Cedar City Field Office Resource Management Plan/Environmental Impact Statement:

Analysis of the Management Situation

Appendix H

Mineral Potential Report

United States
Department of the Interior
Bureau of Land Management

MINERAL POTENTIAL REPORT

For The

Cedar City Planning Area

Cedar City Field Office

Encompassing Approximately 1.52 Million Acres
Beaver and Iron Counties, Utah

Prepared by:

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June 22, 2012
(Date)

United States
Department of the Interior
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SUMMARY AND CONCLUSIONS

The following summary and report use a mineral occurrence potential rating scheme developed in U.S. Bureau of Land Management (BLM) Manual 3031 (see Appendix A), along with a Utah Geological Survey development potential rating scheme that was derived from the BLM occurrence potential scheme (also given in Appendix A). Only the mineral occurrence potential is given a level of certainty determination. Unless otherwise spelled out, some sections of the following report use abbreviations to express both the mineral occurrence potential and the level of certainty of occurrence (i.e., M/C indicates a moderate potential for mineral occurrence and certainty level of C). Although development potential is rated high (H), moderate (M), or low (L) based on reasonable current market assumptions and known development plans, it is impossible to provide a certainty level for future developments because there is too much uncertainty about future market developments to predict development potential with a level certainty beyond a few years.

Leasable Commodities

Oil, Gas, and Coal Bed Gas

The Cedar City Planning Area (CCPA) has petroleum plays within the Basin and Range Province, and part of the Colorado Plateau Province in the southeast. Two additional plays have been defined by the Utah Geological Survey (UGS) for this study. Each of the five plays was analyzed separately in this report with regard to its occurrence and development potential in spite of some spatial overlap. Each play was treated individually because the overall differences in the nature and extent of their reservoirs, and the differences in timing of hydrocarbon generation and migration from source rocks means that petroleum deposits in each play may not necessarily be vertically superimposed. Two of the CCPA plays, the Unconformity A and Permo-Triassic, were rated as having high (H) occurrence potential with a certainty level of B. The other three plays, the Late Paleozoic, Paleozoic Devonian-Pennsylvanian, and the Coal-bed Gas, were rated as moderate (M) occurrence potential, each with a certainty level B. All of the plays were rated as having low (L) development potential, except for the Cedar Valley part of the Unconformity A play which has a moderate (M) development potential. Future interest in exploring for oil and gas on the CCPA will be governed by a number of conflicting factors. A climate of increasing environmental restrictions will likely dampen interest. Conversely, improved technology for finding oil and gas, better understanding of petroleum systems, plus higher energy prices and dwindling domestic supplies may promote more industry interest in exploring the wildcat areas of the CCPA where proven production has not been demonstrated. Central to petroleum development potential will be the availability of federal lands for leasing.

While not a true predictor of future drilling activity, historical drilling rates were used to help estimate future levels of oil and gas development activity on the CCPA. The UGS estimates that reasonably foreseeable development during the next 20 years could entail the drilling of 16 new wildcat wells for oil and gas, and the acquisition of up to 2414 km (1500 mi) of seismic data in the CCPA. The total area disturbed by these activities is estimated at 636 hectares (ha; 1572 acres [ac]). Reclamation of all the area disturbed by seismic activities (487 ha; 1204 ac) and about 94% of the well pads and roads (140 ha [346 ac]; all but one well pad) are expected to take place during the planning horizon leaving a net disturbance from oil and gas exploration and development of 8.9 ha (22 ac). The reasonably foreseeable development analysis does not include any discoveries of new petroleum fields; should a new field be discovered, higher levels of drilling and disturbance would occur, requiring more site-specific environmental impact study.

Coal

The CCPA part of the Kolob coalfield coincides with a Known Recoverable Coal Resource Area (KRCRA) with thicker coals rated as having high (H) occurrence potential with a certainty level of D, while the remaining areas underlain by Cretaceous rocks are given a moderate (M) occurrence potential with a certainty level of B. Although no plans to mine coal from the CCPA part of the Kolob coalfield are publicly known to exist, and no future exploration for coal is anticipated, the KRCRA area is rated as having moderate (M) development potential, while all other coal-bearing areas are rated as low (L) development potential. The Dakota coals in the KRCRA are relatively thick, generally shallow, but have high sulfur content so, at present, there is no expected surface disturbance from exploration or mining of coal in the CCPA during the next 20 years. However, rapid expansion of international markets and development of new clean coal technologies could provide presently unforeseen future development opportunities that could change the present forecast of no disturbance. In light of these unforeseen opportunities for future development, the known minable coal deposits in the KRCRA should be evaluated based on established unsuitability criteria by the BLM in this planning effort in case a lease application should arise in the next 20 years.

Geothermal

The CCPA incorporates a principal portion of the region loosely described as the Sevier thermal area, or STA, which extends across a broad area of the Basin and Range and Transition Zone. The STA is characterized by elevated heat flow, active faults, abundant young igneous rocks, and encloses all of Utah's known moderate- and high-temperature geothermal systems (> 100°C; 212°F). Geothermal resources in this region are classified as hydrothermal convection systems where meteoric water moves downward along faults and fractures, becomes heated by the Earth's geothermal gradient, and rises through the process of free convection (buoyancy from density contrasts due to heating/expansion) or forced convection (fluids move upward due to hydrostatic pressure). Young (<500 ka) intrusive bodies probably provide a source of heat at depth in the case of the resource at the Roosevelt Hot Spring area, and possibly at Cove Fort-Sulphurdale.

Identified, commercially viable, geothermal resource areas within the CCPA are situated in four widely spaced locations that have experienced power generation and direct-use development since the early 1980s. The Cove Fort-Sulphurdale, Roosevelt, and Thermo Hot Springs occurrence potential is rated at high with a certainty level of D (H/D using the U.S. Bureau of Land Management [BLM] mineral occurrence potential classification system [appendix A]), while the Newcastle area has a moderate occurrence potential with a certainty level of C (M/C). The first three of these areas are rated high (H) for development potential in the next 20 years, while the Newcastle area has moderate (M) development potential. Although new development will depend on economic conditions, government incentives, and competing energy costs, we expect all four geothermal areas (Cove Fort-Sulphurdale, Roosevelt Hot Springs, Thermo Hot Springs, and Newcastle) will undergo continued expansion by as much as 90 megawatts of electrical (MWe) power into the foreseeable future (20-year time frame). Such expansion would not only include additional exploration activities (geophysical surveys, well drilling), but also power plant and transmission facilities construction. The addition of four new power plants is estimated to entail 2 ha (5 ac) per plant for a total plant disturbance of 8 ha (20 ac). Drilling at these four sites would entail a total of about 25 new exploration/power supply wells, with each well involving about 1 ha (2.5 ac) of disturbance. Thus, the total disturbance from these 25 new wells would be about 25 ha (63 ac).

The remainder of the CCPA within the STA (mostly within and around the margins of the Escalante Desert) is rated as having low occurrence potential with a certainty level of B (L/B) and low (L) development potential, but if there is a strong push for renewable energy, there could be some additional geothermal exploration in the form of geophysical prospecting and shallow, temperature-gradient drilling. About 10 deep, geothermal test wells are estimated for the Newcastle (5 wells) and the Beryl (5 wells) areas, with a total disturbance for all 10 wells estimated at 10 ha (25 ac). These two areas are rated as moderate (M) occurrence potential with a certainty level of C and B, respectively; their development potential is moderate (M) as no definitive future plans have as yet been announced.

Potash (Alunite)

All potash potential in the CCPA is directly tied to alunite potential, as potash, specifically potassium sulfate, is a product of alunite processing. The largest alunite deposit in the country, the Blawn Wash deposit, is located in the CCPA along with other deposits of varying size. The resource, although unconventional, represents a large potential source of potash and alumina. Known alunite mines and prospects have high (H) occurrence potential with a certainty level of D, and other altered zones in the CCPA also have high (H) occurrence potential, but with a lower certainty (H/C). Significant work was conducted historically to define the Blawn Wash deposit, and a renewed interest in the deposit has followed increased potash prices. Recent activity, including a pending drilling program, indicates that development of alunite within the CCPA is a possibility in the near future, and development potential is considered high at the Blawn Wash deposit and moderate (M) in other areas. Depending on extent of development of the alunite resource, disturbance is estimated to range from 25 to 160 ha (62 to 400 ac).

Locatable Commodities

Copper

There is a high (H/D) mineral occurrence potential and a high (H) development potential for copper (Cu) deposits in the Beaver Lake, Rocky Range, and San Francisco mining districts in Beaver County. Each of these districts has known Cu resources and has undergone considerable exploration and development activity over the last half century. Currently (October 2011) the bankruptcy proceedings of the Western Utah Copper Company have resulted in a hiatus in this legacy of work; however, renewed exploration and development is anticipated immediately following some kind of legal settlement. The expected disturbance caused by Cu development in each of these districts is estimated at from 100 to 800 ha (250 to 1980 ac).

The Star district is classified as moderate (M/C) for mineral occurrence potential and low (L) for the future development of Cu resources. The anticipated disturbance associated with work in this district for Cu exploration is likely to be less than 30 ha (74 ac).

Gold-Silver

The history of significant past Ag production in the Escalante mining district and the reported occurrence of Ag in the wall rocks and below the current mine workings suggest intermittent periods of continued exploration at the Escalante mine. In addition, the mill tailings probably contain roughly 127,573 kg (4.5 million ounces) of refractory Ag, again suggesting that the district is likely to see future exploration and development activity. The Escalante district is classified as high (H/D) for mineral occurrence potential and high (H) for development potential. The total estimated disturbance for a mine and mill operations at the Escalante Ag project would be approximately 200 ha (490 ac).

The Fortuna, Gold Springs, Newton, and Stateline mining districts all have some encouraging factors for future Au-Ag development, but no obvious indication of near-term success. These districts are all ranked as moderate (M/C) for mineral occurrence potential and moderate (M) for development potential.

The Antelope Range, Confidence, and Modena areas have each had little or no production and a limited history of exploration. These three districts are given a low (L/B or L/C) ranking of Au-Ag and low (L) for development potential.

Iron

There is a high (H/D) potential for mineral occurrence and high (H) development potential for iron (Fe) deposits in the Iron Springs (Pinto) mining district of Iron County. The current (September 2011) global commodities boom and weak U.S. dollar have inflated the price of Fe ($175 per metric ton; $159 per short ton) above the inflation adjusted historical prices (roughly $50 per metric ton; $45 short ton) resulting in a strong demand for internationally traded metals. This assures the continued exploitation of the Comstock-Mountain Lion deposit and a very close examination of several of the other historically defined Fe resources in the Iron Springs district, in particular the large Rex deposit.

The Iron Peak and Rocky Range mining districts also contain small, known Fe resources; however, these areas have a moderate (M/C) mineral occurrence potential and low (L) development potential. Similar, but smaller Fe ±W ± base metal occurrences are reported from the Beaver Lake, Blawn Mountain, Bradshaw, Granite, Star, and Washington mining districts, all in Beaver County, and all have a low (L/B) mineral occurrence potential and low (L) development potential. These Fe resources may offer some potential for a specific end use (coal heavy media wash plant, cement plant additive, smelter flux), but are not large enough or pure enough for consideration to use in the steel industry.

Lead-Zinc

The San Francisco and Star mining districts are rated as having moderate (M/C) mineral occurrence potential, and moderate (M = San Francisco) or low (L = Star) development potential of lead-zinc (Pb-Zn) ±Ag ±Au resources. The Horn Silver and Golden Reef mines in the San Francisco district are believed to have the greatest potential. The Bradshaw, Lincoln, and Washington district are rated as having low (L/B) mineral occurrence potential with a certainty level of B, and low (L) development potential for Pb-Zn ±Ag.

Mercury

The only area in the CCPA rated as having moderate (M/C) mineral occurrence potential for mercury (Hg) is the Pink Knolls district, and it has a low rating for development potential. The Cina mine in the Pink Knolls district has been thoroughly investigated as a possible source of Hg and S. Other districts with known Hg occurrences are the Blue Mountain district, Bradshaw district, Brimstone area, and San Francisco district which are all rated as low (L/B) for mineral occurrence potential and low (L) for development potential.

Molybdenum

The presence of a significant molybdenum (Mo) resource in the Pine Grove mining district suggests the potential for development at some point in the future. However, there is no current exploration in the district and the likelihood of development in the future is deemed low in the near future, but high in the long term. The Pine Grove mineral resource rated high (H/D) for mineral occurrence potential and high (H) for development potential and the future area of disturbance associated with mineral exploration, development, and extraction could range from 100 to 400 ha (250 - 990 ac).

Broken Ridge is a high-quality, deep Climax porphyry Mo target which has seen no historic production or significant exploration. Nonetheless, because of the high-silica garnet- and topaz-bearing rhyolite and strong surface Mo-Sn-W-B-Be-Bi-F-La-Li-Mn-Nb-Th-Y geochemical anomaly the deep target is given a moderate (M/B) rating for mineral occurrence potential and moderate (M) for development potential. Exploration efforts will likely result in significant surface disturbance (100 ha; 250 ac) in the next 20 years.

The Blawn Wash, Antelope Range, Escalante (The Point), Modena, Newton (North Creek, Sheep Rock), Stateline, and Typhoid Spring areas are thought to have the potential for future porphyry Mo exploration, but the results of such work are considered too speculative to rate higher than low (L/A) for mineral occurrence potential and low (L) for development potential.

Tungsten

The Granite mining district on the southeast flank of the Mineral Mountains stock is rated as having the best tungsten (W) potential, moderate (M/C) for occurrence and moderate (M) for development, in the CCPA. Other areas with past W production or known W occurrences include Rocky Range, Lincoln, Star, San Francisco, and Bradshaw; however, all of these areas are rated low (L/B) for mineral occurrence potential and low (L) for development potential. Other districts with nominal W production or occurrences include Pine Grove (Mo), Rocky Range (Cu), San Francisco (Cu), and Star (Pb-Zn), but these areas are not rated for W.

Uranium

A number of areas within the CCPA have had minor uranium (U) production or have known U occurrences. The Blawn Mountain district has low (L) occurrence potential with a certainyt level of B, and the Newton district has low (L) occurrence potential with a certainty leve of C, with both mining districts having had minor historical U production in the 1950s and 1960s. However, both are rated as having low (L) potential for future development. Several other areas, including the Blue Mountain, Broken Ridge, Pink Knolls, and Stateline districts, have recognized U mineralization, but are not seen as having development potential and are all ranked L/A for mineral occurrence potential and low (L) for development potential.

Salable Commodities[1]

Barite

The few known occurrences and mining districts with barite in the CCPA are rated high (H/D and H/B) for occurrence potential. Development potential for barite is low (L), and it occurs only as a secondary commodity within the CCPA. The San Francisco district produced small amounts in the past as a byproduct, and any additional production would also be as a byproduct. No disturbance related to barite is projected for the CCPA.

Building Stone

Building stone resources are widespread and areas of high (H/D and H/C) occurrence potential are present within the CCPA. Building stone is actively mined at a number of locations, often for landscaping purposes. Development will likely continue in the CCPA at current or slightly increased levels. Development potential at known quarries is high (H), and potential is moderate (M) at known host units with the exception of restricted lands. Total estimated disturbance over the next 20 years is about 130 ha (320 ac).

Common Clay

Although areas of high (H/D and H/B) occurrence potential for common clay are present in the CCPA, lack of historical exploration and minimal development of clay resources suggests

[1] Some of the commodities discussed under Salable Commodities maybe subject to location under the 1872 Mining Law or the "Common Vanities" Act of 1955. See Introduction, 1.2 Lands Involved, p. 23, for general discussion.

that little development will occur in the future. Small-scale extraction for local purposes is possible, but development potential is considered low (L). Disturbance is not expected to exceed 20 ha (49 ac).

Crushed Stone and Ballast

Crushed stone and ballast resources with high (H/D and H/C) occurrence potential are widespread throughout the CCPA, and large amounts of ballast have been produced at the Milford Quarry 1. Therefore, development potential is considered high (H) at existing quarries. However, development beyond the ballast quarry has been limited, and potential is considered low (L) at proper host formations for crushed stone. Development is projected to continue at current to slightly increased levels over the next 20 years, and disturbance is roughly estimated to range from 120 to 160 ha (300 - 400 ac).

Fluorspar/Fluorite

Fluorite resources are present within the CCPA, and small-scale historical production has occurred primarily in the Washington and Blawn Mountain mining districts. Known occurrences and prospects of fluorite have high (H) occurrence potential with a certainty level of D, while the Washington and Blawn Mountain districts' occurrence potential is rated H/C. Other fluorite bearing districts have moderate (M/B) occurrence potential. Because of the relatively small size of the deposits, little activity has occurred in the CCPA since the 1940s. For the same reason, minimal future development is projected; however, some exploration for larger deposits may occur in known fluorite districts. Development potential of fluorite in the Washington and Blawn Mountain districts is moderate (M), and is low (L) at other known fluorite-bearing districts. A rough estimate of disturbance over the next 20 years is from 25 to 50 ha (62 to 125 ac).

Gemstones

The primary gemstone of interest in the CCPA is red beryl at the Ruby Violet mine. Although large-scale developments have not been realized, small-scale development will certainly occur with larger-scale development possible at the mine. Also, Picasso marble and other gemstones will continue to be extracted at small scales intermittently. Occurrence potential at known mines is high (H/D). Development potential is high (H) at the Ruby Violet mine and known Picasso marble mines, and moderate (M) at other known gemstone sites. Rough disturbance estimates related to gemstone extraction within the CCPA is 25 to 40 ha (62 to 99 ac) over the next 20 years.

Gypsum

Gypsum occurs primarily in the southeast part of the CCPA in the Jurassic Carmel Formation in the Hurricane Cliffs, where its occurrence potential is high (H/C). At known gypsum mines, occurrence potential is also ranked high (H/D), but is ranked moderate (M/B) within less significant geologic units. Historically, little production of gypsum has come from the CCPA, and little production is expected for the foreseeable future due to better-defined and better-developed deposits elsewhere in Utah. Development potential at known mines or prospects in Cedar Canyon is moderate (M), and is low (L) elsewhere. Small amounts of extraction will likely occur in the Cedar Canyon area, but disturbance is not expected to exceed 25 ha (62 ac).

High-Calcium Limestone and High-Magnesium Dolomite

A number of geologic units present potential for high-calcium limestone and high-magnesium dolomite in the CCPA, but very little investigation has occurred. Geologic units known to host high-calcium limestone have a high (H/B) occurrence potential, and other limestone-bearing units have moderate (M/A) occurrence potential. Little known development has occurred, and little is expected, in part, due to well-established, high-volume production north of the CCPA in the Cricket Mountains. Development potential within the CCPA is considered low (L). Small-scale development for local use is possible, but disturbance is expected to remain under 20 ha (49 ac) for the next 20 years.

Kaolinite

A number of kaolinite deposits with high (H/D and H/C) occurrence potential are present in the CCPA, and periodic exploration and development has occurred primarily in the Blawn Mountain and White Mountain areas. The Sandy Wash 4 quarry has consistently produced kaolinite for about the last decade, but future production at the quarry may be hampered due to high mercury levels in the rock, which is problematic for the primary market – cement raw material. Development potential is considered high (H) at known mines and prospects, and is considered moderate (M) within alteration zones with known kaolinite occurrence. The level of development of kaolinite will likely depend on the status of existing markets (cement raw material) and potential for new markets. Projected disturbance ranges from 25 to 100 ha (62 to 250 ac) due to a high degree of uncertainty.

Lapidary Material

A variety of lapidary materials are present within the CCPA with a high occurrence potential (H/D and H/C). The banded, multi-colored opal at the Opal Mound is of primary interest in the area. Development potential is high (H) at known pits and prospects, and is moderate (M) within Quaternary rhyolite, which is a potential source of obsidian. Development will be intermittent and small-scale, and disturbance is estimated to be less than 25 ha (62 ac) over the next 20 years.

Lightweight Aggregate

Lightweight aggregate resources in the form of perlite and pumice are present in the CCPA. The primary deposits are in Quaternary rhyolite in the Mineral Mountains, and a well-defined resource is at the North Pearl Queen mine. These deposits have a high (H/D and H/C) occurrence potential. As there is a known resource, development potential is high (H), but extent of development will depend on demand and market. At known mines and prospects elsewhere in the CCPA there is a high occurrence potential (H/D), and development potential is moderate

(M). Occurrence potential is moderate (M/B) and development potential is low (L) within other host formations. Disturbance for the next 20 years is roughly estimated to range from 20 to 80 ha (49 to 198 ac).

Sand and Gravel

Sand and gravel resources with high (H/D and H/C) occurrence potential are widespread throughout the CCPA, primarily in Quaternary alluvial deposits. Numerous pits and prospects are present, and much of the resource development has occurred near Cedar City and the Interstate 15 corridor. Development potential is high (H) at existing pits and prospects, as well as near major transportation corridors. Elsewhere in the CCPA where proper host formations exist and land use is not restricted, development potential is moderate (M). Development of sand and gravel resources will continue at current or increased levels over the next 20 years, and disturbance is estimated to be up to 250 ha (620 ac).

Silica

Potential for occurrence of high-purity silica exists in the CCPA ranging from high (H/D) to moderate (M/A), and one permitted small mine produced negligible amounts of silica in recent years. Development potential of silica resources is low (L) as indicated by lack of significant historical production. Disturbance related to silica extraction is not expected to exceed 20 ha (49 ac) over the next 20 years.

Sulfur

Native sulfur deposits exist in the CCPA, with the most significant deposit at Sulphurdale. Known deposits have a high (H/D) occurrence potential. However, development potential of the deposit is low (L) as the vast majority of the world’s sulfur supply is produced as a byproduct of other extractive industries. Minor development may occur at Sulphurdale, but disturbance is expected to be less than 20 ha (49 ac).

Summary

The total expected surface disturbance in the CCPA from energy and mineral development during the next 20 years is tallied in the table below:

Table 1. Summary of estimated surface disturbance from energy and mineral developments in the CCPA during the next 20 years.

Activity	Average Annual Disturbance	Cumulative Disturbance
Petroleum Drilling	7.5 ha (18.4 ac)	149 ha (368 ac)
Petroleum Seismic	24.4 ha (60.2 ac)	487 ha (1204 ac)
Geothermal	7.6 ha (19.0 ac)	152 ha (380 ac)
Alunite	8.0 ha (19.7 ac)	160 ha (395 ac)
Copper	56.5 ha (139.6 ac)	1130 ha (2792 ac)
Gold-Silver	25.0 ha (61.8 ac)	500 ha (1236 ac)
Iron	58.0 ha (143.3 ac)	1160 ha (2866 ac)
Lead-Zinc	10 ha (24.7 ac)	200 ha (494 ac)
Mercury	2.5 ha (6.2 ac)	50 ha (124 ac)
Molybdenum	15.0 ha (37.1 ac)	300 ha (741 ac)
Tungsten	1.3 ha (3.1 ac)	25 ha (62 ac)
Building Stone	6.5 ha (16.1 ac)	130 ha (321 ac)
Common Clay	1.0 ha (2.5 ac)	20 ha (49 ac)
Crushed Stone – Ballast	7.0 ha (17.3 ac)	140 ha (346 ac)
Fluorite	2.0 ha (4.9 ac)	40 ha (99 ac)
Gemstones	2.0 ha (4.9 ac)	40 ha (99 ac)
Gypsum	1.0 ha (2.5 ac)	20 ha (49 ac)
High-Calcium Limestone	0.9 ha (2.2 ac)	18 ha (44 ac)
Kaolinite	3.0 ha (7.4 ac)	60 ha (148 ac)
Lapidary material	1.0 ha (2.5 ac)	20 ha (49 ac)
Lightweight aggregate	2.5 ha (6.2 ac)	50 ha (124 ac)
Sand and Gravel	12.5 ha (30.9 ac)	250 ha (618 ac)
Silica	0.9 ha (2.2 ac)	18 ha (44 ac)
Sulfur	0.9 ha (2.2 ac)	18 ha (44 ac)
GRAND TOTAL	**257.0 ha (635.1 ac)**	**5137 ha (12,694 ac)**
Reclaimed O&G	31.4 ha (77.5 ac)	627 ha (1550 ac)
Net Disturbance	**225.6 ha (557.5 ac)**	**4510 ha (11,144 ac)**

1.0 INTRODUCTION

1.1 Purpose and Scope

The purpose of this mineral potential report is to document and assess the mineral resource occurrence and development potential within the Cedar City Planning Area (CCPA), covering Beaver, Iron, and a small portion of northern Washington Counties, Utah. This report further evaluates the reasonably foreseeable development of those resources within the next 20 years to help with U.S. Bureau of Land Management (BLM) planning efforts.

This report draws upon, and updates where necessary, previous work by the Utah Geological Survey (UGS), and prior BLM planning documents with leasing analyses for oil, gas, coal, and geothermal from earlier management plans of the Pinyon, and Cedar, Beaver, Garfield, and Antimony areas (BLM, 1983, 1986). This report also incorporates the play concept for analysis of oil and gas resource potential as developed by the U.S. Geological Survey (USGS: Beeman and others, 1996; Charpentier and others, 1996; Gautier and others, 1996). The USGS defines an oil and gas play as "a set of known or postulated oil and (or) gas accumulations sharing similar geologic, geographic, and temporal properties, such as source rock, migration pathway, timing, trapping mechanism, and hydrocarbon type" (Gautier and others, 1996). Recent UGS geographic information systems-based publications on the geothermal (Blackett and Wakefield, 2004), oil and gas (Chidsey and others, 2004), limestone (Tripp, 2005), and building stone (Boleneus, 2008) resources were included in the current UGS analysis. The information provided in this report is based upon published data mentioned above and other information provided by the U.S. Bureau of Land Management's Utah State Office and Cedar City Field Office, Utah state agencies, and industry. Limited field studies were conducted. The following report uses a mineral occurrence potential rating scheme developed in BLM Manual 3031 (see Appendix A), along with a UGS development potential rating scheme that was derived from the BLM occurrence potential scheme (also in Appendix A). Identified energy and mineral resources are classified according to the BLM occurrence potential rating system found in BLM Manual 3031 and the UGS development potential rating system (both given in appendix A).

This report provides an intermediate level of detail for mineral assessment as prescribed in BLM Manual 3031 for planning documents. Mineral information in this report may be used in the preparation of the Cedar City Field Office Resource Management Plan and associated Environmental Impact Statement required by the Federal Land Policy and Management Act and the National Environmental Policy Act. Mineral resource occurrence ratings provided in this report are for all lands within the CCPA regardless of the land ownership. This report is not a decision document and does not present specific recommendations on the management of mineral resources.

The Energy Policy Conservation Act (EPCA) study is based on the USGS estimation of undiscovered, technically recoverable resources; Energy Information Administration (EIA) reserve calculations; and an estimate of restrictions or impediments to the development of those resources and reserves (U.S. Departments of Interior, Agriculture, and Energy, 2003). Although the main purpose of the EPCA report is to classify the availability of land for leasing and leasing stipulations, resources are also evaluated. The calculation of resources is primarily mathematical and the estimates, provided on a basin-wide scale, cross state boundaries and are of limited use on a more local, planning area scale. Within the planning area, evaluating the USGS oil and gas plays and the individual field-scale information provides a better basis for determining oil and gas potential than trying to extrapolate local conditions from the broader EPCA report.

Forecasting the mineral resource developments anticipated to occur in the next 20 years is a difficult assignment. You must first recognize the geological environment for potential economic mineral development and then project current and historic commodity requirements forward two decades. This latter task essentially requires forecasting commodity prices, which are renowned for past spikes and crashes, and the next twenty years are not likely to be less cyclical. Just over the last decade, commodity price indices reached record lows in October 2001 and near-term (30 year) record highs in July 2008. Deciding whether the relatively high commodity prices of the last 5 years (2006 to 2010) are just the latest spike or the "new normal" has been difficult, but we have leaned toward the latter interpretation.

1.2 Lands Involved

The CCPA is located in southwestern Utah and the boundaries of the CCPA generally consist of the Beaver County line to the north, the Beaver and Iron County lines to the east, the Iron-Washington county boundary to the south (except for a small portion of northwestern Washington County near Enterprise), and the Utah-Nevada state boundary to the west. No major waterways occur in the CCPA.

Land ownership and administration in the CCPA are shown in figure 1.2.1. There are approximately 1,519,442 ha (3,574,574 ac) of land within the CCPA, of which approximately 851,836 ha (2,104,933 ac) of public land are administered by the BLM. The CCPA encompasses lands where BLM-administered federal minerals underlie surface that is not administered by the BLM. These lands include the following:

- Part of Zion National Park and Cedar Breaks National Monument over BLM minerals totaling about 3555 ha (8785 ac).
- Parts of the Dixie and Fishlake National Forests totaling about 142,668 ha (352,540 ac).
- Split-estate lands under private surface totaling about 32,582 ha (80,512 ac).
- Split-estate lands under Utah state surface totaling about 3839 ha (9486 ac).

BLM minerals management policy falls into three categories: leasable, locatable, and salable. Leasable minerals (oil and gas, coal, geothermal, and potash) are subject to disposal under the authority of the Mineral Leasing Act of 1920, as amended by lease or exploration license/permit. A classification for leasable minerals, such as a Known Recoverable Coal Resource Area (KRCRA) or a Known Potash Leasing Area (KPLA), defines an area where a potentially valuable deposit has been identified and where competitive leasing is required.

Locatable metallic minerals (copper, gold, iron, lead, mercury, molybdenum, silver, tungsten, uranium, and zinc) are subject to mining claim location under the amended authority of the Mining Law of 1872. Salable minerals are subject to disposal under the authority of the

Materials Act of 1947, as amended (the Act of July 23, 1955), by contract sale or free use permit. Community pits may be designated on known deposits of salable minerals for the purpose of ensuring a supply of material by providing a superior right over subsequent claims or entries of the lands. The Act of July 23, 1955, referred to as the "Common Varietites Act," determined that many common varieties of mineral materials are not locatable under the 1872 Mining Law. To be locatable such mineral material must have some unique property giving it a distinct and special value as defined by regulation, status, and case law since passage of the 1955 Act. Many of the mineral commodities listed under Salable Commodities in the CCPA, which include barite, building stone, common clay, crushed stone and ballast, fluorspar and fluorite, gemstones, gypsum, high-calcium limestone and high-magnesium dolomite, kaolinite, lapidary material, lightweight aggregate, sand and gravel, silica, and sulfur, may fall under the Common Varieties Act. Although many of these nonmetallic or industrial minerals have been listed under salable minerals, some may be located under the Mining Law of 1872. There can be controversy over whether a commodity is common, and therefore disposed of as salable, or whether the material is uncommon, and therefore disposed of by location. In order to distinguish between common and uncommon varieties of material the case law has defined the following five McClarty guidelines:

1. there must be a comparison of the mineral deposit in question with other deposits of such minerals generally;
2. the mineral deposit in question must have a unique property;
3. the unique property must give the deposit a distinct and special value;
4. if the special value is for uses to which ordinary varieties of the mineral are put, the deposit must have some distinct and special value for such use; and
5. the distinct and special value must be reflected by the higher price which the material commands in the market place.

To be determined as an uncommon variety of material, one or more of the above guidelines must be satisfied to be locatable under general mining laws.

2.0 DESCRIPTION OF GEOLOGY

2.1 STRATIGRAPHY

2.1.1 Precambrian

Within the BLM's CCPA, the oldest rocks are Proterozoic-aged banded gneiss exposed along the west frontal fault of the Mineral Mountains (figures 2.1.1.1a and b). These rocks have been dated at 1750 Ma, and consist of resistant, light- to dark-gray biotite, quartz, K-feldspar, hornblende, and plagioclase gneiss, and local schist (Rowley and others, 2005). The oldest sedimentary-metasedimentary rocks occurring in the CCPA are Neoproterozoic in age, and are exposed in the Wah Wah and San Francisco Mountains. Neoproterozoic sediments were derived from the low continental interior to the east, and deposited westward in shallow-marine environments (Hintze and Kowallis, 2009). Neoproterozoic rocks in the San Francisco Mountains are located in the upper plate of the Frisco thrust fault, and also in the upper plate of the Reservoir and other thrust faults on the west side of the Wah Wah Mountains. The Neoproterozoic sequence in these areas generally consists of marine transgressive-regressive deposits of limestone (Blackrock Canyon Limestone), phyllitic shale or argillite (Inkom Formation), and quartzite (Mutual Quartzite).

2.1.2 Cambrian

In Utah, an erosion interval occurs between deposition of the latest Proterozoic sediments and the earliest Cambrian sediments. Cambrian sedimentary rocks in western Utah were deposited in a shallow-marine basin depositional environment or miogeocline, which was located west of a hinge line that marked the western edge of the shallow marine depositional environment of the stable craton (Hintze and Kowallis, 2009). Sediments laid down in early Paleozoic time thicken westward to over 6 km (19,685 ft) in the subsiding, deeper, miogeoclinal basin, and thin east of the hinge line to less than 1.6 km (5249 ft) on the stable, shallow, craton shelf. Within the CCPA, Cambrian-aged rocks are exposed in the San Francisco, Beaver Lake, Wah Wah, and Blue Mountains, and Indian Peak Range (Hintze and Kowallis, 2009). The Cambrian sequence in these areas generally consists of a Lower Cambrian quartzite (Prospect Mountain Quartzite) overlain by a Lower to Middle Cambrian thin shale and limestone (Pioche Formation), followed by a Middle to Upper Cambrian thick limestone and dolomite section (Wah Wah Summit, Orr, and Notch Peak Formations) with minor shaly interbeds (figures 2.1.1.1a and b).

2.1.3 Ordovician

Ordovician sedimentary rocks in western Utah were deposited in a westward-thickening miogeocline depositional environment like that of the underlying Cambrian sequence. Warm shallow waters extended many tens of kilometers offshore and organisms capable of building reefs appeared during Early Ordovician time (Hintze and Kowallis, 2009). Within the CCPA, Ordovician-aged rocks are exposed in the San Francisco, Beaver Lake, and Wah Wah Mountains, and Indian Peak and Needles Ranges (Hintze and Kowallis, 2009). In Utah, Ordovician strata are composed of a three-fold sequence consisting mostly of sandy bioclastic rocks in the Lower Ordovician (House and Fillmore Formations), thick quartz sandstones in the Middle Ordovician (Eureka and Watson Ranch Quartzites), and dolomites in the Upper Ordovician (Ely Springs Dolomite).

2.1.4 Silurian

Silurian sedimentary rocks in western Utah were deposited in a westward-thickening miogeocline depositional environment like that of the underlying Cambrian and Ordovician sequences. Silurian rocks form a sheet averaging 300 m (984 ft) thick in western Utah, and are mostly light and dark gray dolomite that can be locally cherty (Hintze and Kowallis, 2009). Silurian stratigraphy in Utah is mostly assigned to one formation, the Laketown Dolomite. Laketown Dolomite is exposed within the CCPA in the Beaver Lake and Wah Wah Mountains, and Indian Peak and Needles Ranges (Hintze and Kowallis, 2009).

2.1.5 Devonian

Sediments continued to be deposited in a westward-thickening miogeocline depositional environment during most of Devonian time, but by the Late Devonian, the simple miogeocline-craton pattern was broken up by the Stansbury Uplift (Hintze and Kowallis, 2009). Lower to Middle Devonian rocks are mainly limestones and dolomites, but in the Late Devonian, as a result of the Stansbury Uplift in Utah and Antler Orogeny in central Nevada, quartz sandstone and silty shale were deposited. Devonian-aged rocks are exposed within the CCPA in the Mineral, Beaver Lake, and Wah Wah Mountains, and Mountain Home, Indian Peak, and Star Ranges (Hintze and Kowallis, 2009). The Devonian sequence in these areas generally consists of a Lower to Middle Devonian dark to light gray dolomite (Sevy and Simonson Dolomites), Middle Devonian dolomite, limestone, and sandstone (Guilmette Formation), and Upper Devonian interbedded limestone, dolomite, sandstone, and shale (Pinyon Peak Formation and Pilot Shale).

2.1.6 Mississippian

During the Mississippian Period in Utah, the general pattern of miogeocline-craton sedimentation continued from earlier Paleozoic time, but superimposed on this was the development of new local basin and uplift features that caused sediments to accumulate in greater thicknesses in some areas relative to adjacent areas (Hintze and Kowallis, 2009). In western Utah, Mississippian sedimentation began with Late Devonian-Early Mississippian-aged clastic fluxes (Pilot Shale) derived from the Antler orogenic belt in Nevada, and dolomitic shelf deposits (Fitchville Formation; figures 2.1.1.1a and b). Within the CCPA, Mississippian-aged rocks are exposed in the Mineral, Beaver Lake, and Wah Wah Mountains, and Mountain Home, Indian Peak, and Star Ranges, and Shaunite Hills (Hintze and Kowallis, 2009). Early Mississippian deposits in these areas represent the most widespread shallow-marine incursion in Utah, and consist of thick fossiliferous limestone (Joana-Gardison-Redwall Limestones). In middle to late Mississippian time, subsidence in western Utah exceeded the rate of sedimentation and a starved basin developed in which phosphatic siltstone and shale (Delle Phosphatic Member of the Woodman Formation) were deposited. In the last half of the Mississippian Period, deposits in these areas were dominated by cyclic marine sedimentation (Humbug Formation and

Great Blue Limestone) (Hintze and Kowallis, 2009). Antler orogenic-belt clastic fluxes (Chainman Shale) from the west in Nevada also occurred during this time.

2.1.7 Pennsylvanian

Tectonic activity at the northwest end of the Ancestral Rockies orogenic belt during Pennsylvanian time produced deep basins and adjacent sharp uplifts in Utah, which determined thickness patterns of Pennsylvanian strata (Hintze and Kowallis, 2009). Shallow-water marine, cyclically interbedded limestone-sandstone-shale sequences were deposited on a broad, relatively stable, carbonate platform in southwestern Utah during Pennsylvanian time. Deposits in this region are generally thinner than Pennsylvanian deposits elsewhere in Utah, because of a broad high (Callville-Piute Platforms) that existed in the area. Pennsylvanian stratigraphy in the area is mostly assigned to one formation, the Callville Limestone. Callville Limestone is exposed within the CCPA in the Mineral, Beaver Lake, and Wah Wah Mountains, and Mountain Home, Indian Peak, and Star Ranges, and Shaunite Hills (Hintze and Kowallis, 2009).

2.1.8 Permian

Deposition of Permian sediments generally followed that of the Pennsylvanian, having the same basins and uplifts controlling erosion and deposition, and most of Utah periodically submerged during much of Permian time (Stokes, 1986). Permian stratigraphy is complex, as a result of several shallow-marine incursions, development of continental sediments to the east, and almost uninterrupted marine deposition continuing in the miogeocline belt to the west. Within the CCPA, Permian-aged rocks are exposed in the Mineral Mountains, Star Range, and Hurricane Cliffs (Hintze and Kowallis, 2009). During the late Early Permian, a regression of the Permian sea toward the north deposited vast marine sandstone (Queantoweap Sandstone) on the Callville-Pakoon-Queantoweap Platform that extended from the southwestern corner of Utah north into Sevier County (Stokes, 1986). Utah was located near the equator during the Permian Period, and together with shallow-shelf seas, produced sediments characteristic of warm, shallow water with high evaporation rates, as evidenced by significant gypsum and dolomite deposits (Pakoon Dolomite, and Toroweap and Kaibab Formations) contained in the Permian rocks.

2.1.9 Triassic

Utah's Early Triassic deposits generally have marine affinities, Middle Triassic deposits are absent resulting in an intervening unconformity, and the overlying Late Triassic deposits have continental origins (Hintze and Kowallis, 2009). Early Triassic strata were deposited similarly to Paleozoic patterns, having thin deposits in eastern Utah and progressively thicker deposits occurring westward towards the miogeocline in southern Nevada. During Middle Triassic time, the Mesocordilleran High in eastern Nevada acted as a barrier to marine flooding and deposition, and sediments were either not deposited or were removed by erosion (Stokes, 1986). In Late Triassic time, eastward subduction on the western continental margin produced the Nevadan Orogeny in the west and a change from marine to continental depositional environments in eastern Utah. Triassic rocks in western Utah are exposed in only a few small scattered outcrops in deep folds, fault blocks, or under thrust plates. In the CCPA they are exposed in the Mineral and Blue Mountains, Star and Rocky Ranges, and Hurricane Cliffs

(Hintze and Kowallis, 2009). Early Triassic strata (Moenkopi Formation) consist of marine and tidal flat mudstone, siltstone, sandstone, and platy limestone, primarily deposited on a broad flat coastal plain that sloped gently westward. Late Triassic strata (Chinle Formation) consist of continental clastics, containing a substantial quantity of reworked volcanic ash, that were deposited in an enclosed continental basin as a sequence of alternating fluvial and lacustrine deposits (Hintze and Kowallis, 2009).

