had ended in the 1940s did not resume. The cumulative gold production was about 300 to 350 ounces along with 50 ounces of silver (Picard, 1980; Doelling, 1975). However, this production total has likely been underestimated considerably (Rakow, 2002). Interest remains in exploring placer opportunities in the upper Crescent Creek Basin.

Although lode gold and silver are known from the apexes of the three largest peaks in the Henry Mountains, almost all of the historical production (approximately 700 oz of gold and 3,000 oz of silver) was derived from the workings in Bromide Basin located at the headwaters of Crescent Creek on the east flank of Mt. Ellen (Picard, 1980) (Maps 14, 15, and 16). In 1891 the Bromide Mine was developed along with the construction of a stamp mill and the town of Eagle City (located 2 mi below the basin). Eagle City quickly became a ghost town. By 1900, the fissure was mined out, but new deposits such as the Kimball-Turner and Bromide Crosscut Mines went into production soon thereafter, and the Bromide Mine was later reopened using deeper underground workings. Deposits in the Bromide Basin have been sporadically worked from 1930 to the present on privately held lands (Picard, 1980). However, the actual production volume from these areas is not known. The only active lode gold- mine in the Henry Mountains is in Bromide Basin, and is located at T. 31 S., R. 10 E., sec. 34. Of the total historic gold production from the Henry Mountains, approximately 75 percent is attributable to underground mining in the Bromide Basin on the east flank of Mt. Ellen—23 percent from Crescent Creek placers and 2 percent from all other sources (Picard, 1980) (Maps 14, 15, and 16). No titanium, zirconium, or molybdenum was produced in the Henry Mountains (from either placer or lode) even though these minerals are associated with gold and silver deposits (Picard, 1980). Significant quantities of copper were produced from the Bromide Basin. Similarly, although copper was produced as an accessory commodity from the gold mining of fissure veins in the Henry Mountains, little production data are available. Most of the copper production was in the Bromide Basin located high on the eastern flank of Mt. Ellen, where total production was about 17,500 pounds (Picard, 1980). Small amounts of copper were also produced from the mines on Mt. Pennell and from the Star Mine on Mt. Hillers (Maps 14, 15, and 16), but production statistics are not available.

Similarly, copper production information associated with radioactive sandstone deposits in eastern Garfield County is not available. Although copper exploration and prospecting activities on Miners Mountain have occurred since 1917, production statistics from the Sinbad Member of the Moenkopi Formation could not be obtained. No copper is now being produced from any mines in the Henry Mountains area.

2. Non-Metals

Most gypsum mined in Utah, as well as in the United States, is calcined for plaster and used in the manufacture of wallboard, lath, and other prefabricated gypsum products. Uncalcined, or raw gypsum, is used in Portland cement as a setting retardant and in agriculture as a soil amendment.

In the planning area, exploration and development of gypsum resources has been focused in the Sevier Valley, where gypsum has been extensively mined from the Arapien Shale since 1918. Historically, most of Utah's gypsum production has been mined from the Arapien Shale in Sevier Valley (UGS, 2002b). In Utah, 500,000 tons of gypsum were produced in 2000 and 390,000 tons in 2001.

Gypsum is a low unit-value, high-bulk commodity, and the most important factors in evaluating a deposit are its proximity to markets and ease of mining (Muntz, 1990). The gypsum deposits in the Sevier Valley, being centrally located in Utah, have been favorable for development with local and regional markets. Most mining has been for the manufacture of wallboard, although the gypsum has been used for other products, such as plaster. Thus, mills for processing gypsum were constructed at Sigurd. The two largest producers in Sevier County have been U. S. Gypsum and Georgia-Pacific Corporation.

Since the early development of the gypsum in the Arapien Shale, transportation networks have improved and population centers have changed. Also, gypsum deposits closer to new and growing markets, such as Las Vegas, have been developed. Georgia-Pacific has recently suspended mining and closed its mill; however, U.S. Gypsum is actively mining and processing gypsum at Sigurd. The main gypsum mines in the Sevier Valley are summarized in Table 8.