2.1.10 Jurassic

Throughout the Jurassic Period in Utah, the Mesocordilleran High in Nevada influenced three distinctly different environments that succeeded each other in the western interior (Stokes, 1986). The first of these paleoenvironments was a sandy desert that formed in the rain shadow east of the Mesocordilleran High, followed by a succession of shallow marine invasions through Canada north of the highland, and finally as the period ended, an extensive river system and shifting fresh-water lake environments east of the highland. Within the CCPA, Jurassic-aged rocks are exposed in the Mineral, Wah Wah, and Blue Mountains, Star Range, Hurricane Cliffs, Iron and Granite Mountain, and Three Peaks areas (Hintze and Kowallis, 2009). In southwestern Utah, Early Jurassic sandstone sequences thicken and pass beneath overthrust plates along Utah's hinge line. Early Jurassic deposits are composed of fluvial sandstones, siltstones, and mudstones (Moenave and Kayenta Formations), and eolian sandstone (Navajo Sandstone; figures 2.1.1.1a and b). Middle Jurassic deposits in southwestern Utah represent a major marine transgression and regression, beginning with interbedded sand and silt grading upward into massive gypsum and interbedded red mudstone (Temple Cap Formation). Marginal marine to marine limestones, shales, and evaporites that include gypsum (Carmel Formation) were deposited during flooding and regression of a shallow seaway. Late Jurassic rocks have been removed by erosion in southwestern Utah, which represents a major unconformity between the Middle Jurassic and overlying Cretaceous rocks in the region (Hintze and Kowallis, 2009).

2.1.11 Cretaceous

The Sevier orogeny shaped Utah's Cretaceous landscape and transformed western Utah into a mountainous region of folded and faulted Precambrian, Paleozoic, and Mesozoic strata, as a result of compression produced by subduction at the western edge of North America (Hintze and Kowallis, 2009). Cretaceous rocks in Utah were mostly deposited during the last half of the period, and are thickest adjacent to the Sevier mountain front and thin eastward. The Late Cretaceous was also the last time an epicontinental sea invaded Utah, where east of the uplift and along a coastal plain large coal deposits formed. Cretaceous-aged rocks are exposed within the CCPA in the Hurricane Cliffs, Iron and Granite Mountain areas, Three Peaks area, Red Hills area, Antelope Range, and hills south of Newcastle, Utah (Rowley and others, 2006; Hintze and Kowallis, 2009). Cretaceous deposits derived from the Sevier orogenic belt to the west are mostly clastic rocks deposited in a coastal plain environment, and are composed of coal-bearing non-marine sandstones and conglomerates (Dakota Formation), and coal-bearing, near-shore sandstones and mudstones (Straight Cliffs Formation) that interfinger eastward with marine shale (Tropic Shale). West of Cedar City the Iron Springs Formation is equivalent to the Dakota and Straight Cliffs Formations, but lacks significant coal deposits.

2.1.12 Tertiary

The poorly understood Paleocene-Eocene Claron Formation sedimentary rocks were deposited in the southwestern arm of Lake Flagstaff (Hintze and Kowallis, 2009). The Claron Formation is temporally equivalent to the Flagstaff Limestone of central and eastern Utah and as designated extends southwestward roughly from a line between Beaver and Escalante. The Claron Formation underlies much of Iron and Washington Counties and thickens easterly to a maximum of over 600 m (1968 ft) near Panguitch and Antimony in Garfield County. The Claron Formation consists of a variegated sequence of mudstone, siltstone, sandstone, limestone, and minor conglomerate deposited in the fluvial and lacustrine environment of an intermontane basin (Hatfield and others, 2010; Robert Biek, personal communication, May 2011).

In the Eocene, southwestern North America was undergoing flat-slab subduction and northeast-southwest compression. The Farallon plate was subducting shallowly along the western United States and northern Mexico, roughly 800 km (497 mi) to the southwest of Utah (Best and others, 1989a; Best and Christiansen, 1991). In the Eocene, magmatism swept southward from Idaho into the north-central Great Basin. Magmatism in the Great Basin was initially centered near Carlin in north-central Nevada about 40 Ma and then rapidly spread eastward toward Bingham Canyon in northwestern Utah.

This calc-alkaline, subduction-related magmatism shifted southward in the early Oligocene forming an east-west belt through west-central Utah (largely Juab County) from the Ibapah batholith in the west, to Eureka in the east (Best and others, 1989a; Best and Christiansen, 1991). The wave of magmatism continued southward in the late Oligocene creating another east-west-trending belt through western and northern Beaver County with intermediate plugs in the San Francisco, Rocky, and Beaver Lake mining districts (figure 2.1.12.1). These stocks are strongly magnetic and result in significant aeromagnetic highs (Bankey and others, 1998). In addition to the intrusion of these causative granodioritic to quartz monzonitic stocks (32–28 Ma) in these districts, localized coeval andesitic flows, e.g. Horn Silver Andesite (33 Ma), were erupted along this belt in the CCPA and farther west. This was followed by much more extensive dacitic tuffs of the Needles Range Group (32–29 Ma) and Isom Formation (27–26 Ma) from calderas farther southwest in southwestern Beaver County, northwestern Iron County, and adjoining eastern Lincoln County, Nevada. In the eastern CCPA and farther east, the Bullion Canyon Volcanics (29–22 Ma) erupted from calderas in the Tushar Mountains of eastern Beaver and western Piute Counties (Best and others, 1989a; Best and Christiansen, 1991).

Subsequently, the intermediate calc-alkaline magmatism gradually transitioned (24–17 Ma) to more bimodal compositions related to the onset of the extension and continental rifting that ultimately produced western Utah's well known Basin and Range topography. This extension and listric faulting resulted in locally significant rotation of pre-Miocene strata. In central Beaver County this magmatism produced an east-west belt of granitic or rhyolitic stocks (23–22 Ma) in the Pine Grove, Blawn Mountain, Blawn Wash, South Star (Moscow stock), Fortuna, and Newton mining districts (figure 2.1.12.1). At the Pine Grove, Blawn Mountain, and Blawn Wash areas these intrusives are high-silica rhyolites. Basin and Range extension ultimately resulted in the formation of deep basins underlying the Hamlin Valley, Pine Valley, Milford Valley, Beaver Basin, portions of the Escalante Desert (near Lund and Newcastle), and Parawon Valley (Bankey and others, 1998).

Magmatism again shifted farther south creating the northeast-trending Iron Axis mineral belt including the Iron Springs district (~22 Ma) in the early Miocene. These stocks are strongly magnetic and are associated with pronounced aeromagnetic highs (Bankey and others, 1998). The Mineral Mountains batholith (28–17 Ma), the largest exposed batholith in Utah at approximately 244 sq km (94 sq mi), is also temporally part of this magmatic episode. Comagmatic volcanism resulted in the eruption of the Blawn Formation (23–18 Ma) in the west, along with the Mount Belknap Volcanics (21–16 Ma) farther east in the Tushar Mountains (Best and others, 1989a; Best and Christiansen, 1991). These volcanic rocks are strongly and widely hydrothermally altered to argillic and advanced argillic alteration, especially at Blawn Wash, Pink Knolls, and the Tushar Mountains (Cunningham and others, 2007). An apparent lull in magmatic activity occurred in the central and western portions of the CCPA during the middle Miocene (between about 16.5 and 13 Ma) (Christiansen and others, 1986), although intrusion, volcanism, and alteration seems to have continued during this period in the Marysvale volcanic field to the east (Rowley and others, 1998; Cunningham and others, 2007).

In the middle Miocene, strongly bimodal magmatism and pronounced extension continued southwestward producing granitic and rhyolitic plugs and coeval mineralization in the Stateline (~18 Ma), Gold Springs (~18 Ma), Marysvale (18–14 Ma), and somewhat later in the Escalante (~12 Ma) and Mineral Mountain (~12 Ma) districts. This bimodal magmatism also produced the basalt and rhyolite volcanic packages of the Steamboat Mountain (13–12 Ma) and Sevier River (15–6 Ma) Formations. The Steamboat Mountain Formation includes high-silica, high-alkali, topaz-bearing rhyolites. Hydrothermal alteration continued unabated during this period with extensive areas of primarily argillic alteration at Typhoid Spring, Modena, and in the Tushar Mountains.

At approximately 13 to 12 Ma (?) a northeast-trending series of normal and strike-slip faulting developed in a broad zone from Modena on the southwest to approximately the Star Range on the northeast, paralleling the northwest margin of the Escalante Desert. This zone, which includes the Bible Springs fault zone (Best and others, 1987a, 1987b), is roughly 30 km (18 mi) wide, up to 100 km (62 mi) long, and has coeval rhyolitic plugs, dikes, and flow domes of the Steamboat Mountain Formation. Portions of this belt are underlain by a coincident aeromagnetic high (Bankey and others, 1998). The volcanic rocks in this belt have locally been affected by silicification, argillic, and advanced argillic alteration along with minor epithermal mineralization. The northwestern margin of this belt from the southern Indian Peak Range to the south end of the Wah Wah Mountains has a coincident lithophile stream-sediment geochemical anomaly with elevated Mo, Th, Sn, and U (Motooka and Miller, 1983; Miller and others, 1990a, 1990b, 1990c, 1990d).

The extensive hydrothermal alteration and mineralization accompanying the wave of Tertiary magmatism gradually dissipated in the Pliocene and Pleistocene (e.g. Gordon or Sulphurdale district). However, extension, predominantly basaltic volcanism, and high geothermal heat flow (Roosevelt and Thermo Hot Springs) have continued in the eastern Basin and Range to the present day (Hintze and Kowallis, 2009).

2.1.13 Quaternary

The beginning of the Quaternary Period in Utah is characterized by the encroachment of lake water and development of stream and river drainage patterns across the lower elevations of the landscape, and glaciers forming at higher elevations (Stokes, 1986). The Quaternary Period consists of the Pleistocene and Holocene Epochs, and deposits are commonly only weakly consolidated. In western Utah, these deposits are mainly lacustrine, alluvial terrace, alluvial/colluvial fan or wedge, fluvial terrace, pediment, eolian sand, playa, and floodplain deposits. Rocks in these deposits are mainly composed of sandstone, quartzite, basalt, limestone, and silicic volcanic rocks (figures 2.1.1.1a and b). Lake Bonneville shoreline deposits generally consist of well sorted sand and gravel benches or terraces and more broadly distributed finer grained material in the deeper portions of the lake. These deposits in the CCPA are exposed to south of Lund, and in the northern part of Beaver County in the Wah Wah and Pine Valleys. Alluvial fan deposits mostly consist of mixed coarse and fine material derived from nearby mountain ranges, were deposited in adjacent down-faulted valleys, and occur throughout the CCPA. Fluvial deposits generally consist of moderately sorted sand and gravel terraces deposited along major drainages. Pleistocene fluvial-alluvial and Holocene fluvial terrace deposits occur throughout the CCPA along major drainages. Extensive surficial sand dune deposits produced by wind action are present in many wide, flat valley areas.

2.2 Geologic History

The CCPA covers parts of three physiographic provinces (figure 2.2.1), which affect the geologic history and geology of the area. These are, from northwest to southeast, the Basin and Range, the Basin and Range/Colorado Plateau Transition, and the Colorado Plateau provinces (Stokes, 1986).

From late Precambrian to early Mesozoic time, Utah was generally located in a large basin-like down-warping of the earth's crust, or a miogeocline, being slightly above or slightly to significantly below sea level. During this time, the Wasatch hinge line separated thin sedimentary rock deposits in eastern Utah from strata an order of magnitude thicker in western Utah, having the hinge line and depositional pattern periodically altered due to several local uplifts (Hintze and Kowallis, 2009). During the Cretaceous Sevier orogeny, western Utah rose greatly having high mountains and eastern Utah was at or below sea level. In the late Eocene, about 40 million years ago, volcanism started in western Utah with huge, periodic explosive volcanic eruptions that lasted about 30 million years. Basin and Range block faulting began during the Middle Miocene producing much of the well known topography in the present Great Basin, and coeval basaltic and rhyolitic volcanism.

The Wasatch Line, roughly dividing western from eastern Utah, was in existence in the Late Precambrian and is a relatively narrow tectonic hinge zone between wide regions of strongly contrasting geologic history in Utah (Stokes, 1986). Generally during the Paleozoic in Utah, the Wasatch Line formed an approximate dividing line between the subsiding miogeocline region to the west containing deeper water marine environments, and the stable craton to the east containing warm, shallow-marine and terrestrial environments. Starting in the middle Paleozoic, major orogenic activity broke up the pattern of earlier periods. The Devonian-Mississippian-age Antler Orogeny deformed and uplifted the continental edge in Nevada and destroyed the western part of the miogeocline, and produced clastic sediments in areas previously dominated by limestone. The Wasatch Line was temporarily obscured again during Pennsylvanian time by the Ancestral Rockies orogenic belt that trended west-northwest from Oklahoma to western Utah (Stokes, 1986).

Along the west coast of North America, steeply dipping subduction beginning in Triassic time produced the Nevadan Orogeny of Late Jurassic-Early Cretaceous age (Hintze and Kowallis, 2009). During this event, island arcs were accreted to the western edge of the North American continent, and in Utah, several small granitic intrusions were emplaced along the Utah-Nevada border during the Jurassic. Compressional effects produced by subduction along the west coast of North America also gave rise to the Sevier Orogeny, which lasted throughout Cretaceous and Paleocene time (Hintze and Kowallis, 2009). The Sevier orogenic belt trended diagonally across Utah from western Iron County to the Cache Valley area in Cache County. In western Utah, this major mountain building event produced high mountains from folding and thrust faulting generated by east-west-directed compressional forces. This event produced multiple eastward-moving thrust sheets, thick deposits of conglomerate and sandstone in western Utah, and thick deposits of shale farther eastward. Major episodes of thrust faulting that occurred during this period thrust large slabs of Neoproterozoic and Paleozoic strata significant distances eastward, and younger thrusts undercut older ones carrying them piggy-back as a stack of thrusts.

In Utah, a period of intense igneous activity occurred for approximately 25 million years during the late Eocene, Oligocene, and early Miocene Epochs, where both intrusive and extrusive igneous rocks were produced on an unprecedented scale, especially in western Utah (Stokes, 1986). During the maximum eruptive phase of this period, between 30 and 20 million years ago, very large volumes of ash falls and flows were produced from explosive calderas, as a result of subduction of a shallow-angled slab that extended an unusual distance inland from the western continental plate boundary (Hintze and Kowallis, 2009). Dacite and rhyolite ash-flow tuffs are the predominant rock type associated with this period. Within the CCPA, the Indian Peak volcanic field and caldera complex, located in the area of the Beaver County, Utah-Nevada border is an example of this most violent eruptive time in the state's history. This magma system ejected approximately 10,000 cubic km (2399 cubic mi) of rhyolite ash flows and dacite over an area more than 55,000 sq km (21,236 sq mi; Hintze and Kowallis, 2009). Granitic intrusions of this age are exposed in the Mineral, San Francisco and Beaver Lake Mountains, and the Indian Peak and Star Ranges, as well as other scattered small occurrences. Laccolithic intrusions also occurred during this period, creating domes as they bent the layered strata upward and formed Iron and Granite Mountains and The Three Peaks in Iron County. Oligocene-aged intrusions produced significant hydrothermal activity and subsequent mineral deposits in western Utah, and those within the CCPA have been explored by numerous mines and prospects.

In mid-Miocene time, much of the plate boundary on the North American west coast changed from subduction to transform forming the San Andreas fault system (Hintze and Kowallis, 2009). This tectonic change also initiated Basin and Range extension in western North American, where north-south-trending, extensional, normal-slip faults developed and significantly increased the east-west width of western North America. The alternating pattern of generally north-south oriented elongated mountain ranges separated by alluvial-fan-dominated valleys in the Great Basin resulted from this extensional faulting. The Wah Wah, Mineral and San Francisco Mountains, and Indian Peak and Mountain Home Ranges are examples of block-faulted, rotated uplifts caused by this tectonic activity in the CCPA. The Hurricane Cliffs east of Cedar City separate the Basin and Range Province to the west from the more layer-cake stratigraphy of the Colorado Plateau Province to the east, and are a result of uplift along the Hurricane fault zone that also formed during this presently active extensional tectonism.

In the middle Miocene, about 17 million years ago, volcanic patterns changed as a result of development of the transform plate boundary on the North American west coast. Extension of the crust caused by this tectonic change resulted in crustal thinning, which brought asthenosphere-derived magmas to the surface, and development of bimodal volcanism in western Utah (Hintze and Kowallis, 2009). Bimodal volcanism produced basaltic cones and lava flows and rhyolitic domes and lava flows across extensive areas in the CCPA, and lasted into the Quaternary Period. Large volcanic deposits of this type and age are exposed in the Wah Wah, Tushar, Black, Harmony, and Bull Valley Mountains, and Indian Peak and Antelope Ranges. In the Mineral Mountains, a rhyolitic dome less than a million years old erupted and the deep residual heat still present represents Utah's largest geothermal resource (Hintze and Kowallis, 2009).

3.0 DESCRIPTION OF ENERGY AND MINERAL RESOURCES

3.1 Leasable Commodities

3.1.1 Oil and Gas

Introduction

The plays described below are generally numbered to correspond with those presented in the USGS's 1995 National Assessment of United States Oil and Gas Resources (Beeman and others, 1996; Charpentier and others, 1996; Gautier and others, 1996). The maps of the play boundaries generally follow the same boundaries used by the USGS, and the descriptions presented here are liberally taken from Beeman and others (1996), Charpentier and others (1996), and Gautier and others (1996). The USGS originally included the Devonian through Pennsylvanian play reservoirs with the Proterozoic-sourced play, but in this report they are separated by the UGS because the Devonian-Pennsylvanian depositional sequence contains both source and reservoir beds and can be considered a discrete play. In addition to the USGS identified plays mentioned above, a new play has been added for coal-bed gas. Some of the plays are hypothetical because they have no proven reserves or production history.

Unconformity "A" Play (USGS play number 1901)

This is a confirmed productive play based on the presence of an unconformity seal (Unconformity "A") at the base of the Quaternary valley fill in most eastern Great Basin valleys and production from the 15 commercial fields in eastern Nevada. The unconformity overlies rocks ranging in age from early Paleozoic to middle Tertiary–rocks of varied lithology, from marine dolomites and limestones, sandstones, siltstones, and shales of varying degrees of metamorphism, and volcanic and plutonic igneous rocks. Unconformity "A" is the seal for all the more important known oil accumulations in the eastern Great Basin. This play is confined to the basin centers with deep Quaternary fill.

Reservoirs: Reservoirs are fractured and porous Paleozoic carbonate beds; lacustrine sandstone, siltstone, and carbonate beds of Tertiary age; and Oligocene and Miocene volcanic rocks, all of highly variable thickness.

Source rocks: Source rocks are organic-rich marine shales of Mississippian and Late Devonian age; lacustrine oil shale and bituminous shale and shaly carbonates of early Tertiary–Late Cretaceous age, in unconformity or fracture communication with overlying reservoirs. The American Petroleum Institute (API) has devised a measuring scale to report the density of liquid petroleum products in degrees API gravity, whereby oil with the least specific gravity has the highest API gravity. Hydrocarbons in this play are mainly oil ranging between 15° and 40° API.

Timing and migration: Because of complicated burial and thermal history, thermal maturity of source rocks varies widely, from mature to overmature to immature, sometimes over short distances. In most areas, Devonian and Mississippian source rocks probably reached the oil-generation stage by Permian or Triassic time, and probably earlier in the strongly subsiding foredeep area of the Antler orogenic belt in eastern Nevada. Early stratigraphic and structural traps formed contemporaneously with the Late Devonian–Mississippian development of the Antler Thrust Belt in Nevada. Most early accumulations were remigrated and/or destroyed during complex Cenozoic structural movements. Generation was restored in late Cenozoic time with subsiding of the graben elements of the Basin and Range structural complex, at which time most preserved accumulations formed.

Traps: Traps are folds, faulted folds, block-faulted beds, slide blocks, stratigraphic pinchouts, and buried hills beneath the valley fill.

Exploration status and resource potential: Drilling depths are highly variable. The play is moderately well explored in Railroad Valley, Nevada, where more than 100 exploratory wells have been drilled, slightly explored in Pine Valley, Nevada, but it is little explored in most other valleys. Existing Nevada fields range in size from 11,735 to over 2,464,303 m^3 (0.1 to 21 million barrels [bbls]) of cumulative oil production through 2009.

Further exploration will require high-resolution geophysical data, aided by high-caliber Rock-Eval and maturity data on source-rock distribution. There should be numerous undrilled structures beneath the valley fill in several valleys containing difficult-to-find targets similar in size to those at Railroad Valley in Nevada.

Late Paleozoic Play (UGS play number 1902, hypothetical)

This hypothetical play is based on the possibility that early-formed traps in carbonate and sandstone reservoirs may be preserved within the upper Paleozoic (Devonian through Permian) section, sealed by interbedded or overlying shales and shaly carbonates or faults, independent of the unconformity "A" trapping system. The play involves differing post-Paleozoic structural styles but is based primarily on the presence or absence of reservoirs, seals, and thermally preserved source rocks of late Paleozoic age. This play occurs where there is little or no basin fill, or primarily the “range” portion of the Basin and Range Province.

Reservoirs: The reservoirs of this play include marine and deltaic marine sandstone and siltstone beds of the Mississippian-Pennsylvanian Diamond Peak and Chainman Formations as well as dolomitized carbonate beds, in part reefoid or moundlike, of the Devonian Sevy, Guilmette, and Simonson Formations, the Mississippian Joana and Monte Cristo Formations, and the Pennsylvanian-Permian Ely and Arcturus Formations. Accessory reservoirs, related to leakage from earlier traps, may be remnants of eroded pre-Cretaceous Mesozoic clastics.

Source rocks, timing, and migration: Primary source rocks are the organic-rich marine Mississippian Chainman, Mississippian-Pennsylvanian Manning Canyon, and Permian Phosphoria and equivalent rocks; secondary potential sources are dark marine shales and shaly carbonates of Pennsylvanian and Permian age. Source rocks are overmature in much of the region but may be mature to immature in specific areas. Oil generation and migration from Mississippian source rocks probably began by Permian time in much of the area and earlier in areas of thick Permian–Pennsylvanian basins, such as the Oquirrh-Sublett basins of Utah and Idaho and the Butte basin belt in eastern Nevada. Timing and generation in Manning Canyon and Phosphoria source rocks is uncertain because of post-Permian erosion in the entire area of the play and the lack of data on the quality of these rocks as source rocks.

Traps: Traps are pre-Tertiary folds, thrusts, and vertical fault blocks; sandstone and (or) carbonate stratigraphic traps; and zones of lateral porosity change and carbonate buildups. Seals are upper Paleozoic shales, argillaceous carbonates, rare evaporates, and fault-associated seals in thrusted areas.

Resource potential: Depth range of reservoirs is highly variable because of several post-depositional periods of structural growth and erosion and the great thickness of Paleozoic rocks in basinal areas. This play can be subdivided into several subplays mainly on the basis of the Total Organic Carbon content and maturity quality of upper Paleozoic potential source-rock facies. The play has reasonably good exploration potential for at least moderate-sized accumulations in selected areas of favorable source rock maturity and structural styles.

Permo-Triassic Unconformity Play (USGS play number 2106)

This Transition Zone play is a downdip extension of the tar sand deposits of south-central Utah. It is based on the assumption that oil migrated generally east and south to form the giant pools that were subsequently biodegraded into the tar sand deposits near the outcrop and heavy oil accumulations in the subsurface. It is named the Permo-Triassic Unconformity Play because all of the known accumulations, shows, and oil staining are associated with this unconformity, either above or below. The oil-and-gas-prone portion of the play area is restricted to the southeastern part of the CCPA. The oil and gas portion of this play may be bounded to the north by carbon dioxide flushing that was generated by intrusion and extrusion of the large pile of Miocene Tushar volcanics at the north end of the Kolob Plateau (Anonymous, 1984).

Reservoirs: The tar sand and heavy oil accumulations are in the Permian White Rim Sandstone. Downdip production has been recorded in southcentral Garfield County at the Upper Valley field from the Timpoweap Member of the Triassic Moenkopi Formation and from the Permian Kaibab Limestone. All of the sandstones are eolian deposits that have excellent porosity and permeability. Thicknesses range from a pinchout edge to 91m (300 feet).

Source Rocks: A wide variety of source rocks have been proposed for the tar sand deposits and, hence, the downdip accumulations. Among the most prominently mentioned are the Mississippian Chainman Shale, Pennsylvanian Paradox Formation, Permian Kaibab Limestone and Phosphoria Formation, and Triassic Moenkopi Formation. A recent addition to this list is the Precambrian Chuar Group. Sprinkel and others (1997) reported that organic geochemical analyses indicate a Permian source for the oil produced at the southcentral Garfield County's Upper Valley field, but the specific source unit is undetermined.

Timing and Migration: Neither the time of generation nor migration is known; although most work suggests that final migration into the Tar Sand Triangle deposits of eastern Garfield and Wayne Counties and northwestern San Juan County occurred after the Laramide Orogeny. Igneous rocks are believed to have reacted with Paleozoic carbonate rocks at depth and created a pulse of carbon dioxide about 30 million years ago that flushed petroleum to the east and south from the north end of the Kolob Plateau (Anonymous, 1984; Chidsey and others, 1998; UGS, 1998), but the exact migration pathways are unknown.

Traps: Both structural and combination traps predominate even though the largest deposit, the Tar Sand Triangle deposit (eastern Garfield and Wayne Counties), is largely a stratigraphic trap. As the hydrocarbons migrated eastward and southward, existing structures (mostly Laramide in age) would have been charged, or filled with hydrocarbons, producing fields such as Upper Valley (southcentral Garfield County) and Virgin (eastern Washington County). In the case of the Upper Valley field, the oil was pushed to the flank of the structure after charging of the reservoirs by hydrodynamic conditions (Allin, 1990). The northern part of the play is likely flushed by carbon dioxide, while petroleum deposits are likely in the southeastern part of the CCPA. Depths to the petroleum deposits range from less than 305 to almost 915 m (1000 - 3000 ft) and seals are provided by shale beds as well as by reduction in permeability due to cementation and clay content.

Paleozoic Devonian-Pennsylvanian Play (UGS play number 2108)

This play in the Transition Zone underlies the southeastern part of the CCPA. It is based on the possibility that early-formed structural and stratigraphic traps may be preserved within the Devonian through Pennsylvanian section, sealed by interbedded or overlying shales and shaly carbonates, or faults. The hydrocarbon area of this play may be restricted to the north by carbon dioxide flushing that was generated by Miocene magmatism associated with the Tushar volcanic rocks at the north end of the Kolob Plateau (Anonymous, 1984).

Reservoirs: Reservoirs include dolomitized carbonate beds, in part reefoid or moundlike, of the Devonian Guilmette Formation, the Mississippian Redwall Limestone, and the Pennsylvanian Callville Limestone. The Redwall produced 1995 m^3 (17,000 bbls) of oil from one well at the Upper Valley field, located to the east of the CCPA in southcentral Garfield County between Tropic and Escalante.

Source Rocks: Primary source rocks are the organic-rich, marine Mississippian Chainman Shale, Mississippian-Pennsylvanian Manning Canyon Shale, and equivalent rocks that occur to the west of the play; secondary potential sources include the Thunder Springs Member of the Mississippian Redwall Limestone and the dark marine shales and shaly carbonates of Pennsylvanian age. Source rocks are immature to overmature to the west of the play area in western Beaver and Iron Counties (Sandberg and Gutschick, 1984).

Timing and Migration: Oil generation and migration from Mississippian source rocks probably began by Permian time in much of the area and earlier in areas of thick Permian–Pennsylvanian basins, such as the Oquirrh basin of Utah and the Butte basin belt in eastern Nevada. Timing and generation in Manning Canyon source rock is uncertain and data are insufficient on the quality of these source rocks.

Traps: Traps are pre-Tertiary folds and vertical fault blocks, sandstone and (or) carbonate stratigraphic traps, and zones of lateral porosity change and carbonate buildups. Seals are equivalent-aged Paleozoic shales, argillaceous carbonates, and rare evaporites that interfinger with and occur as lateral equivalents of the reservoir units.

3.1.2 Coal-Bed Gas

Cretaceous Coal-Bed Gas Play (UGS play number 2100)

This coal-bed-gas play was defined by the UGS to cover potential reservoir areas of the coal-bearing Upper Cretaceous units of south-central Utah. The coal-bearing unit of the CCPA is the Dakota Formation of south-central Utah. The CCPA coal-bed-gas play is on figure 5.1.1.1.

Reservoirs: The coals of the Dakota Formation were deposited by a series of coalescing delta complexes derived from a westerly source. Coal beds are generally developed in a 10- to 16 km (6- to 10-mi)-wide band that developed landward of the delta front sandstone bodies. Carbonaceous shale and sandstone that interfinger with the coal beds may also be charged with some coal-bed-derived gas. A few shallow coal beds from the Dakota Formation with less than 305 m (1000 ft) of cover have been tested from coal exploration holes, and the methane content from these samples ranges from no methane up to about 0.4 m^3/t (13 ft^3/st) (Doelling and others, 1979). These numbers are not encouraging, but deeper coal beds in the area may contain more methane. In 2002, Legend Energy drilled the Pugh 8 well in section 34, T. 38 S., R. 5 W. (about 4 miles northeast of the town of Alton), cored two Dakota coal beds between 367 and 377 m (1203 and 1236 ft), and reported gas shows from these coals. The well was plugged and abandoned in early 2004, but no specific gas content data have been released.

Source Rocks: The reservoir coal beds act as a source for gas for themselves; the gas can either be thermogenic gas generated during increasing coalification, or biogenic gas that was generated by bacteria introduced by more recent groundwater movement through the coal beds. Carbonaceous shale has also been shown to be a source of gas at the Drunkards Wash field in Carbon County (Lamarre, 2001). Available coal quality data indicate the coal in the CCPA is mostly subbituminous in rank (Doelling and Graham, 1972) and thus, would not have generated more thermogenic gas than 1.5 to 3 m^3/t of coal (50 to 100 ft^3/st). Limited desorption data from 14 samples from similar Dakota coals with less than 244 m (800 ft) of cover have gas contents ranging from no gas up to 0.4 m^3/t (14 ft^3/st) of coal (Doelling and others, 1979) and average about 0.1 m^3/t (4 ft^3/st). The deeper coals would need to have significantly higher gas contents to be economically attractive, but given the subbituminous rank of the coal in these fields, the gas content will not likely be more than 3 m^3/t (100 ft^3/st), which would not be economic at current market prices.

Timing and Migration: Vitrinite, a coal component derived from woody material, increases its petrographically measured light reflectivity during increasing thermal alteration associated with greater coalification. Limited vitrinite reflectance data from the Dakota coals in the CCPA indicate that the Upper Cretaceous coals in this area are low rank (borderline subbituminous to bituminous), with vitrinite reflectance levels of less than 0.57%, and are therefore immature to just entering the oil generation window (Hucka and others, 1997). Initial thermogenic gas was possibly generated in the Eocene during maximum burial. Late-stage biogenic gas generation would have begun during uplift, cooling, and dissection during the late Pliocene and Pleistocene.

Traps: Coal-bed gas is held in the matrix of the coal by the hydrostatic pressure of the groundwater in the coal bed. Fractures in the coal beds (cleats) allow the gas and water to be communicated to the well bore. Higher rank coals tend to have more closely spaced fracture development, but structure may enhance coal fracture development whereby better fracture networks are developed along fold axes and faults. Up dip migration may also have influenced the accumulation of coal-bed gas deposits if the coal beds pinch out before they reach the surface. In areas with active hydrologic systems of recharge and groundwater flow, bacteria introduced by groundwater can generate secondary biogenic methane in the coal beds. Depths of the coal-bed reservoirs in this play range from zero to about 915 m (3000 ft).

3.1.3 Coal

Introduction

Beds of coal thick enough to be mined commercially occur in the Dakota Formation in the CCPA of south-central Utah (Doelling and Graham, 1972). The Dakota coals occur in the western part of the Kolob coalfield; the coal-bearing area is shown on figure 5.1.3.1. Local lenses and stringers of coal can be found in the Straight Cliffs and Iron Springs Formations of the CCPA, but none are thick enough for commercial development.

Kolob Coalfield

The coals of the Dakota Formation were deposited by a series of coalescing delta complexes derived from a westerly source. Coal beds are generally found in a 10- to 16-km- (6- to 10-mi-) wide band that developed landward of the delta-front sandstone bodies. The coals interfinger with carbonaceous shale and sandstone. Within the CCPA, the Dakota is about 300 m (1000 ft) thick, thinning to the east and thickening to the west (Doelling and Graham, 1972). The Kolob field lies to the west of the Sevier fault zone, which drops strata to its west down by 300 to 600 m (1000 to 2000 ft). The Kolob coalfield has two coal zones in the upper 50 m (150 ft) of the Dakota, provisionally named the “Upper Culver” and “Lower Culver” beds. These two coal zones are lenticular in nature and thin or split into thinner plies with intervening shale across the CCPA. Only the Upper Culver bed reaches commercially minable thickness in the study area.

The Dakota coals crop out along the southern margin of the Markagunt Plateau. The coal-bearing strata generally dip less than 5 degrees to the north-northeast, although the dips may locally be greater near faults or along some monoclinal folds present in the CCPA (Doelling and Graham, 1972). The 915-m (3000-ft) cover line above the Dakota coals, which is near the current maximum depth for coal mining, usually conforms very closely to the base of the Claron Formation. The area prospective for coal-bed gas would extend from 300 to 1500 m (1000 to 5000 ft) of cover. The 300-m (1000-ft) cover line for the Dakota coals is approximately at the Tropic-Straight Cliffs contact, while the 1500-m (5000-ft) cover line would roughly coincide with the upper contact of the Claron Formation.

The Dakota Formation coal is generally of subbituminous A rank in the Kolob field. This rank is reflected in a high moisture and low heat content for the coal in the study area. The moisture contents reported by Doelling and Graham (1972) appear low for subbituminous coal and may reflect drying of the samples before analysis; therefore only samples with at least 10% moisture were compiled in table 3.1.3.1 below. The sulfur content of these coals is generally high and averages about 5.6%, while the ash content is usually between 5 and 10%. These coal beds are as thick as the coal beds mined from the Blackhawk Formation in the coalfields of central Utah, but are lower in heat content and higher in sulfur content.

Doelling and Graham (1972) provided estimates of the coal resource in beds at least 1.2-m (4-ft) thick down to a depth of 900 m (3000 ft) for the Kolob field, and from those estimates the approximate amount of in-place minable coal in the CCPA portion of the field can be determined. The CCPA portion of the Kolob coalfield is equivalent to the Coal Creek, Cedar Mountain, and northern part of the Kolob Peak quadrangles (figure 3.1.3.1) of Doelling and Graham (1972). The topography of this area is steep, resulting in no coal that is surface minable; therefore, no surface minable resource was estimated, and all of the 345.1 million t (379.6 million st) of coal in the part of the Kolob field within the CCPA would probably be mined by underground methods. A breakdown of the Kolob coal resource by Doelling and Graham's quadrangles is given in table 3.1.3.2.

Table 3.1.3.1. Coal quality data for the Upper Culver coal in the Kolob coalfield (as-received basis; from Doelling and Graham, 1972). Only samples with >10% moisture reported.

Mine/ prospect	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulfur	Btu/lb	Air-dried loss	Doelling & Graham Quadrangle
Culver	13.2	35.6	41.8	9.5	4.4	NA	5.4	Cedar Mtn
Culver	14.2	33.4	42.5	9.9	5.4	9930	2.8	Cedar Mtn
Kanarraville	12.6	36.4	36.2	4.8	5.2	10940	1.6	Cedar Mtn
Kleen Koal	10.3	37.7	47.3	4.7	5.7	11270	2.8	Cedar Mtn
Kleen Koal	13.1	35.5	45.6	5.8	5.8	10880	6.3	Cedar Mtn
Kleen Koal	13.5	35.5	45.4	5.6	5.9	10860	7.1	Cedar Mtn
Kleen Koal	13.0	35.1	46.2	5.7	5.8	11050	6.7	Cedar Mtn
Kleen Koal	13.0	35.7	45.6	5.7	5.8	10930	6.7	Cedar Mtn
Kleen Koal	12.8	37.9	43.6	5.7	5.9	10830	3.8	Cedar Mtn
Kleen Koal	12.5	38.1	42.9	6.5	5.9	10790	3.3	Cedar Mtn
Kleen Koal	12.8	37.1	42.5	7.6	6.0	10500	3.8	Cedar Mtn
Kleen Koal	15.0	35.9	39.7	9.4	5.9	9990	6.8	Cedar Mtn
MPCC 7B	10.4	42.1	37.2	10.3	6.6	10290	NA	Cedar Mtn
MPCC X3A	12.0	42.6	39.2	6.2	6.2	9710	NA	Cedar Mtn
MPCC X2A	13.7	35.9	37.7	21.7	5.2	8480	NA	Cedar Mtn
MPCC X2A	17.3	46.1	26.7	9.4	4.9	9380	NA	Cedar Mtn
Williams No. 1	12.2	39.7	40.0	8.1	5.6	11430	3.7	Cedar Mtn
Williams No. 2	13.4	35.4	43.3	5.9	5.7	10710	6.8	Cedar Mtn
Williams No. 2	12.6	37.9	42.5	7.0	5.4	10740	4.2	Cedar Mtn
Williams No. 2	13.1	38.1	42.0	6.8	5.9	10660	5.2	Cedar Mtn
Koal Kreek	10.4	36.3	43.7	9.6	5.8	10870	1.8	Coal Creek
Outcrop	14.3	34.7	45.7	5.3	5.0	9950	4.8	Coal Creek
MEAN	**13.0**	**37.4**	**41.7**	**7.8**	**5.6**	**10485**	**4.6**	
STD DEV	**1.5**	**3.0**	**4.5**	**3.6**	**0.5**	**698**	**1.8**	

Table 3.1.3.2. Original in-place minable coal resource for the Kolob coalfield within the CCP by quadrangle (in millions of metric tons [t]; modified from Doelling and Graham, 1972).

Coal at least 1.2 m (4 ft) thick with less than 914 m (3000 ft) of cover

Doelling & Graham Quadrangle	Hectares	Average thickness	t	Reliability
Coal Creek	2196	1.89 m (6.2 ft)	53.4	Indicated
Coal Creek	2771	1.83 m (6.0 ft)	65.3	Inferred
Cedar Mountain	7110	1.98 m (6.5 ft)	184.2	Meas.+ Ind.
Cedar Mountain	943	1.89 m (6.2 ft)	24.0	Inferred
northern Kolob Peak	704	1.98 m (6.5 ft)	18.2	Inferred
TOTAL	13,725	1.89 m (6.2 ft)	345.1	

3.1.4 Geothermal

Introduction

Geothermal energy is the heat that originates within the earth. The earth is an active thermal engine (Wright and others, 1990). Many of the large-scale geological processes that have helped to form the earth's surface features are powered by the flow of heat from inner regions of higher temperature to outer regions of lower temperature. Generation of new oceanic crust at spreading centers such as the mid-Atlantic ridge, motion of the great lithosphere plates, uplifting of mountain ranges, release of stored strain energy by earthquakes, and eruption of volcanoes are all powered by the outward transport of internal heat. Plastic, partially molten rock at estimated temperatures between 590°C and 1200°C (1090°F and 2190°F) is postulated to exist everywhere beneath the earth's surface at depths of 100 km (60 mi) or less. By comparison, using present technology applied under favorable circumstances, holes can be drilled to depths of about 10 km (6 mi), where temperatures range upward from about 150°C (300°F) in average areas to perhaps 600°C (1110°F) in exceptional areas.

Exploitable geothermal resources originate from transport of heat to the surface through several geological and hydrological processes. Geothermal resources commonly have three components: 1) a heat source, 2) relatively high-permeability reservoir rock, and 3) water to transfer the heat. In general, the heat source for most of the high-temperature resources (>150°C [302°F]) appears to be a molten or recently solidified intrusion, whereas many of the low-temperature (<100°C [212°F]) and moderate-temperature (between 100° and 150°C [212° – 302°F) resources seem to result from deep circulation of meteoric water with heating due to the normal increase in temperature with depth. In most geothermal systems, fracture permeability controls water movement, but intergranular permeability is also important in some systems. Water is the ideal heat transfer fluid because it has a high heat capacity and high heat of vaporization, and can, therefore, transport more heat per unit volume that any other common fluid. A number of high-temperature resources occur in the Basin and Range Province as the result of deep circulation along major faults in a region of high heat flow.

Geothermal resources are commonly classified, in order of increasing economic importance as (1) magma, (2) hot dry rock, (3) geopressured, and (4) hydrothermal. Hydrothermal resources can be further classified into conduction-dominated regimes and hydrothermal convection systems. For the most part, only convective hydrothermal resources have been commercially developed.

White and others (1971) and Henley and Ellis (1983) have discussed models for high-temperature convective hydrothermal systems. A body of molten, or recently solidified, hot (300° to 1200°C [572° – 2192°F) rock presumably underlies higher-temperature hydrothermal resources. Interaction of this hot rock with groundwater causes heating of the groundwater, which then rises by buoyancy effects or differences in hydrostatic head. Most fluid in hydrothermal systems is derived from meteoric water (Craig, 1963). A free convective circulating system is set up with the heated water ascending in the center of the system along zones of permeability, spreading outward in the shallow subsurface or discharging to the surface, and with cool water descending along the margins and recharging the system. Rapid convection produces nearly uniform temperatures over large volumes of the reservoir. The temperatures and pressures generally lie near the curve of boiling point versus depth for saline water, and sporadic boiling may occur. Whether or not steam actually exists in a hydrothermal resource depends, among other less important variables, on temperature and pressure conditions at depth. Escape of hot fluids at the surface is often minimized by a near-surface, sealed zone or cap-rock formed by precipitation from the geothermal fluids of minerals in fractures and pore spaces (Wright and others, 1990).

Most thermal springs, geothermal manifestations, hydrothermal resources, and all of the presently known sites that are capable of electric power generation are in the western half of the United States, including Alaska and Hawaii. Low- and intermediate-temperature resources are much more plentiful than are high-temperature resources. There are many thermal springs and wells that have water at temperatures only slightly above mean annual air temperature, the temperature of most non-geothermal shallow groundwater (Wright and others, 1990).

With few exceptions, the higher temperature geothermal areas in Utah occur either in the Basin and Range Province or within the Transition Zone (figure 5.1.4.1). Mabey and Budding (1987) proposed the name "Sevier thermal area" for a region of southwest Utah where most of the state's known moderate- and high-temperature (>90°C [194°F]) hydrothermal systems occur. The Sevier thermal area (figure 5.1.4.1) covers a portion of the eastern Basin and Range Province, and part of the Basin and Range-Colorado Plateau transition zone. The area, which includes all of the Sevier, Black Rock, and Escalante Deserts of southwestern Utah, is characterized by (1) abundant late Cenozoic normal faults, (2) Tertiary plutonic and volcanic rocks and Quaternary basalt, (3) high regional heat flow, and (4) a complex structural history.

Escalante Desert

The Escalante Desert (also called the Escalante Valley) is a northeast-southwest elongate basin measuring approximately 120 by 45 km (76 by 28 mi) that includes much of the Sevier thermal area as defined by Mabey and Budding (1987). Mountains and hills composed primarily of Tertiary ash-flow tuff and younger volcanic flows and domes surround it. Ash-flow tuff units range in age from 32 to 19 Ma. Rhyolite and dacite flows and domes range in age from 13 to 8.5 Ma (Rowley and others, 1979). Upper Tertiary and Quaternary unconsolidated and semi-consolidated material, likely more than 1.6 km (1 mi) thick, fill the deeper parts of the valley (Blackett and Shubat, 1992).

The Escalante Desert lies between two major, roughly east-west-oriented igneous belts, also known as mineral belts. The Pioche-Marysvale igneous belt (Oligocene) lies to the north, and the Delamar-Iron Springs igneous belt (Miocene) lies to the south. Rowley and others (in prep) describe the igneous belts as "consisting of extremely voluminous ash-flow tuffs, lava flows, and volcanic mudflow breccia that erupted from large east-trending igneous belts made up of intrusions and eruptive centers (Rowley, 1998; Rowley and others, 1998; Rowley and Dixon, 2001)." These researchers go on to describe the igneous belts as "bounded by east-trending faults, folds, and strings of vents, hot springs, and hydrothermally altered rocks." They use the term "transverse zones" to identify these poorly understood, deep-seated structures that serve to focus intrusive activity and high heat flow. These east-west transverse zones mark boundaries of areas to the north and south characterized by different rates, types, and amounts of east-west deformation. As such, transverse zones may be analogous to transform faults, which are especially prominent features in the ocean basins (Ekren and others, 1976, 1977; Rowley and others, 1978, 1998; Rowley, 1998; Rowley and Dixon, 2001).

Gravity studies by Pe and Cook (1980) suggest the presence of many Basin and Range block-faulted structures buried beneath the Escalante Desert. However, the Antelope Range fault located on the southeast side of the valley is the only large-scale, mapped fault showing displacement during the Quaternary (Anderson and Christenson, 1989).

The principal water-bearing unit of the Escalante Desert consists of unconsolidated and semi-consolidated materials of Quaternary age. Another groundwater source consists of water in Tertiary volcanic rocks along the low-lying margins of the Escalante Desert (Mower, 1982). Groundwater use for irrigation from the principal water-bearing unit of the Escalante Desert has modified the natural subsurface drainage patterns. Subsurface water in the southwest part of the valley discharges to a large water-table depression near the community of Beryl Junction. Subsurface water within the northeast portion of the valley discharges to the northeast, the natural drainage direction, toward the Milford area. Recharge to the groundwater system is from subsurface inflow from bedrock as well as inflow from stream channels. Recharge is also from irrigation and direct precipitation (Klauk and Gourley, 1983).

Cove Fort-Sulphurdale Geothermal Area

The Cove Fort-Sulphurdale geothermal area lies on the northwest side of the Tushar Mountains, and is roughly 32 km (20 mi) north along Interstate Highway 15 from the town of Beaver (figure 5.1.4.1). The Tushar Mountains consist primarily of mid-Tertiary quartz latite and alkali rhyolite ash-flow tuffs of the Marysvale volcanic field. To the north, the Pavant Range consists of thrusted, pre-Tertiary sedimentary rocks and tilted Tertiary sediments. Tertiary volcanics of the Marysvale field overlap the pre-Tertiary sedimentary rocks on the south end of the Pavant Range. A large basaltic andesite flow of Pleistocene age lies a few km (1 -2 mi) to the west of the geothermal area (Hintze, 1980; Mabey and Budding, 1987).

Ross and Moore (1985) described the results of geological investigations, presented the findings of detailed geophysical studies, and proposed a conceptual model for the geothermal system at Cove Fort. They characterized the system as resulting from a combination of complex geologic structures that localize the geothermal source. The oldest structures are Sevier-age thrust faults, mapped to the north in the Pavant Range and penetrated by deep drilling at Cove Fort. Moore and others (1979) reported that one deep drill hole (Utah State 31-33) at Cove Fort intersected Paleozoic dolomite thrust above Triassic siltstone and limestone.

Basin and Range tectonism produced numerous north-northeast-striking high-angle normal faults, in addition to large penecontemporaneous gravitational slide blocks[2]. The gravity-slide blocks are low-permeability layers that cap portions of the geothermal system. At the surface, the trends of faults are delineated by local alignments of sulfur deposits, acid-altered alluvium, and gas seeps. The surface manifestations occur throughout an area of about 47 sq km (18 sq mi) and probably reflect boiling and degassing of chloride-rich brine from a thermal water table 400 m (1312 ft) below the surface. Dry steam at about 150°C (302°F) is produced from relatively shallow production wells (180-400 m [591-1312 ft] deep) completed into fractured reservoir rocks near Sulphurdale.

Mother Earth Industries, Inc. installed the first power-generation facility at Cove Fort in 1985. It originally consisted of four binary-cycle power units with a total capacity of 3 MW (gross). The power system was later supplemented by a turbine generator (2 MW gross), placed upstream from the binary units in order to take advantage of the temperature and pressure conditions of the producing reservoir. In the fall of 1990, the City of Provo in cooperation with the Utah Municipal Power Authority (UMPA), dedicated the Bud L. Bonnett geothermal power plant. The plant, rated at 8.5 MW (gross), became the third geothermal power facility owned by UMPA and Provo to go on-line at the Sulphurdale field. Because H_2S was produced as a non-condensable component of the dry steam, the facility included a sulfur abatement process.

The UMPA/Provo plant shut down in 2003 with the facility and resource holdings changing ownership. Presently, Enel North America controls the main geothermal resource at Sulphurdale with plans to build a 30 to 40 MW binary plant. Enel has performed exploratory activities, including production drilling, for the past several years.

Roosevelt Hot Springs Geothermal Area

The Roosevelt Hot Springs geothermal area is situated on the west flank of the Mineral Range in Beaver County, roughly 16 km (10 mi) northwest of the town of Milford (figure 5.1.4.1). It is the most studied geothermal system in Utah. Ward and others (1978) and Ross and others (1982) presented geological, geophysical, and geochemical data for the Roosevelt hot springs geothermal area. Mabey and Budding (1987) summarized the findings of previous workers. The Mineral Range is primarily a complex of Tertiary-age intrusions and Precambrian metamorphic rocks crosscut by a low-angle, west-dipping detachment zone and Basin and Range faults. The active geothermal system is associated with relatively young igneous activity, expressed as Quaternary rhyolite domes (0.5-0.8 Ma) within the Mineral Range, recent Basin and

[2] Rowley and others (2011) suggest that previously interpreted gravity glide planes may, instead, represent Tertiary volcanic rocks lying atop an erosional unconformity, stratigraphically above Paleozoic sedimentary formations.

Range-style north-south faulting on the west side of the range, an older east-west fault system, and a still older system of near-vertical faults associated with the low-angle detachment zone. The Opal Mound fault, an important conduit for geothermal fluids, defines the western boundary of a small graben that contains much of the geothermal resource. Production from the Roosevelt geothermal area is primarily from highly fractured Tertiary granite and Precambrian metamorphic rocks. Geothermal resources at Roosevelt hot springs have been of commercial interest since the early 1970s, and have been actively developed for power generation since the late 1970s (Moore and Nielson, 1994).

Typical heat flows at the Earths surface are between 0.001 W/m^2 and 0.1 W/m^2. At the Roosevelt Hot Springs geothermal area, heat-flow studies (Wilson and Chapman, 1980) identified an area of anomalous heat flow extending about 5 km (3.1 mi) wide and 20 km (12.5 mi) long. The anomalous heat-flow values in excess of 1000 mW/m^2 (23.9 HFU) enclose an area roughly 2 km (1.2 mi) wide by 8 km (5 mi) long that is thought to coincide with the near-surface part of the geothermal system. Using teleseismic data of Robinson and Iyer (1981) and gravity data of Carter and Cook (1978), Becker and Blackwell (1993) developed a conceptual model for the Roosevelt Hot Springs geothermal system. Teleseismic data delineate an anomalous low velocity zone extending from the upper mantle to within 5 km (3.1 mi) of the surface. The gravity anomaly appears to coincide with the low-velocity zone. The interpreted body has (1) a density contrast with the surrounding rock of approximately -150 kg m^{-3}(-9.4 lbs ft^{-3}), (2) a roughly cylindrical shape extending from perhaps as deep as the Moho to within 4-6 km (2.5-3.7 mi) of the surface, and (3) a typical diameter of 15 km (9.3 mi). This low-velocity body is the likely source of the elevated heat flow at Roosevelt Hot Springs.

Rocky Mountain Power (RMP), a subsidiary of PacifiCorp, operates the Blundell geothermal power station at the Roosevelt Hot Springs geothermal area. Forrest (1994) provided a detailed account of development at Roosevelt Hot Springs from 1972 through 1993. The main power unit is a single-flash, 26 MW (gross) GE-turbine generator constructed in 1984. RMP produces geothermal brine for the single-flash unit from four wells that tap a production zone in fractured, crystalline rock. The hot brine is flashed to steam in surface separators. The steam is then piped to the single-flash unit and the fluid fraction (geothermal brine at temperatures of 177°C [351°F]) is directed to a 10 MW binary-cycle plant – an air-cooled Ormat power unit constructed in 2008. From the Ormat unit, the spent geothermal brine is returned into the reservoir through three, gravity-fed, injection wells. Depths to the production zone range generally between 382 and 2232 m (1253 – 7323 ft). Reservoir temperatures are typically between 240°C and 268°C (464° - 514°F).

Thermo Hot Springs Geothermal Area

The Thermo Hot Springs geothermal area is located within the northeast part of the Escalante Desert in southern Beaver County (figure 5.1.4.1). Thermal water discharges from two large spring mounds, situated near the axial drainage of the Escalante Desert valley. The Shauntie Hills, northwest of the hot springs, and the Black Mountains to the southeast consist of mainly Tertiary lava flows and volcaniclastic deposits (Rowley, 1978).

Northeast-oriented normal faults displace Quaternary valley-fill units and form a broad zone of faulting in and around the hot spring mounds. Faults mapped within the volcanic units of the low hills southeast of the thermal area, and within the Black Mountains, exhibit a dominant northwest orientation. The orientation of these two sets of structures and the position of the hot springs suggest that a structural intersection localizes the geothermal system. Regional gravity data suggest that a subsurface fault with about 100 m (several hundred ft) of displacement (down to the west) passes through the hot springs area (Mabey and Budding, 1987). Blackett and Ross (1992) reported a negative self-potential (SP) anomaly about 1 km (0.6 mi) southeast of the spring mounds, which suggests the possibility of upward-flowing geothermal fluid.

Republic Geothermal, Inc. (1977) contributed temperature-gradient, geophysical, and geochemical data resulting from geothermal studies in the area. The data package includes temperature-gradient borehole data (27 boreholes), water analyses, and production-test and temperature data from a deep (2221 m [7287 ft]) exploratory drill hole (Escalante 57-29). Mabey and Budding (1987) reported written communication from Republic indicating that this drill hole penetrated alluvium to about 350 m (1148 ft), volcanic rock to 960 m (3150 ft), and sedimentary-metamorphic rocks to 1500 m (4921 ft) where granite was encountered. The granite extended to total depth of the Escalante 57-29 drill hole. Republic measured static temperatures on January 6, 1978, revealing a maximum temperature of 173.7ºC (344.6°F) at a depth of 2043 m (6703 ft) – the maximum depth of recorded temperatures.

Maximum measured water temperature in the springs is 89.5ºC (193.1°F) and estimates of the discharge range from about 30 to 120 L/min (7.9 to 31.7 gpm). Rush (1983) estimated the reservoir temperature between 140º and 200ºC (284° – 392°F). Geothermometers applied to three water analyses of the hot springs yielded equilibrium temperatures ranging from 110º to 148ºC (230° - 298°F), while fluid samples from the Escalante 57-29 well yielded geothermometer temperatures ranging from 166º to 241ºC (331° - 466°F).

Interest in geothermal development at Thermo was renewed in 2008 as Raser Technologies and other developers began acquiring leases in the area. Exploratory and production drilling of up to eight new wells ensued, followed by construction of a modular-type, 10 MW binary power plant. Raser entered into a power purchase agreement with the City of Anaheim, California for delivery of up to 12 MW of geothermal generated power.

Newcastle Geothermal Area

The Newcastle area is located near the south end of the Escalante Valley in Iron County (figure 5.1.4.1). The area is underlain by an aquifer containing low- and moderate-temperature geothermal fluid. The UGS and the University of Utah (U of U) analyzed 27 thermal-gradient drill holes, performed geophysical surveys and geologic mapping, and wrote an assessment of the resource (Blackett and Shubat, 1992). The UGS and U of U have continued monitoring of the Newcastle Geothermal System as development has proceeded (Blackett and others, 1997; Blackett, 2004, 2007).

The unincorporated town of Newcastle -- located near State Highway 56 connecting Cedar City, 48 km (30 mi) to the east, to a number of small communities in the Escalante Valley to the west -- lies just north of the center of the geothermal system. Cedar City is situated along Interstate Highway 15, and is served by a Union Pacific rail-line and a scheduled-service airport. The Escalante Valley, westward from Newcastle, is an agricultural region that has produced potatoes, alfalfa, corn, and livestock.

The Newcastle geothermal resource, a low- to moderate-temperature hydrothermal system, was discovered accidentally in 1975 during pump testing of an irrigation well. Upon pump testing of the well, Christensen Brothers -- a local farming company -- discovered that the well had penetrated a geothermal aquifer. Termed a “blind” geothermal resource, there are no obvious surface manifestations such as hot springs or fumaroles to suggest that a geothermal system is present at depth. The water in the well was near the boiling point and reportedly flashed to steam when pumped to the surface. Subsequent studies by the U of U Department of Geology and Geophysics (Chapman and others, 1981), the UGS (Blackett and Shubat, 1992), and the U of U Research Institute (Ross and others, 1990, 1994) defined a buried zone of suspected geothermal upflow along the nearby Antelope Range fault, which is postulated as the source of the hot water. Studies also defined a shallow aquifer that channels the outflow of geothermal fluids into the subsurface of Escalante Valley.

Since 1980, several commercial greenhouse developers have used the geothermal fluid for space heating of greenhouses. The largest of these developers, Milgro Nurseries (which began operations in 1992), now operates more than 10.2 ha (25.2 ac) of greenhouses. Geothermal production wells, typically 152 m (500 ft) deep, tap the geothermal fluid in this unconfined aquifer. The fluids cool by conduction and probably mix with shallow groundwater at the system margins. A maximum temperature of 130°C (266°F) was measured in 1981 in a geothermal exploration well (Unocal well CHR-1), which penetrated the geothermal aquifer (outflow plume). However, more recent thermal-gradient exploratory holes drilled nearby record a maximum temperature of about 118°C (244°F) within the outflow plume (Blackett, 2007). Production wells at the greenhouses generally produce fluids in the range of 75° to 95°C (167° - 203°F).

Beryl Area

DeArman #1 Well: The Beryl area is located within the southern Escalante Valley of Iron County, south of the Wah Wah and Indian Peak ranges, near the rail sidings of Beryl and Zane. Goode (1978) reported a temperature of 149°C (300°F) from a depth of 2134 m (7000 ft) measured within a 3748-m- (12,297-ft-) deep well that he termed “De Armand #1.” Goode also reported that, upon testing, the well flowed at a rate of 3785 L/min (1000 gpm) and that the water contained less than 4000 mg/L total dissolved solids. No flowing temperature was given. According to records obtained from the Utah Division of Water Rights, three companies - McCulloch Oil Corporation (MCR Geothermal Corp.), Geothermal Kinetics, Inc., and Utah Power & Light Company - formed a partnership to drill and complete a well referred to as “MCO-GKI-UPL-DeArman #1." The well was located in the SW¼, SE¼, SW¼, section 18, T. 34 S., R. 16 W., and drilled during the spring of 1976. Documents filed with the Division of Water Rights during December of 1981, and correspondence dated November 12, 1985, suggest that the well was drilled to a depth of at least 2361 m (7746 ft) and that it did not comply with state-regulated abandonment procedures at that time.

A well drilling/completion report, filed by Loffland Brothers Drilling Company of Farmington, New Mexico, was obtained through the Utah Division of Water Rights (State Engineer's Office) for this well. The report was received on February 3, 1977. The well owner was recorded as McCulloch Oil Corporation of Los Angeles. The total drilled depth was recorded as 3748 m (12,297 ft) with a completed depth of 2461 m (8074 ft). The well was perforated from 2365 to 2374 m (7759 – 7789 ft). The document records an artesian flow of 3180 L/min (840 gpm) with a water temperature of 96°C. The driller's well log indicates valley fill deposits to 488 m (1601 ft), volcanic rocks to 1407 m (4616 ft), carbonate rocks to 1626 m (5335 ft), volcanic rocks to 1810 m (5938 ft), then alternating zones of carbonate rocks, sandstone, and lost circulation to total depth.

Pe and Cook (1980) provided a summary of the geologic units penetrated within the DeArman #1 well. Drilling encountered the following lithologies in descending order:

(a) claystone (mixed with sand, silt, and welded tuff near the base) from 143 to 495 m (469 – 1624 ft);
(b) welded tuff from 495 to 1405 m (1624 – 4610 ft);
(c) limestone and dolostone from 1405 to 1622 m (4610 – 5322 ft);
(d) a mixture of volcanic rocks and limestone/dolostone from 1622 to 1884 m (5322 – 6181 ft);
(e) cuttings of 70% quartz monzonite with 30% welded tuff between 1698 and 1726 m (5571 – 5663 ft);
(f) dolostone, limestone, and shaly limestone from 1884 to 2353 m (6181 – 7720 ft) with some altered volcanics from 2168 to 2189 m (7113 – 7182 ft);
(g) lost circulation from 2354 to 2581 m (7723 – 8468 ft);
(h) limestone, dolostone, and minor shaly limestone from 2581 to TD at 3748 m (8468 – 12,297 ft).

Note: Occasional slickensides were found at 2177 m (7142 ft) and between 2890 and 2893 m (9482 – 9491 ft).

MCR State #1 Well: Klauk and Gourley (1983) made no mention of the above-referenced ("DeArman") well, but reported a temperature of 60°C (140°F) measured at a depth of 2461 m (8074 ft) within an unnamed geothermal test well located in the NE¼, NE¼, NW¼, section 22, T. 34 S., R. 16 W. This location corresponds to a well reportedly drilled in 1976 by MCR Geothermal Corp., and referred to as "State #1" (letter from Utah Division of Water Rights to Insurance Company of North America, dated November 12, 1985). Pe and Cook (1980) refer to "Geothermal test well State #1" located about 5 km (3 mi) east of the DeArman #1 well and drilled to a total depth of 1520 m (4987 ft). They report the well penetrated the following lithologies in descending order:

(a) soft clay valley fill from 143 to 235 m (469 – 771 ft);
(b) "soft conglomerate" from 235 and 253 m (771 – 830 ft);
(c) siltstone from 253 and 280 m (830 – 919 ft);
(d) shale from 280 to 576 m (919 – 1890 ft);

(e) a mixture of welded tuff and quartz monzonite porphyry from 576 to 581 m (1890 – 1906 ft);
(f) moderately hard quartz monzonite from 581 to 1390 m (1906 – 4560 ft);
(g) an "open" fracture zone penetrated between 1390 and 1396 m (4560 – 4580 ft);
(h) altered quartz monzonite porphyry in a fracture zone from 1396 to 1409 m (4580 – 4623 ft);
(i) No samples were recovered from 1409 to 1520 m (4623 – 4987 ft).

The bottom-hole temperature of 81°C (178°F) was observed at 1396 m (4580 ft) according to Pe and Cook (1980).

Wood's Ranch: Wood's Ranch is located just south of the Wah Wah Mountains in the northwest part of the Escalante Valley in Iron County (L. Wood on figure 5.1.4.1). One of two wells, a 61-m- (200-ft-) deep water well drilled for irrigation on the ranch, produces 36.5°C (97.7°F) water. No hot springs are present. A self-potential survey performed by workers from the University of Utah and the UGS (Ross and others, 1991a, b) revealed a broad, negative SP anomaly interpreted as thermal up-flow. Beyond the SP survey and one water analyses, no exploration has been carried out on the property. Chemical geothermometers suggest reservoir temperatures in the range of 100° to 115°C (212° - 239°F). The warm water produced from the well may be a mixture of thermal water and non-thermal groundwater from the Escalante Valley aquifer. The area is somewhat remote with no incorporated communities nearby. The Union Pacific rail line crosses the Escalante Valley within 1.6 km (5.2 mi) of Wood's Ranch. Access roads into the area are both improved county and BLM roads, and jeep trails. Land ownership in the vicinity of the thermal wells is private. Surrounding lands are federal and state owned.

3.1.5 Potash (Alunite)

Potash potential in the CCPA is exclusively as a product from alunite processing. Alunite represents a significant possible source of potash and alumina in the CCPA. The chemical formula of pure alunite is $KAl_3(SO_4)_2(OH)_6$, and alumina (aluminum oxide) and potassium sulfate, used for fertilizer, can be recovered from the alunite through processing. Although there is no current production of alunite in the U.S. due to the economics of processing, the largest alunite deposit in the country is located in the southern Wah Wah Mountains at the Blawn Wash (or NG) deposit. Most alunite deposits are the product of alteration and replacement of Tertiary volcanic and volcaniclastic rocks that are typically rhyolitic, and this is the case for the significant deposits within the CCPA (Hall, 1978).

The Blawn Wash deposit is exposed on a number of ridges located primarily in the south half of T. 29 S., R. 15 W., in Beaver County. Oligocene and Miocene porous and tuffaceous rocks of the Blawn Formation and Needles Range Group are the primary hosts of the tabular to funnel-shaped alunitic alteration (Hofstra, 1984; Krahulec, 2008). Hofstra (1984) conducted detailed mapping of the deposit, which included delineation of zones of alteration that include: a siliceous cap zone; a quartz-alunite zone (the primary ore zone); a hematite-clay zone (clay is primarily kaolinite); and propylitic zones. Hofstra (1984) dated the formation of alunite at 22.5 Ma, and suggested that the alunitic alteration is genetically related to a normal-fault system and nearby rhyolite plugs. Resource estimates for the deposit range from 630 million t (694 million st) at greater than 30% alunite to 725 million t (800 million st) at an unspecified grade (Earth

Sciences, Inc., 1974; Hall, 1978). Earth Sciences, Inc., the company that conducted the initial exploration of the deposit, developed a mine plan for an area (known as Area C) that contained approximately 91 million t (100 million st) at about 35 to 40% alunite according to one estimate and 150 million t (165 million st) at an unspecified grade according to another estimate, but never mined the area (BLM, 1977; Hofstra, 1984).

Another significant alunite deposit in the CCPA is the Pine Valley deposit, also known as the PV deposit, located in Iron County along a ridge primarily in section 5, T. 32 S., R. 16 W., but is also found in sections 4, 8, and 11. Miocene tuffs and related volcaniclastics are the primary host of the alunite alteration at this deposit (Best and others, 1987a). Mineralogy at the site is similar to the Blawn Wash deposit. A siliceous cap on the ridge is present, and kaolinite, hematite, and quartz occur with the alunite. Earth Sciences, Inc. estimated a moderate resource potential for this deposit. A few km (1 – 2 mi) south of the Pine Valley deposit is the SX alunite deposit. The deposit is located on the Beaver County–Iron County border in the vicinity of sections 26, 32, 33, 35, and 36, T. 30 S., R. 15 W., and sections 4, 5, and 6, T. 31 S., R. 15 W. Oligocene volcanic and volcaniclastic rocks host the alunite deposits that are separated into an east and west area by Paleozoic sedimentary units that are devoid of any alunitic alteration (Best and others, 1987a). The deposit is exposed on four separate hills, and the alunite zones are highly silicified. Earth Sciences, Inc. estimated a moderate resource for this deposit. An additional alunite deposit lies just west of the Pine Valley deposit primarily in sections 1, 2, and 3, T. 32 S., R. 17 W., but few details are known of the deposit (Best and Davis, 1981).

The White Mountain deposit is an east-west trending deposit that flanks White Mountain on the east and west sides in south-central Beaver County. The deposit is located in sections 7 through 11, T. 29 S., R. 13 W., and sections 1, 11, and 12, T. 29 S., R. 14 W. (Stringham, 1963). Miocene rhyolites and tuffs of the Blawn Formation host the alunitic alteration in this area (Best and others, 1989b). Alunite, kaolinite, quartz, and hematite are the most common minerals in the altered areas, and often alunite and kaolinite are in similar proportion (Stringham, 1963). Earth Sciences, Inc. identified a small and likely uneconomic resource at this deposit in the 1970s.

A number of smaller deposits are also present in the CCPA. A replacement deposit in Tertiary rhyolites, the Sheeprock deposit, is northwest of Beaver in section 7, T. 28 S., R. 6 W. Hall (1978) estimated the resource at Sheeprock as 2 million t (2.2 million st) at 30% alunite. The Big Pinto Spring deposit is located in the Indian Peak Range on a ridge in section 35, T. 30 S., R. 18 W. Earth Sciences, Inc. investigated the deposit, hosted by Tertiary volcanics, but found the alunitization to be low-grade and inconsistent (Hall, 1978). The Modena deposit is in Iron County in sections 26 and 35, T. 34 S., R. 19 W., and contains alunitized Tertiary tuff breccia with grades up to 30% alunite. Hall (1978) suggested that the deposit is not large enough to be economic. Stringham (1964) reported small patches of alunite southwest of Squaw Peak in sections 2 and 11, T. 28 S., R. 13 W., and Erickson and Dasch (1963) reported alunitic alteration in the Black Mountains in section 9, T. 31 S., R. 11 W. Both alunite deposits are hosted by Tertiary volcanic and volcaniclastic rocks, and are small. The Red Bird #1-8 deposit is located in Iron County in section 33, T. 31 S., R. 16 W., but is described as a small resource (Utah Mineral Occurrence System [UMOS]). Stringham (1967) reported some alunitic alteration in the southeast part of the San Francisco Mountains (east-central part of T. 27 S., R. 13 W.), but did not indicate any economic occurrences.

The Blawn Wash, White Mountain, Squaw Peak, and Black Mountain areas are also discussed in the kaolinite section of this report.

3.2 Locatable Minerals

3.2.1 Copper

Utah is the second leading Cu producing state in the U.S., trailing only Arizona. While porphyry Cu production from the Bingham district in northern Utah is by far the largest source of Cu in the state, significant production has also been derived from the base metal replacement districts at Tintic, Park City, Ophir, and Big and Little Cottonwood. In the CCPA, the largest Cu producers have been the Rocky Range, Beaver Lake, and San Francisco mining districts. These districts are Oligocene, calc-alkaline, intrusive-centered mining districts in central Beaver County and the Cu is directly related to the stocks, primarily occurring in skarns and breccia pipes.

The Rocky Range skarn deposits seem to fit both the porphyry Cu, skarn-related (18a) and the Cu skarn (18c) USGS ore deposit models (Cox, 1986c; Cox and Theodore, 1986); however, to date, no porphyry Cu deposit has been recognized in the Rocky Range. Copper-rich breccia pipes are reported in the San Francisco (Cactus mine) and Beaver Lake (OK mine) mining districts. Copper-rich breccia pipes are known to be associated with porphyry Cu deposits (Sillitoe, 1985), but are not described as a separate USGS ore deposit model from the porphyry Cu model 17 (Cox, 1986b); however, some world class porphyry Cu mining districts (e.g. Cananea, Mexico) have derived an important part of their production from breccia pipes (Sillitoe, 1985).

Beaver Lake District, Beaver County

The Beaver Lake mining district covers the Beaver Lake Mountains, which are located about 16 km (10 mi) northwest of Milford and 14 km (9 mi) east of the San Francisco district, in central Beaver County. The northern Beaver Lake Mountains are composed of a complexly faulted sequence of Paleozoic sedimentary rocks intruded by a large quartz monzonite stock on the south and east. The southern Beaver Lake Mountains are primarily Oligocene Horn Silver Andesite (~35 Ma) intruded and domed by the probably coeval OK biotite-hornblende granodiorite stock (~31 Ma; Best and others, 1989a).

The OK mine is the principal deposit in the Beaver Lake district and developed a small, magmatic-hydrothermal, sub-vertical, pegmatitic breccia pipe hosted by the 4.7 km^2 (1.8 mi^3) Cactus granodiorite plug (Wray, 2006a). Mineralization occurs as blebs of chalcopyrite along with molybdenite flakes and minor pyrite in a N. 80º W.-striking, steeply north-dipping, weakly mineralized zone cutting across the granodiorite. At the surface, the breccia pipe is roughly 30 by 15 m (100 by 50 ft) in plan, and plunges about 65º north-northeast (Prenn and Havenstrite, 2005). The known, higher grade, Cu-Au-Mo-Ag mineralization occurs mostly along the footwall of the breccia and has been mined by a combination of underground and open-pit methods. The mine lies within a zone about 200 m (660 ft) long by 70 m (230 ft) wide of quartz-sericite altered stockwork veining surrounding the small pegmatitic breccia. Scheelite has also been reported locally in the pegmatitic OK ore.

Immediately southeast of the OK mine, and just north of the old Beaver Harrison shaft, a west-northwest-trending zone of sheeted fracturing with bornite, chalcopyrite, native copper, and molybdenite on the joints occurs in the granodiorite. This zone, called the Mary I, contains an estimated mineral resource of about 1 million t (1.1 million st; table 4.2.1.1) according to Wray (2006a). In summary, the OK – Beaver Harrison mine area appears to be an unusual type of small porphyry Cu-Au-Mo system.

A large area (about 5 km^2 [1.9 mi^3]) of pervasively altered Horn Silver Andesite lies just northeast of the OK mine. The alteration is very strong, texturally destructive, quartz-sericite-pyrite ±andalusite ±topaz, but geochemically barren at the surface. A few drill holes have tested this large area with very limited success, the maximum intercept being just 64 m (210 ft) of 0.08% Cu.

Rocky Range, Beaver County

The Rocky Range mining district lies immediately south of the Beaver Lake district in central Beaver County and just 9 km (5.6 mi) northwest of Milford. The Rocky Range, proper, consists of a low range of hills about 180 m (590 ft) high and about 6.5 km (4.0 mi) long. Geologically the district is composed of a series of relatively small xenoliths of Permian and Triassic (?) sedimentary rocks in a large, quartz monzonite stock (~30 Ma; Best and others, 1989b). The stock also intrudes and possibly domes the east-dipping Horn Silver Andesite on the east flank of the range.

The largest early producer in the Rocky Range was the Old Hickory mine, whose Fe-Cu-Ag-rich ores were initially used as smelter flux. Scheelite was discovered in the Old Hickory ore in the late 1930s and the mine produced a limited quantity of W-Cu ore into the 1950s (Wray, 2006a). The history of the district changed with the discovery of the Bawana Cu skarn by the Cerro Verde Mining Company in about 1960 (Whelan, 1982). This was followed by the discovery of several other small Cu skarn deposits and the larger Valley deposit at depth in the pediment on the southwest flank of the range by Anaconda in 1961 (Wray, 2006b). These discoveries resulted in several generally unsuccessful attempts at Cu production from the small, open-pitable skarns. Most of the problems with the Rocky Range Cu skarn deposits were the relatively small size and partial oxidation, resulting in small pits with high stripping ratios and poor metallurgical recoveries.

The Rocky Range hosts a series of mineralized Permian-Triassic limestone xenoliths in a large (15 km^2 [5.8 mi^2]) quartz monzonite composite stock. This stock appears to have been passively injected, stoping its way upward (Whelan, 1982). The deposits are typically metamorphosed to anhydrous, prograde, garnet-diopside-epidote skarns containing magnetite-chalcopyrite-bornite ±scheelite mineralization. Current mineral resources are estimated from one large (Valley) and six small skarn deposits. More than 80% of this Cu resource is in the Valley skarn deposit, which would make it either a typical porphyry Cu-related skarn (USGS model 18a), or one of the world's largest non-porphyry-related Cu skarns (USGS model 18b) (Cox, 1986c; Cox and Theodore, 1986).

San Francisco District, Beaver County

The San Francisco (Preuss, Newhouse, Frisco) mining district is located in the southern San Francisco Mountains of north-central Beaver County. The district is centered on the Oligocene Cactus granodiorite stock which intrudes a section of Neoproterozoic clastic sedimentary rocks that have been thrust over lower Paleozoic sedimentary rocks. The stock is medium- to coarse-grained, dark-gray, mafic rich, and strongly magnetic. The district is zoned from a central Cu ±Mo zone (Cactus stock) through a medial Pb-Zn-Ag zone to a distal Au-Pb zone. The production history of the district is dominated by the Cactus and Horn Silver mines. The Cactus mine is a tourmaline breccia pipe hosted in the 23 km^2 (8.9 mi^2) Oligocene (~31 Ma) Cactus granodiorite stock.

A series of small Cu ±Pb ±Zn ±Ag ±W skarn deposits are developed in folded Ordovician Pogonip Group carbonates on the south flank of the Cactus stock, including the Cupric, Washington, and Imperial mines. These deposits can be viewed as part of an anhydrous, prograde metamorphic halo adjacent the essentially unaltered stock (USGS Cu skarn model 18c). The largest of these Cu deposits is the Imperial mine which developed a garnet-diopside-chalcopyrite-pyrite ±magnetite skarn in a synclinal trough of Wah Wah-Juab Limestone. A couple of narrow, steeply north-dipping, altered quartz monzonite porphyry dikes were injected near the axis of this syncline (McKelvey, 1973).

The Cactus mine developed a Cu-rich, magmatic-hydrothermal breccia pipe hosted in the Cactus stock (Wray, 2006b). The Cactus pipe occurs with a few dozen smaller breccia pipes along a northwest-trending zone of weak phyllic alteration, veining, and aplite and quartz monzonite porphyry dikes cutting directly across the Cactus stock. The Cactus breccia pipe is about 250 by 60 m (820 by 200 ft) in plan, elongated to the northwest, and plunges steeply to the north. The pipe has been followed to a depth of about 275 m (900 ft) by underground workings. The primary mineralization in the pipe is coarse-grained, quartz-pyrite-chalcopyrite ±molybdenite associated with several textural varieties of tourmaline and anhydrite.

A zone of weak porphyry Cu stockwork mineralization occurs in a few moderately deep drill holes as a series of chalcopyrite-bearing veins adjacent to and beneath the Cactus breccia pipe. Early veins tend to be steeply dipping (>65º), irregular, diffuse, and low-sulfidation. Late veins are generally shallower dipping (15 - 35º), planar, and intermediate-sulfidation. The best known drill intersection (30.5 m [100 ft] of 0.22% Cu and 105 ppm Mo at a depth of 427 m [1400 ft]) lies close to the down-plunge projection of the Cactus breccia pipe. The San Francisco mining district appears analogous to the Copper Creek district in Arizona, where hundreds of small Cu-Mo mineralized breccia pipes overlie an unusual, flat-lying, American Eagle porphyry Cu shell at depth (Guthrie, 1994).

A series of grossly similar, but smaller phyllically altered, breccia pipes, some with abundant black tourmaline, cutting the Cactus stock lie to the southeast of the Cactus mine for a distance of over 2 km (1.2 mi) toward the Frisco Contact mine. The Frisco Contact mine is part of a large area (>9.3 km^2 [>3.6 mi^2]) of mapped hydrothermal alteration (Stringham, 1967) called the Frisco Summit sulfide system (Petersen and Wray, 2001; Wray, 2006b). The Frisco Summit alteration is primarily argillic and advanced argillic alteration of the Oligocene Horn Silver Andesite with from 1 to over 5 wt.% pyrite, which has been shown to extend to considerable depth (Stringham, 1967; Best and others, 1989b; Wray, 2006b). The Frisco Summit sulfide system has also been recognized as an induced polarization phase high and as a corresponding aeromagnetic low (Wray, 2006b).

Star District, Beaver County

The Star district encompasses a complex series of small mines in the Star Range, 10 km (6.2 mi) west of Milford in central Beaver County. The Star Range is basically an east-dipping homocline of upper Paleozoic strata in the upper plate of the Blue Mountain thrust, which was intruded by a series of Tertiary stocks. The stocks belong to two distinctly different groups, the older Oligocene (~30 Ma) quartz monzonite on the north and east, and a younger Miocene (~21 Ma) granite to the southwest (Best and others, 1989b). Copper mineralization appears to be stronger with the older stocks; in particular, better Cu values are seen near the Milford Flats stock on the east.

The Milford Flats section of the Star district has produced only limited tonnages of Pb, Cu, Zn, and Ag ore. Mineralization is associated with the 3.4 km^2 (1.3 mi^2), medium-grained, Milford Flat quartz monzonite porphyry stock (30-28 Ma). Abou-Zied (1968) suggests a district zonation from base-metal dominant ores near the intrusive (Vicksburg and Estelle mines) to high precious metal values peripherally (Gold Crown mine). However, no areas of porphyry Cu-style alteration are recognized.