Table 8. Major Gypsum-Producing Mines for Wallboard and Other Products in the Planning Area

Mine Name	Operator	Status	Location	Notes
Sigurd	Georgia-Pacific	Inactive	T. 23 S., R. 1 W., T. 22 S., R.1 E.	Wall board mill shut down; mining inactive and quarries on public land reclaimed.
Jumbo-Jensen	U.S. Gypsum	Active	T. 22 S., R.1 W.	Mining on patented (private) land at numerous quarries.
Mayfield	Georgia-Pacific	Reclaimed	T. 19 S., R. 2 E., sec. 30	Quarry mined out in late 1980s.

As previously stated, the gypsum deposits in the Arapien Shale are discontinuous and contorted. Thus, quarries are usually relatively small (less than 10 acres), but numerous within outcrops of gypsum-bearing beds. The purity and texture of gypsum deposits vary considerably, depending on the interbedded silt, sand, and carbonate mud. For the manufacture of wallboard, minable gypsum is typically 80–95 percent pure.

In addition, to the mills constructed at Sigurd, primarily for the manufacture of wallboard, Diamond K has constructed a mill at Richfield. At this mill, gypsum that is mined at the San Rafael Swell in Emery County is processed (pulverized) for uses such as pharmaceutical applications. Also, gypsum from deposits in the San Rafael Swell have been processed at the Sigurd mills for the production of wallboard and plaster.

Exploration and development of gypsum deposits in the eastern part of the planning area have been limited. As previously stated, gypsum is present in the Carmel and also the Summerville Formations. However, these deposits have been too distant for traditional gypsum markets, such as wallboard and plaster, to be economic to mine. Doelling (1975) reports limited use in local markets, historically. However, selenite crystals for mineral specimens are mined from the Carmel Formation in Cathedral Valley in northern Wayne County. These prospects are small surface pits for the extraction of surface exposed specimens.

C. SALABLE MINERAL DEPOSITS

1. Sand and Gravel

Sand and gravel are salable mineral commodities as directed by the Material Sale Act of 1947. In 2001, sand and gravel (including crushed stone) were the second-highest contributors to the value of industrial minerals produced in Utah (UGS, 2002). These materials were produced in every Utah county by commercial operators and government agencies. Year 2001 production statistics show that 27.9 million tons of sand and gravel and 11.6 million tons of crushed rock were produced, with a combined value of $168.4 million (USGS Mineral Commodity Summary). Although production information from individual counties is not available, the greatest production of sand and gravel in Utah is from Pleistocene Lake Bonneville shoreline deposits that are extensive and close to major urban centers, where construction activity is greatest (Tripp, 1991).

Past and present exploration and development of sand and gravel deposits in the planning area has been for local public works projects. The largest single project was the construction of Interstate 70 construction in the 1970s through the early 1990s. Because sand and gravel are generally the lowest-priced of industrial mineral products, transportation costs from the pit to the point of end use are a large part of the cost to consumers. As such, even short transportation distances can adversely affect the cost of the final product, and it is imperative that sand and gravel sources be located as close as possible to the point of use and major roadways. For this reason, the sand and gravel industry is widely dispersed across Utah, and disposal sites are generally associated with roadways and near population centers.

Within the planning area, there are approximately 57 active sand and gravel disposal sites on BLM public land, that have been authorized for free use, as community pits, and as mineral material sales under the Materials Act. Of the 57, 18 are designated as free use permits, 34 as community pits, and 5 for mineral material sales (BLM, 2003). The free use sites are authorized for disposal to county road departments; community pits for multiple disposals for personal or commercial use; and sales to exclusive authorized purchasers. These disposal sites are shown on Map 17, respectively as free use permits, community pits, and mineral material sales and negotiation areas. Most are near major roadways. The disposals from the free use sites are the largest volume disposals, up to 20,000 cubic yards annually; whereas, the disposals from the community pits are generally smaller in the range of a 30-500 cubic yards per individual sale. The exclusive mineral material sales are also generally small volume disposals. The only currently authorized, exclusive mineral material sale is for sand near Fayette. In terms of volume, disposals to the county road departments account for the largest share of mineral material disposals in the Field Office from BLM authorized sites.

These sand and gravel deposits are generally Quaternary alluvial or alluvial fan deposits. However, in the western part of the field office, sand and gravel disposals include a few sites for weathered colluvial shale and may also include late Tertiary alluvium and Quaternary pediments. In the eastern part of the field office, sand and gravel, as a commodity code, are generally disposed as fill material. On Map 17, fill material is not distinguished from sand and gravel.