The ore deposits in the Star district are largely veins and associated mantos (carbonate replacement bodies), generally closely associated with the stocks. The veins cut both the quartz monzonite and Kaibab Limestone roof pendants, which have been recrystallized and metamorphosed. The mantos have various orientations, but generally plunge moderately easterly or northeasterly along the intersection of the easterly trending, steeply dipping veins and east-dipping favorable host strata. The known mantos are all small, but have high-grade Pb-Zn-Ag ±Cu ore. Some of the mantos, particularly those near the Harrington-Hickory mine, have strongly anomalous Mo.

3.2.2 Gold-Silver

Utah is the third ranked Ag and fourth ranked Au producing state in the U.S. The bulk of Utah's precious metal production has come from porphyry Cu (Bingham) or base metal replacement districts (Tintic and Park City); however, sedimentary-rock-hosted Au-Ag deposits (Mercur) and vein deposits (Escalante and Gold Mountain) have also been significant producers. In the CCPA, Au-Ag has been produced from the Oligocene intrusive centered mining districts (San Francisco, Beaver Lake, Rocky Range, and Star) in Beaver County, as the byproduct of base metal skarn or replacement production, and also from Miocene Au-Ag vein districts (Antelope, Enterprise, Fortuna, Gold Springs, Indian Peak, Newton, Stateline). The Oligocene intrusive centered mining districts were discussed under the Cu section of this report and this section will focus on the Miocene Au-Ag vein districts. There are a few prospects that have some affinities to sedimentary rock-hosted Au-Ag deposits in the CCPA, but no production has been attempted from this deposit type in the area. Most of these sedimentary-rock-hosted Au-Ag occurrences are associated with the Oligocene calc-alkaline intrusive centered districts of Beaver County.

The Au-Ag veins of the CCPA are primarily low-sulfidation, crustiform, epithermal veins best categorized as USGS model 25c (Mosier and others, 1986). These deposits (23 to 9 Ma), which have also been termed quartz-adularia-type, are primarily precious metal dominant, hosted in intermediate to felsic volcanic rocks associated with Miocene bimodal basalt-rhyolite magmatism. The veins may have a decreasing Au:Ag ratio (higher Ag) and increasing base metal content with depth. The primary gangue minerals are typically quartz, calcite, adularia, barite, fluorite, rhodochrosite, and the ore/sulfide minerals are argentite, native gold, native silver, pyrite, galena, wulfenite, sphalerite, mercury, tellurides (sylvanite), and possibly jordisite (Bullock, 1981). Sulfides are typically not abundant in the ore. These deposits are similar in age, associated volcanism, and geological setting to more famous mining districts in the Great Basin, such as Bullfrog, Florida Canyon, Midas, and Sleeper (John, 2001). John (2001) notes that the bimodal magmas associated with these low-sulfidation Au-Ag veins also had low oxygen and water contents and could “be affiliated with reduced Mo-Sn-W-rich porphyry systems.” This later assertion will be discussed later in the molybdenum section.

Antelope Range, Iron County

The Antelope Range (Silver Belt) mining district contains generally northwest-striking veins hosting epithermal, Ag-Au-sulfosalt mineralization. The Antelope Range is primarily a northeast-dipping, faulted homoclinal sequence of Miocene volcanic rocks and has had mostly insignificant past production. The veins vary in dimensions, but are typically 0.6 to 1.2 m (2.0 to 3.9 ft) wide with a maximum width of 14 m (46 ft), and can be followed along strike for 30 to 1400 m (100 to 4600 ft). The veins are generally vuggy quartz-calcite with abundant barite and some base metals. Hypogene sulfide minerals include pyrite, galena, chalcopyrite, sphalerite, and the sulfosalts pearceite, tennantite, stromeyerite, and proustite. Maximum grades from vein samples are 300 ppm Ag and 7.5 ppm Au (low Au:Ag ratio), and the samples are also anomalous in Cu, Pb, Zn, As, Sb, Hg, Ba, Mo, and W (Shubat and McIntosh, 1988). There is a zone of weak, but pervasive argillic alteration and hematitic staining of the Miocene Racer Canyon Tuff about 3 km (1.8 mi) northwest of Silver Peak, southwest of the bulk of the mineralization. Shubat and McIntosh (1988) interpreted mineralization as the product of episodic boiling of hydrothermal fluids at about 200°C (390°F) related to rhyolitic and dacitic volcanism (about 8.5 Ma).

Confidence District, Iron County

The Confidence (Eagle Valley district, NV) mining district lies in the southern White Rock Mountains of northwesternmost Iron County. The main mineralized feature is the west-northwest-trending Confidence vein with the largest development at the Confidence mine, some 200 m (660 ft) into Lincoln County, Nevada. The old Bergin Au-Ag mine lies on the southeastern projection of this vein into Utah (Tingley and Castor, 1991).

Escalante District, Iron County

The Escalante mining district is a large district and the principal Ag producer in the CCPA. The Escalante vein was staked in 1896 by Heber Holt and Heber Grant, operated briefly during the Great Depression, and then again briefly in 1958 when it was acquired by Sam Arentz and produced 11,800 t (13,000 st) for flux. The problem for the mine was that the vein was modest grade (about 300 ppm Ag) and below the water table (50 m [160 ft] deep) in a porous tuff which dictated heavy dewatering (up to 210,000 m^3 [275,000 yd^3] per day). However, the lateral continuity and fairly consistent grade of the vein eventually overcame these difficulties and the mine became an important producer in 1981, operating until 1990 (Arentz, 1978; Fitch and Brady, 1984). The underground operation was started by Ranchers Exploration and Development Corporation, which was taken over in 1984 by the Hecla Mining Company.

The mine was developed principally on a single persistent quartz-calcite vein cutting late Miocene rhyolitic volcaniclastic sediments of the "mine series" (210 m [690 ft] thick), approximately temporally equivalent to the Steamboat Mountain Formation. The main vein is 1100 m (3600 ft) long, 1.5 to 14 m (4.9 to 46 ft) wide (average 8 m [26 ft]), strikes N. 27° E., and dips 70° W. on average. The vein is cut by a very gently dipping, bedding-parallel fault at a depth of about 100 m (330 ft) that displaces the upper part of the vein about 12 m (39 ft) west. The main vein reportedly horsetails into multiple smaller veins to the southwest (Fitch and Brady, 1984). Adularia from the vein has been dated at 11.6 ±0.5 Ma (Siders, 1985a, b). Fluid inclusion studies show average homogenization temperatures of 206°C (403°F) with salinities of 0 to 19.5 wt% (Holloway and Petersen, 1990).

The main economically mineralized area is a zone of supergene Ag enrichment from about 60 to 210 m (200 to 690 ft) in depth. The Ag is leached and sub-ore grade (200 to 275 ppm Ag) at the surface where the vein is also narrower (1.2 to 3 m [3.9 to 10 ft] wide) and Ag also continues at depth in the primary (fresh sulfide) zone, but the grade is diminished (15 to 300 ppm Ag). The vein is strongly crustiform-banded (repeated mineralizing events), vuggy, white quartz-calcite and dark gray Fe-Mn oxides with minor Cu-As-oxides. The principal Ag minerals in the enriched zone are very fine-grained chlorargyrite and rare native silver. The main ore/sulfide minerals in the primary zone are argentite, galena, sphalerite, pyrite, hematite, jalpaite, and rare native silver and gold. Gangue minerals include several generations of quartz with subordinate calcite, fluorite, barite, and rare adularia. Calcite, fluorite, and galena appear to be increasing with depth (Fitch and Brady, 1984). The vein is surrounded by a 3- to 15-m- (10- to 50-ft-) wide selvage of silicification with low Ag grades (70 to 300 ppm), which grades outward to a weak calcitic alteration with minor sericite, calcite, chlorite, and kaolinite. Limited trace element geochemistry shows anomalous Pb, Zn, Cu, Au, and Mo associated with the Ag veins.

Although virtually all of the production from the Escalante mining district is derived from the Escalante vein, other smaller veins and zones of hydrothermal alteration occur over an area of some 40 km^2 (15 mi^2). Much of this alteration occurs on and/or near The Point, a knoll some 7 km (4 mi) north of the Escalante mine (Siders, 1985a, b; Biehl, 1986). At The Point, the volcanic facies of the rhyolite of Beryl Junction (10.8 Ma) is locally silicified and iron stained in spatial association with intrusives and flow domes of the rhyolite member (Siders, 1985a, b).

The Escalante vein was mined using a modified vertical crater retreat system at roughly 680 t (750 st) per day. The mine was accessed via a -14% decline using diesel equipment with haulage and undercut levels at roughly 30.5 m (100 ft) levels. Silver was recovered at an onsite mill and cyanidation plant and refinery. The average Ag recovery was approximately 80% (Hogan and others, 1982; Burger, 1984). While resources undoubtedly remain in the wall rocks and beneath the stopes in the old mine, the wallrock resources are likely to be spotty and difficult to mine at this point and the resource at depth is lower grade (15 to 300 ppm Ag) and likely to require even greater dewatering efforts.

Fortuna District, Beaver County

The Fortuna district is a little recognized and insignificant Au-Ag producer located on the north end of Beaver Basin, about 20 km (12 mi) north of Beaver. The district is mentioned by Butler and others (1920) as having northwest-trending, banded quartz-carbonate ±adularia veins cutting generally easterly dipping, propylitized Oligocene Bullion Canyon Volcanics rhyodacite porphyry host rocks. The rhyodacite porphyry wall rocks are silicified immediately adjacent to the veins. Native gold reportedly occurs with limonite after pyrite in the veins (Butler and others, 1920) with grades to over 10 ppm Au. In addition to Au and Ag, the veins are also anomalous in As, Sb, and Hg. The mine workings consist of scattered shafts and a very small open cut (1000 t [1100 st]?) at the Fortuna mine. The rhyodacite porphyry host rocks are also cut by a series of Miocene felsite porphyry dikes (9.1 Ma) and mineralization may be related to the Rhyolite of Gillies Hill, some of which are high-silica rhyolites (Evans and Steven, 1982).

Gold Springs District, Iron County

The Gold Springs mining district (Pike's Diggings) lies in the Paradise Mountains along the Nevada border in northwestern Iron County. Production was derived from a series of generally northerly trending, moderately east-dipping, epithermal, low-sulfidation, banded or crustiform, quartz-carbonate-adularia ±pyrite veins cutting Miocene volcanic rocks. From older to younger, the volcanic sequence consists of andesitic flows, ash-flow tuffs, and rhyolitic flows. These volcanic rocks are cut by porphyritic rhyolitic intrusives (16.5 Ma) associated with the Gold Springs depression (caldron). The rhyolite porphyry, which lies across the state line in Nevada, is phyllically to argillically altered (Williams and others, 1997). Veins near the Gold Springs depression are higher in Au and the more distal veins carry higher Ag. Geochemical sampling indicates elevated Mo, F, Pb, Cu, Mn, Te, Hg, and U associated with the Au-Ag veins (Williams and others, 1997). A shaft near the center of the porphyritic rhyolite (on Bull Hill, NV) is developed on a Au-Ag-rich, fluorite-hematite-clay pipe (Perry, 1976). Ferrimolybdite is reported from the Jumbo lode (Butler and others, 1920). The Charley Ross mine (NV), immediately south of the Gold Springs depression, intersected a body of "talc" 12 m (39 ft) wide containing locally high Au-Ag values, apparently as sylvanite (Higgins, 1908).

Modena Area, Iron County

Butler and others (1920) report the occurrence of some Au-Ag quartz-carbonate veins with minor Fe and Mn oxides cutting rhyolite near Modena in westernmost Iron County. Eppinger and others (1990) note four prospects near the mouth of Modena Draw in altered 13 to 10 Ma rhyolite. The north-south-trending veins are crustiform banded, are up to 3 m (10 ft) thick, locally develop into a stockwork, and wall rocks are silicified, argillized, or propylitized (Eppinger and others, 1990). Hall (1978) discussed the occurrence of alunite veins in the Modena area.

Newton District, Beaver County

Newton is a modest mining district located north of Beaver on the west flank of the Tushar Mountains covering part of the Marysvale volcanic field. The host rocks are predominantly Oligocene-Miocene Bullion Canyon calc-alkaline andesitic volcanic rocks intruded by Miocene monzonite, quartz latite, and rhyolite porphyries. Mineralization in the district is predominantly small, auriferous, low-sulfidation, epithermal, quartz-carbonate veins with some U-Mo-W shows. This mineralization, for the most part, appears to be associated with Miocene Mount Belknap (about 18 Ma) rhyolite porphyries (Cunningham and others, 1984a).

Precious metal production from the Newton district has been primarily from the Sheep Rock and Rob Roy mines near the western range front fault. The Sheep Rock mine develops a 1.5- to 7.5-m- (4.9- to 24.6-ft-) thick, white “comby” quartz-carbonate ±fluorite vein trending N. 20° E. 70° SE. cutting sericitized and pyritized Bullion Canyon Volcanics andesite porphyry. Ore minerals are reportedly argentite and native gold (Butler and others, 1920). In addition to high-grade Au and Ag (39 ppm and 1600 ppm, respectively from direct shipping ore), samples from the Sheep Rock mine are weakly anomalous in Mn, Pb, and possibly Te. The wall rocks of the vein contain sericite, pyrite, and are locally strongly silicified (Cunningham and others, 1984b).

The Rob Roy mine has produced a little rich Au ore from a northeast-striking, moderately west-dipping, Fe-oxide-stained quartz-carbonate vein cutting the Miocene Indian Creek equigranular monzonite stock (23 Ma?) and associated Bullion Canyon Volcanics (Butler and others, 1920; Cunningham and others, 1984b). Nine vein samples taken by W.J. Garmoe of the Anaconda Company in 1964 averaged 7.2 ppm Au and 6.4 ppm Ag (data in UGS files). Wall rocks of the vein are bleached and strongly sericitized. Steven and Morris (1987) report that similar, albeit lower-grade mineralization, also occurs farther southeast on Cork Ridge.

Stateline District, Iron County

The Stateline mining district lies along the Nevada border in extreme northwestern Iron County, 11 km (7 mi) north of Gold Springs. The rocks exposed at Stateline consist of a thick sequence of Miocene volcanic rocks. From older to younger the sequence consists of andesitic flows, ash-flow tuffs, and rhyolitic flows. These volcanic rocks are cut by pale olive, rhyolite dikes (16.5 Ma), locally cut by small quartz veins near the Ofer mine.

Precious metal production is derived from a series of conjugate, north-northeast-trending (N. 5-20° E.) and more productive west-northwest-trending (N. 70-80° W.), epithermal, low-sulfidation, brecciated, quartz-adularia-carbonate-pyrite ±fluorite veins including the district's three principal mines, the Ofer, Margarette, and Johnny. The north-northeasterly trending veins dip to the west at about 60º and the west-northwesterly striking veins dip an average of 65º north (Smith, 1902). The veins are typically about 1 to 6 m (3 to 20 ft) wide and can be traced on the surface for 150 to 750 m (490 to 2460 ft). The Au:Ag ratio of the ores increase from west to east across the district (Smith, 1902). The Ofer mine on the west produced high-grade Ag ore (700 ppm Ag), and the Johnny mine on the east averaged of just 110 ppm Ag, but had better Au values (Thomson and Perry, 1975).

The ore is localized in shoots within the veins. The ore shoots on the east-west vein set rake about 45º NW, which roughly parallels the intersection of the two vein sets. Vein wall rocks are generally argillized. The principal Ag mineral in the district is chlorargyrite associated with other unidentified non-sulfide Ag-bearing minerals in the Fe, Mn, and Mo oxides. The Ofer and Johnny mines reached primary argentite, sylvanite, and pyrite ore (Thomson and Perry, 1975; Bullock 1981). High-grade float has been found in the Stateline district suggesting the possibility of undiscovered small bodies along known veins or hidden and covered veins (Thomson and Perry, 1975).

AMAX Exploration, Inc. acquired a land position in the center of the Stateline district in 1980-81 and defined a 1 km^2 (0.4 mi^2) area of intense phyllic alteration, disseminated pyrite, and quartz veining south of the Ofer mine. Geochemical sampling revealed local areas of strongly anomalous Ag (up to 1300 ppm), Au (up to 35 ppm), F (up to 46%), Mo (up to 380 ppm), and Mn (up to 2.6%) associated with moderately anomalous Be, U, Sn, and Pb (AMAX Exploration Inc., 1981, unpublished corporate report in UGS files).

Other Gold-Silver Districts

The Blue Mountain district is located in south-central Beaver County, 20 km (12 mi) north of Lund. The district encompasses the Blue Mountain, Jockey Road, and Iron Mine Wash areas and lies astride the east-trending, Miocene, Blue Ribbon lineament of Rowley and others (1978), an insignificant producer or iron ore flux (Bullock, 1970). Low-grade, distal disseminated Au-Ag mineralization (0.5 ppm Au) has been explored over the past three decades. The best mineralization occurs in the lower portion of the Middle Cambrian strata above the Blue Mountain thrust.

Good grade Au mineralization is also known from the Golden Reef mine in the northern San Francisco district and the Horn Silver mine in that district is the second largest silver producer in the CCPA. Both of these mines continue to have exploration efforts directed at them and this is very likely to continue in the future. These mines are both reported on in greater detail under the Lead-Zinc section of this report.

Epithermal Au-Ag potential is suspected at the Cina Hg-S mine in the Pink Knolls area. The Cina mine area is currently being drill tested for Au by Newmont Mining Corporation. Additional information on the Pink Knolls area is under the Mercury section of this report.

3.2.3 Iron

Utah ranks fifth in the nation in iron (Fe) ore production (Eppinger and others, 1990). The only significant Fe resources in the CCPA occur in the northeast-trending Iron Axis mineral belt, extending over 100 km (60 mi) through Iron County from Iron Peak on the northeast, through the Iron Springs mining district, to the Bull Valley district on the southwest. The Fe mines, prospects, and occurrences in the Iron Axis are all associated with 22 to 20 Ma calc-alkaline intermediate plugs (Rowley and others, 2006). The deposits are loosely classified by Eppinger and others (1990) as Fe skarn (USGS model 18d; Cox, 1986e).

Iron Springs, Iron County

The Iron Springs (Pinto) mining district is the most productive Fe district in the western United Stated (about 100 million t [110 million st] of Fe ore) and still host's significant remaining Fe resources. The Iron Springs ore bodies are associated with three oval-shaped Miocene (about 21.7 Ma), calc-alkaline, porphyritic, quartz monzonite laccoliths, from southwest to northeast: Iron Mountain (15.3 km^2 [5.9 mi^2]), Granite Mountain (7.5 km^2 [2.9 mi^2]), and Three Peaks (>20 km^2 [>7 mi^2]) (Rowley and others, 2006). The Granite Mountain laccolith has a large subsidiary lobe to the southwest that lies unexposed beneath the Neck of the Desert between Iron Mountain and Granite Mountain. The apexes of these three laccoliths and the Neck of the Desert lobe of the Granite Mountain intrusive are fairly consistently spaced on about 7 km (4 mi) centers.

The porphyritic quartz monzonite is green-gray, fine-grained quartz and K-spar with plagioclase phenocrysts, lesser hornblende, augite, and biotite, and accessory magnetite, ilmenite, apatite, titanite, and zircon. The three intrusions are nearly identical in composition. Erosion has removed most of the intrusive and sedimentary rock carapace on the Three Peaks laccolith, while the least erosion has occurred on the Iron Mountain laccolith. The laccoliths are also similar texturally, but Three Peaks intrusive appears coarser grained (Bullock, 1970), presumably as a result of a deeper level of erosion on this laccolith. Deep drilling at Iron Mountain (over 610 m [2000 ft]) has intersected coarser grained intrusive similar to that at Three Peaks (Ratté, 1963). The intrusions are not believed to have vented to the surface.

The interpretation that the intrusives are laccoliths was confirmed by an ARCO Oil and Gas exploration hole (Three Peaks #1) targeting an anticlinal flexure beneath the laccolith. This hole, about 1.6 km (1 mi) west of the exposed Three Peaks quartz monzonite porphyry, intersected the intrusive at 708 m (2323 ft) and exited its bottom at 1496 m (4908 ft) reentering Carmel Formation which appears to have been thickened by thrusting and accompanying folding (Van Kooten, 1988).

The three exposed laccoliths occur along a slightly arcuate, 30-km-long (19-mi-long) northeast-trend that represents the heart of the more extensive northeast-trending Iron Axis mineral belt. The northwest-dipping, Sevier-age, Iron Springs Gap thrust system had its major thrust plane in a zone of weakness between the massive Navajo Sandstone and the relatively incompetent beds at the base of the overlying Carmel Formation. This thrust fault is the frontal thrust of the Sevier fold-and-thrust belt and with an associated broad anticline helped localize the laccoliths (Mackin, 1968; Bullock, 1970; Van Kooten, 1988; Eppinger and others, 1990). This results in a pronounced asymmetry with generally moderate dips of 20 to 40° on the sedimentary carapace over the laccoliths on the northwest flanks of the laccoliths and very steep to vertical or overturned bedding on the southeast flanks.

There are three basic types of primary Fe deposits in the Iron Springs district: veins, breccia bodies, and skarn/replacement ore bodies (Butler and others, 1920). All ores are primarily magnetite (Fe_3O_4 – 72% Fe) and hematite (Fe_2O_3 – 70% Fe) with minor martite (hematite pseudomorphs after magnetite), maghemite, and goethite. The primary gangue minerals include calcite, quartz, dolomite, phlogopite, apatite (fluorapatite), quartz, siderite, ankerite, diopside, magnesite, gypsum, barite, epidote, andradite garnet (Ca-Fe), vesuvianite (idocrase), scapolite, albite, tourmaline, chlorite, tremolite, actinolite, wollastonite, hedenbergite, siderite, and a handful of sulfides including pyrite, marcasite, chalcopyrite, bornite, galena, and cinnabar. Coarse phlogopite with calcite occurs in altered, but unmineralized, Carmel Formation rocks. Pyrite and other sulfide minerals are very rare, except for the most part as late-stage, fracture-controlled phases. The old Duncan pit on the south end of Iron Mountain, had the highest bulk sulfide content of any ore in the district. Magnetite ore textures indicate cross-cutting veinlets and progressive replacement of the limestone along bedding planes lead to virtually massive magnetite containing only very minor apatite, carbonates, and trace calc-silicate minerals. In the upper, thinly-layered, silty rocks of the Homestake Limestone, more incomplete magnetite replacement results in very fine alternating layers of magnetite and unreplaced host rock. Diopside-calcite assemblages are locally present, but mostly in breccia cavities in ore and along fractures in the quartz monzonite, but not in the limy or siliceous Homestake Formation (Pedersen, 2011). The magnetite-rich deposits tend to be “hard” ores and hematite-rich ores are “soft” ores.

Because magnetite is quite resistant to oxidation and weathering, alluvial/colluvial ores (cutoff grade of 6%) have also been mined in the district. The alluvial deposits averaged only about 10% Fe, but were very amenable to screening and magnetic separation by a self-propelled mobile, dry placer, magnetic separator. This operation was begun by Utah Construction and Mining Company in 1964 on the northeast flank of Iron Mountain (about 1.5 km [0.9 mi] to the east of the Comstock-Mountain Lion [C-ML] deposit) and successfully operated at about 270,000 t (300,000 st) per year for about 18 years. This operation mined to depth of 30 – 60 m (100 – 200 ft; Bullock, 1973).

The veins are the least important ore type and primarily occur in radial and concentric fractures/joints within the quartz monzonite porphyry laccoliths. About a third to half of the altered joints in the intrusive contains some magnetite with accessory hematite, apatite, calcite, pyrite, and pyroxene (Young, 1948; Bullock, 1970). These veins range from 2 - 5 cm (1 – 2 in) to over 3 m (10 ft) wide and up to 640 m (2100 ft) long, with the larger veins typically occurring in radial joints. In the early days of the district the magnetite veins often stood up as black, narrow, ridges up to 10 m (33 ft) high in the less resistant quartz monzonite porphyry (Butler and others, 1920). The veins are predominantly hard magnetite and occasionally display coarse, euhedral magnetite and long prismatic apatite crystals clearly grown in open space. The abundant apatite in these veins may give the ore a deleterious phosphorous content (>0.25% P). Bullock (1970) suggests that some of the larger veins may host ore bodies of over 100,000 t (110,000 st). The Great Western mine on the southwest side of the Three Peaks laccolith is believed to have been the most productive vein in the district at about 80,000 t (88,000 st). The veins are often recognized as the mineralizing conduits (feeders) for the larger skarn/replacement ore bodies.

Breccia ores occur as irregular bodies in premineral fault zones, adjoining skarn/replacement ores, and even possibly as collapse breccia pipes. The breccias are typically heterolithic, matrix-supported, sub-angular to sub-rounded, and may contain clasts 3 - 5 m (10 – 15 ft) in diameter. Fragments can include quartz monzonite, limestone, and magnetite ore (Butler and others, 1920). Breccia ores represent some of the largest ore bodies including the Blowout mine and portions of the Rex, Lindsay, and Comstock ore bodies. The Blowout breccia, for example, was 260 m (850 ft) long, 120 m (390 ft) wide, over 240 m (790 ft) deep and produced over 6.5 million t (7.2 million st) of nearly 60% Fe. The core of the Blowout pipe "was high in quartz which occurs mainly in vugs. White and drusy quartz was present, and amethyst quartz was common near the surface. The ore also contained galena, chalcopyrite, bornite, and pyrite, with the pyrite content increasing with depth" (Bullock, 1970). Amethyst and sulfides are more common in the breccias ores than the skarn/replacement deposits. "In some cases minor replacement of the breccia fragments has taken place, and where limestone fragments are involved complete replacement by iron ore is expected, but the greatest proportion of the ore apparently occurs as open-space filling (Ratté, 1963).

The largest and most important ore bodies are stratabound skarn/replacement ores principally in the Middle Jurassic Homestake Limestone Member of the Carmel Formation surrounding the laccoliths. The Homestake Limestone is about 76 m (250 ft) thick and is primarily composed of extensively recrystallized and bleached micrite. The Homestake Limestone, equivalent to the Co-op Creek Member regionally, is often separated from the intrusive by an isochemical metamorphosed (hornfels) siltstone of the underlying Temple Cap Formation (10 to over 30 m [33 to over 100 ft] thick). The Homestake Limestone is overlain by the Dakota Conglomerate (15 m [50 ft]), which is in turn overlain by a very thick (>1000 m [>3300 ft]) section of Iron Springs Formation of interbedded sandstones, siltstones, and mudstones. The Temple Cap hornfels is primarily wollastonite and hydrogrossular with minor clinopyroxene, calcite, and forsterite.

Stratabound skarn/replacement mineralization begins at the base of the Homestake Limestone where it usually has the best grade (>50% Fe); however, the whole Homestake Limestone may ultimately be replaced. At the still unmined Rex deposit on the west side of Iron Mountain, mineralization extends upward from the Homestake Limestone into the overlying brecciated Dakota Conglomerate and Iron Springs Formation. The skarn/replacement ore bodies are tabular, stratabound, pod-shaped deposits typically from 100 m (330 ft) to as much a 1000 m (3300 ft) long, and may range up to approximately 80 million t (88 million st). The skarn/replacement deposits occur near the igneous contacts, coinciding with zones of strong jointing and veins in the underlying quartz monzonite. The skarn/replacement deposits commonly occur as infolded blocks, roof pendants, or along faulted intrusive contacts. In form, the skarn/replacement deposits resemble skarns, but the paucity of readily recognizable coarse-grained, calc-silicate minerals has resulted in these deposits typically being referred to as replacement bodies. In this report the hybrid term skarn/replacement deposits is used for these deposits. The principal gangue minerals are calcite, apatite, quartz, garnet, and phlogopite. Phlogopite, pyrite, and apatite are more abundant in the upper thin-bedded Homestake Limestone where the primary sedimentary structure may be preserved (Ratté, 1963; Wray and Pedersen, 2009). The C-ML deposit is a prime example of the skarn/replacement type deposit and was originally estimated to host some 60 million t (66 million st) of ore (Bullock, 1970). The A&B skarn/replacement orebody on the south side of Iron Mountain has been traced by drilling to a depth of over 600 m (2000 ft). A few of the skarn/replacement deposits, particularly in the steeply dipping rock on the southeast flanks of the laccoliths, terminate downward into breccia bodies, e.g. Armstrong deposit.

Mineralization in the skarn/replacement ores is black and generally finely granular with fairly even grade and sharp, distinct ore-waste boundaries. Inclusions of unreplaced limestone are not common and can usually be rejected during mining. Skarn/replacement ore is generally very finely crystalline magnetite, soft and easily crushed and may be oxidized to earthy brown or red hematite near the surface. The Desert Mound skarn/replacement orebody, however, is unusual in that it was primarily hematite (Ratté, 1963). Phosphorous in the apatite and fluorine in the apatite and phlogopite are deleterious during smelting. These elements are erratically distributed and appear to be concentrated near faults and veins (Young, 1948).

The Homestake mine, just north of the C-ML open pit, is the only deposit in the district with appreciable copper, with assays from four ore samples ranging from 0.14% to as high as 1.97% Cu. The Cu tends to occur on the outer, distal margin of the Fe deposits. The Homestake mine has also produced a little Pb-Ag ore (Butler and others, 1920). A late, red, siliceous vein was found cutting the Desert Mound orebody that contained significant Hg, Sb, As, and Te (Ratté, 1963).

The origin of the Iron Springs ore deposits has long been controversial. Mackin (1968) proposed an innovative deuteric release model while Ratté (1963) and Bullock (1970) suggested a more ordinary contact metasomatic-hydrothermal model. Recent work by Barker (1995) has reinforced the deuteric release model; however, questions remain (Wray and Pedersen, 2009). Briefly, the deuteric release model is described as follows (Mackin, 1968; Barker, 1995):

1. Intrusion of the quartz monzonite laccoliths to a shallow depth (less than 2000 m [6560 ft]) along a northwest-dipping thrust fault;
2. Rapid formation of a chilled contact of 30 to 60 m (100 to 200 ft) on the laccolith (peripheral shell) effectively sealing all fluids into the still molten interior;
3. Crystallization of the remaining interior magma to a crystal mush with a trapped, interstitial magmatic fluid;
4. Deuteric alteration of early crystallized minerals by the remaining, residual fluid (interior);
5. Local development of extension joints and faults, especially in areas of late intrusive distension (growth);

6. Leaching of Fe from biotite and hornblende by deuteric fluids in the selvage margins (1 cm to 1 m [0.5 in to 3.3 ft] wide) of the joints/veins in the outer quartz monzonite porphyry (zone of selvage joints);
7. Outward migration of these Fe-rich deuteric fluids along the selvage joints forming veins and replacement in the adjoining Homestake Limestone.

Mass balance calculations for the estimated 200 million t (220 million st) of reported Fe ore production and reserves requires an estimated 40 km^3 (9.6 mi^3) of quartz monzonite be leached of about 1% Fe along the selvage joints (Barker, 1995). Barker (1995) makes the case that this volume of leached quartz monzonite is present in the district, but makes no provision for the very probable additional hundreds of millions of tons of ore that had yet to be delineated or were almost certainly present over the currently deeply eroded apexes of the three exposed laccoliths. These speculative resources would likely require an additional 100 km^3 (24 mi^3) of leached quartz monzonite, which do not appear to be present in the district.

Interestingly however, Barker (1995) reports that the zone of selvage joints (proposed source of the Fe) at the Three Peaks pluton is just 0 to 150 m (0 to 500 ft) thick, on Granite Mountain it is 300 m (1000 ft) thick, and at Iron Mountain it is nearly 500 m (1600 ft) thick. This correlates well with both the proposed level of erosion of the laccoliths (see above) and the Fe production from these individual intrusives with Three Peaks yielding the smallest, Granite Mountain next, and Iron Mountain both the largest production and current reserves.

The breccia ore bodies are also difficult to account for with the deuteric release model (Ratté, 1963; Bullock, 1970, 1973). The breccia ores show evidence of fluid over-pressurization and some of the breccia ores even contain fragments of unreplaced quartz monzonite, the proposed source of the mineralizing fluid.

On the other hand, the confirmation that the intrusive bodies are indeed laccoliths and not plugs (Van Kooten, 1988) raises problems for the contact metasomatic-hydrothermal model. Being a laccolith, rather than a cupola over a larger magma chamber, makes access to a deeper magmatic reservoir underlying the small exposed intrusive potentially untenable (Rowley and Barker, 1978). In addition, the Iron Springs district shows none of the usual district-scale metal zoning typical of magmatic-hydrothermal centered systems, e.g. proximal Cu, medial Pb-Zn, and distal Mn.

In summary, neither mineral deposit model seems to exactly explain the known Fe deposits in the Iron Springs district. However, overall the deuteric release model seems to fit the characteristics of the Fe ore bodies better than the contact metasomatic-hydrothermal model. One apparent problem with the Mackin-Barker model is the calculation of the bulk composition of tens of cubic kilometers (well over 100 billion t [110 billion st]) of altered intrusive (zone of selvage joints) from five rock-chip samples (Barker, 1995, table 2). Potentially, additional Fe may have come from the deuterically altered interior zone, which is also apparently slightly depleted in total Fe (0.33%) compared to the fresher peripheral shell (Barker, 1995, table 2) and this could have added substantially to the total metal available for the formation of the Fe deposits.

Comstock-Mountain Lion (C-ML) Fe Deposit: The C-ML Fe orebody is located on the northeast flank of the Iron Mountain laccolith and is currently (October 2011) in production. The C-ML deposit is a large skarn/replacement orebody in a roof pendant of Homestake Limestone. Mineralization is continuous from the Dear breccia ores on the southeast, through the Comstock mine, to the Mountain Lion mine on the north, a distance of approximately 1.2 km (0.7 mi). The Homestake orebody is located some 300 m (1000 ft) farther north of the Mountain Lion. Production began on the Comstock orebody by Colorado Fuel and Iron Company (CF&I) in 1956 and by Columbia Iron Mining Company on the Mountain Lion deposit in 1970. Substantial portions of the C-ML orebody were oxidized and contained soft, friable ore averaging about 46% Fe. Open-pit mining at the C-ML had an average stripping ratio of about 1:1 (Gin, 1989). Production from the C-ML deposit was approximately 10 million t (11 million st) by 1970 (Bullock, 1970) and considerable additional ore has been mined since then.

The C-ML deposit was drilled out by CF&I and Columbia in the 1940s and 1950s with a total of 390 holes totaling 33,024 m (108,346 ft). Eight of these holes were twinned by Palladon in 2009 to confirm the validity of the previous work. This has resulted in the completion of a Canadian NI 43-101 report that proposes a two-phase mining program starting on the southern, shallower pit (Comstock) and a second phase developing the northern, deeper part of the orebody (Mountain Lion).

The run-of-mine operations are currently (October 2011) operating smoothly, with monthly averages of approximately 166,000 dry t (183,000 dry st) of high-grade (+53% Fe) direct shipping ore sent out in April and May. However, taking higher than average grade ore now to meet direct shipping contract specifications, results in the average grade of the remaining resource being diminished. This difficulty is partially offset by the ongoing construction of a 1.8 million t (2.0 million st) per year magnetic concentration plant at Iron Mountain.

Rex Fe Deposit: The Rex (Milner Hill) Fe orebody is located on the west flank of Iron Mountain approximately 4 km (2.5 mi) south of the currently operating C-ML mine. The Rex deposit is the largest orebody in the Iron Springs district and was discovered by ground magnetic surveys focused on the margins of the stocks. Scattered mineralization is present on the surface over the Rex deposit in the Iron Springs Formation cropping out on Milner Hill. High-grade Fe ore (about 44% Fe) occurs in the Homestake Limestone Member at depth beneath low-grade mineralization in the overlying Dakota Conglomerate and lower Iron Springs Formation (about 26% Fe). This, unfortunately, results in the early years of an open-pit operation running lower-grade ore and the best grades not being produced until near the end of the mine life. Mineralization in the Homestake Limestone Member is virtually continuous to the historic Burke open-pit to the southeast. In total, the Rex mineralization is over 230 m (750 ft) thick in a peculiar concave upward, bowl-shaped orebody (Bullock, 1970). The Rex deposit occurs at an average depth of approximately 213 m (699 ft) under a sequence of upper Iron Springs Formation sandstone, siltstone, and shale (Gin, 1989). The Rex deposit has never been in production.

The Rex deposit was drill delineated by U.S. Steel in the 1950s on approximately 61-m (200-ft) centers with some 30-m (100-ft) infill holes and some 122-m (400-ft) centers near the margins in of the deposit. All of the historic drill holes are vertical and core recovery was generally good, averaging 93% (Wray, 2005). Small bench-scale magnetic tests (Davis tube) were run on -100 mesh samples from most of the mineralized drill intervals representing some 14,326 m (47,000 ft) of drilling and large batch-scale tests were performed on composited drill intervals to define the ore's magnetic concentration characteristics. Two early 1960s Columbia Iron Mining Company reports comparing open-pit and underground operations found that the operating costs of an underground operation would be 1.5 times more expensive than open-pit costs, would only recover ⅔ as much Fe from the deposit, and daily underground production rates would be lower. This is likely due to the complex geometry/faulting of the orebody making underground mining more difficult (Gin, 1989).

The Rex pit was designed with a 45° pit wall and will require pre-mine stripping of about 75 million m^3 (98 million yd^3) and an additional 138 million m^3 (180 million yd^3) of stripping during mining. Pre-mine stripping was expected (in 1989) to take four to six years and cost $100 to 150 million; adjusted for inflation to 2011 dollars this is approximately $180 to 270 million. The overall life-of-mine stripping ratio is about 4:1 waste to ore tons (Gin, 1989). Mackin (1968) reports that the historic stripping limit was 2 waste yd^3 to 1 ore st, which would be crudely similar to 4:1 waste to ore tons.

U.S. Steel completed an open-pit development plan for the Rex orebody in 1964, updating it in 1975. This 1975 study estimated capital costs at $152,662,000 for a 1,800,000 t (2,000,000 st) per year operation with operating costs of $17.17 per t ($15.58 per st) of agglomerated concentrate (Gin, 1989); adjusted for inflation to 2011 dollars this is $638 million and $65.11 ($59.07), respectively. A 1991 Cyprus Minerals Company study of a significantly larger 3,356,000 t (3,699,000 st) per year crushing, concentrating, and pelletizing plant estimated a construction cost of $361 million and an operating cost of $9.20 per t ($8.35 per st) of ore; inflation adjusted to roughly $596 million and $15.19 ($13.78), respectively, in 2011 dollars.

Other Known Iron Springs Resources: Various unpublished reports refer to other, smaller Fe deposits and low-grade stockpiles. A Pincock, Allen & Holt report (1991) mentions a 4.5 million t (5.0 million st) low-grade stockpile by the Burke open-pit and a 2.4 million t (2.6 million st) resource remaining in the Duncan open-pit, both on the southwest end of Iron Mountain near the proposed Rex development (table 4.2.3.1). Similarly, the Homestake mine, just north of the Mountain Lion, also hosts a small, but good grade, open-pitable resource.

Gin (1989) reports on several significant, albeit probably subeconomic, undeveloped Fe deposits likely requiring underground development due to the depth to the top of the orebody. These deposits include the A&B (105 m [344 ft] deep) and McCahill (200 m [660 ft] deep) on the south end of Iron Mountain and the Section 2 (335 m [1100 ft] deep) and Section 9 (245 m [800 ft] deep) deposits under the Neck of the Desert. Recent aeromagnetic work on Iron Mountain shows that the A&B deposit has a surprisingly strong magnetic expression, potentially indicating even larger ore possibilities at yet greater depth. Similarly, the Tip Top and Excelsior mines, both past producers which lack significant current resources, have unexpectedly strong magnetic expressions, again suggesting potential reserves at depth.

Other Fe Mines

The CCPA covers a number of other Fe occurrences, prospects, and mines. These deposits are very unlikely to be exploited as sources of iron production, but have some potential as fluxes, feedstock to cement plants, or heavy media for coal wash (beneficiation) plants. Some minor prospecting has occurred at Iron Peak, about 8 km (5 mi) east-northeast of Paragonah on the Markagunt Plateau, Iron County. The Iron Peak prospects are similar to, but much smaller than those in the Iron Springs district. The Iron Peak Fe prospects are associated with a small Miocene (20.2 Ma) dioritic laccolith which intrudes up through the Paleocene Claron Formation and into the overlying Tertiary volcanic rocks (Rowley and others, 2006).

The Rocky Range, 8 km (5 mi) northwest of Milford, Beaver County, hosts a number of low-sulfidation Cu-Fe ±W skarn deposits (see Copper section of this report). These prospects were primarily productive for Cu, but the Fe was exploited as a source of flux in the late 1800s and early 1900s. The principal Fe deposit in the Rocky Range is the Old Hickory mine, which Bullock (1970) estimates contains a resource of approximately 80,000 t (88,000 st) averaging perhaps 45% Fe. A magnetite byproduct was produced from the recent (2009) copper mining from the Maria Cu skarn for use in a coal wash plant. The Rocky Range is discussed at greater length under the Copper sections of this report.

Similar mines and prospects to the Old Hickory, but with smaller Fe ±W ± base metal showings are also reported from the Beaver Lake, Blawn Mountain, Bradshaw, Granite, Star, and Washington mining districts all in Beaver County. Each of these districts is discussed in detail under other sections of this report.

These other Fe resources may offer some potential for a specific end use such as heavy media in coal wash plant, as cement plant additive, or as a smelter flux. However, these resources are not large enough or pure enough for steel industry use.

3.2.4 Lead-Zinc

Utah is the second leading state in the production of Pb and fourth in production of Zn. The majority of this production comes from the Bingham, Tintic, and Park City districts in northern Utah. However, the CCPA has several mining districts with Pb-Zn production, nearly all in Beaver County. The majority of this production has come from polymetallic vein and replacement deposits (model 19a) with lesser production from Zn-Pb skarns (model 18c) (Morris, 1986; Cox, 1986d).

The most important Pb-Zn districts in the CCPA are the San Francisco and Star, followed by modest production from the Bradshaw, Lincoln, and Washington mining districts. Several other districts in the CCPA have had small or minor Pb-Zn production or known Pb-Zn occurrences.

Bradshaw District, Beaver County

The Bradshaw mining district occupies the southwestern slopes of the Mineral Mountains in central Beaver County. The Mineral Mountains expose a large, mostly gray, alkalic, high-silica, composite Oligocene-Miocene (25 to 18 Ma) granitic, monzonitic, and syenitic batholith (200 km^2 [77 mi^2]), the largest exposed batholith in Utah. The main granitic phase of the Mineral Mountains batholith has an interpreted age of about 18 to 17 Ma. The batholith has been strongly rotated to the east (40º - 85º), so that the east side of the mountain is nearly the paleo-top of the batholith. This rotation is evident from the subvertical dip of the Bullion Canyon Volcanics (29 - 22 Ma) on the east flank of the range (Coleman and others, 2001; Rowley and others, 2005).

The Bradshaw district production came primarily from cave-filling deposits in the Devonian and Mississippian carbonates in the Cave and Hecla mines, respectively (Earll, 1957), adjoining the southern margin of the Mineral Mountain granite batholith.

Lincoln District, Beaver County

The Lincoln mining district occupies the southern and southeastern flank of the Mineral Mountains near Minersville and adjoins the Bradshaw district to the southeast. The ores occur as small skarns and replacement deposits developed in the Pennsylvanian-Permian carbonates near the Miocene (23-21 Ma) Lincoln monzonite-granodiorite stock (Rowley and others, 2005).

The Lincoln district has had limited production and little recent exploration activity, so the development potential, at least in the near future, is considered to be low. The district is likely to have sporadic exploration efforts continuing into the future, but is unlikely to see development.

San Francisco District, Beaver County

The San Francisco (Preuss, Newhouse, Frisco) mining district is located in the southern San Francisco Mountains of north-central Beaver County. The district is centered on the Oligocene (~31 Ma) Cactus granodiorite stock which intrudes a section of Neoproterozoic clastic sedimentary rocks that have been thrust over lower Paleozoic sedimentary rocks. The district is zoned from a central Cu ±Mo zone (Cactus stock) through a medial Pb-Zn-Ag zone to a distal Au-Pb zone.

Mineralization at the Horn Silver mine is developed in a very steeply east-dipping normal fault, which juxtaposes moderately northwest-dipping Cambro-Ordovician carbonate rocks on the west and shallow east-dipping, altered Oligocene volcanic rocks on the east with brecciated granodiorite at depth along the fault. Throw on the fault is over 500 m (1600 ft), down to the east. Mineralization occurs in a crudely arrowhead-shaped orebody over 215 m (705 ft) long at the surface, 30 m (98 ft) wide, and reaching a point at a depth of about 315 m (1033 ft). The deposit resulted from a combination of breccia filling and replacement, mostly of the hanging wall volcanic rocks, although mineralization is also known in the footwall carbonates. The orebody was strongly oxidized to a depth of approximately 200 m (660 ft) (Wray, 2006b). The primary ore/sulfide minerals in the mine are galena, sphalerite, pyrite, jamesonite, tetrahedrite, argentite, stibnite, and chalcopyrite. Gangue and alteration minerals include quartz, alunite, barite, calcite, gypsum, jarosite, kaolinite, and wollastonite (Perry and McCarthy, 1977).

The Beaver Carbonate mine lies about 5 km (3 mi) northeast of the Horn Silver and has been a moderately productive Pb-Ag mine. The deposit is localized along an east-northeast-trending fault, which dips steeply to the north with the Cactus stock to the north and andesitic volcanic rocks to the south. Production is estimated at 84,000 t (93,000 st) of high-grade Pb-Ag ore. Mineralization consists of crustiform banded quartz-adularia-galena-sphalerite-chalcopyrite-pyrite veins associated with the fault zone (Wray, 2006b).

The Golden Reef Pb-Au-Ag mine, about 4 km (2.5 mi) north-northeast of the Cactus stock, has had limited production, estimated at 630 t (690 st) of ore averaging 8.7% Pb, 4.1 ppm Au, and 7.8 ppm Ag (Wray, 2006b). In addition to Pb-Au-Ag, the mineralization is anomalous in Te-Sb-As-Hg. The Golden Reef mine lies along the N. 5º E.-striking, steeply east-dipping Golden Reef fault zone (up to 30 m [100 ft] wide) separating Neoproterozoic and Paleozoic sedimentary rocks on the west from Horn Silver andesite on the east. The ore is described as brecciated Caddy Canyon Quartzite characterized by black, hydrothermal quartz with fine-grained, disseminated barite, pyrite, and galena.

Star District, Beaver County

The Star district encompasses a complex series of small mines in the Star Range, 10 km (6 mi) west of Milford in central Beaver County. The Star Range is basically an east-dipping homocline of upper Paleozoic strata in the upper plate of the Blue Mountain thrust, which was intruded by a series of Tertiary stocks. The stocks belong to two distinctly different groups; the older Oligocene (~30 Ma) quartz monzonite on the north and east and a younger Miocene (~21 Ma) granite to the southwest (Best and others, 1989b). Primary ore/sulfide minerals reported are galena, sphalerite, chalcopyrite, tetrahedrite, pyrite, molybdenite, greenockite, rhodochrosite, fluorite, scheelite, magnetite, and bismuthinite. Calc-silicate minerals developed in the skarns include garnet, epidote, hedenbergite, and diopside (Bullock, 1981).

For the purposes of this description, the Star district is broken down into four sub-areas: (1) Moscow section in the southwest, (2) Vicksburg section in the southeast, (3) Shenandoah section in the west-center, and (4) Harrington section in the northeast. The Moscow area (1) has the largest production and is situated adjacent to the Moscow granite (22-21 Ma) and south of Elephant Canyon. Mineralization occurs predominantly as replacement deposits and "chimneys" (local parlance for small mantos) along northeast- and east-trending veins. Deposits are typically hosted near the top of the east-dipping Devonian carbonate section beneath a shale contact. Production has included Zn, Pb, Ag, and Cu with geochemical Bi, Cd, and Mn often with a fluorite gangue. Sampling by Abou-Zied (1968) suggests average ore grades of approximately 13% Zn, 7% Pb, 170 ppm Ag, and 1% Cu. Production has mostly come from the Moscow (~50,000 t [55,000 st]) and adjoining mines.

The Vicksburg section (2) has had only minor production and is associated with the Vicksburg quartz monzonite stock (30-28 Ma). The deposits are largely Pb, Cu, Zn, and Ag veins and associated “chimneys” with various orientations. The veins cut both intrusive and Kaibab Limestone roof pendants which have been recrystallized and metamorphosed (Abou-Zied and Whelan, 1973).

The Shenandoah section (3) is located north of Elephant Canyon and mineralization appears to be related to small quartz monzonite porphyry plugs and dikes (30-28 Ma?). This section had modest Pb, Cu, Zn, and Ag production with minor Mn and barite in the gangue. Mineralization occurs generally in replacement deposits typically trending N. 45º E. and hosted in the Pennsylvanian Callville Limestone (?). The principal mines are the Cedar-Talisman and Wild Bill.

The Harrington section (4) of the Star district is the second largest producer, mostly from the Harrington-Hickory and the Rebel mines. There are a number of diverse intrusive phases in this section and mineralization is often in prograde garnet skarns in the Kaibab Limestone. The mineralization is typically stratabound and trends N. 50° E. Production is dominantly Pb, Zn, Cu, and Ag with geochemical Mo, Sb, W, and V. There are also two small W skarn deposits in this section of the district.

Washington District, Beaver and Iron Counties

The Washington (Indian Peak) district lies in the Indian Peak Range in southwestern Beaver County and adjoining portions of Iron County. The bulk of the mineralization has been derived from fissured and replaced Paleozoic sedimentary rocks; however, Tertiary volcanic rocks associated with the Indian Peak caldera are hosts locally.

Most of the district’s production was derived from the Arrowhead mine, much of this during the high demand period of World War II. The mine developed small, north-northwest-trending, high-grade, Zn-Pb carbonate replacement ore bodies in a window of Ordovician Pogonip Group surrounded by Oligocene volcanic rocks. Mineralization is associated with very strongly altered Miocene (?) rhyolite dikes (Jones, and Wilson, 1945).

3.2.5 Mercury

Utah historically has not been an important Hg producing state; however, there have been half a dozen mines with known production. The Mercur district, in the Oquirrh Mountains, is Utah’s largest Hg producing district at 3469 flasks[3], as a byproduct of sedimentary-rock-hosted Au mining (Mako, 1999). Other known producers are the Congar Hill mine (102 flasks) in the Willow Springs district of the Deep Creek Mountains and the Lucky Boy mine (88 flasks) in the Ohio district near Marysvale (Beckman and Kerns, 1965).

In the CCPA, the primary Hg prospects lie in the Pink Knolls area, although anomalous Hg is also known from the adjoining Blue Mountain district (Tar Claims), San Francisco district (Golden Reef mine), Bradshaw district (Cave mine), and Brimstone (Sulfur Knoll). The Pink

[3] The standard commercial trading unit of Hg is a flask that weighs 34.5 kg (76 lbs).

Knolls and Brimstone prospects best fit the hot-spring Hg deposit type (model 27a; Rytuba, 1986).

Pink Knolls Area, Beaver and Iron Counties

The Pink Knolls area lies astride the east-trending, Miocene, Blue Ribbon lineament of Rowley and others (1978). Pink Knolls is not an organized mining district, has no known production, but has seen sporadic mineral exploration activity over the last half century. The following paragraph is a synopsis of unpublished company reports associated with this exploration activity, much of it recorded by Willard D. Pye in 1969 and 1970.

The Cina mine, Iron County, hosts cinnabar and native sulfur along a northeast-trending, moderately west-dipping, normal fault between strongly altered Blawn Formation rhyolitic tuffs in the northwest hanging wall and unaltered Middle Cambrian Trippe Limestone in the footwall (Best and others, 1987b; Steven and Morris, 1987). Mineralization can be traced along the fault zone for a distance of about 2 km (1.2 mi), but is most intense in areas with easterly trending cross-faults. The main fault is filled with 0.3 to 3 m (1 to 10 ft; average ~0.75 m [2.5 ft]) wide zones of opal and chalcedony and paleo-hot-spring "fumaroles" occur along the zone sporadically. Red cinnabar is found as thin seams in the chalcedony along with black metacinnabar, sulfur, and/or white, coarse-grained gypsum. Cinnabar is primarily concentrated in the vein/fault itself under the siliceous sinter capping. The cinnabar occurs as disseminated specks, intergranular fillings, and veinlets. Sulfur occurs as lenses/pods in porous zones in the gypsum-bearing altered tuff hanging wall.

Other Hg Districts

Mercury prospects or weak anomalies in the Blue Mountain district (Tar Claims), San Francisco district (Golden Reef mine), Bradshaw district (Cave mine), and Brimstone (Sulfur Knoll) are seen as unlikely targets for future Hg development.

3.2.6 Molybdenum

Utah is the third leading Mo producing state in the U.S., due to production from the Bingham Canyon porphyry Cu-Au-Mo deposit. While the CCPA has no recorded Mo production, there are several mineral deposits with known Mo resources. There are also several Mo-rich deposit types present in the CCPA including Climax porphyry Mo (model 16), porphyry Cu-Mo (model 21a), polymetallic replacements (model 19a), and low-sulfidation quartz veins (model 25c) (Ludington, 1986; Ludington and Plumlee, 2009; Cox, 1986f; Morris, 1986; Mosier and others, 1986). In addition, the CCPA could host as of yet unrecognized porphyry Mo, low-F (model 21b) type deposits which is something of an intermediate step between Climax porphyry Mo and porphyry Cu-Mo deposits (Theodore, 1986).

The Pine Grove district hosts a Climax porphyry Mo resource and several other districts in the CCPA have potential for undiscovered Climax porphyry Mo systems. The San Francisco and Beaver Lake districts contain known porphyry Cu-Mo breccia pipe resources. Molybdenum-rich polymetallic replacement deposits are known in the San Francisco, Beaver

Lake, and Star districts. Low-sulfidation quartz veins with anomalous Mo are recognized in the Antelope Range, Stateline, and Gold Spring districts.

The Climax porphyry Mo deposits are associated with high-silica rhyolites of the Miocene bimodal suite. In addition to Mo, Climax porphyry Mo deposits are known to be enriched in a suite of dominantly lithophile elements, including Be, B, Ce, F, La, Mn, Nb, Rb, Th, Sn, W, U, and Y.

Only Climax porphyry Mo systems will be discussed in this section. The porphyry Cu-Mo breccia pipe resources are discussed under the Copper (table 4.2.3.1), polymetallic replacement deposit are discussed under the Lead-Zinc, and low-sulfidation quartz veins are covered under the Gold-silver sections of this report.

Pine Grove District, Beaver County

The Pine Grove mining district lies in the Wah Wah Mountains of western Beaver County. The mining district was historically a minor Zn-Pb-Ag producer and had considerable Mo exploration beginning in 1974. Pine Grove hosts a giant, Climax-type porphyry Mo deposit related to a sub-volcanic, silicic-alkalic, high-silica rhyolite porphyry plug which intrudes a thick sequence (over 1800 m [5900 ft]) of Late Proterozoic and Early Cambrian quartzose clastic sedimentary rocks. The Pine Grove rhyolite porphyry (23-22 Ma) is a steep-walled, oval-shaped plug covering about 1km^2 (0.4 mi^2). Molybdenum mineralization occurs mostly along the margins of the Pine Grove porphyry beginning at a depth of about 900 m (3000 ft; Staff, 1984; Keith and others, 1986).

According to Keith and others (1993), the evidence that Pine Grove is a Climax-type porphyry Mo deposit includes (1) multiple intrusions of high-silica rhyolite, (2) large tonnage of high-grade ore, (3) accessory fluorite [CaF_2], topaz [$Al_2(SiO_4)F(OH)$], and huebnerite [$MnWO_4$] in or above the ore zone, (4) lack of appreciable Cu in the system, and (5) accessory monazite, xenotime, and ilmenorutile in the intrusive phases. The commonly published reserve figure for Pine Grove is 113 million t (125 million st) at 0.17% Mo at a minimum 300-m (980-ft) width and a 0.12% Mo cutoff grade (Sillitoe, 1980). No important mineral exploration has been done on the property since about 1983. Because porphyry Mo deposits tend to occur in clusters, there would appear to be good potential for the discovery of additional Mo resources in the district.

Broken Ridge Area, Iron County

The Broken Ridge area is located 15 km (9 mi) west of Lund in Iron County, outside of any defined mining district. The Broken Ridge anomaly is covered by a sequence of mid-Miocene (12 Ma) Steamboat Mountain Formation rhyolitic flows, domes, tuffs, and vitrophyres intruded by small, coeval rhyolites and vent breccias. Compositionally, the leucocratic alkali rhyolites average just over 75% SiO_2, 4.83% K_2O, 1114 ppm F, and may be garnet- and topaz-bearing (Duttweiler and Griffitts, 1989). The Broken Ridge area is cut by northeast-trending, high-angle normal faults, most prominently the Bible Springs fault zone, where most of the displacement is contemporaneous with the Steamboat Mountain Formation (Duttweiler and Griffitts, 1989).

Considerable advanced argillic alteration is recognized along the Bible Springs fault zone, primarily in the lower Steamboat Mountain Formation siliciclastic rocks. A zone a 3 - 5 km (2 – 3 mi) west of Broken Ridge (hill 6470; PV alunite deposit) is held up by an 1800 m (5900 ft) long by 400 m (1300 ft) wide zone of advanced argillic alteration. The hill is composed of alunite, kaolinite, silica, hematite, and limonite with strong silicification along the ridge crest.

Geochemical levels of Mo-Sn ±U ±Th ±W are reported from a 50 km^2 (19 mi^2) area at Broken Ridge. Rock-chip samples from the Broken Ridge area carry as much as 200 ppm Mo, 300 ppm Sn, 200 ppm W, 2000 ppm B, 500 ppm Be, 500 ppm Bi, 1.7% F, 1000 ppm La, 300 ppm Li, 5000 ppm Mn, 200 ppm Nb, 1000 ppm Rb, 1000 ppm Th, and 1000 ppm Y, particularly near Mountain Spring Peak (Tucker and others, 1981; Duttweiler and Griffitts, 1989). Cassiterite was identified in heavy mineral concentrate samples from drainages of this area and probably occurs in lithophysae in the volcanic rocks. The Broken Ridge area could be considered a very low-grade rhyolite-hosted Sn deposit (model 25h; Reed and others, 1986). Spessartine, identical in composition to those in the coeval volcanic rocks at Pine Grove, is also found in these heavy mineral concentrate samples (Duttweiler and Griffitts, 1989).

The recognized mineralization at Broken Ridge (no production) occurs in a small, N. 55º E.-trending breccia about 100 m (330 ft) long by 10 m (33 ft) wide adjacent to a small vent breccia. The breccia consists of silicified rhyolite fragments in a dark siliceous matrix. Mineralization is quartz-cassiterite-hematite-fluorite and is anomalous in Sb-As-U-Zn-W-Be-Mn. Alteration consists of weak silicification outside of the pipe (Duttweiler and Griffitts, 1989). The USGS' National Geochemical Database (NGDB) rock-chip samples near this breccia assay up to 1000 ppm Sn, but only 15 ppm Mo and 6.6 ppm W; however, rock-chip samples (2.4 km [1.5 mi] to the southwest) along the Bible Springs fault zone and near the Mountain Spring Peak rhyolite plug (5.6 km [3.5 mi] to the south) both report 20 to 200 ppm Mo and 150 and 200 ppm W.

Broken Ridge has been suggested (Tucker and others, 1981; Steven and Morris, 1987; Duttweiler and Griffitts, 1989) as the top of a porphyry Mo system and is deserving of more extensive mineral exploration.

Other Mo Districts

Although the Pine Grove district is the only area in the CCPA with a known porphyry Mo resource, other districts may also present exploration and development potential for similar deposits at depth. Many of these districts have intusives of similar age and composition to Pine Grove. In particular, the Blawn Wash area of Beaver County, just 10 km (6 mi) southeast of Pine Grove, has high-silica rhyolites of the same age (~23 Ma) and appears particularly prospective (Hofstra, 1984; Bove and Koenig, 2009; Hofstra and Rockwell, 2009). The Blawn Wash area is discussed in greater detail under the alunite section of this report.

Huebnerite (known above the Pine Grove Mo ore zone) is reported from the Louise group of claims on Pole Creek, about 16 km (10 mi) northeast of Beaver in the Newton district.

Newton is a small mining district located north of Beaver on the west flank of the Tushar Mountains and is part of the Marysvale volcanic field. Everett (1961) reports that huebnerite occurs in quartz stringers in porphyry. Workings on this prospect include a 12 m (39 ft) adit and prospect pits. Similarly, Butler and others (1920) report wolframite from the head of nearby North Creek. And finally, Cunningham and others (1984b) note the presence of Tungsten Hollow as a tributary to the South Fork of North Creek. The Newton district is discussed further under the gold-silver and uranium sections of this report.

The Typhoid Spring area, 10 km (6 mi) to the west of Broken Ridge (Steven and Morris, 1987), has a much more extensive area (10 km^2 [3.9 mi^2]) of hydrothermal alteration developed in Steamboat Mountain volcanic rocks, but with far weaker surface geochemistry. Similarly, an extensive area of alteration (12 km^2 [4.6 mi^2]) is mapped in the Bull Valley area west of Steamboat Mountain or roughly an additional 6 km (4 mi) west of Typhoid Spring (Best and Davis, 1981).

The Harrington section of the Star district includes the Harrington-Hickory and the Rebel mines. There are a number of diverse intrusive phases in this section and mineralization is often in prograde garnet skarns in the Kaibab Limestone. The mineralization is typically stratabound and trends N. 50° E. Production is dominantly Pb, Zn, Cu, and Ag with strong geochemical Mo (to 1100 ppm), Sb, W, and V. There are also two small W skarn deposits in this section of the district. The Moscow granite section of the Star district also has anomalous Mo, to 3870 ppm at the Magnolia shaft. Two other mines in the district also report anomalous Mo, with 200 ppm Mo and 200 ppm Sn at the Mammoth mine, and 200 ppm Mo and 150 Sn at the Gold Crown mine (Motooka and Miller, 1983; Miller and others, 1990a, 1990c). The Star district is discussed further under the Lead-Zinc sections of this report.

The Washington-Indian Peak mining district lies on the Blue Ribbon lineament about 17 km (11 mi) from the Nevada state line. The district is a modest F-Pb-Zn producer from small veins cutting Oligocene volcanic rocks in both Beaver and Iron Counties; however, mineralization is related to Miocene (about 20 Ma) alkali-rich, high-silica rhyolite containing greater than 75% SiO_2 and about 5% K_2O (Grant, 1979). All of this suggests excellent, but speculative potential for a porphyry Mo system at depth.

As noted previously in the Au-Ag section, the Miocene bimodal rhyolitic magmas associated with low-sulfidation Au-Ag veins have low oxygen and water contents and could potentially "be affiliated with reduced Mo-Sn-W-rich porphyry systems" (John, 2001). Many of these veins report wulfenite in the oxide zone and/or are geochemically anomalous in Mo. The mining districts that probably are the most prospective in this regard are the Antelope Range, Escalante (The Point), Modena, Newton, and Stateline districts. Each of these districts has mapped areas of strong hydrothermal alteration which could indicate a porphyry Mo deposit at depth.

3.2.7 Tungsten

Utah does not have a significant history as a tungsten (W) producing state, having an estimated total production of just 385.5 t (425 st) of WO_3. Utah's largest W producing districts, in decreasing order of importance, are the Gold Hill (Clifton), West Tintic, Rosebud, and Notch Peak mining districts, all outside the CCPA. The CCPA's most notable W districts are the Rocky Range, Granite, Lincoln, and Star with minor production from the San Francisco and Bradshaw districts, all in Beaver County.

The W in these districts is primarily derived from small W skarn deposits (model 14a) and as a byproduct of small Cu skarn deposits (model 18b) (Cox, 1986a; Cox and Theodore, 1986). Utah's W production has primarily been driven by brief periods of high W prices as a result of high demand during the war years of 1915-1919, 1938-1949, and 1951-1956 (Everett, 1961).

Granite District, Beaver County

The Granite mining district covers a 13-km-long (8-mi-long) by 1.5-km-wide (0.9-mi-wide) strip along the southeast flank of the Mineral Mountains in east-central Beaver County. The Mineral Mountains expose a large, mostly gray, alkalic, high-silica, composite Oligocene-Miocene (25 to 18 Ma) granite, monzonite, and syenite batholith (200 km^2 [77 mi^2]), the largest exposed batholith in Utah. The main granitic phase of the Mineral Mountains batholith has been interpreted to have an age of about 18 to 17 Ma. The batholith has been strongly rotated to the east (40º - 85º), so that the east side of the mountain is near the paleo-top of the batholith. This rotation is evident from the steep easterly dip of the Oligocene Bullion Canyon Volcanics (29 - 22 Ma) on the east flank of the range (Coleman and others, 2001).

Mineralization is developed in tabular garnet-vesuvianite-epidote ±diopside ±tremolite ±wollastonite skarns formed near the eastern (upper) contact of the quartz monzonite and the Mississippian Deseret Limestone (?). The quartz monzonite porphyry is finer grained at this contact and there are numerous minor pegmatitic phases and quartz veins associated with the border facies. The carbonates are broadly conformable to the granite contact, strike to the north-northeast, and dip very steeply. The carbonates are skarnified for a distance of a couple hundred meters (several hundred feet) from the batholith and marbleized or bleached for a few hundred meters (several hundred feet) more (Sibbett and Nielson, 1980). The skarns are generally prograde and anhydrous.

Very low-grade W mineralized skarn may be up to 250 m (820 ft) long, 10 m (30 ft) wide, and 30 m (100 ft) deep, although the ore mined to date occurs in much smaller (just a few hundred tons), higher-grade (0.7% WO_3), structurally controlled, brecciated pods unevenly distributed within these broader low-grade zones (Everett, 1961). The W skarns range from dark brown, massive garnet lenses near the granite to pale yellow-green banded epidote-zoisite marble beds in the outer contact zone (Crawford and Buranek, 1945). The primary ore mineral is scheelite which occurs as small disseminated crystals typically found with pyrite and fluorite. Crawford and Buranek (1945) note that nearly all of the scheelite fluoresces cream-yellow instead of the normal blue-white, which suggests isomorphous substitution of Mo for W and Everett (1961) reports a W ore sample from the district as running 0.53% WO_3 and 0.15% Mo. A water sample for Mud Springs, near the Garnet and Contact mines, also reports anomalous Mo (89 ug/L) and U (740 ug/L) (McHugh and others, 1980a).

Other ore/sulfide minerals reported from the district include galena, sphalerite, argentite, molybdenite, chalcopyrite, bismuthinite, and barite (Bullock, 1981). Scheelite, beryl, and helvite occur in some of the pegmatites. Powellite is present locally in the skarns (Hobbs, 1945). The district shows a broad, but poorly defined zonation from Pb-Zn-rich ores on the north and south to higher W, Sn, and Mo in the center, near the Garnet and Contact mines. Some NGDB rock samples from the Granite district run up to 450 ppm Sn and 70 ppm Mo.

Other W Districts, Beaver County

In addition to the Granite district, the Rocky Range (Cu), Lincoln (Pb-Zn), Star (Cu and Pb-Zn), San Francisco (Cu and Pb-Zn), and Bradshaw (Pb-Zn) districts have all had some minor W production, mostly from just one or two small Cu-W skarns or Pb-Zn replacement deposits. However, each of these districts has had more complete treatments in the Copper or Lead-Zinc sections of this report and will not be covered further here.

In addition, the Pine Grove district (Mo) is known to have minor scheelite associated with the deep, porphyry Mo ore resource and huebnerite occurs above the ore zone, but no W grades are reported for the resource.

Huebnerite is also reported from the Louise group of claims on Pole Creek, about 16 km (10 mi) northeast of Beaver in the Newton district. Newton is a small mining district located north of Beaver on the west flank of the Tushar Mountains. It is part of the Marysvale volcanic field. Everett (1961) reports that huebnerite occurs in quartz stringers in porphyry. Workings on this prospect include a 12 m (39 ft) adit and prospect pits. Similarly, Butler and others (1920) report wolframite from the head of nearby North Creek. Furthermore, a small side canyon of the South Fork of North Creek about 3.5 km (2.2 mi) southeast of this area is called Tungsten Hollow (Cunningham and others, 1984b).

Geochemical levels of W-Mo-Sn are reported from the Broken Ridge area, 15 km (9 mi) west of Lund in Iron County. The Broken Ridge area is associated with 12 Ma Steamboat Mountain topaz-bearing, high-silica rhyolite plugs, dikes, vent breccias, and flow domes which could be suggestive of a W skarn environment at depth (Duttweiler and Griffitts, 1989). The Broken Ridge area is discussed in greater detail in the Mo section of this report.

3.2.8 Uranium

Utah is the third largest uranium producing state in the U.S. (about 59,000 t [65,000 st] U_3O_8, recovered), but nearly all of this production (~98%) is from the Colorado Plateau of southeastern Utah. The total contribution from the Great Basin portion of Utah is crudely estimated at about 691 t (762 st) U_3O_8.

The total historical U production from the CCPA is roughly estimated at approximately 20,710 t (22,830 st) of ore averaging 0.19% U_3O_8 or about 36 t (40 st) of U_3O_8 (recovered), the vast majority of which was derived from Beaver County (Chenoweth, 1990). The majority of these deposits are best considered volcanogenic U (model 25f) (Bagby, 1986).

Blawn Mountain, Beaver County

The Blawn Mountain mining district is located in southwestern Beaver County, approximately 11 km (7 mi) southeast of Pine Grove. The Staats mine on the west end of the district is the largest historical producer. The mineralization at the Staats mine is associated with one of several small, silicic-alkalic, porphyry plugs known to be associated with the Miocene Blawn Formation volcanic rocks. These plugs include the Pine Grove porphyry, Staats rhyolite, and the Blawn Wash plugs. Keith and others (1986) report a 23-22 Ma date for the Pine Grove porphyry. The small topaz rhyolite plug adjacent to the fluorite-U mineralization at the Staats mine intrudes a sequence of Silurian and Devonian carbonates and was dated at 20.2 Ma (Mehnert and others, 1978).

The fluorite ore zones at Blawn Mountain, which grade approximately 75 to 90% CaF_2, are typically about 1 m (3 ft) in width and a few tens to just over 30 m (~ 65 - 100 ft) in length near the rhyolite contact. The autunite and uranophane after uraninite occur as small flakes and coatings in gouge zones adjacent to the fluorite with typical grades of less than 0.2% U_3O_8 (Whelan, 1965; Bullock, 1976). Lindsey and Osmonson (1978) note the occurrence of low-level geochemical anomalies for Sn, Mo, and Be associated with the rhyolite stock. David A. Lindsey (retired USGS, written communication, July 2007) notes the occurrence of good crystalline cassiterite in a fluorite breccia near the Staats mine.

Newton District, Beaver County

Newton is a modest mining district located north of Beaver on the west flank of the Tushar Mountains covering part of the Marysvale volcanic field. The host rocks in the Newton district are predominantly Oligocene-Miocene Bullion Canyon calc-alkaline andesitic volcanic rocks intruded by Miocene monzonite, quartz latite, and rhyolite porphyries. Mineralization in the district is primarily small, low-sulfidation, epithermal, quartz-carbonate veins with some Au-Ag-Mo ±W ±U. This lithophile mineralization appears to be associated with Miocene Mount Belknap (20-18 Ma) rhyolite porphyries (Cunningham and others, 1984a).

The primary U producer in the Newton district is the Mystery-Sniffer mine on Indian Creek. The volcanic rocks near the mine are pervasively propylitized. Mineralization is contained in a complex east-west-trending, moderately north-dipping (30° to 70°), argillized normal fault zone cutting Bullion Canyon Volcanics between the Indian Creek Stock to the west and the Mount Belknap Caldera to the east. The surface geology is complicated by large landslide blocks. Mineralization consists of pockets of disseminated, crystalline apple-green torbernite and yellow autunite (uranium phosphate minerals) with some fluorite, marcasite/pyrite, and quartz stringers in gray clay zone (Wyant and Stugard, 1951). The "ore shoots" are described as small, irregular, narrow (6 m [20 ft] wide), and discontinuous within larger blocks of weakly mineralized (0.055% U_3O_8) ground as much as 60 m (200 ft) wide and 400 m (1300 ft) long. Some mineralization is also reported from both the hanging wall and footwall of the fault zone. An altered rhyolite dike may occur along the fault zone (Osterstock and Gilkey, 1956; Cunningham and others, 1984b).

The Newton district has numerous other U prospects and occurrences, mostly in the western half of the district, and they have similar geology to the Mystery-Sniffer mine (Callaghan and Parker, 1961). However, none of these prospects has any recognized production and most rock-chip samples from the district report less than 0.1% U_3O_8.

Miller and others (1980a, b) also suggest that the Beaver basin, which adjoins the Newton district to the west, could host sandstone-type U mineralization based on the high U content in the source area volcanic rocks flanking the basin to the east in the Tushar Mountains and the high U granites to the west in the Mineral Mountains.

Other U Districts

In addition to the historical U production from the Newton and Blawn Mountain mining districts, several other districts in the CCPA have U prospects or occurrences. These include the Stateline, Broken Ridge, Pink Knolls, and Blue Mountain districts. None of these other districts are likely to have any future disturbance for U exploration and/or development.

3.3 Salable Minerals[4]

3.3.1 Barite

A few small barite occurrences are known in the CCPA. Barite in the area is generally a secondary commodity, and would only be produced as a byproduct from production of other commodities. Barite in the CCPA is primarily of hydrothermal origin and precipitated from solution in veins. Barite occurs at the Horn Silver Mine in the San Francisco district as an alteration mineral in bedded limestone (UMOS; Brobst, 1969). The mine is located in section 23, T. 27 S., R. 13 W., Salt Lake Base Line and Meridian (SLBM), and the primary commodities are silver and lead. Three additional occurrences are described in UMOS in the CCPA, and all occur as vein deposits. One of the deposits is in the San Francisco mining district at the Golden Reef mine, which is primarily a lead deposit located in section 24, T. 26 S., R. 13 W., SLBM. The other two occurrences are found at prospects known for copper, silver, lead, and zinc in the Antelope Range in southern Iron County in sections 29 and 34, T. 35 S., R. 14 W., SLBM. Another minor occurrence is reported in the Mineral Mountains in section 32, T.27 S., R. 8 W., SLBM as part of a Cu-Mo-bearing quartz vein system (UGS files). Brobst (1969) reported occurrences at a few other locations in Beaver County including the Antelope Springs district, the Cactus mine (San Francisco district), and the Granite district, but did not give specific location information.

3.3.2 Building Stone

The term building stone in this chapter is used broadly and includes rock used for flagstone, landscaping, decorative groundcover, fieldstone, paving blocks, ashlar, and other

[4] Some of the commodities discussed under Salable Commodities maybe subject to location under the 1872 Mining Law or the "Common Vanities" Act of 1955. See Introduction, 1.2 Lands Involved, p. 23, for general discussion.

similar uses. Building stone potential is widespread and found in numerous geologic units within the CCPA. Most of the building stone in the CCPA is produced for decorative and landscaping uses, and the source rock is often selected for durability and color. Historically and recently, Paleozoic carbonates (units C3, O, PP, P2), often marbleized, and Tertiary rhyolites (Tvu, Tov, Tmv, Tmr, Tmb) are the most common materials extracted from the CCPA for building stone use. Table 3.3.2.1 summarizes known building stone quarries in the CCPA.

Table 3.3.2.1. Building stone quarries in the planning area.

Name	Current Permit	Rock Type	Map Symbol	Specific use	Data Source	UTM, Zone 12, NAD27 Northing (meters)	Easting (meters)
King 1 & 2	No	unknown	Tmb	dec stone	DOGM	4266129	276790
Indian Queen Marble	No	marble	C3	Unknown	DOGM, Bol. 2008	4264749	297976
Southern White/Mountain Rose	Yes	marble	O	Unknown	DOGM, Bol. 2008	4259150	298500
Red 1 & 12	No	unknown	Tvu?	dec stone	DOGM	4260706	303126
Frisco White	No	marble, limestone	unknown	Unknown	DOGM	4255149	299697
Bright 1 & 2	Yes	rhyolite	Tov	landscape stone	DOGM, Bol. 2008	4179880	258039
Rhyolite (Color Country Rock)	Yes	rhyolite	Tov	dec, landscape stone	DOGM, Bol. 2008	4176762	260404
Quartz Hill	No	rhyolite	Tov	dec stone	DOGM	4175025	257733
RMS No. 1/Mtn. Spring Peak	Yes?	rhyolite	Tmr	aquarium stone	DOGM, Bol. 2008	4213184	272228
Flin Quarry	No	rhyolite/tuff	Tov?	Unknown	UMOS	4195525	241760
Red Hill 1	No	rhyolite	Tov	Unknown	DOGM	4229155	286623
Courgraph	Yes	limestone	C3?	Unknown	DOGM, Bol. 2008	4225260	291880
Red Devil	No	rhyolite	Tvu	landscape stone?	DOGM	4174121	279303
unnamed quarry	No	sandstone	?	Unknown	UMOS	4199800	334175
West Swale	No	rhyolite/tuff	Tvu	dimension stone, flagstone	UMOS	4204425	361440
unnamed quarry	No	rhyolite/tuff	Tvu	orn stone	UMOS	4203080	360390
Aqua Green 1 & 2	No	rhyolite/tuff	Tvu	orn, dec stone	DOGM, UMOS	4203750	365825
Dendrite/Mountain Fern	No	rhyolite	Tmv	dec, veneer stone	UMOS	4251130	369880
Red Emerald (Ruby Violet)	Yes	rhyolite	Tmr	landscape stone	DOGM, Bol. 2008	4237652	285604
Star Range Dolomite	No	marble, dolomite	P2	groundcover, landscape boulder	Bol. 2008, UMOS	4247328	317251
White Elephant	No	dolomite, marble?	PP	groundcover, landscape boulder	Bol. 2008	4238610	332122

Cambrian limestones (C3) and marbleized limestones in the San Francisco and Wah Wah Mountains have provided building stone. Extensive exposures of marbleized limestone exist in the Wah Wah Mountains, and additional exposures are in the Indian Peak Range. On the west slopes of the San Francisco Mountains, Dennis (1930) and Barton (1968) reported large deposits of white dolomitic marble within the unit, and Dennis (1930) noted that the dolomitization provides weathering resistance for the rock. The Indian Queen Marble quarry operated in this deposit, specifically in Cambrian Orr Formation (C3), in sections 33 and 34, T. 26 S., R. 13 W., SLBM, but is now reclaimed. The Courgraph quarry also produces building stone from the Cambrian Swasey Limestone (C3) on the east side of the Wah Wah Mountains in section 36, T. 30 S., R. 14 W. Details of products produced from these quarries are unavailable.

Marble is also being mined on the southern end of the San Francisco Mountains in Ordovician-aged Pogonip Group limestones (O). The Southern White/Mountain Rose quarry has an active and approved permit with DOGM, and is primarily in sections 15 and 16, T. 27 S., R. 13 W. The quarry produces white and pink crushed stone likely used for decorative groundcover. The Ordovician limestones also crop out in the Needles Range, the Indian Peak Range, and in small amounts in the Wah Wah Mountains; however, the degree to which these limestones have been altered to marble at the other localities is unknown.

Another Paleozoic unit, P2, was mined in the Star Range, which includes Permian Kaibab and Toroweap Formations. This unit was mined for a bright white dolomitic marble for groundcover and landscape boulders at the Star Range Dolomite mine, which Boleneus (2008) described as having a resource of several thousand tons within the mine area and additional reserves beyond. The Star Range Dolomite mine is in section 21, T. 28 S., R. 11 W. The White Elephant quarry, which is located in section 13, T. 29 S., R. 10 W., extracted dolomitic marble (?) from unit PP, which includes the Callville Limestone in the Mineral Mountains. Boleneus (2008) noted a small reserve, a few hundred to a thousand tons, for the quarry.