Not included in the above totals are disposals to the Utah Department of Transportation. Disposals to UDOT are completed as a right-of-way authorization under Title 23 of the Federal Highway Act.

Sand and gravel are also extracted from state and private lands within the planning area. These include commercial operations, which are mostly on private land near population centers. In addition, county road departments or UDOT also have disposal sites on private land within the planning area. These operations are also not included in the total of 57 as given above. However, as obtained from the UMOS data base, past disposal sites, regardless of land ownership, are displayed on Map 17.

2. Clays Including Alunite

In Utah, the most common use for clay is for brick and tile. Within the planning area, clay has been used for swelling clays such as bentonitic clay, reservoir liner material, Fuller's earth, and other applications. As previously, discussed alunite is also addressed in this section, although alunite could be potash, alumina, or clay. Also, the alunite is associated with kaolinitic clays. Most of the clay resources in the planning area have a volcanic association.

Prospects, occurrences and mines are shown on Map 18, without differentiation to the degree of development or to the type of clay, such as clay, bentonite, and other clay commodities. This information was obtained from the UMOS data base.

Three commercial clay operations are active in the western part of the planning area. These are listed in Table 9.

Table 9.: Clay Mines in the Planning Area

Mine Name	Operator	Product	County	Location
Koosharem	Paradise Management Corporation	Kaolinite	Piute	T. 27 S., R. 2 W., sec. 2
South RCS Mine	Redmond Minerals, Inc.	Bentonite	Sanpete	T. 20 S., R. 1 W., sec. 24
Western Clay	Western Clay Company	Bentonite	Sevier	T. 21 S., R. 1 W., sec. 2

The Koosharem Mine is located in Box Creek on the Sevier Plateau, approximately 8 miles northwest of Greenwich, Utah. Highly kaolinitized volcanic rock is being mined from a surface pit. The South RCS and Western Clay mines are located near each other on the west side of Sevier Valley, north of Redmond. The clay is processed at a plant in Aurora. These deposits are volcanic in origin.

In addition, Fuller's earth has been prospected and mined in the hills west of Aurora. Bentonitic clay deposits near Elsinore, Marysvale, and Kingston have been extracted, mainly for its swelling capacity, and the development has been very limited, mainly for local, small projects. Again, these clays have a volcanic association with the Marysvale volcanic field.

Historically, alunite near Marysvale has been prospected or mined for potash alum, alumina, and fertilizer. As previously stated, the alunite deposits may be either clay alteration (replacement of volcanic rocks) or vein deposits. For convenience, alunite is included in this discussion on clay, although not all alunite is a clay or a salable mineral. In the replacement deposits, kaolinitic clays are associated with the alunite in complex depositional patterns, and the composition and grade of alunite and kaolin varies considerably. Information on historic alunite mines in the Marysvale region is summarized in Table 10.

Table 10. Historical Alunite Mines in the Marysvale Region

Mine Name	District	Deposit Type	Comments
Mineral Products	Mt. Baldy	Vein	Produced 250,000 tons of alunite from 1915 to 1920
Bradburn	Mt. Baldy	Vein	3,600 feet of workings
Christmas	Mt. Baldy	Vein	Located on the crest of Alunite Ridge
Edna (Aetna)	Mt. Baldy	Vein	Located on the crest of Alunite Ridge
Sunshine	Mt. Baldy	Vein	Located on the crest of Alunite Ridge
L&N	Mt. Baldy	Vein	Located on saddle between Cottonwood and Pine Creeks
Winkelman	Gold Mountain	Replacement	1,500 tons produced; also called Copper Butte
Pittsburgh	Gold Mountain	Replacement	Distribution spotty and masses small
Close In	Mt. Baldy	Replacement	Over 2 million tons of ore estimated in place
White Horse	Henry	Replacement	Ore body contains 50 percent alunite
White Hills	Henry	Replacement	Low-grade deposit averaging less than 35% alunite
Big Star	Henry	Replacement	Only contains a small amount of high-grade ore
Big Chief	Henry	Replacement	Extensive amounts of low-grade ore
Yellow Jacket	Henry	Replacement	Mineralized area is approximately 4 mi^2
Potash Butte	Henry	Replacement	Very-low-grade alunite; prospect only
Mary's Lamb	Henry	Replacement	Prospect only, not a commercial deposit
J&L	Henry	Replacement	5,000 tons of ore mined between 1937 and 1940
Divide	Henry	Replacement	Prospect only
Aluminum Queen	Henry	Replacement	Two quarries excavated at the 9,600-ft level
Aluminum Bar	Henry	Replacement	Large area of altered rock at 10,000 ft on Marysvale Peak
Sheep Rock	Newton	Replacement	Prospect only

Source: Callaghan (1973).