Also in the San Francisco Mountains just south of the Indian Queen Marble quarry, Dixon (1938) described the Tertiary granitic intrusive (Ti) as being suitable for building stone. Dixon (1938) noted that the stone takes a good polish, and the small grains of biotite are favorable when polishing. No known production of building stone has come from this or any other intrusive in the CCPA.

Rhyolite is mined for building stone in a number of places within the CCPA. In some low hills west of Beryl Junction, Oligocene red rhyolite (Tov) is mined. The Bright quarry, a DOGM large mine, has an active, approved permit for crushed landscape rock located in sections 21, 22, 27, and 28, T. 35 S., R. 17 W. Boleneus (2008) described the rhyolite as primarily reddish brown, but having a variety of colors. The quarried rhyolite is a volcaniclastic member that Siders (1985a, b) noted as being silicified, iron-stained, and hydrothermally altered. The volcaniclastic unit is confined to the northeasternmost part of the hills, and resources for the quarry are estimated at several hundred thousand tons (Siders, 1985a, b; Boleneus, 2008). About 3 km (2 mi) southeast of the Bright quarry is an active, approved permitted small mine known as the Rhyolite #1 quarry that produces decorative aggregate and landscape boulders. The quarry is located in section 35, T. 35 S., R. 17 W. Boleneus (2008) did not quantify the quarry's resource, but suggested that it is large. The rock at the Rhyolite #1 quarry is quite similar to that from the Bright quarry, but is slightly less brightly colored and is part of the rhyolitic flow member (Siders, 1985a, b). Rock of similar quality may extend to the southwest where additional Oligocene volcanic rocks (Tov) are present. Slightly southeast of the Rhyolite #1 quarry, a small prospect (Quartz Hill) is located in section 3, T. 36 S., R. 17 W.

On the south end of Broken Ridge, which is west of Lund, the RMS No. 1/Mountain Spring Peak small mine produces decorative stone for aquarium use in Miocene volcanic rhyolite (Tmr). The quarry is located in sections 1 and 12, T. 32 S., R. 16 W. Boleneus (2008) described the rhyolite as porcelaneous, which is desirable for aquariums; resource size is unknown but thought to be large.

Building stone potential also exists in the Mesozoic units in the southeastern part of the CCPA. Elsewhere in Utah, companies are extracting the Dakota Formation (K1), the Navajo Sandstone (Jg), the Chinle Formation (Tr2), and the Moenkopi Formation (Tr1) for building stone, all of which are exposed in the CCPA (Boleneus, 2008). No known development has occurred in Mesozoic formations in the CCPA.

3.3.3 Common Clay

This section addresses potential for common clays within the CCPA. Common clays are primarily used for ceramic materials such as brick, tile, or pottery (Keith and Murray, 2006). Although a number of potential sources exist in the CCPA, little extraction and little investigation of the suitability of deposits for common clay applications has occurred in the area. The main potential source for common clay in the CCPA is from sedimentary shale units, which are widespread, and occur in Precambrian through Cretaceous units.

The main Precambrian shale unit is the Inkom Formation (PCs), which is found primarily in the San Francisco Mountains and the west flank of the Wah Wah Mountains (Hintze and others, 1984; Steven and others, 1990). Four Cambrian units are shale-bearing: the Pioche Formation (C2) in the Wah Wah Mountains and Beaver Lake Mountains, the Chisholm Formation (C2) in the Wah Wah Mountains and Beaver Lake Mountains, the Whirlwind Formation (C2) in the Wah Wah Mountains, and the Steamboat Pass Shale Member of the Orr Formation (C3) in the Wah Wah and San Francisco Mountains (Abbott and others, 1983; Hintze and others, 1984; Lemmon and Morris, 1984; Hintze and Kowallis, 2009). The Ordovician Kanosh Shale (O) is exposed in the southern Wah Wah Mountains, the San Francisco Mountains, and the Indian Peak Range, and the Devonian Pilot Shale (D) crops out in the Mountain Home and Indian Peak Ranges (Abbott and others, 1983; Hintze and others, 1984; Hintze and Kowallis, 2009).

Triassic shale-bearing units include the Moenkopi Formation (Tr1) and the Chinle Formation (Tr2). The Moenkopi Formation crops out along the Hurricane Cliffs east of Cedar City, in the southern Mineral Mountains, and in the Star Range. The Chinle Formation can also be found along the Hurricane Cliffs and in the Star Range. The Jurassic Moenave Formation (Jg) is exposed along the Hurricane Cliffs, and contains shale. A number of Cretaceous units contain shale: the Dakota Formation (K1), the Tropic Shale (K1), the Straight Cliffs Formation (K2), the Wahweap Formation (K2), and the Iron Springs Formation (K2). These units, with the exception of the Iron Springs Formation, are exposed east of Cedar City in the Hurricane Cliffs and Cedar Mountain. The Iron Springs Formation is exposed in the hills just west of Cedar City (Rowley and others, 2006; Hintze and Kowallis, 2009).

A BLM-operated community pit supplying common clay is located in section 19, T. 28 S., R. 7 W. The pit is located on a deposit of Quaternary (lacustrine?) silty clay, and has been utilized locally for pond lining. Clay for pond lining material has also been extracted adjacent to the Escalante silver mine (NE ¼ of T. 36 S, R. 17 W.) for tailing impoundment and near the Circle 4 Farms (T. 31 S., R. 13 W.) for hog sewage lagoons. The clay at the Escalante silver mine was produced from weathered volcanics, and the clay used at the hog farms is reportedly from clay-rich lacustrine deposits.

One occurrence of montmorillonite, the Radio Towers prospect, is reported on the south end of Blue Mountain in section 11, T. 31 S., R. 14 W., SLBM. The deposit is a weathered, volcanic air-fall tuff that also includes kaolinite, and is described as small (UMOS).

3.3.4 Crushed Stone and Ballast

Rock suitable for crushed stone and railroad ballast is plentiful in the CCPA. Carbonates (limestones and dolomites) are the most commonly used material for crushed stone, followed by granite and traprock, which includes basalt and andesite (Langer, 2006). Common materials mined for ballast include limestone, dolomite, quartzite, basalt, and granite (Barksdale, 1991). Large quantities of rock are mined for ballast in the CCPA in the Milford area at Milford Quarry 1. The quarry is located in the Rocky Range northwest of Milford in section 14, T. 27 S., R. 11 W. The stone from the quarry is part of the Horn Silver Andesite, which consists of porphyritic flows ranging from andesite to dacite and quartz latite (Best and others, 1989b). Tripp (2001) reported that the quarry had sufficient reserves to produce ballast for 50 years at an annual production rate of about 450,000 t (500,000 st). Additional outcrop of the Horn Silver Andesite can be found to the northwest in the Beaver Lake Mountains and farther to the west in the San Francisco Mountains, so there is potential for additional reserves; however, the suitability of the nearby deposits is unknown. Construction riprap was previously mined just south of the Milford Quarry 1 in the on the west side of section 23, T. 27 S., R. 11 W. Riprap was later mined just northeast of the Milford Quarry 1.

The Nichols Pit is an active operation producing crushed stone from what appears to be the Three Peaks laccolith, a quartz monzonite porphyry (Rowley and others, 2006). The quarry is located about 9 km (5.5 mi) northwest of Cedar City, and was originally a sand and gravel pit that eventually began mining bedrock. The quarry is located in sections 21 and 22, T. 35 S., R. 12 S.

In the northwest part of the CCPA, two small prospects for crushed stone are in the Wah Wah Mountains in sections 28 and 29, T. 26 S., R. 15 W. The Summit and Kelleys prospects are both in Cambrian quartzites (C3).

Numerous unexploited formations with potential for crushed stone or ballast exist in the CCPA. Massive carbonate and quartzite units with potential are summarized in table 3.3.4.1. Other units with high potential include igneous intrusive rocks (Ti) and basalt flows (Qb). Other volcanic units in the CCPA could also be potential sources of crushed stone, but are often not as uniform as desired.

Table 3.3.4.1. Geologic units with crushed stone and ballast potential. Units from Hintze and Kowallis (2009).

Formation Name	Age	Map Symbol
Massive carbonate units (limestone and dolomite)		
Howell Limestone	Cambrian	C2
Peasley Limestone	Cambrian	C2
Dome Limestone	Cambrian	C2
Swasey Limestone	Cambrian	C2
Eye of Needle Limestone	Cambrian	C2
Pierson Cove Formation	Cambrian	C2
Trippe Limestone	Cambrian	C2
Wah Wah Summit Formation	Cambrian	C3
Orr Formation	Cambrian	C3
Notch Peak Formation	Cambrian	C3
House Limestone	Ordovician	O
Juab and Wah Wah Limestone	Ordovician	O
Crystal Peak Dolomite	Ordovician	O
Ely Springs Dolomite	Ordovician	O
Laketown Dolomite	Silurian	S
Sevy Dolomite	Devonian	D
Simonson Dolomite	Devonian	D
Guilmette Formation	Devonian	D
Pinyon Peak Limestone	Devonian	D
Joana Limestone	Mississippian	M1
Gardison Limestone	Mississippian	M1
Redwall Limestone	Mississippian	M1
Deseret Limestone	Mississippian	M2
Humbug Formation	Mississippian	M2
Great Blue Limestone	Mississippian	M2
Callville Limestone	Penn.-Perm.	PIP
Pakoon Dolomite	Permian	P1
Toroweap Formation	Permian	P2
Kaibab Formation	Permian	P2
Moenkopi Formation, Timpoweap Member	Triassic	TR1
Carmel Formation, Co-op Creek Member	Jurassic	J1
Quartzite units		
Caddy Canyon Quartzite	Precambrian	PCs
Mutual Quartzite	Precambrian	PCs
Prospect Mountain Quartzite	Cambrian	C1
Eureka Quartzite	Ordovician	O
Watson Ranch Quartzite	Ordovician	O
Pinyon Peak Formation, Cove Fort Quartzite Member	Devonian	D
Talisman Quartzite	Permian	P2

3.3.5 Fluorspar/Fluorite

A number of fluorspar/fluorite occurrences are found in the CCPA, but they are generally low-grade and siliceous with limited resources (Bullock, 1976). Within the CCPA, fluorite occurs as veins or breccia filling (often in fault zones), as skarn deposits related to contact metamorphism, as disseminations in a host rock, or as a combination of these deposits. Fluorite mines, prospects, and occurrences are summarized in table 3.3.5.1, and the more significant deposits are discussed below. The largest deposits of fluorite and the areas with the highest potential in the CCPA are in the Washington mining district in the Indian Peak Range. The largest producer in the CCPA, to date, is the Cougar Spar mine located in section 10, T. 30 S., R. 18 W., SLBM. The fluorite at the mine occurs along a steep, northeast-dipping fault zone that places intrusive quartz diorite porphyry (Ti) in contact with Tertiary Needles Range Formation volcanics (Tov). The fluorite occurs in veins and breccia filling within the fault zone that can be traced for over 3.2 km (2 mi). The fault zone can be up to 61 m (200 ft) wide with minable fluorspar widths up to 6 m (20 ft) thick, but averaging 3 m (10 ft). The fluorite tends to be massive and light green to white with minor brown and purple and is associated with quartz and calcite. During the height of production at the Cougar Spar mine, 1944 to 1945, the average grade of the ore was 42% fluorite (Everett and Wilson, 1951; Thurston and others, 1954; Bullock, 1976). Bullock (1976) roughly estimated total remaining resource for the Cougar Spar mine at about 9100 t (10,000 st) of similar grade to the ore previously produced.

Two other mines, the Blue Bell and the J.B., have also produced fluorite from the Washington district. The Blue Bell mine is located less than 2 km (1.2 mi) northwest of the Cougar Spar mine and is in section 4, T. 30 S., R. 18 W. The fluorite at Blue Bell is found in veins and lenses along a northwest-striking, nearly vertical fault zone in volcanics of the Needles Range Formation (Tov). The fluorite is massive, typically light-green to white, and was deposited with quartz and calcite (Frey, 1947; Thurston and others, 1954; Bullock, 1976). The workings along higher concentration zones of fluorite are about 4 m (12 ft) wide, but fluorite mineralization is up to 12 m (40 ft) wide. Fluorspar from the Blue Bell mine ranges from 45 to 70% fluorite. The larger lenses of fluorite were primarily near surface and are mostly depleted (Bullock, 1976). The J.B. mine is located in sections 19 and 30, T. 30 S., R. 17 W. The fluorite at J.B. occurs along veins and breccia filling along a steep fault zone within the Needles Range Formation (Tov) and was deposited with quartz and calcite (Everett and Wilson, 1950; Thurston and others, 1954; Bullock, 1976). At least six fluorite-bearing veins are reported that range from 12 to 66 m (40 to 218 ft) long and 1 to 3 m (4 to 11 ft) thick. The fluorite is crystalline and is generally colorless to pale green (Everett and Wilson, 1950; Bullock, 1976). Bullock (1976) reported sampling ore that averaged 24% fluorite, and he roughly estimated a maximum in-place resource of 18,000 t (20,000 st) of ore at 10% fluorite. A number of other known fluorite deposits occur within the Washington district/Indian Peak Range area, including one other producing mine, the Utah mine (table 3.3.5.1).

Table 3.3.5.1. Fluorspar mines, prospects, and occurrences.

Name	UTM Zone 12, NAD27 Northing (meters)	Easting (meters)	Fluorite Resource	Data Source (see below)	Deposit Type	Fluorspar Production metric tons	Mining District	Comments
2 R's/Skyline	4244050	336050	small	1	skarn	0	Bradshaw-Lincoln	not a primary commodity
Big Pass/Blue Star	4241050	340500	small	1, 2	skarn	45	Granite	not a primary commodity
Bismuth	4243660	343381	small	1	skarn	0	Granite	not a primary commodity
Contact/Cedar	4245400	344150	small	1, 2	skarn	0	Granite	not a primary commodity
Garnet/Juniper	4245000	344050	small	1, 2	skarn	0	Granite	not a primary commodity
Mystery-Sniffer	4254510	365590	small	1, 2	vein, dissemination	0	Newton	with Uranium
U-Beva	4249200	367290	small	2	vein, dissemination	0	Newton	with Uranium
Wild Bill	4249800	312200	small	1, 2	vein, dissemination	small?	Star-North Star	not a primary commodity
Daisy	4235300	274100	small to med?	1, 2	vein/fault related?	800	Blawn Mountain	with Uranium
Iron Queen	4236830	274720	small	1, 2	dissemination	0	Blawn Mountain	not a primary commodity
Producer Mine	4234990	274300	small	1, 2	vein/breccia	0	Blawn Mountain	with Uranium
Staats/Monarch	4236300	274100	small to med?	1, 2, 3	vein/fault breccia	4400	Blawn Mountain	with Uranium
Cupric	4259100	298830	small	1, 2	skarn	0 or small	San Francisco	not a primary commodity
Black Bart	4244000	311100	small	1, 2	dissemination	0	Star-North Star	
Fluorine Ledge	4246700	311700	small	1, 2, 3	vein, dissemination	small	Star-North Star	
Flourite/Virginia	4244100	310800	small	1, 2, 3	vein	45	Star-North Star	
Hub	4245450	311900	small	1, 2, 3	dissemination	0	Star-North Star	not a primary commodity
Lady Bryan	4245000	311600	small	1, 2, 3	skarn	small?	Star-North Star	
Luckie Boy	4246400	312100	small	1, 2, 3	vein	small	Star-North Star	
Manassas	4245800	311800	small	1, 2, 3	vein, dissemination	small	Star-North Star	
Monte Christo	4245700	311300	small	1, 2, 3	vein	small?	Star-North Star	
Moscow	4245900	312080	small	1, 2, 3	dissemination	0	Star-North Star	not a primary commodity
State Land	4243600	311300	small	1, 2	vein, dissemination	small	Star-North Star	
Sullivan Group	4246300	311100	small to med?	1, 2	dissemination	small	Star-North Star	
Hanley Claims	4246610	311078	unknown	4	unknown	unknown	Star-North Star	
Unnamed	4244550	311750	small	2	vein, dissemination	small?	Star-North Star	not a primary commodity
Unnamed	4244100	311470	small	2	vein	small	Star-North Star	
Blue Bell	4234100	249750	medium?	1, 2, 3, 5	vein, fault controlled	1800	Washington	
Cougar Spar	4232930	251180	medium	1, 2, 3, 4, 6	vein, fault controlled	15500	Washington	
Doughout/Dugout	4232500	249200	small	1, 2, 3	vein	small	Washington	
J.B.	4229000	255350	medium	1, 2, 3, 4, 7	vein, fault controlled	>2000	Washington	
Lost Sheep	4230400	247300	small	1, 2, 3	vein	small	Washington	
Noonday	4233750	250480	small	1, 2, 3	vein, fault controlled	small	Washington	

Name	UTM Zone 12, NAD27 Northing (meters)	Easting (meters)	Fluorite Resource	Data Source (see below)	Deposit Type	Fluorspar Production metric tons	Mining District	Comments
Utah	4228400	254550	small to med?	1, 2, 3	vein, fault controlled	950	Washington	
Unnamed	4225250	252200	small	2	vein	small	Indian Peak	
New Arrowhead	4223340	253240	small	2	vein	0	Indian Peak	not a primary commodity
Pine Grove Summit	4245290	274600	small	2	dissemination	0	Pine Grove	
Unnamed	4227600	278000	small	2	vein	small	Pink Knolls	with Uranium
Desert View 1	4223800	274800	small	2	vein	small	Pink Knolls	with Uranium
Quartzite	unknown	unknown	small	3	vein	9	Star-North Star	in southeast part of range
Cabin	unknown	unknown	small	3	vein	unknown	Star-North Star	in southeast part of range

Sources: 1 - Bullock, 1976; 2 - UMOS; 3 - Thurston and others, 1954; 4 - DOGM; 5 - Frey, 1947; 6 - Everett and Wilson, 1951; 7 - Everett and Wilson, 1950

The Staats mine, in the Blawn Mountain district, was the second most productive mine in the CCPA, and is located in section 36, T. 29 S., R. 16 W. The fluorite at the Staats mine occurs along a faulted contact between a Tertiary rhyolite-porphyry plug and Silurian Laketown Dolomite and Devonian Sevy Dolomite (D). The purple, massive to crystalline fluorite occurs in lenses and pods in the fault zone that are 1 to 2 m (2 to 6 ft) wide, 2 to 3 m (5 to 10 ft) long, and 8 m (25 ft) or more in depth. The fluorite was selectively mined and averaged over 85% fluorite. Uranium occurs with the fluorite, and has been commercially produced from the mine (Bullock, 1976). Thurston and others (1954) suggested that there is additional ore worth recovering at the mine, but gave no indication of quantity. However, Bullock (1976) indicated that future potential for commercial fluorite is low. Other deposits in the Blawn Mountain district include the Daisy mine, which is a past producer of fluorite (table 3.3.5.1).

A number of fluorite prospects exist within the Star-North Star mining district primarily on the west side of the Star Range (table 3.3.5.1). Most of the occurrences are a combination of vein, dissemination, and skarn deposits in Paleozoic carbonates. The deposits are relatively small and have little potential for future development; however, minor production has come from this district. Five fluorite-bearing skarn deposits are found in the Mineral Mountains in the Granite and Bradshaw-Lincoln districts, but the deposits are quite small. Other small deposits can be found in the Indian Peak, Newton, Pine Grove, and Pink Knolls districts (table 3.3.5.1).

Dasch (1969) suggested that fluorine could be produced from fluorapatite as a byproduct from iron mining in the Iron Springs mining district in the southeastern part of the CCPA.

3.3.6 Gemstones

By far, the most important gemstone in the CCPA is red beryl. The Ruby Violet (or Red Emerald) mine is located in the southern Wah Wah Mountains in Beaver County, and is the only known economic deposit of red beryl in the world. The Ruby Violet mine is located mostly in section 29, T. 29 S., R. 14 W. Rhyolite of the Miocene Blawn Formation (~20 Ma) hosts the red beryl, which occurs exclusively in shrinkage fractures (Abbott and others, 1983; Keith and others, 1994). The deposit is located in a structural graben that may have been a paleo-drainage, allowing sufficient surface water, an important component of red beryl formation, to infiltrate shrinkage fractures. The rhyolite is topaz bearing, has high F content, and low Ca content, all of which are characteristic of red beryl deposits. Iron staining along the fractures is also common as iron and manganese oxides may react with beryllium fluoride vapors, alkali feldspar, and meteoric water to form the beryl (Keith and others, 1994; Christiansen and others, 1997). The fractures are often filled with kaolinite, illite, and smectite. At the mine, fractures producing red beryl occur every few meters (6 – 12 ft).

At the mine site, red beryl was produced from an area about 900 m by 1900 m (3000 ft by 6200 ft), with a higher producing zone about 50 m by 850 m (160 ft by 2790 ft) in the central part of the rhyolite flow. The Harris family, who owns the mineral rights to the deposit, reported a grade of about 0.54 carats of facetable red beryl per t (0.6 carats of facetable red beryl per st) of material mined. Shigley and others (2003) reported a proven and probable resource, as determined by Kennecott Exploration Company, of over 0.9 million t (1 million st) of ore at an approximate grade of 0.23 grams per t (0.008 ounces per st) with zones of 4.5 grams per t (0.16 ounces per st). About 10% of the material would be suitable for faceting. Kennecott's exploration of the deposit also indicated additional nearby targets for additional work.

An additional red beryl mine, the Wah Wah mine, is located in Iron County in section 24, T. 31 S., R. 17 W. Red beryl, topaz, and bixbyite are reported to occur at the Wah Wah mine, which is hosted in rhyolite of the Miocene Steamboat Mountain Formation (Best and others, 1987a).

Picasso marble, another gemstone material, occurs in the southern Mineral Mountains in altered limestones. The marble is known to occur in sections 17, 20, and 29, T. 29 S., R. 9 W. Picasso marble is silicified and exhibits unique coloring and patterning making it desirable for polished specimens and sculpting. Activity, although minimal, has occurred within the last decade at the Sliver 1-2 mine and the Sliver 3-4 mine, which are located in section 17 and 20, respectively. Boleneus (2008) noted that the principal target at the Sliver 3-4 mine is a silicified limestone ledge about 1 m (3 ft) thick, and the reserves are large but undefined. Reclamation has begun at the Sliver 1-2 mine.

DOGM has permitted other gemstone mines in the Rocky Range and Wah Wah Mountains. Earth's Partners, LLC extracted unidentified gemstones from the Munchkin 1-2-3 mine in section 25, T. 26 S., R. 16 W., and the Carol Mine in section 22, T. 27 S., R. 11 W. Both mines are currently reclaimed. In section 25, T. 26 S., R. 16 W., in the southern Wah Wah Mountains, exploration occurred for gem grade quartz crystals.

3.3.7 Gypsum

Most of the gypsum resources in Utah are found in the Pennsylvanian Paradox Formation, the Jurassic Carmel Formation, the Jurassic Arapien Shale, and the Jurassic Summerville Formation (Tripp, 2007). Only the Carmel Formation (J1) is found in the CCPA, and it crops out in the southeastern portion along the Hurricane Cliffs east of Cedar City. The basal part of the Paria River Member of the Carmel Formation contains the gypsiferous units. Biek (2007a, b) described the gypsum in the Paria River Member as alabaster, a massive, fine-grained gypsum that is commonly white. In the southernmost part of Iron County, Biek (2007a, b) reported the total thickness of the Paria River Member as 15 to 48 m (50 to 160 ft). The upper portion of the Paria River Member consists of bedded limestone.

Thomas and Taylor (1946) reported a 31 m (101 ft) thick section of "massive resistant white alabaster gypsum in one great bed" in Cedar Canyon in section 24, T. 36 S., R. 11 W., SLBM. Similarly, Averitt (1962) reported massive gypsum at the base of the Paria River Member that is 30 m (100 ft) thick and capped by 9 m (30 ft) of limestone along the cliffs south of Cedar City. Until recently, the Paria River Member was mapped as the Curtis Formation (Thomas and Taylor, 1946; Averitt, 1962; Withington, 1969) or the "Gypsiferous member" of the Carmel Formation (Averitt and Threet, 1973). The Paria River Member gypsum is well exposed in Cedar Canyon in section 18, T. 36 S., R. 10 W., and a few small quarries and prospects are located in the area, including the permitted Salt Creek mine, which has produced minimal amounts of gypsum in recent years.

Best and others (1989b) noted that the Permian Toroweap Formation (P2), which is predominantly a limestone unit, contains at least one gypsum bed in the Star Range that is commonly eroded away at the surface. The thickness of this bed is unreported, but is likely thin as evidenced by little development. An occurrence of secondary gypsum is also reported in the Star Range about 10 km (6 mi) southwest of Milford in section 31, T. 28 S., R. 11 W., SLBM. The gypsum occurs along fractures in highly fractured limestone of the Toroweap Formation (UMOS). Another fracture-hosted occurrence of gypsum is reported in the Indian Peak Range in T. 29 S., R. 19 W., SLBM (UMOS). The host rock is Upper Cambrian limestones. Both secondary occurrences are described as being small.

Extraction of gypsum at depth in the CCPA may be limited by the presence of anhydrite. Anhydrite is the non-hydrous form of calcium sulfate ($CaSO_4$), which is converted to the more useful gypsum, hydrated calcium sulfate ($CaSO_4.2H_2O$), by surface and groundwater. Withington (1969) noted that in semiarid regions, such as Utah, hydration of anhydrite has often not occurred beyond 9 m (30 ft) below the surface.

Other geologic units in the CCPA are reported to contain gypsum, but none in significant quantities.

3.3.8 High-Calcium Limestone and High-Magnesium Dolomite

Potential for high-calcium (hical) limestone and high-magnesium (himag) dolomite is present within the CCPA, primarily within Paleozoic carbonate units. Hical limestone and himag dolomite are used for a number of applications, but are primarily used in the production of lime and dolomitic lime. Currently or historically there is no production of hical limestone or himag dolomite in the CCPA; however, Tripp (2005) reported a number of units in Utah with hical limestone potential, and many of those units are found within the CCPA and are presented in table 3.3.8.1 (for reference see figure 2.1.1.1a). Although not mined in the CCPA, Graymont Western US Inc. and Ash Grove Cement Company mine a zone of hical limestone from the Cambrian Dome Limestone (C2) for lime and cement production, respectively. Graymont mines the Dome Limestone in the Cricket Mountains slightly to the north of the CCPA. In the CCPA, the Dome Limestone crops out in the Wah Wah Mountains, the Beaver Lake Mountains, and Blue Mountain (Lemmon and Morris, 1984; Weaver and Hintze, 1993; Hintze and Kowallis, 2009). Graymont also mines hical limestone from the Devonian Guilmette Formation (D) in northeastern Nevada for lime production. Hintze and Kowallis (2009) reported Guilmette Formation exposure in the Mountain Home Range, the Indian Peak Range, the southern Wah Wah Mountains, and the Star Range. Western Clay Company has mined the correlative equivalent of the Tertiary Claron Formation (T1), the Flagstaff Limestone, for hical limestone in eastern Millard County (Tripp, 2007). The Claron Formation crops out in the southeast part of the CCPA.

Limited analytical data is available for hical limestone in the CCPA. Tripp (2005) reported a 4.5-m (15-ft) chip sample from the Wah Wah Mountains in the Cambrian Wah Wah Summit Formation (C3) that contained 95.5% $CaCO_3$; and a sample representing an unknown thickness, also from the Wah Wah Mountains in the Eye of the Needle Formation (C2), contained 96.7% $CaCO_3$. Tripp and others (2006) reported three grab samples from the Star Range: two from the Permian Kaibab Formation (P2) that contained over 95% $CaCO_3$, and one from the Mississippian Formation of Rose Spring Canyon (M2), which contained 99% $CaCO_3$.

The Silurian Laketown Dolomite (S) is found within the CCPA, and is known to contain himag dolomite elsewhere (Williams, 1958; Morris, 1964). The Marblehead Company mined the unit for dolomitic lime production at the Lakeside Mountains in Tooele County (Morris, 1964). The Laketown Dolomite crops out in the Beaver Lake Mountains, the Indian Peak Range, and the southern Wah Wah Mountains (Abbott and others, 1983; Lemmon and Morris, 1984; Best and others, 1987b; Hintze and Kowallis, 2009). Morris (1964) noted that the Devonian Simonson Dolomite and Guilmette Formation (D) contain zones of himag dolomite with low impurities in western Utah. The Simonson Dolomite is exposed in the Indian Peak Range, the southern Wah Wah Mountains, the Star Range, the Beaver Lake Mountains, and the Mineral Mountains (Hintze and Kowallis, 2009). Other units in the CCPA containing massive dolomite that may have zones of himag dolomite include the Cambrian Wah Wah Summit Formation (C3), the Cambrian Notch Peak Formation (C3), the Ordovician Crystal Peak Dolomite (O), the Ordovician Ely Springs Dolomite (O), the Devonian Sevy Dolomite (D), and the Permian Pakoon Dolomite (P1) (Hintze and Kowallis, 2009). Little analytical data is available for himag dolomite within the CCPA; Tripp and others (2006) included two analyses of grab samples from undifferentiated Paleozoic dolomites in the Rocky Range that are marginally pure.

Table 3.3.8.1. Geologic units with high-calcium limestone potential from Tripp (2005), for reference also see figure 2.1.1.1a.

Formation Name	Age	Map Symbol
Howell Limestone	Cambrian	C2
Dome Limestone	Cambrian	C2
Eye of Needle Limestone	Cambrian	C2
Pierson Cove Formation	Cambrian	C2
Trippe Limestone	Cambrian	C2
Wah Wah Summit Formation	Cambrian	C3
Orr Formation	Cambrian	C3
Pogonip Group	Ordovician	O
Guilmette Formation	Devonian	D
Fitchville Formation	Miss.-Dev.	?
Redwall Limestone	Mississippian	M1
Joana Limestone	Mississippian	M1
Gardison Limestone	Mississippian	M1
Deseret Limestone	Mississippian	M2
Humbug Formation	Mississippian	M2
Formation of Rose Spring Canyon	Mississippian	M2
Great Blue Limestone	Mississippian	M2
Kaibab Formation	Permian	P2
Moenkopi Formation	Triassic	TR1
Kayenta Formation	Jurassic	Jg
Carmel Formation	Jurassic	J1
Claron Formation	Tertiary	T1

3.3.9 Kaolinite

Kaolinite, a high-alumina clay, occurs in a number of areas in the CCPA and is generally the product of hydrothermal alteration of rhyolitic rocks. The primary deposits are at Blawn Mountain, White Mountain, Squaw Peak, and the Black Mountains. Kaolinite zones in these areas tend to be irregularly shaped and patchy. Other, scattered prospects and deposits are also present.

At the Blawn Mountain deposits, kaolinite is found in altered Miocene rhyolitic volcanics that have intruded Paleozoic carbonates. The kaolinite is massive and typically has a tan or white color. The tan color is indicative of iron staining, but the coloration is thought to be surficial. Samples collected by Whelan (1965) suggest that some of the kaolinite is relatively pure with small amounts of hematite, dolomite, and quartz contamination. Mapping by Whelan (1965) indicates irregularly shaped outcrop and float areas of kaolinite in section 30, T. 29 S., R. 15 W., SLBM, but prospecting and mining have also occurred in sections 29 and 35, T. 29 S., R. 15 W., and sections 26 and 35, T. 29 S., R. 16 W. (Van Sant, 1964). The largest zone mapped by Whelan (1965) is an irregularly shaped area of kaolinite float about 450 m by 90 m (1480 ft by 300 ft). Whelan (1965) described the kaolinite resource as “significant tonnages,” but provided no resource numbers. The Sandy Wash 4 (or Blawn Mountain) quarry, which has consistently produced kaolinite since 2004, is located on the western edge of section 30, T. 29 S., R. 15 W.

Hofstra (1984) reported the presence of kaolinite in association with alunite in altered Tertiary tuffaceous rocks in numerous sections primarily in the south half of T. 29 S., R. 15 W.

White Mountain's core is composed of Paleozoic carbonates and is surrounded on all sides by Tertiary volcanic rocks (Tvu), which host the kaolinite deposits in the area. Stringham (1963) mapped kaolinitic alteration of ignimbrites on the west and east sides of White Mountain. He described the kaolinite-bearing zones as white to slightly purplish with an earthy appearance and as associated with alunite. Thin-section evaluation indicated that both kaolinite and alunite occur together in similar quantities throughout the alteration areas. Stringham (1963) suggested that kaolinite may be more dominant in the western part of the area, and alunite may be more dominant in the east. Halloysite, a clay mineral similar to kaolinite, is also found in the area (Van Sant, 1964). Mapped areas of intense kaolinite and alunite include sections 1 and 12, T. 29 S., R. 14 W., and sections 7, 8, 9, 10, and 11, T. 29 S., R. 13 W. (Stringham, 1963). Kaolinite prospects or quarries are located in all of those sections with the exception of section 1, T. 29 S., R. 14 W. One of the larger kaolinite/alunite areas mapped by Stringham (1963) in section 8, T. 29 S., R. 13 W., is about 600 m by 300 m (1970 ft by 980 ft). Van Sant (1964) reported kaolinite and halloysite deposits in the southwest ¼ of T. 29 S., R. 13 W., originally located by Edward Schoo, but did not give detailed location information. A few 12-m- (40-ft-) deep drill holes were completed at the deposits and bottomed out in clay. Van Sant (1964) indicated that both deposits may be suitable for low-duty refractory material, but that the quality in the deposits appeared to be variable. An additional, nearby kaolinite quarry is located in section 33, T. 28 S., R. 13 W.

About 10 km (6 mi) north of White Mountain and slightly southwest of Squaw Peak, Tertiary rhyolitic rocks (Tvu) have been altered to kaolinite. Stringham (1964) described the kaolinite as white with some hematite and limonite staining, soft, and having an earthy luster. The kaolinite at this deposit does not exhibit the associated alunite that the White Mountain deposit does. Stringham (1964) mapped kaolinite zones in sections 2, 3, and 10, T. 28 S., R. 13 W. UMOS records show small prospects and pits in all those sections. The largest kaolinite zone straddles sections 3 and 10 and has an outcrop about 900 m (2950 ft) long and 60 m (200 ft) wide.

Altered Miocene rhyolites contain kaolinite and alunite zones in the northwest part of the Black Mountains. Erickson and Dasch (1963) mapped zones primarily in section 9, T. 31 S., R. 11 W. containing kaolinite, alunite, and quartz in the most intensely altered areas. The largest mapped kaolinitic zone has a diameter of about 600 m (1970 ft). A kaolinite prospect is located in section 9.

A few kaolinite prospects are present in the southern Wah Wah Mountains including the retired Kerry mine (section 33, T. 31 S., R. 16 W.), the Zane 1 and 2 prospect (section 30, T. 32 S., R. 15 W.), and the True Value and True Value # 1 prospect (section 25, T. 32 S., R. 16 W.). At the south end of Blue Mountain, the Radio Towers prospect is in section 11, T. 31 S., R. 14 W., and reportedly contains both kaolinite and montmorillonite. Van Sant (1964) reported on the Denny deposit in the Star Range (southwest ¼ , T. 28 S., R. 11 W.), but indicated a limited usefulness for the clay. Van Sant (1964) also reported vein and tabular clay (likely kaolinite) deposits in the west ½ of T. 30 S., R. 14 W. on Pine Valley Road. The vein deposit did not appear to have commercial quantities, but the tabular deposit may allow some open-pit mining.

Stringham (1967) reported some argillic alteration that included kaolinite in the southeast part of the San Francisco Mountains (east-central part of T. 27 S., R. 13 W.), but did not indicate any economic occurrences. A final kaolinite prospect is located in the northern part of the CCPA in the Wah Wah Mountains in section 30, T. 26 S., R. 15 W.

The kaolinite in the Blawn Wash, White Mountain, Squaw Peak, and Black Mountain alteration areas are also discussed in the Potash sections of this report.

3.3.10 Lapidary Material

Lapidary material in the CCPA occurs in the form of opal, agate, chalcedony, geodes, and obsidian. The Opal Mound area on the west side of the Mineral Mountains (primarily sections 9 and 16, T. 27 S., R. 9 W.) is host to opaline sinter deposits that were formed by hot spring activity. Parry and others (1978) describe the sinter as being thin-bedded and multicolored. Multiple companies have held the rights to the deposit in the past, including Penney's Gemstones, LLC and the Stone Art Company, but no current mining permits exist at the site.

A permitted agate mine, the Lost Gems #1 mine, is located in section 22, T. 30 S., R. 14 W., just west of Blue Mountain. The mine is operated by Penney's Gemstones, LLC, producing a red and blue agate. Two gem grade chalcedony prospects are located on the southwest edge of the CCPA. The chalcedony is deposited in veins that are hosted by Tertiary welded tuffs. The deposits are in sections 1 and 11, T. 35 S., R. 20 W. Two geode localities occur within the CCPA in section 32, T. 30 S., R. 18 W., and section 18, T. 33 S., R. 19 W.; essentially no details on either occurrence are known. Obsidian occurs in a Quaternary rhyolite flow (Qr) near the perlite deposit that hosts the North Pearl Queen mine (sections 2 and 11, T. 27 S., R. 9 W.). The obsidian occurs in beds and pods within the rhyolite flow. Obsidian likely occurs at the other recent, highly silicic rhyolite flows (Qr) in the Mineral Mountains.

3.3.11 Lightweight Aggregate

Lightweight aggregate exists in the form of perlite and pumice within the CCPA. Perlite and pumice are volcanic in origin, and both tend to be highly silicic and rhyolitic in composition, so areas of occurrence are often coincident. Pumice can also be dacitic to basaltic; however, less silicic pumice does not tend to have commercial value (Presley, 2006). Perlite is volcanic glass that contains 2 to 5 wt % water and can expand significantly when heated (Barker and Santini, 2006).

Most of the known occurrences of perlite and pumice are in Quaternary rhyolite flows (Qr) in the Mineral Mountains. One of these deposits, and the most significant known perlite deposit in the CCPA, is at the North Pearl Queen mine (or Pearl Queen; also known as the Schoo mine on BLM ground) in the northeast part of T. 27 S., R. 9 W., SLBM. A 0.78 Ma obsidian-rich rhyolite flow makes up the deposit, which ranges from 5 to 30 m (16 to 100 ft) thick and averages 24 m (80 ft) thick. The deposit roughly covers about 111 ha (275 ac) and contains an estimated resource of 23 million t (25 million st). Textural zones have been defined in the deposit ranging from pumiceous and shardy to granular to "onion-skin" perlite (Tripp, 2000). Other occurrences of pumice and perlite are known in Ranch Canyon, also in the Mineral

Mountains, several kilometers south of the North Pearl Queen mine. Nackowski and Levy (1959) reported a "Ranch Canyon deposit" in section 35, T. 27 S., R. 9 W., that contains both perlite and pumice.

Olsen and Williams (1960) described a perlite deposit west of Enterprise in the southern part of the CCPA. The deposit is reported to be along Shoal Creek Canyon, and claims were located in section 7, T. 37 S., R. 18 W., SLBM. Section 7 is not within the CCPA, but Tertiary volcanic units (Tmv, Tvu) from that section extend into the CCPA. Olsen and Williams did not provide reserve numbers, but described the amount of good quality perlite as large.

An additional known occurrence of perlite is in the southwest part of the CCPA in T. 36 S., R. 20 W., SLBM in Miocene volcanic rocks (Tmv). Localized perlite has also been identified in volcanic units (Tov, Tmv) in T. 32 S., T. 33 S., and T. 34 S., SLBM along the Utah-Nevada border (Williams and others, 1997). Small pumice deposits have been identified in the southern Wah Wah Mountains in T. 28 S., R. 14 W. and T. 29 S., R. 14 W., SLBM (UGS files). An additional pumice occurrence is found west of Sulphurdale in a Quaternary basalt flow (Qb) in section 17, T. 26 S., R. 7 W., SLBM. Because the pumice is in a basalt flow, it is unlikely to have economic significance as lightweight aggregate; however a BLM community pit is located at the deposit that produces cinders as lightweight aggregate for manufactured soil.

Potential for additional deposits of perlite and pumice exists within the extensive volcanic units within the CCPA. These units include undifferentiated Tertiary volcanic rocks (Tvu), Oligocene volcanic rocks (Tov), Miocene volcanic rocks (Tmv), Miocene rhyolite (Tmr), and Quaternary rhyolite (Qr).

3.3.12 Sand and Gravel

Sand and gravel deposits are widespread in the CCPA, and primarily consist of unconsolidated Quaternary alluvial and colluvial material (Qa). Alluvial material constitutes most of the unconsolidated material deposited within the wide valleys in the area, and is well-distributed throughout the CCPA. Other units with potential include older alluvial and colluvial fan deposits (Qao), which tend to flank ranges; eolian sand deposits (Qe), which are primarily found in the southwest part of the CCPA in the Escalante Desert; and lacustrine deposits (Ql), which include Lake Bonneville deposits. Lithology of the gravel within the various deposits will generally reflect proximal sources, and is controlled by the geology of nearby ranges. Therefore, gravel lithology within the CCPA will be diverse from deposit to deposit, reflecting the diverse geology of the area.

UMOS reports 170 sand and gravel pits and prospects within the CCPA. Because sand and gravel is widespread in the CCPA, the location of the pits is primarily driven by proximity and accessibility to end use. Therefore most of the pits are located along major transportation corridors, particularly Interstate 15 and other paved roads. About 40% of the pits are along the Interstate 15 corridor in alluvial deposits (Qa).

Most of Utah's sand and gravel production is from Lake Bonneville deposits, and two of the primary producing shoreline benches, the Bonneville and the Provo, are present within the

CCPA (Currey, 1982; Currey and others, 1984; Tripp, 2001). A significant length of the Bonneville shoreline exists in the north-central part of the CCPA in the Escalante Desert and reaches as far south as Lund. The Bonneville shoreline and a short length of the Provo shoreline are present in Wah Wah Valley (Currey, 1982; Currey and others, 1984). Although Bonneville deposits represent a proven source of sand and gravel elsewhere, only a few deposits have been exploited near Bonneville benches in the CCPA, as much of the shoreline is far from end users.

The Utah Department of Highways (1965, 1966) conducted and published results from suitability tests on a number of existing and potential sand and gravel pits in the CCPA. The tests determined the suitability of materials for highway construction. The Department of Highways performed most of the tests on Quaternary alluvial material along primary transportation corridors, and the majority of the tests indicated suitable material.

3.3.13 Silica

Potential for high-purity silica in the CCPA exists, but little detailed information is available on the quality of potential deposits. Current information suggests that the two units with the most potential are the Ordovician Eureka Quartzite (O) and the Cretaceous middle sandstone of the Grand Castle Formation (K3). The Eureka Quartzite has been mined elsewhere for high-purity industrial silica, and crops out in the northwest portion of the CCPA (Herron, 2006; Tripp, 2007). The unit is exposed in the Wah Wah Mountains near Blawn Mountain, the Indian Peak Range, and the Needle Range. The Eureka Quartzite varies in thickness, but is commonly 50 to 60 m (164 to 197 ft) thick (Steven and others, 1990; Abbott and others, 1983).

The White Sands quarry is a small active silica mine in the CCPA that extracts silica from the middle sandstone of the Grand Castle Formation. The middle sandstone is a light-colored, fine- to medium-grained sandstone that ranges in thickness from about 30 to 85 m (100 to 277 ft; Biek and others, 2010). The unit is exposed primarily south of Parowan in the Hurricane Cliffs. The White Sands quarry is located in section 23, T. 35 S., R. 9 W, SLBM. Another prospect in the middle sandstone is located in section 8, T. 35 S., R. 8 W., SLBM. In UMOS, the deposit size for both prospects is described as small.

A small silica prospect is reported in section 18, T. 26 S., R. 6 W., SLBM near Sulphurdale. The silica source is chert that has replaced latite porphyry in the proximity of some normal faults (UMOS). Opaline sinter in the Opal Mound area represents another, probably low-potential, silica deposit. The Opal Mound area is in section 16, T. 27 S., R. 9 W., SLBM, northeast of Milford. Parry and others (1978) analyzed six samples from Opal Mound that ranged in silica content from 75.8 to 95.8%. DOGM reports a retired silica mine south of Blue Mountain in section 2, T. 31 S., R. 14 W., called North Blue Mountain Silica; however, no details of this mine are known.

A number of other units throughout the CCPA have high-purity silica potential, but limited or no data is available that assesses their suitability. Precambrian units with potential include the Caddy Canyon Quartzite and the Mutual Quartzite (PCs) which crop out in the San Francisco Mountains and the west flank of the Wah Wah Mountains (Steven and others, 1990). The only Cambrian unit with potential is the Prospect Mountain Quartzite (C1), which occurs in the Wah Wah Mountains and the Beaver Lake Mountains (Lemmon and Morris, 1984; Steven and others, 1990). The other Ordovician (O) unit with potential, besides the Eureka Quartzite, is the Watson Ranch Quartzite which has limited exposure in the San Francisco Mountains (Hintze and others, 1984). The Devonian Cove Fort Quartzite Member of the Pinyon Peak Formation (D) crops out in the San Francisco Mountains and Star Range (Hintze and Kowallis, 2009). Silica-rich Permian units (P1?) include the Talisman Quartzite exposed in the Star Range, and its equivalent, the Queantoweap Sandstone, in the southern Mineral Mountains (Steven and others, 1990; Rowley and others, 2005). Mesozoic units of interest include the Jurassic Navajo Sandstone (Jg), exposed in the Wah Wah Mountains, Star Range, Mineral Mountains, and Hurricane Cliffs; and the Kayenta Formation (Jg), exposed in the Hurricane Cliffs (Steven and others, 1990; Rowley and others, 2005; Rowley and others, 2006; Biek and others, 2010).

Ketner (1969) reported composite analyses of five samples of the Mutual Formation, three samples of the Kayenta Formation, and five samples of the Navajo Sandstone. The analyses show content of elements that are considered deleterious for many industrial uses. The three sandstones contain measureable amounts of impurities, but no locations are tied to the samples limiting the usefulness of the results.

3.3.14 Sulfur

The largest sulfur deposit within the CCPA is the Sulphurdale (or Home mine) deposit, which is part of the Cove Creek sulfur deposits. The Cove Creek deposits extend north and south of Cove Fort about 7 km (4 mi) in each direction. The deposits trend along and are genetically related to a fault zone and geothermal system on the northwest edge of the Marysvale volcanic field (Moore and Samberg, 1979). The sulfur primarily impregnates rhyolitic tuffs and andesites, but is also found in veins and cylindrical masses that are 3 to 5 m (10 to 15 ft) in diameter. The sulfur occurs in native form, but also as iron sulfides, commonly pyrite (Lee, 1907; Wideman, 1957; Mount, 1969). Most of the Cove Creek deposits, with the exception of Sulphurdale, are in Millard County, north of the CCPA. The Sulphurdale deposit and mine are in the northeasternmost part of the CCPA, primarily in section 7, T. 26 S., R. 6 W., SLBM. At Sulphurdale, the sulfur is primarily found in a bedded tuff (Rodriguez, 1960), and is bounded on the east by a locally silicified fault zone (Moore and Samberg, 1979). Rodriguez (1960) estimated the maximum dimensions of the ore body at about 460 m by 240 m (1510 ft by 790 ft). Mount (1969) reported the resource at Sulphurdale as 510,000 t (560,000 st) of 20% sulfur extractable by surface mining.

A small native sulfur deposit is in section 11, T. 29 S., R. 14 W., SLBM, known as the Brimstone sulfur deposit. The sulfur is found in veins and is disseminated in rhyolitic tuffs near a spring (UMOS; Mount, 1969). Sulfur is also found at the Cina mine in the southern Wah Wah Mountains in section 5, T. 31 S., R. 15 W., SLBM. The host rocks of the deposit are limestones and dolomites, and mercury is the primary potential commodity at the mine (UMOS).

4.0 MINERAL EXPLORATION, DEVELOPMENT, AND PRODUCTION

4.1 Leasable Minerals

4.1.1 Oil and Gas

Very limited exploration for oil and gas has occurred within the CCPA (figure 5.1.1.1). As of 2011, there have been no producing oil fields in the CCPA. A total of 20 well locations were drilled within the CCPA between 1947 and 2010 (table 4.1.1.1). One coal-bed methane well and one test of the Permo-Triassic play were drilled in the eastern CCPA, and the 18 others were drilled in the Basin and Range part of the western CCPA. Occasionally a similar location was drilled more than once when a hole was deepened or was redrilled if the original hole was lost to caving or lost drill strings. Tabulating the past drilling by 5-year increments from 1945 to 2010 shows that drilling per increment has varied from a minimum of no holes to a maximum of four holes per 5-year period with the most active periods from 1945-50 (3 wells), 1971-1985 (9 wells), and 2006-2010 (4 wells).

Table 4.1.1.1. List of oil and gas exploration drill holes and plays tested in the CCPA.

Operator	Well_Name	County	Section	Tnship-Rge	Oil-gas shows	Play Tested	Date Spud
Bridger Petroleum Corp.	Federal 1	BEAVER	15	26S-17W	None	1901	12/28/1974
Huskly Oil Co.	Federal 10-13	BEAVER	13	26S-17W	None	1901	2/2/1981
Badger Oil Corp.	Lulu State 1	BEAVER	2	29S-8W	None	1902	4/19/1981
Hunt Oil Company	USA 1-25	BEAVER	25	27S-16W	None	1902	6/3/1993
Delta Petroleum Corp.	Beaver Federal 21-14	BEAVER	21	30S-7W	None	1902	8/21/2008
McCulloch Geothermal Corp.	Acord 1-26	BEAVER	26	26S-10W	None	1901	4/21/1979
Jenkins & McQueen	Adams 1 (Rush Lake 1)	IRON	9	34S-11W	853 m, oil in Dakota Fm?	1901	12/16/1947
Southern Utah Oil	Fee 1	IRON	9	34S-11W	10 BPD at 1143-1225m; Navajo?	1901	5/15/1948
Jenkins & McQueen	Adams 2	IRON	9	34S-11W	NA	1901	11/25/1950
Mountain Fuel Supply Co.	Little Salt Lake Government 1	IRON	9	34S-10W	None	1902	4/24/1963
Pan American Petroleum Corp.	Fee 1-B	IRON	1	34S-15W	None	1901	11/11/1970
Mountain Fuel Supply Co.	Shurtz Creek	IRON	9	37S-11W	Weak to good oil shows in Pk + Pt	2106	5/12/1973
Odessa Natural Corp.	Cedar City 1	IRON	18	36S-11W	Weak to good oil shows in Pk + Pt	1901	3/26/1975
Cabot Corp.	Cedar City Unit 1	IRON	29	36S-11W	None	1902	2/5/1978
Hunt Oil Co.	Table Butte U-1	IRON	36	33S-15W	None	1901	11/25/1983
ARCO Oil & Gas Co.	Three Peaks 1	IRON	17	35S-12W	Trace of oil in Kaibab Ls	1902	6/14/1984
Delta Petroleum Corp.	Federal 23-44	IRON	23	33S-10W	None	1902	10/9/2007
Cedar Mountain Gas	Clark 1-28	IRON	28	37S-10W	None	2100	8/2/2009
Tidewater Oil & Gas Co.	Vanterra Rush Lake #2	IRON	9	34S-11W	NA	1901	11/21/2010
U.S. Steel Corp.	Unknown?	IRON	31	33S-10W	None	1901	Pre-1971?

Note: Pk = Permian Pakoon Dolomite; Pt = Permian Toroweap Formation

In spite of limited drilling, BLM records indicate that approximately 180,895 ha (447,000 ac) of federal land are currently under lease for oil and gas (including coal-bed gas) within the CCPA, with about 65% of the leases in Iron County and remainder in Beaver County (figure 4.1.1.1). Only about 6% of the current leases fall within the Colorado Plateau or Transition Zone plays (play numbers 2100, 2106, and 2108) of the eastern part of Iron County, while 94% of the leases fall within the Basin and Range Province play (play numbers 1901 and 1902) of Beaver and western Iron Counties.

Unconformity A Play (USGS play number 1901)

This play has seen the most exploration with 11 wells testing potential reservoirs, three wells in Beaver County and eight wells in Iron County. Two early wells (1947 and 1948) of the 11 wells had shows of oil; both wells were in section 9, T. 34 S., R. 11 W., north of Cedar City in the western Cedar Valley of Iron County (table 4.1.1.1). Veal (1976) reports that the Odesssa Natural Corp. Cedar City 1 well (section 18, T. 36 S., R. 11 W.) had spooty to good oil shows in the Pakoon Dolomite, and a weak oil show in the Toroweap Formation based on AMSTRAT logs and reports. The shows may have been from the Dakota and Navajo formations. In 2010, Tidewater Oil and Gas drilled a new well in the same section as the previous two 1940's wells with shows, but the results of the new well are still being held confidential. Thus, the play remains unproductive and unproven in the CCPA. There is very sparse drilling of this play with only 11 tests over a vast area. The area with the best development potential is the Cedar Valley with three past shows, and ample room for additional test drilling, particularly updip of the past shows. Van Kooten (1988) and Hurlow (2002) report seismic data already has been shot over the Cedar Valley area, allowing this area to be one of the first to attract further exploration attention. Reprocessing of the 1980's vintage seismic data would be needed to help define sub-Quaternary fill depth, stratal architecture, and potential targets.

Late Paleozoic Play (UGS play number 1902-hypothetical)

This play would encompass ancient structures under the existing ranges that retained their petroleum even after extension of the area in the late Cenozoic. Seven of the past wells drilled could be considered tests of this play, with three in Beaver County and four in Iron County. This play is hypothetical, but one show of trace amounts of oil was reported from the Kaibab Limestone in the ARCO Three Peaks #1 well in section 15, T. 35 S., R. 12 W. A surface hydrocarbon soil anomaly around the ARCO well was also reported by Van Kooten (1988). With a long period for post-generation leakage from this play's structures following their formation in the Mesozoic, and the possibility that extension provided leakage pathways, the chances of success for this play are relatively low.

Permo-Triassic Unconformity Play (USGS play number 2106)

This play has been tested by only one well in the CCPA, the Mountain Fuel Supply Shurtz Creek well in section 9, T. 37 S., R. 11 W. Veal (1976) reports this well had weak to good oil shows in the Permian Pakoon and Toroweap Formations based on his study of

AMSTRAT logs and reports. This play may be prospective for oil, but carbon dioxide generation associated with nearby volcanic activity may have flushed the oil southward.

This play has been productive farther east in southcentral Garfield County along the Upper Valley Anticline at the Upper Valley oil field. According to production records, the medium-sized Upper Valley field (1964 discovery) was Utah's 17th largest oil producer in 2010, and had produced a cumulative total of 3.28 million m^3 (28.0 million bbls) of oil and 2.89 million m^3 (102 million ft^3) of gas as of the end of 2010 (from the DOGM website found at: https://fs.ogm.utah.gov/pub/Oil&Gas/Publications/Reports/Prod/Field/Fld_Dec_2010.pdf).

Paleozoic Devonian-Pennsylvanian Play (UGS play number 2108)

No wells were drilled in the CCPA that penetrated Devonian through Pennsylvanian strata of this play in eastern Iron County. This play may be prospective for oil, but carbon dioxide generation associated with nearby volcanic activity may have flushed the oil southward.

4.1.2 Coal-Bed Gas Play (UGS play number 2100)

No coal-bed gas production has come from the CCPA, and only one exploration well has been completed there. Doelling and others (1979) report gas desorption data from 14 coal cores taken from southern Utah coalfield exploration wells; one from Johns Valley, two from the Alton field, and 11 from the Kaiparowits Plateau field. The gas content measured from similar southern Utah subbituminous coal samples ranges from no gas to 0.4 cc/gm (14 cf/t), which is reasonable for shallow cores of subbituminous rank coal. In 2009, Cedar Mountain Gas, LLC drilled one well to test for coal-bed gas in the Cretaceous strata in the Iron County portion of the CCPA. The 614.8-m-deep (2017-ft) Clark 1-28 well was plugged and abandoned in section 34, T. 38 S., R. 5 W., and had no show of gas reported in the Cretaceous Straight Cliffs section penetrated; the operator did not report whether the deeper Dakota coals were reached or tested. Although coal beds of sufficient thickness are present in the CCPA coal-bed gas play, the low rank of the coal and its corresponding low gas content makes the potential for establishing commercial coal-bed gas production correspondingly low in these relatively deep and thin coals.

4.1.3 Coal

Despite the large coal resource present in southern Utah's coalfields, little coal production has come from the area in general, and the CCPA has seen a small amount of past production prior to 1970. A significant underground minable coal resource still exists in the Kolob field within the CCPA (Doelling and Graham, 1972). At least 26 small coal mines and prospects are known within the CCPA in the Kolob field of the CCPA (table 4.1.3.1, modified from Doelling and Graham, 1972). All of these small mines were developed to provide fuel for local heating and domestic use. Coal mining apparently began in 1854, but no coal mine has been active in the CCPA since 1969. Production estimates from Doelling and Graham (1972) and estimated production from old coal mine maps and reports indicate the cumulative production from all the historic mines and prospects was probably about 764,951 t (841,450 st), 402,452 t (442,700 st) from the Coal Creek quadrangle mines, and 362,499 t (398,750 st) from the Cedar Mountain quadrangle mines. Past production probably recovered only about 35% of the in-place resources, so the amount of coal disturbed by past mining was about 2.2 million t (2.4 million st) of the original in-place minable resource of 345.1 million t (379.6 million st). This leaves remaining minable coal in the CCPA of 342.9 million t (377.2 million st). The recoverable coal could be approximately 118.2 - 163.6 million t (130 – 180 million st) depending on the mining method used. The high sulfur content of the coal (>5%), and the uncertainty over potential carbon dioxide emission regulations will severely limit potential domestic markets for this coal in the next 20 years.

Table 4.1.3.1. List of past coal mines and estimated production (metric tons) for the CCPA.

Mine Name	County	Quadrangle	Start Year	End Year	Production
Cluff	Iron	Coal Creek	1885	1940's	4545
Condies	Iron	Coal Creek	Unknown	Unknown	909
Corry	Iron	Coal Creek	1885	1920's	13636
Koal Kreek	Iron	Coal Creek	1890	1963	181818
Leyson	Iron	Coal Creek	1854	1890	909
MacFarlane	Iron	Coal Creek	1890	1965	22727
Monolith 5A	Iron	Coal Creek	1949	1949	45
Rail Tram	Iron	Coal Creek	Unknown	Unknown	364
Square Mountain	Iron	Coal Creek	1927	1931	909
Walker	Iron	Coal Creek	Unknown	Unknown	227
Webster, Brayton, Lunt, Nelson	Iron	Coal Creek	1935	1963	119545
Webster No.2	Iron	Coal Creek	1963	1969	54545
Wood & Taylor	Iron	Coal Creek	1881	1910?	2273
Culver	Iron	Cedar Mtn	1903	1966	6364
Davis	Iron	Cedar Mtn	Unknown	Unknown	682
General Steam	Iron	Cedar Mtn	Unknown	Unknown	409
Graff	Iron	Cedar Mtn	1915	Unknown	909
Graff Point No.1 & 2	Iron	Cedar Mtn	Unknown	Unknown	909
Kanarraville	Iron	Cedar Mtn	1873	thru 1907	1818
Kleen Koal	Iron	Cedar Mtn	1937	1952	31818
Monolith prospects	Iron	Cedar Mtn	1949	1954	455
Pollock	Iron	Cedar Mtn	Unknown	1906	909
Thompson	Iron	Cedar Mtn	1906	Unknown	45
Tucker No.s 1-3	Iron	Cedar Mtn	1938	1966	254545
Williams No.1	Iron	Cedar Mtn	1934	1938	13636
Williams No.2	Iron	Cedar Mtn	1938	1950	50000
ESTIMATED TOTAL	Iron		**1854**	**1969**	**764951**

4.1.4 Geothermal

Cove Fort-Sulphurdale

Huttrer (1992) provides a detailed history of exploration at the Cove Fort-Sulphurdale geothermal area between 1972 and 1992. Leasing of private (and state?) lands began in 1972 by Thermex Company, followed by other companies such as Steam Reserve (AMAX), Phillips Geothermal, Grace Geothermal, Union Geothermal, and Hunt Minerals. Initial exploration was done by Thermex, which relied on geologic mapping and geophysical surveys (microearthquake, resistivity, and thermal-gradient studies).

Following designation of the Known Geothermal Resource Area (KGRA) in 1975, Union Geothermal acquired most of the federal lands within the KGRA and began evaluating them. Initially Union drilled 53 thermal-gradient holes and followed with extensive resistivity surveys. The U of U also performed regional gravity and magnetic studies as part of federally funded research.

Beginning in 1977, Union entered into a cost-share research program with the predecessor to the U.S. Department of Energy (DOE) and drilled three deep exploratory holes. The data from these holes (wells 31-33, 42-7, and 14-29) and other information were made public through DOE's Industry Coupled Program (Mabey and Budding, 1987). The wells 31-33, 42-7, and 14-29 were drilled to depths of 1591 m (5220 ft), 2313 m (7586 ft), and 799 m (2621 ft), respectively. Maximum recorded temperatures were 146°, 178°, and 91°C (295°, 352°, and 196°F), respectively. Because Union considered the resource potential at Cove Fort somewhat less than viable at the time, they terminated their exploration program.

In 1983, Mother Earth Industries (MEI) obtained private leases from Steam Reserve and Forminco, and federal leases acquired by Union. In October 1983, MEI began drilling exploratory well 34-7 where drillers encountered a 689 kPa (100 psi), 177°C (351°F) dry steam resource at 355 m (1165 ft). The well blew steam, uncontrolled for 24 days until it was successfully capped. In 1984, MEI completed wells 34A-7 and 34B-7 within 61 m (200 ft) of 34-7 as dry steam producers. The three wells penetrated steam at about 354 m (1161 ft), below Tertiary volcanic rocks, within highly silicified breccia (Huttrer, 1992).

In 1985, MEI drilled three production-scale wells on federal leases north of the steam field (34-7 wells). Well 34-30 (758 m [2487 ft] deep), located 0.8 km (0.5 mi) northeast of Cove Fort, penetrated 174 m (571 ft) of volcanic rock, entering groundwater at 357 m (1171 ft). Well 34-30 reportedly produced 862 L/min (228 g/min) of 102°C (216°F) fluid with some H_2S. Well 66-28, located just south of I-70 near the northeast corner of the leasehold, penetrated 482 m (1581 ft) of volcanic rock and encountered water at 500 m (1640 ft). Maximum recorded temperature in well 66-28 was 157°C (315°F). MEI well 47-6 was located about 0.8 km north-northeast of Union 42-7. Well 47-6 penetrated 347 m (1138 ft) of volcanic rock, encountered water at 381 m, and had a maximum recorded temperature of 158°C (316°F) (Huttrer, 1992).

In 1986, MEI drilled well 24-7 about 91 m (299 ft) southwest of the 34-7 well complex to a depth of 424 m (1391 ft). Drilling was reportedly terminated above the water table to prevent "drowning" of the dry-steam zone (Huttrer, 1992).

In 1987, MEI performed soil-mercury and various geophysical surveys, plus drilled ten shallow (~ 30 m [98 ft]) temperature-gradient boreholes distributed throughout the private land holdings. MEI also drilled two slim-diameter wells offsetting existing steam-producing wells. Well S-87-1 was located 46 m (151 ft) northeast of 34B-7 and drilled to 316 m (1037 ft) depth. This well penetrated 277 m (909 ft) of volcanic rock, encountering a mixture of thermal and non-thermal groundwater, failing to produce steam. Well S-87-4 was located 113 m (371 ft) southeast of 34B-7, drilled to 316 m (1037 ft), penetrating 287 m (942 ft) of Tertiary Three Creeks Tuff before entering the steam zone at 287 m (942 ft) within highly silicified rocks of the Permian Coconino (Queantoweap) Sandstone (Huttrer, 1992; Rowley and others, in prep.).

During 1988-1989, MEI drilled six slim holes and "twinned" three of them with production-scale (large diameter) wells. All production-scale wells and all but one of the slim holes produced steam. The wells showed that the thickness of volcanic rocks decreased to the south and west corresponding to the decreasing depth to the Permian silicified sandstone, and attributed to N-S/E-W trending normal faults with blocks predominantly upthrown to the east and south (Huttrer, 1992).

No additional wells were drilled until 1991 after steam-zone pressure losses of 138 kPa (20 psi) due to power plant demands were realized. Well P91-4, located at the northwest corner of the Sulphurdale sulfur pit, penetrated 256 m (840 ft) of volcanic rock, encountered 221 kPa (32 psi) steam (cased off) at 258 m (846 ft), encountered groundwater at 317 m (1040 ft), and entered liquid-dominated geothermal reservoir (158°C [316°F]) at 345 m (1132 ft) in Paleozoic carbonate rocks. Air-lift tests yielded 5678 L/min (1500 g/min) of fluid. The well penetrated low-permeability, quartz monzonite rocks, at temperatures up to 163°C (325°F), from 607 m (1991 ft) to total depth of 745 m (2444 ft; Huttrer, 1992; Verity, 1992).

Additional research of the geothermal field and reservoir continued following the purchase of the operations and leaseholds in the mid-1990s by Provo City and Utah Municipal Power Agency (UMPA). Although little exploration was done, additional reservoir testing was done (Moore and others, 2000; Barker and others, 2002), and another exploratory well, BO1-1, was completed in 2002 (Moore, 2003). This well was drilled to 598 m (1962 ft) and encountered primarily volcanic rocks including an upper latite porphyry (to 125 m [410 ft]), Tertiary Joe Lott Tuff (125 – 189 m [410 – 620 ft]), and Three Creeks Tuff (to TD at 598 m [1962 ft]). Temperatures recorded to just above the casing shoe at 398 m (1306 ft) approached 110°C (230°F) with an estimated temperature gradient of 227°C/km (12.5°F/100 ft; Barker and others, 2002).

MEI began operation of the Cove Fort Power Station #1 in 1985, which originally consisted of four binary-cycle power units with a total capacity of 3 MW (gross). The power system was later supplemented by a turbine generator (2 MW gross), placed upstream from the binary units in order to take better advantage of the temperature and pressure conditions of the producing reservoir. In the fall of 1990, the City of Provo in cooperation with UMPA, dedicated the Bud L. Bonnett geothermal power plant at Cove Fort. The plant, rated at 8.5 MW (gross), became the third geothermal power facility owned by UMPA and Provo to go on-line at the Sulphurdale field.

Power generation at the field was ended in 2003 as UMPA sold the project and properties. Enel North America eventually acquired the project and properties and expanded their leasehold in 2008. Since then, Enel has conducted other geological and geophysical studies in addition to drilling six wells out of a planned nine-well program (Daren Daters, verbal communication, November 2010). However, much of this new information is proprietary. Enel's reported plans are to dismantle the existing facilities and build a new geothermal binary power plant with an initial capacity between 25 and 40 MWe.

Roosevelt Hot Springs

Forrest (1994) provides a detailed chronology of activities and events (paraphrased in the following paragraphs) related to exploration and development at the Roosevelt Hot Springs geothermal area from the late 1950s through 1993. The springs themselves issued from a small area about 1.5 km (0.93 mi) north of the present power plant site and were reported to have a small discharge as late as 1957. By 1966, however, the springs were dry although small fumaroles were emitting water vapor and gases (as they do today).

Earliest drilling occurred in December 1967, when E. Davie and A.L. MacDonald drilled an exploratory well to 24 m (79 ft) depth into some of the opaline hot spring deposits in section 16, T. 27 S., R. 9 W. They reportedly encountered hot water and abandoned the first hole. They then moved the rig 91 m (300 ft) east and drilled another well to 50 m (164 ft) depth, encountering hot water that flashed to steam. This well was temporarily plugged but reopened and deepened to 81 m (266 ft), also encountering hot water that flashed to steam. This second well is generally described as the "discovery well."

Phillips Petroleum Company began exploration activities in 1972, prior to the first issuance of federal geothermal leases in 1974. Following the issuance of leases, Philllips drilled six exploratory wells and two observation holes. Phillips' first "commercial" discovery was well No. 3-1 completed near the end of 1975. The Roosevelt Hot Springs Unit was approved in April 1976. Mabey and Budding (1987) state that the Roosevelt Hot Spring geothermal area is the most studied geothermal area in Utah, and they provide a synthesis of these early studies.

By 1979, Phillips and other operators had completed eleven geothermal test wells within the Unit. Six of the wells were considered capable of producing geothermal fluid in "commercial quantities." They included: Phillips No. 3-1, No. 13-10, No. 54-3, and No. 25-15; AMAX-Thermal Power-Obrien (ATO) No. 14-2 and No. 72-16. Phillips well No. 12-35 was considered productive, but non-commercial. Four wells were non-productive: Phillips No. 82-33 and No. 9-1, Getty Oil No. 52-21, and ATO's No. 24-36. In addition to the deep tests, eight observation holes were drilled ranging in depth from 536 m to 706 m (1759 – 2316 ft).

In September of 1980, Phillips and UP&L entered into a power purchase agreement for generation of 20 MWe from the geothermal resource at Roosevelt Hot Springs. As part of the agreement, a 1.6 MW biphase[5] power generating unit was installed at well No. 54-3 as a demonstration of the resource. The unit was designed by Biphase Energy Systems (now Douglas Energy Company, Placentia, California) with additional funding from Electric Power Research Institute and UP&L (Chaisson, 2004).

In March 1982, UP&L started construction of the 20-megawatt steam turbine facility, and in April 1982, Phillips began drilling well No. 27-3 followed by well No. 35-3. These two new wells, together with No. 54-3 and No. 13-10, would provide the steam supplied to the power plant. In February 1983, a "Participating Area" was created with the Unit that encompassed the productive wells up to that time.

Following construction of facilities and steam/brine gathering pipelines, the plant began producing electricity on June 9, 1984, and in October 1984 was dedicated as the Blundell power plant (Blundell Unit 1). From late 1984 through early 1985, modifications were made to the steam gathering system and efficiency improvements were made to the turbine generator bringing capabilities of the plant up to 25.7 MW.

On September 9, 1985, a blow-out occurred on production well No. 27-3, and the well was eventually plugged. A replacement well (No. 27-3A) was completed, but was unsuccessful and was also plugged.

In April 1986, Phillips sold their geothermal holdings to Chevron Resources Company. Later the same year, Chevron oversaw the completion of the second replacement for well No. 27-3. This new well was designated No. 28-3.

In October 1989, well No. 35-3 was taken off line and eventually plugged and abandoned due to a casing leak.

In 1990, down-hole chemical inhibitor systems were installed in all production wells to prevent scale build-up. Also in 1990, Chevron sold their holdings in the Roosevelt Hot Springs Unit and several other resources to California Energy Company, which became the operator at Roosevelt in January 1991. Shortly afterward, CalEnergy contracted for the drilling of a replacement for well No. 35-3. Well No. 45-3 was drilled to 1386 m (4547 ft), completed and placed into service in summer 1991.

As of 1994, there were four production wells (No. 13-10, No. 28-3, No. 45-3 and No. 54-3) to supply steam to the Blundell plant's turbine generator. Three wells were used for supply with a fourth held in reserve. Brine collection from well-head separators and the steam condensate was returned to the subsurface through three injection wells (No. 14-2, No. 82-33, and No. 12-35).

PacifiCorp, parent of UP&L, merged with Scottish Power in 1999, was later purchased by Scottish Power in 2001, and still later (in 2006) was purchased by MidAmerican Energy

[5] In principle, the biphase stage does the same job as a single-flash stage, but extracts extra power from the fluid stream by converting kinetic energy in the brine to shaft power (Chaisson, 2004).

Holdings Company. Currently, PacifiCorp is a wholly owned subsidiary of MidAmerican Energy Holdings Company.

In April 2006, PacifiCorp announced a plan to expand the Blundell plant by adding an 11 MW "bottoming cycle" binary power unit (Blundell Unit 2). The company contracted Ormat Nevada, Inc. to build an Ormat Energy Converter unit to extract heat from the hot brine return fluid. CEntry Constructors & Engineers were selected for engineering design and construction of the project, which was completed in November 2007.

PacifiCorp has reported the concept of adding a third unit of about 35 MW capacity; however, the company has not announced any imminent plans for such a facility (Mike Saunders, Utah Renewable Energy Business Summit, 11/15/2010 presentation).

Since 2009, Rocky Mountain Power (RMP, successor to UP&L) has drilled one additional production well (~ 1500 m [4921 ft]) and one additional injection well (~ 2100 m [6890 ft]). As of August 2011, the new wells had not been connected to RMP's geothermal power system but RMP reports that the engineering and design work that would integrate the new wells into the power system is nearing completion (Garth Larsen, verbal communication, August 2011).

Thermo Geothermal Area

The first accounts of the hot springs at what is now Thermo were from early explorers of the 1776 Dominguez-Escalante expedition when in the fall of that year, the explorers "cast lots" at an encampment on the spring mounds to decide whether to push on to California or return to Santa Fe. Exploration for geothermal resources began roughly 200 years later when Republic Geothermal and others drilled a number of exploratory boreholes and performed geophysical surveys in the Thermo area during the mid-1970s (Republic Geothermal, Inc., 1977). The USGS performed detailed geologic mapping in the Thermo area (Rowley, 1978). The area was also included in a number of regional studies such as Rowley and Lipman (1975), Klauk and Gourley (1983), Rush (1983), and Sawyer and Cook (1977).

No development had taken place since these early efforts until 2005, when several companies began to acquire land holdings (mostly private and state leases). Eventually, Raser Technologies, Magma Energy Corp., Radion Energy LLC, and Energy Minerals Inc. acquired federal leases.

In 2008, Raser Technologies began drilling production and injection wells mostly on state geothermal leases. Raser also began construction of a modular, 10 MW (net) facility at their Thermo site by coupling 50 UTC Power (a United Technologies Company) PureCycle, 280 kW, binary-cycle units together. Although no well information is available to the public, Raser planned to drill three production and four injection wells at the site. Raser also reported that the first well drilled encountered water temperatures in excess of 127°C (261°F; Michael Hayter, presentation to the Utah Geothermal Working Group, April 22, 2008). In April of 2011, Raser Technologies filed Chapter 11 documents in U.S. Bankruptcy Court seeking protection through a restructuring agreement with bondholders and secured creditors. The company has reportedly re-emerged as Cyrq Energy.

Newcastle

Since 1980, several commercial greenhouse developers have used the geothermal fluid for space heating of greenhouses. The largest of these developers, Milgro Nurseries (which began operations in 1992), now operates more than 10.2 ha (25 ac) of greenhouses. The Newcastle geothermal resource was discovered in 1975 by local farmers (Christensen Brothers) while drilling a water well. As they test pumped the aquifer, the produced fluids flashed to steam at the surface and it was later discovered that down-hole temperatures in the shallow (152 m) well exceeded 100°C (212°F) (maximum temperature – 107.8°C [226°F] between 85 and 95 m [279 – 312 ft; Mabey and Budding, 1987]).

Following this discovery a number of geothermal companies and government researchers (UNOCAL, Hunt, Phillips, USGS, and others) became interested in the resource and explored the area surrounding Newcastle during the late-1970s by drilling temperature-gradient boreholes and performing various geophysical studies (Mabey and Budding, 1987). Interest in electric power generation from the site eventually waned, however, and agribusiness companies became interested in the direct-use (greenhouse enterprizes) potential of the resource. Troy Hygro Systems drilled a production well near the original site of the discovery well, built several Quonset-style greenhouses (for production of hydroponically grown tomatoes), and excavated a large fluid disposal/percolation impoundment. This installation was followed by two other similar greenhouse operations by Hildebrand and Legant, who also drilled production wells and excavated fluid-disposal ponds.

In 1989, the UGS, in cooperation with the U of U and U.S. DOE, conducted geological, geophysical, and geochemical studies at Newcastle to further define the geothermal resource (Blackett and Shubat, 1992). In addition to the existing, shallow temperature-gradient boreholes, the researchers drilled 12 even shallower (~ 20 m [66 ft]) gradient holes for heat-flow determinations, performed detailed gravity and magnetic surveys, performed resistivity and self-potential surveys, obtained water samples for analyses, and other studies.

In 1992, Milgro Nurseries, of Oxnard, California, became interested in developing a greenhouse complex at Newcastle for production of potted flowers (mainly chrysanthemums). Milgro's facility now encloses 10.2 ha (25 ac) of space for a wide variety of products. Since becoming established in the area, Milgro has drilled three production wells[6], three injection wells, and two exploratory boreholes. The two exploratory boreholes (MN-6 and MN-7; in Blackett, 2004) were drilled in cooperation with the U.S. DOE in advance of possible small-scale geothermal power production using binary technology.

In December of 2008, S4 Consultants, Inc. of Denver, Colorado obtained a 194 ha (479 ac) federal geothermal lease (UTU-86738) near Newcastle reservoir, somewhat removed from the identified geothermal resource area. In July of 2009, Renewable Energies LLC of Cedar

[6] One of these wells, (MN-5) drilled to 290 m (1051 ft) depth (max temperature – 114°C [237°F]) is not presently used due to low permeability.

City, Utah obtained a 92.3 ha (228 ac) federal geothermal lease (UTU-87418) near what has been mapped as the heat-flow high for the Newcastle geothermal system.

Beryl Area

According to records obtained from the Utah Division of Water Rights, three companies - "McCulloch Oil Corporation (MCR Geothermal Corp.), Geothermal Kinetics, Inc., and UP&L Company" - formed a partnership to drill and complete a well referred to as "MCO-GKI-UPL-DeArman #1." The well was located in the SW¼, SE¼, SW¼, section 18, T.34S., R.16W. and drilled during the spring of 1976. Documents filed with the Division of Water Rights during December of 1981 and correspondence dated November 12, 1985, suggest that the well was drilled to a depth of at least 2361 m (7746 ft) and that it did not comply with state-regulated abandonment procedures at that time. Klauk and Gourley (1983) made no mention of the above-referenced ("DeArman") well, but reported a temperature of 60°C (140°F) measured at a depth of 2461 m (8074 ft) within an unnamed geothermal test well located in the NE¼, NE¼, NW¼, section 22, T. 34 S., R. 16 W. This location corresponds to a well reportedly drilled in 1976 by MCR Geothermal Corp., and referred to as "State #1" (letter from Utah Division of Water Rights to Insurance Company of North America, dated November 12, 1985).

4.1.5 Potash (Alunite)

Although no exploitation of alunite has occurred in the CCPA, alunite was mined just east of the area near Marysvale during World War I as a source of potash fertilizer, and during World War II as a source of alumina. Neither operation survived as an economically viable post-war endeavor.

During the 1970s, Earth Sciences, Inc. discovered several alunite deposits within the CCPA, including the Blawn Wash, Pine Valley, and SX deposits. Alumet JV, a joint venture of Earth Sciences, Inc., National Steel Corporation, and the Southwire Company, conducted exploratory drilling of these deposits and the White Mountain deposit as well. Extensive drilling and testing was conducted at the Blawn Wash deposit, and a mine plan was prepared for part of the deposit (Krahulec, 2008). An Environmental Impact Assessment was completed by Earth Sciences, Inc. in 1974 and a Final Environmental Statement was issued by the BLM in 1977 (Earth Sciences, Inc., 1974; BLM, 1977). However, as a result of poor economics and high up-front capital costs, the project was not realized. Earth Sciences, Inc. maintained some mineral rights in the CCPA, but in 1998 released all their holdings (Krahulec, 2008).

Recently, Utah Alunite LLC purchased leases for the Blawn Wash deposit. The company also purchased much of Earth Sciences' data and is further evaluating the deposit. They are planning a drilling program for fall 2011 that includes over 20 holes that will be focused primarily on Area C, which was Earth Sciences, Inc. primary target for mining. Further investigation of additional deposits to the south is also planned, including the deposit west of the Pine Valley area.

4.2 Locatable Minerals

4.2.1 Copper

Beaver Lake District, Beaver County

The Beaver Lake district was organized in 1871, and has produced approximately 1 million tonnes of ore averaging about 0.88% Cu, recovered, nearly all from the OK mine pegmatitic breccia pipe. Beaver Lake is the ninth most productive Cu mining district in Utah. An inferred Cu resource (table 4.2.1.1) remains in the OK mine area in a zone about 200 m (660 ft) long by 70 m (230 ft) wide of quartz-sericite altered stockwork veining surrounding the small pegmatitic breccia. The Mary I, to the southeast of the OK, contains an estimated mineral resource of about 1 million t (1.1 million st; Wray, 2006a).