Historically, an estimated 306,000 tons of alunite were mined from the Marysvale region. In 1969, the resource estimate was approximately 3.7 million tons with an average alunite content of 54 percent as summarized by the USGS (1969). Additional, lower-grade resources are estimated at 26 million tons, containing at least 20 percent alunite.

In the eastern part of the planning area, clay (including bentonite) has been prospected and mined from several locations. These clay of principle interest has been deposited in the Brushy Basin Member of the Morrison Formation; however, clays in the Dakota Sandstone have also been worked. The clays are altered volcanic ash deposited within the sedimentary formations. The largest sale on BLM land has been to Plateau Resources for bentonitic clay in the Brushy Basin Member near Ticaboo. At Blind Trail Wash in the Dakota Sandstone on the west side of the Henry Mountains, the clay has been sampled in small test pits. However, the clay has generally been used locally.

3. Stone and Industrial Minerals

Stone has been removed from various locations in the planning area, involving various formations. Uses include building stone, decorative stone, riprap, coal rock dust, and agricultural applications.

On Map 19, existing stone disposal sites on BLM public land are shown as "Stone Disposal Sites." These sites are either community pits or exclusive sale sites. Active stone quarries on BLM, private or state lands listed in Table 11.

Table 11. Active Stone Quarries in the Planning Area

Quarry Name	Operator	Material	County	Location
Trace Mine	Peak Minerals Azomite, Inc.	Volcaniclastic rocks, Moroni Formation	Sanpete	T. 17 S., R. 1 W., sec. 4
Claim 35	AG Hold Association	Joe Lott Tuff	Sevier	T. 25 S., R. 4 W., sec. 30
B&C Quarry	B&H Limestone	Limestone, Green River Formation	Sanpete	T. 18 S., R. 1 E., sec. 32
Green River Community Pit	Multiple operators	Limestone, Green River Formation	Sanpete	T. 18 S., R. 1 E., sec. 35
Antelope Valley	Zamaroni	Limestone, Green River Formation	Sanpete	T. 19 S., R. 1 E., sec. 2
Redmond	Western Clay Company	Limestone, Green River Formation	Sevier	T. 21 S., R. 1 E., sec. 5
Hass Limestone–Gunnison	B&H Limestone	Limestone, Green River Formation	Sanpete	T. 19 S., R. 2 E., sec. 16
Nine Mile Quarry	Danny Bown	Limestone, Green River Formation	Sanpete	T. 19 S., R. 2 E., sec. 16
Young	John Young	Limestone, Green River Formation	Sanpete	T. 19 S., R. 2 E., sec. 16
Temple Strike	Bill Day	Limestone, Green River Formation	Sanpete	T. 19 S., R. 2 E., sec. 16, 21
Cream Time	Lanny Jensen	Limestone, Green River Formation	Sanpete	T. 20 S., R. 2 E., sec. 8
J&J	Zachary Jensen	Limestone, Green River Formation	Sanpete	T. 20 S., R. 2 E., sec. 8
Mayfield	Phyllis Bown	Limestone, Green River Formation	Sanpete	T. 20 S., R. 2 E., sec. 17
Perry Estate	State Stone	Limestone, Green River Formation	Sanpete	T. 18 S., R. 3 E., sec. 6
Jensen Quarry	State Stone	Sandstone, Moenkopi Formation	Wayne	T. 29 S., R. 4 E., sec. 13

Table 11. Active Stone Quarries in the Planning Area

Quarry Name	Operator	Material	County	Location
Quality Stone	Quality Stone	Sandstone, Moenkopi Formation	Wayne	T. 29 S., R. 4 E., sec. 13
Quality Stone	Quality Stone	Sandstone, Moenkopi Formation	Wayne	T. 29 S., R. 4 E., sec. 24
Torrey	American Stone	Sandstone, Moenkopi Formation	Wayne	T. 29 S., R. 5 E., sec. 8
Torrey Buff	Young Stone Supply	Sandstone, Moenkopi Formation	Wayne	T. 29 S., R. 5 E., sec. 16
Capitol Reef Community Pit	Multiple operators	Sandstone, Moenkopi Formation	Wayne	T. 29 S., R. 5 E., sec. 17
Torrey Quarry	State Stone	Sandstone, Moenkopi Formation	Wayne	T. 29 S., R. 5 E., sec. 20

Source: BLM, 2004; UDOGM, 2004.

The stone at the Trace mine of Peak Minerals is quarried from the Moroni Formation for nutritional supplements, mainly for livestock, and soil amendments for gardening. The stone at the Redmond quarry of Western Clay is mined from the Flagstaff Formation for industrial uses such as coal rock dust for the coal mines in the Wasatch Plateau. This mine is shut-down and has been replaced by a new operation in Juab County near Scipio Lake. Otherwise, the quarries listed are for dimension or decorative stone. The two stones of primary interest for building or decorative use are limestone in the Green River Formation in the western part of the planning area and sandstone in the Moenkopi Formation in the eastern part. Most of the quarries on the Green River limestone are on private or state land near Mayfield, although BLM has one community pit near Gunnison.

One listing is provided for the Joe Lott Tuff in Table 11. This site on National Forest has had intermittent operations over the years. Three locations are shown on Map 19 as BLM community pits that encompass the Joe Lott Tuff, south of Monroe. These sites are inactive. The Joe Lott Tuff, historically, was used in southern Sevier County as a dimension stone for historic buildings. In the 1980s, the stone was evaluated for making building blocks from pulverized material; however, a sustained market has apparently not developed, although interest in such a use periodically continues to be expressed by the public.

Not listed in Table 11 are small quarries for a banded volcanic rock in the Antelope Range, as none of these quarries are currently active, although one new quarry is in the process of being authorized and developed. The quarried stone is altered stone of the Bullion Canyon Volcanics. This stone has been marketed as a decorative and ornamental rock.

The site at the north end of Piute Reservoir was for andesite that used as riprap in rehabilitation work for the dam at this location. The site is now reclaimed.

Most of the stone quarries in the planning area are relatively small disposal sites, generally less than 5-10 acres. The disposals from BLM public lands range from a few tons to a few thousand tons per year.

4. Humate

Most humate in Utah is mined from coal beds in the Ferron Sandstone at the Coal Cliffs in southwest Emery County. However, within the eastern part of the planning area, coal beds in the Ferron Sandstone also crop out around the perimeter of the Henry Mountains syncline, west of the Henry Mountains, and three humate mines (two on BLM land and one on state land) are active. These mines are located in north-central Wayne County south of the Emery county line.

The humate mines are generally small operations, and the tonnage produced is relatively small. Thus, the mines are generally active only intermittently, depending on market demand. Most, if not all, of the humate being mined in Utah is used as a nutritional supplement.

5. Other Minerals

In the planning area, mineral materials, mineral specimens, and semiprecious gemstone have included interest in petrified wood, agate, chalcedony, jasper, cryptocrystalline quartz, selenite, alabaster, fluorite, sphalerite, and galena. In the eastern part of the planning area, petrified wood, jasper, agate, and chalcedony are collected primarily from the Morrison Formation, although also found in the Cedar Mountain and Chinle Formations. Gypsum beds in the Jurassic Carmel Formation at some outcrop localities contain selenite and alabaster crystals that are suitable for specimen collecting and carving. Fluorite, sphalerite and galena are mostly associated with the volcanic terrane of the western part of the planning area. Most of the collecting is for personal hobby or recreational rockhounding. However, limited development has occurred for selenite, as previously discussed, at Cathedral Valley.

4. MINERAL OCCURRENCE POTENTIAL AND LIKELIHOOD OF DEVELOPMENT OF MINERAL RESOURCES

In this section, the potential for mineral occurrence, the level of certainty of that occurrence, and the likelihood that these resources will be developed during the expected planning horizon of 15 years are evaluated. This classification is based on BLM Manual 3031. A copy of the BLM mineral potential classification system is provided in Attachment 2. Mineral resources in the planning area that are considered most likely to be developed are oil and gas, gypsum, sand and gravel, and stone. Coal is also likely to be developed, but is not addressed in this report.