Rocky Range, Beaver County

The Rocky Range district was organized in 1872 and has a long history of Cu, Fe, and W production in fits and spurts up to 2009. Rocky is the eighth most productive Cu mining district in Utah. The history of the district changed with the discovery of the Bawana Cu skarn in about 1960 leading to the discovery of several other small Cu skarn deposits, and a year later the larger Valley deposit was found by Anaconda at depth in the pediment on the southwest flank of the range (Whelan, 1982; Wray, 2006b). These discoveries resulted in several attempts at Cu production from these skarns that were generally unsuccessful due to the small size, partially oxidized ore, and poor metallurgical recoveries.

Past district production is estimated at about 816,000 t (900,000 st) averaging roughly 2% Cu and minor W, Mo, Au, and/or Ag (Wray, 2006a). The current estimated mineral resource, from one large (Valley) and six small skarn deposits, is roughly 27.8 million t (30.6 million st) averaging about 1.4% Cu. More than 80% of this Cu resource is in the Valley skarn deposit (table 4.2.1.1). The Valley deposit lies beneath 70 to 400 m (230 to 1300 ft) of alluvium in the pediment west of the smaller, subcropping skarn deposits in the range.

San Francisco District, Beaver County

The San Francisco (Preuss) district was organized in 1871, is roughly the eighth largest metal district in Utah, and the production history is dominated by the Cactus and Horn Silver mines. San Francisco is the sixth most productive Cu mining district in Utah. Wray (2006b) estimates past production from the Cactus mine at about 1.27 million t (1.40 million st) averaging recovered grades of 1.23% Cu, 0.34 ppm Au, and 6.8 ppm Ag and reportedly still contains a similar sized mineral resource (table 4.2.1.1). Much of the rest of the base metal production from the San Francisco district has come from 1 million t (1.1 million st) of high-grade, supergene-enriched Horn Silver replacement ore running over 18% Pb and 592 ppm Ag, recovered (Perry and McCarthy, 1977).

Table 4.2.1.1. Copper resources in Beaver County, Utah.

Mine	District	Tonnes	Cu %	Au ppm	Ag ppm	MoS_2 %	Deposit Type	Source
Mary I	Beaver Lake	1,000,000	0.35				Sheeted fracture set	Prenn and Havenstrite, 2005
Ok	Beaver Lake	1,195,000	0.75	0.34		0.02	Breccia pipe	Prenn and Havenstrite, 2005
Bawana Extension	Rocky Range	1,096,000	1.84				Skarn	Unpublished data in UGS files
Candy B	Rocky Range	10,521,000	0.82				Skarn	Western Utah Copper, 2009
Copper Ranch	Rocky Range	292,000	1.13			0.02	Skarn	Prenn and Havenstrite, 2005
Hidden Treasure	Rocky Range	776,000	1.79	0.34	34.3		Skarn	Prenn and Havenstrite, 2005
Maria	Rocky Range	557,000	1.25	0.69	21.3		Skarn	Prenn and Havenstrite, 2005
Sunrise	Rocky Range	267,000	2.72				Skarn?	Unpublished data in UGS files
Valley Skarn	Rocky Range	23,600,000	1.38	0.34			Skarn	Unpublished data in UGS files
Cactus	San Francisco	1,500,000	1.80	0.32	7.5	0.01	Breccia pipe	Unpublished data in UGS files
Cactus Porphyry	San Francisco	9,000,000	0.18				Porphyry copper	Unpublished data in UGS files
Imperial	San Francisco	900,000	0.75	0.10	8.6		Skarn	Unpublished data in UGS files

All of the mineral resources listed in this table are considered to be inferred, but are classified as H/D in the BLM mineral occurrence potential classification system.

Star District, Beaver County

The Star district was organized in 1870 and the North Star district followed the next year. The district's historic production (about 180,000 t [200,000 st]) has primarily been from Pb-Zn-Ag-rich carbonate replacement deposits. The known mantos are small, ranging from a few thousand to upward of 50,000 t (55,000 st) of production of high-grade Pb-Zn-Ag ±Cu ore, mostly above the water table.

4.2.2 Gold-Silver

Antelope Range, Iron County

The Antelope Range has no known recorded history of production. However, the earliest discoveries were made in the 1870s and these mines are likely to have shipped a few tons of better grade (300 ppm Ag?) ore by cart, possibly to the Silver Reef district for treatment (Shubat and McIntosh, 1988).

Confidence District, Iron County

The Confidence district is located on the Nevada-Utah mine north of the Stateline district. No production has been recorded in the Confidence district (Tingley and Castor, 1991).

Escalante District, Iron County

The Escalante district is a large historical mining district and the principal Ag producer in the CCPA. The total production from the Escalante mine, the only productive mine in the district, is estimated at 2.33 million t (2.57 million st) averaging slightly over 240 ppm Ag and 0.077 ppm Au, recovered, producing 510,290 kg (18 million ounces) of silver and 161.6 kg (5700 ounces) of gold, making it the sixth most productive Ag district in Utah. The mine operated from 1981 to 1990. In addition, the Escalante mine has reported unmined Ag in the vein wall rocks and at depth below the mine workings that suggests the likelihood for intermittent periods of continued exploration. In addition, the mill tailings probably contain roughly 127,570 kg (4.5 million ounces) of refractory Ag, again suggesting that the district is likely to see future exploration and development activity.

Fortuna District, Beaver County

The Fortuna district is an insignificant historic Au-Ag producer located on the north end of Beaver Basin. The district has undergone sporadic exploration and drill testing, including numerous drill holes by Cordex south and southwest of the main shaft area in the early 1990s.

Gold Springs District, Iron County

The Gold Springs district was a modest Au producer (about 263.7 kg [9300 ounces] total), some of it from Nevada, between 1897 and 1948 (Perry, 1976). Portions of Gold Springs are currently (September 2011) held by High Desert Gold Corporation/Pilot Gold Inc. (355 claims, 2968 ha [7334 ac]) and they are actively exploring the vein system for exploitable Au-Ag mineralization. They have drilled 16 reverse circulation holes totaling 1569 m (5148 ft) and two core holes totaling 276 m (906 ft). There is a reported inferred mineral resource on the Jumbo vein of approximately 9,392,155 tonnes (10,353,000 tons) at 0.57 ppm Au and 12.9 ppm Ag.

Modena Area, Iron County

The Modena area, located in the hills immediately north of the old Modena railroad station 11 km (7 mi) west of the Nevada state line, has yet to see any production.

Newton District, Beaver County

Newton is a modest mining district north of Beaver that was organized in 1892. The district produced some Au-Ag beginning in 1893 (Butler and others, 1920) along with minor amounts of Mn and U. The most productive Au-Ag years of the district appear to have been during the depths of the Great Depression in the 1930s. The district realized some minor renewed production for U in the 1950-60s. The total production is estimated at 107.7 kg (3800 ounces) Au, 3912 kg (138,000 ounces) Ag, 3850 kg (8488 lbs) Mn, and 29,145 kg (64,253 lbs) U_3O_8.

Stateline District, Iron County

The Stateline district veins were initially discovered in the early 1890s and by 1896 the district was organized and most of the known lodes had been discovered. Some on-site mills were erected, but were not very profitable. The district was a modest Au-Ag producer (about 72 kg [2540 ounces] Au and 2618 kg [91,348 ounces] Ag), nearly all from Utah, with sporadic production between about 1897 and 1948 (Thomson and Perry, 1975). Pilot Gold Inc. currently controls portions of the Stateline mining district (167 claims, 1396 ha [3450 acres]) and reports surface assays on rock samples to 35 ppm Au and 1300 ppm Ag.

4.2.3 Iron

Iron Springs District, Iron County

The Iron Springs (Pinto) mining district is the most productive Fe district in the western United Stated (about 90 million t [100 million st] of Fe ore) and still hosts significant Fe resources. The Fe content of the ore has historically averaged about 50% Fe. The Iron Springs deposits were first recognized by Mormon scouts in 1849, but the district wasn't organized until 1868 (Pinto). Early and relatively unsuccessful pioneer Fe production lasted until 1876 yielding a total of only about 385 t (424 st) of pig iron (Mackin, 1968). Ore production then essentially halted until 1923, when the Columbia Iron Mining Company (purchased by the U.S. Steel Corporation in 1929) built a blast furnace south of Provo and began the first large-scale operations on the Pioche mine at the north end of Granite Mountain. The following year Utah Iron Corporation (Archibald Milner) began mining at Desert Mound. Mining was initially by glory hole methods, but soon shifted to open-pits utilizing steam shovels and narrow-gauge rail cars (Seegmiller, 1998).

Due to the prevalence of magnetite in the ores, ground magnetic surveys at Iron Springs were begun in about 1930. Several ore bodies were soon outlined at Desert Mound and Iron Mountain. In 1943, the U.S. Bureau of Mines (USBM) and USGS began a cooperative ground magnetic surveying project focused on the intrusive-sedimentary rock contacts. Several magnetic highs were delineated and mineralization was encountered in follow-up drilling (Young, 1948). At least 58 separate ore bodies have been found in the Iron Springs district (Gin, 1989).

The exigencies of World War II resulted in the construction of the much larger Geneva steel mill at Ironton, near Orem, in the early 1940s. Peak district annual production of about 4.8 million t (5.3 million st) occurred in 1953 under the stimulus of the Korean War. All Iron Springs ore was direct shipped to open hearth furnaces until 1961, when a 2300 t (2540 st) per day magnetic concentrator was setup in the district (Bullock, 1970). District production supplied three different smelters for reduction: Columbia/U.S. Steel/Geneva Steel facilities at Ironton, Utah; Colorado Fuel & Iron's smelter in Pueblo, Colorado; and Kaiser Steel Corporation's plant in Fontana, California (Gin, 1989). Large-scale production from numerous ore bodies by a variety of companies continued until finally coming to a halt in 1982. Production was continued, on a somewhat smaller scale, by Geneva Steel from 1987 to 1995. CML Metals Corporation revived small-scale production from the Comstock/Mountain Lion deposit in 2009 based principally on the proven open-pit resource (table 4.2.3.1). The Iron Springs district is ranked as roughly the fourth most productive mining district in Utah in terms of value.

Table 4.2.3.1. Mineral resources in the Iron Springs mining district, Iron County, Utah.

Mine/Stockpile	Million t	Fe	Resource Classification	Source
C-ML pit	23.2	49.6%	Probable Reserves	Abbott and others, 2011
C-ML stockpiles	8.3	33.9%	Probable Reserves	Abbott and others, 2011
C-ML Subtotal	31.5	45.5%	Probable Reserves	Abbott and others, 2011
Rex deposit	89.1	39.0%	Measured Resource[2,3]	Pincock, Allen & Holt, 1991
Burke stockpile	4.5	40.0%	Inferred Resource[2]	Pincock, Allen & Holt, 1991
Duncan pit	2.4	42.9%	Indicated Resource[2]	Pincock, Allen & Holt, 1991
Homestake mine	3.3	50.5%	Indicated Resource[2]	Gin, 1989
A&B	11.8	54.6%	Indicated Resource[2]	Gin, 1989
McCahill	14.2	48.6%	Indicated Resource[2]	Gin, 1989
Section 2	8.3	50.7%	Indicated Resource[2]	Gin, 1989
Section 9	27.9	47.4%	Indicated Resource[2]	Gin, 1989
District Total	192.9	43.7%		

[1] All resources in this table are classified as H/D in the BLM mineral occurrence potential classification system.

[2] The Pincock, Allen & Holt (1991) and Gin (1989) reports do not specifically note resource classification, which is estimated here from context.

[3] At a variable cut-off grade of 15 to 20% Fe.

The C-ML deposit is currently (October 2011) in production with a reserve (table 4.2.3.1) that should last roughly 11 years at a mining rate of approximately 2 million t (2.2 million st) per year. Ideally, the Rex deposit would be developed next, with sufficient lead time so that the 4 to 6 years of pre-stripping anticipated at the Rex orebody would be completed just prior to the exhaustion of the C-ML deposit so that there can be a smooth production transition from the C-ML to the Rex ores. The small Burke stockpile and the remaining Duncan and Homestake resources could be exploited to help extend this time window. At the current rate of production, the Rex deposit would provide an additional 50 year life to the operation. Ultimately, depending on future metal prices and the status of existing equipment/operations, the currently subeconomic and covered, but high-grade A&B and possibly even the McCahill, Section 2, and Section 9 deposits could eventually be exploited.

Iron Peak Area, Iron County

The Iron Peak area has no recorded production and has seen very little exploration in the last half century. Bullock (1970) estimates an Fe resource of less than 4500 t (5000 st) averaging 62% Fe.

4.2.4 Lead-Zinc

Bradshaw District, Beaver County

The Bradshaw mining district was organized in 1871 and production has totaled approximately 10,000 t (11,000 st) averaging a recovered grade of about 9.6 ppm Au, 926 ppm Ag, and 4.5% Pb with minor Cu-Zn.

Lincoln District, Beaver County

The Lincoln district is known as one of the oldest mining areas in Utah, and was originally organized as the Pioneer district in 1864, although initial production reportedly began well before this in 1854 (Butler and others, 1920). Despite its long history, the district has seen only minor production (<10,000 t [<11,000 st]) of Pb-Zn-Cu-Au-Ag ±W ±Bi ores (Perry and McCarthy, 1977).

San Francisco District, Beaver County

The San Francisco mining district was organized in 1871 (the adjoining Preuss district in 1872) and is roughly the eighth largest metal mining district in Utah. San Francisco is the fifth and sixth most productive district in Utah for Pb and Zn, respectively. The production history of the district is dominated by the Cactus Cu mine and famous Horn Silver Pb-Zn mine (Wray, 2006b). Most of the San Francisco district's Pb-Zn production came from the Horn Silver mine on the southeast side of the Cactus stock, with considerably lesser production from the Beaver Carbonate mine to the east. The Horn Silver, discovered in 1875, became an important early mining/smelting operation and operated continuously until 1931, and then sporadically into the 1960s. The Horn Silver produced roughly 935,000 t (1,030,000 st) of high-grade, replacement ore running over 18% Pb and 592 ppm Ag, recovered (Perry and McCarthy, 1977).

During the 1980s and 1990s, a succession of exploration groups drill tested the Golden Reef property including Hunt, Ware and Proffett (10 holes), Newmont Exploration Limited (9 holes), Dotson Exploration, Inc. (7 holes), and Barrick Resources (USA), Inc. (9 holes). Drill intersections run as high as 1.5 m (5 ft) of over 4 ppm Au (William B. Wray, written communication, April 2007).

Star District, Beaver County

The Star district was organized in 1870 and the North Star district followed the next year. Star is the eighth and tenth most productive district in Utah for Pb and Zn, respectively. The district's historic production is about 180,000 t (198,000 st) at an average recovered grade about

14% Pb and 340 ppm Ag with byproduct Zn, Cu, Au, and minor W primarily from small skarn and carbonate replacement deposits. The individual mantos production ranges from a few thousand to upward of 50,000 t (55,000 st) of high-grade Pb-Zn-Ag ±Cu ore, mostly mined above the water table.

Washington District, Beaver and Washington Counties

The Washington mining district was organized in 1879, and has been a modest fluorite producer (18,000 t [20,000 st]) with minor, intermittent Pb-Zn and lesser Ag-Cu-Au production (Bullock, 1976; Perry and McCarthy, 1977). The total metal production is estimated at some 3175 t (3500 st) averaging about 14% Pb, 8% Zn, and 33.5 ppm Ag.

4.2.5 Mercury

Pink Knolls Area, Beaver and Iron Counties

Pink Knolls is not an organized mining district and has no known production, but has seen sporadic mineral exploration activity over the last half century. USBM geologists visited the King Iron Fe prospect (Beaver County) in 1945 and the Cina (Katie, Cima) Hg-S site (Iron County) in 1950. One unpublished report in the UGS files suggests that the original Cina claims were staked by Horace Carter in 1946. In 1950, the only physical work that had been done at the Cina mine was a 4 m (13 ft) shaft.

Several unpublished company reports in the UGS files suggest the Cina mine was thoroughly investigated as a Hg prospect in the late 1960s and early 1970s including drilling, trenching, underground development, calculation of mineral resources, metallurgical studies, economic evaluations, market analysis, and possibly some pilot-scale test mining. Subsequent to this effort, the Cina mine area was explored by Exxon (1978-81), Noranda Exploration (1983), Superior Oil (1983-84), Western Minerals Corp. (1989-90), Fair Sky Minerals (2006-09), and Newmont (2010-current). The Exxon program was reportedly exploring for volcanic-hosted uranium while the majority of the later programs were likely for Au-Ag.

The very crudely estimated mineral resource at the Cina mine is reportedly 310,000 t (340,000 st) averaging 0.37% Hg (unpublished reports in UGS files).

4.2.6 Molybdenum

Pine Grove District, Beaver County

The Pine Grove mining district was organized in 1873 and was historically a minor Zn-Pb-Ag producer. However, beginning in 1974 the district began a period of considerable deep porphyry Mo exploration and predevelopment work that continued into the 1980s. The commonly published reserve figure for Pine Grove is 113 million t (125 million st) at 0.17% Mo at a minimum 91-m (300-ft) width and a 0.12% Mo cutoff grade. No important mineral exploration or development work has been done on the property since about 1983.

Broken Ridge Area, Iron County

The Broken Ridge area's mineral potential wasn't recognized until the late 1970s when a USGS Conterminous United States Mineral Assessment Program (CUSMAP) heavy-mineral-concentrate stream sediment survey turned up anomalous Sn and Mo in Fourmile Wash near Broken Ridge (Motooka, and Miller, 1983). However, no drill testing of this deep exploration target is believed to have occurred. Some of the Broken Ridge area is currently (August 2011) covered by unpatented mining claims.

Other Molybdenum Districts

Several other districts in the CCPA have recognized Mo mineralization, like the Star Range, or have potential deep, underlying porphyry Mo systems, including the Blawn Wash and Newton mining districts. However, none of these areas have recognized historic Mo production.

4.2.7 Tungsten

Granite District, Beaver County

The Granite district was organized in 1863 followed by the North Granite district in 1865. Early work centered on Bi and Ag production; the W ores were not discovered until much later (Butler and others, 1920). The Granite district saw limited W production during the World War II era. The district has produced several hundred tons of W ore and a similar tonnage of Zn-Pb-Cu ±Bi ores. Most of the W production was from the Garnet and Big Pass area mines in the southern end of the district (Crawford and Buranek, 1945). Everett (1961) reports estimated inferred resources from the Mineral Mountains of 46,250 t (50,980 st) of 0.29% WO_3; probably mainly in and around the Garnet mine.

Other Tungsten Districts

The Bradshaw, Broken Ridge, Lincoln, Pine Grove, Rocky Range, San Francisco, and Star mining districts all have known W occurrences. However, none of these districts have any significant recognized W resources.

4.2.8 Uranium

Blawn Mountain, Beaver County

The first mention of mining in the Blawn Mountain area is a very brief note about Fe mining on the east flank of the range in the 1880s (Butler and others, 1920). The Staats fluorite mine, on the south flank of Blawn Mountain, was first staked in 1931 and subsequently purchased by Fred Staats and associates in 1938. The fluorite property was worked by a small open cut and has an estimated 244 m (800 ft) of underground workings. Some 4404 t (4855 st) of fluorite were mined from 1935 to 1951. During the 1950s, U was discovered at the Staats mine and an additional 2514 t (2771 st) of 0.24% U_3O_8 ore were shipped. The area was heavily explored for U again in the mid-1970s, and then for Mo in the late 1970s and early 1980s, following the discovery of the deep, Climax-type porphyry Mo deposit at Pine Grove.

Newton District, Beaver County

The Newton district produced some Au-Ag, beginning in 1893 (Butler and others, 1920), along with a minor amount of Mn at a later date. The most productive Au-Ag years for the district appear to have been during the depths of the Great Depression in the 1930s. Uranium was discovered in the district in about 1950, following on the heels of the Marysvale U district (1949) 30 km (19 mi) to the northeast. Anomalous surface radioactivity was followed up by six bulldozer cuts, three of which exposed mineralization followed by the driving of three progressively deeper adits.

The Newton district produced about 16,377 t (18,053 st) of 0.18% U_3O_8 or 29 t (32 st) of U_3O_8, mainly from the Mystery-Sniffer mine in the 1950s to 1960s. Doelling (1974) reports an estimated mineral resource at the Mystery-Sniffer mine of about 9000 t (9900 st) at 0.2% U_3O_8.

Other Uranium Districts

Several other districts in the CCPA have U prospects or occurrences, including the Blue Mountain, Broken Ridge, Pink Knolls, and Stateline districts. However, none of these other districts have any recorded U production or resources.

4.3 Salable Minerals[7]

4.3.1 Barite

Around 1960, the Horn Silver Mine produced small amounts of barite as a byproduct (Brobst, 1969). No other barite activity in the CCPA is known.

4.3.2 Building Stone

The Indian Queen Marble quarry in the San Francisco Mountains began operations in the mid-1990s and produced stone through 2002. The maximum annual production was 10,000 t (11,000 st) in 1999, but the mine is now reclaimed. The Courgraph quarry also began operating in the mid-1990s and maintains a current permit. The quarry has not produced since 2002 (Boleneus, 2008), but there was some quarry development in 2007 (DOGM). The maximum production from the Courgraph quarry was in 2001 at 1600 t (1760 st; Boleneus, 2008).

[7] Some of the commodities discussed under Salable Commodities maybe subject to location under the 1872 Mining Law or the "Common Vanities" Act of 1955. See Introduction, 1.2 Lands Involved, p. 23, for general discussion.

Great American Resources LLC, the operator of the Southern White/Mountain Rose mine in the San Francisco Mountains, has recently applied for a large mine permit with DOGM. This quarry has little historical production, but did produce 7300 t (8000 st) of rock in 2008 (DOGM). The Star Range Dolomite quarry was reclaimed and closed as of 2010. The mine last produced an unknown, but likely minimal, amount of product in 2003 (DOGM).

The Bright quarry is classified as a large mine, and is currently operated by Neil Bradshaw. The mine produced 130,000 t (143,000 st) of landscape rock from 2003 through 2008, and continues to produce stone at lower volumes since 2008 (DOGM files). Most of the landscape rock produced from the Bright quarry is shipped to St. George, Mesquite, and Las Vegas (Boleneus, 2008). The Rhyolite #1 quarry is currently operated by JP Excavating, Inc., and has only produced small amounts of stone; the most recent production numbers available are from 2009 when 640 m^3 (840 yd^3) of stone were produced. Slightly southeast of the Rhyolite #1 quarry, a permit was opened around 2005 for the Quartz Hill quarry. Very little production came from the quarry, and it has been reclaimed and the permit closed (DOGM files). Terra Resources LLC's RMS No. 1/Mountain Spring Peak mine has produced small amounts of decorative rock for aquariums; however the mine was reclaimed in 2010 by BLM. Dennis (1930) and Dixon (1938) noted that rhyolite was quarried for building stone near Beaver in the early 1900s but no detail is provided on where or how much stone was quarried.

Boleneus (2008) noted that the Red Emerald mine (or Ruby Violet mine), a red beryl gemstone producer, test marketed small amounts of reject waste from their ore processing plant for landscape rock.

4.3.3 Common Clay

No known exploration for and little development of common clay resources has occurred in the CCPA. However, the BLM operates a community pit for common clay west of Mandersfield in the NE ¼ of section 19, T. 28 S., R. 7 W. The pit is located on a deposit of Quaternary lacustrine (?) silty clay. The clay is used locally for pond lining, and has likely been in use since the 1960s. Several thousand m^3 (yd^3) have been removed to date. A large volume of clay was also utilized in lining the Escalante silver mine tailings impoundment. The clay was extracted immediately adjacent to the site and consisted of weathered volcanics. Circle 4 Farms reportedly has a clay pit in the upper Escalante Valley that produces clay from lacustrine deposits of Lake Bonneville. The clay is used as an underliner for their hog sewage lagoons. In Utah, most common clay development and production occurs in close proximity to Salt Lake City, although some bentonite is being extracted in Sevier and Sanpete Counties (Tripp, 2007).

4.3.4 Crushed Stone and Ballast

A large quantity of ballast has been mined in the CCPA. About 6,600,000 t (7,300,000 st) of ballast has been produced at the Milford Quarry 1 (section 14, T. 27 S., R. 11 W.) since 1998. The quarry was originally owned by Twin Mountain Rock Company, but was purchased by Martin Marietta Materials, Inc. in 2009. An average of 510,000 t (560,000 st) of ballast has been produced each year at the quarry, and over 557,000 t (614,000 st) were mined in 2010. Significant development has occurred at the quarry including an overland conveyor that delivers the mined material to processing facilities in section 12, T. 27 S., R. 11 W. The Twin Mountain Rock Company also produced construction riprap from quartz monzonite exposed in the Hidden Treasure copper mine and dumps, as well as dumps from other adjacent mines at the south end of the Rocky Range in 2000 and 2001. Twin Mountain replaced these sources with a small riprap quarry on granitic rock about 1.7 km (1 mi) north of their ballast rock quarry. The riprap is marketed to the Union Pacific railroad for embankment material.

The Nichols Pit is an active large mine that produces crushed stone. Previously, only sand and gravel was produced from the pit, but bedrock was later crushed for use. In 2006, about 143,000 t (158,000 st) was produced from the pit, but the quantity of crushed stone versus sand and gravel is unknown. In the last few years, little production has come from the pit. The material from the pit is shipped to Cedar City for use in ready-mix concrete and asphalt.

Two small operations exist in section 32, T. 35 S., R. 12 W., and produce crushed stone and riprap from remnants of the iron mines. The Iron County West Rip Rap Pit produced small amounts of riprap from waste rock from the Iron Mines, but the permit closed in 2010. The Walker Iron Mine Placer produces small amounts of crushed stone from iron mine tailings.

4.3.5 Fluorspar/fluorite

Fluorite production in the CCPA was primarily from 1935 to 1945 in the Washington and Blawn Mountain mining districts. Most of the production came from the Cougar Spar mine, which produced about 15,500 t (17,000 st) of fluorspar ore. In 1943, a 136 t (150 st) per day jig mill was constructed, and most of the production, over 14,474 t (15,955 st), occurred shortly thereafter in 1944 and 1945. Both surface and underground mining methods were employed at the Cougar Spar mine, but most production came from underground methods (Everett and Wilson, 1951; Thurston and others, 1954; Bullock, 1976). No significant production has occurred since 1945. Near the Cougar Spar mine, the Blue Bell mine produced about 1180 t (1301 st) of ore from 1941 through 1944 and 653 t (750 st) in 1969. In 1975, the Allied Chemical Corporation performed exploratory drilling of both the Cougar Spar and Blue Bell deposits. Two holes were drilled at Cougar Spar and three holes at Blue Bell, but significant ore was not encountered at either site (Bullock, 1976). AMAX acquired and drilled one hole in the Cougar Spar property in 1978 (for molybdenum), but abandoned the property in 1981.

In 1942 and 1943, a minor amount of fluorspar, less than 27 t (30 st), was mined from the J.B. mine, and an additional 1161 t (1280 st) of ore was mined in 1972 and 1973 (Bullock, 1976). From 2000 to 2004, Breccia Development, Inc. held a small mine permit at the J.B. mine. The Division of Oil, Gas, and Mining (DOGM) reported that they mined and stockpiled 900 t (1000 st) of material. Several hundred tons of recovered material were transported to the Lund rail siding and reportedly shipped to southern California to be tested as cement kiln additive to lower the fusion temperature and reduce NOx emissions. A small amount of stockpiled material is still available at the site.

The other significant producer in the CCPA was the Staats/Monarch mine, which produced a total of 4404 t (4855 st) of fluorspar. Nearly 3175 t (3500 st) tonnes were produced from 1935 to 1945 and the remainder was produced from 1948 to 1951. During the 1950's the Staats mine produced uranium ore (Bullock, 1976).

In the 1940's, a few hundred tons of fluorspar was produced from the Star-North Star district (Dasch, 1969; Bullock, 1976). Currently, there are no fluorite mines with active permits in the CCPA. Table 3.3.5.1 summarizes fluorite production in the CCPA. Little production of fluorspar has occurred recently in Utah, and that production has been centered at Spor Mountain where there are better-known and larger deposits than those within the CCPA (Tripp, 2007).

4.3.6 Gemstones

Most of the gemstone exploration, production, and development in the CCPA has revolved around red beryl. Much of the description below of the activities at the Ruby Violet mine are taken from Shigley and others (2003). Lamar Hodges discovered the red beryl deposit in 1958, and his family worked the deposit until 1976, when the property was sold to the Harris family, who regularly mined at least 1800 t (2000 st) of ore per year until 1994. In 1994, Kennecott Exploration Company leased the property from the Harris family and began to define the resource at the deposit with nearly 3962 m (13,000 ft) of core from 56 drill holes and bulk sampling of about 11,000 t (12,100 st) of ore. Kennecott stopped additional development of the colored gemstone initiative in 1996. Gemstone Mining Inc. subsequently purchased a lease option from the Harris family and did additional mapping, sampling, and drilling, which led to application of a large mining permit from the State of Utah. However, in 2001, Gemstone Mining Inc. (GMI), declared bankruptcy, missed a lease/purchase payment to the Harris family, and all mining activity ceased. GMI immediately commenced reclamation of the mining disturbances during the fall of 2001. The unpatented mining claims reverted back to the mining claimants, which was composed of the Harris family and a partnership of Earle Foster and Marlo Cropper. While GMI was carrying out reclamation of the site, Foster and Cropper, under the company name Red Emerald Inc., applied for a small mine permit to mine the upper pit area, located on the mining claims that they controlled on the property. This permit was granted and subsequently replaced by a large mine permit in 2004. The current active permit area is about 2.8 ha (7 ac). The permit area was campaign mined by Rancho Equipment Services in 2005 and 2006 and then idled. Small scale recovery operations within the permit area have been carried out since then by a friend of the family (Clay Holman) during the summer months. The Harris family portion of the property, the lower pit area, has been idle since GMI reclamation work from 2001 through 2003. No permit is active for the lower portion of the deposit. An estimated 60,000 carats of red beryl, 10% of that suitable for faceting, has been produced at the site in the last 25 years.

The Wah Wah mine, a prospect-scale excavation in the Steamboat Mountain area, which contains red beryl, topaz and bixbyite, began intermittent activity in the 1990s. Initially excavation occurred with hand tools and later (2001) with trackhoe excavation, but the prospect has been mostly idle since 2006. The red beryl crystals are small and bladed and have very limited markets. The prospect is presently undergoing reclamation and permit release.

Picasso marble was produced in the southern Mineral Mountains for polished specimens and sculpting material. Penney's Gemstones, LLC produced small amounts, tens of tons per year, in the last decade from the Sliver 1-2 and Sliver 3-4 mines. Blasting and excavating followed by hand sorting occurs to select the product, which has been marketed locally and was also shipped to China (Boleneus, 2008). Reclamation has begun at the Sliver 1-2 mine, and no other Picasso marble mines have current permits.

Earth's Partners, LLC extracted a few tons of material for unidentified gemstones from the Carol mine and Munchkin 1-2-3 mine, but both mine permits are closed. DOGM reports that the quarries are reclaimed. In section 25, T. 26 S., R. 16 W., in the southern Wah Wah Mountains, exploration occurred for gem grade quartz crystals. No known development resulted from the exploration.

4.3.7 Gypsum

No large-scale production has occurred to date in the CCPA. Early in Cedar City's history, small amounts of gypsum were mined from the Carmel Formation in Cedar Canyon for use as plaster. Mammoth Plaster and Cement Company mined gypsum briefly in 1923, also in Cedar Canyon, for cement retarder (Averitt, 1962).

DOGM records show five gypsum mines within the CCPA. Currently, only one gypsum mine has an active, approved permit. Progressive Contracting Inc. operates the mine, known as the Salt Creek mine, which is in Cedar Canyon in section 18, T. 36 S., R. 10 W. Tripp (2001) reported that 88 t (97 st) were produced by a previous operator of the Salt Creek Mine in 1998 (known then as the Dry Creek Mine); however, recent annual reports submitted to DOGM suggest that no activity has occurred at the mine since then. All of the other previously permitted mines, with one exception, are also in Cedar Canyon near the Salt Creek mine. The additional mine reported by DOGM is in the Star Range. DOGM permitted all of the mines as small mines, with less than 2 ha (5 ac).

4.3.8 High-Calcium Limestone and High-Magnesium Dolomite

Little exploration, development, or production of hical limestone or himag dolomite has occurred within the CCPA. In 2010, Progessive Contracting Inc. applied for an exploratory permit (Tent City Project) for hical limestone on the west side of Wah Wah Summit in an unknown formation. Progressive intended to test limestone in specialty markets demanding high-calcium carbonate content, whiteness, and low heavy metals.

Graymont Western US Inc. mines large volumes of hical limestone and himag dolomite in the Cricket Mountains north of the CCPA. Graymont is producing the hical limestone from the Cambrian Dome Limestone (C2) and himag dolomite from the Limestone of Cricket Mountains (C2) for production of lime and dolomitic lime (Tripp, 2007; Hintze and Kowallis, 2009).

4.3.9 Kaolinite

In 1963, small tonnages of kaolinite and alunite were shipped from Blawn Mountain to Salt Lake City for use as refractories (Whelan, 1965). Since then Sandy Nell has overseen the most significant known production from the Sandy Wash 4 (or Blawn Mountain) quarry (section 30, T. 29 S., R. 15 W.), which has produced about 300,000 t (330,000 st) of kaolinite that is used as a cement raw material. The quarry's production peaked in 2006 (73,000 t [80,000 st]) and has declined since, producing only about 20,000 t (22,000 st) in 2010. Other recent activity at Blawn Mountain includes exploration at the Mickey Project by Sandy Nell, which is west of Sandy Wash 4 in section 26, T. 29 S., R. 16 W. No production came from the site and it has been reclaimed. Also, Peck Rock and Products has a current small mine permit (Blawn 1-4 SMO) in section 30, T. 29 S., R. 15 W., northeast of Sandy Wash 4. Production from this quarry amounts to about 9000 t (10,000 st), and is also sold as a high-alumina feedstock for cement manufacture. Alunite and mercury contents in portions of these deposits present ongoing challenges to continued production as cement raw material. New EPA rules on mercury emissions for cement kilns may preclude use of these deposits due to their high mercury content.

At the White Mountain deposit, one quarry, the White Mountain 2, had a recently active, approved permit. However, very little activity has occurred at the quarry located in section 8, T. 29 S., R. 13 W., and the quarry permit has been rescinded.

4.3.10 Lapidary Material

Little activity has occurred in the CCPA in regards to lapidary material. The Opal Mound area has probably seen the most activity, and a few hundred tons of material has been extracted from small pits and trenches at the site. DOGM reports that the most recent mine permit holder, the Stone Art Company, has reclaimed their workings and applied for permit closure.

Minimal amounts of agate have been extracted from the Lost Gems #1 mine by Penney's Gemstones, LLC. The site has been inactive for the past ten years and the BLM notice expired in 2011. Conversations between BLM and the operator suggest the site will be reclaimed rather than reauthorized.

4.3.11 Lightweight Aggregate

The first significant production of pumice and perlite began in Utah in 1947 in a deposit west of Enterprise. The perlite was used for lightweight aggregate, and the mine produced for an unknown length of time. Most early production of these commodities came from Beaver and Millard Counties (Nackowski and Levy, 1959; Olsen and Williams, 1960; Van Horn, 1969). The North Pearl Queen mine was one of the early perlite producers, and is located within the CCPA. The mine produced perlite ore from 1950 to 1966, but did not produce again until recently, starting in 1998 (Tripp, 2000). The North Pearl Queen mine has the only approved mining permit for perlite and pumice within the CCPA; this permit is for a "large mine," larger than 2 ha (5 acres). Recently, however, the mine has had no production, and is undergoing reclamation. The last ore mined was in 2004 when 31,000 t (34,000 st) of perlite were produced. The current operator of the mine is the Basin Perlite Company. All recent perlite mining of significance in Utah during the past few years has occurred in Tooele County at the Harborlite perlite mine.

When the North Pearl Queen mine began producing again in 1998, a perlite processing facility was opened in Milford. The processing facility had a capacity of about 90,000 t (100,000 st) per year, and was sold in 2005 to World Minerals, which is now a subsidiary of Imerys. The facility last operated in 2006, when it was supplied with ore from the Black Springs mine in Millard County (Tripp, 2007). Imerys has since moved the processing plant to Antonito, Colorado.

Another previously permitted perlite and pumice mine in the Mineral Mountains is located in Ranch Canyon about 8 km (5 mi) south of the North Pearl Queen Mine, but little activity occurred at the mine. DOGM permitted four additional pumice mines in Ranch Canyon in the 1990s, but none of the mines are currently active.

DOGM granted an exploration permit in 2005 to S&B Industrial Minerals to investigate perlite in the southwestern part of the CCPA in T. 36 S., R. 20 W., SLBM. The permit was closed in 2006. In early 2011, a group applied for a Conditional Use Permit Application from Milford City to crush, screen, and dry about 15 t (17 st) per day of perlite, but the current status of the application is unknown (Milford City, 2011).

4.3.12 Sand and Gravel

In the past and currently, sand and gravel development is concentrated along major transportation corridors, particularly along Interstate 15. About 40% of the sand and gravel pits within the CCPA are along Interstate 15, which also includes Cedar City, the major population center within the CCPA. In 2009, Utah produced approximately 28.1 million t (31 million st) of sand and gravel, and only a small percentage of that amount would have been produced in the CCPA (Bon and Krahulec, 2010).

The Mine Safety and Health Administration reports at least 10 intermittent, but active, sand and gravel operations within the CCPA. Many of the larger sand and gravel operations extract Quaternary alluvial material near the boundary of T. 35 S., R. 11 W. and T. 35 S., R. 11 W., adjacent to the Cedar City Municipal Airport. At least four companies have pits in this area: Ashdown Brothers Construction, Inc.; Schmidt Construction, Inc.; Sunroc Corporation; and Western Rock Products.

4.3.13 Silica

The only known silica production from the CCPA is from the White Sands mine in Cretaceous middle sandstone of the Grand Castle Formation. The White Sands mine provided flux for processing at the iron mines west of Cedar City. The Silica Sand Company has maintained a small mine permit (less than 2 ha [5 ac]) at the White Sands mine since 1993, but very little production has occurred. However, minimal amounts of ore (9 m^3 [12 yd^3]) were extracted as recently as 2009 for unknown purposes (DOGM).

The Eureka Quartzite is mined for silica in central Millard County at the Tule Valley quarry. Broken Arrow Inc. maintains a current permit at the small mine, but the most recent production was in 2005 (Tripp, 2007).

4.3.14 Sulfur

The Cove Creek deposits produced about 30,500 t (33,600 st) of sulfur from 1885 to 1952 (Mount, 1969), and averaged about 900 t (1000 st) per year from 1890 to 1906 (Wideman, 1957). In 1893, all domestic production came from the Cove Creek deposits. Most of the sulfur ore from Cove Creek was produced from Sulphurdale (the Home mine). The sulfur ore was processed using thermal processes until 1951, when a flotation mill was constructed at the site. However, very little production came from the mill or from a solution-process plant constructed in 1955 (Wideman, 1957). DOGM files indicate that some exploration may have occurred at the site in the late 1980s, but no development has resulted.

Although, the Brimstone sulfur deposit had some prospecting, no known production has come from the deposit (Mount, 1969). Most sulfur in Utah is currently produced as a byproduct of smelting, by Kennecott, and oil refining; the vast majority of sulfur produced worldwide is also as a byproduct (Ober, 2006; Tripp, 2007).

5.0 POTENTIAL FOR THE OCCURRENCE AND DEVELOPMENT OF ENERGY AND MINERALS

5.1 Leasable Minerals

5.1.1 Oil and Gas

Introduction

Petroleum development potential is tied to the industry's varying interest in pursuing possible targets and to the nature and size of those targets. To date, no oil or gas fields have been found in the CCPA. Oil fields in eastern Nevada are estimated to range from 0.6 to 132 million m^3 (0.1 to 21 million bbls), or tiny to small in size. Nearby Utah analogue fields for potential discovery size include the Upper Valley field, a medium sized one with an estimated 157 to 314 million m^3 (25 to 50 million bbls) of recoverable oil, or the Covenant field, a large field with 314 to 628 million m^3 (50 to 100 million bbls) of recoverable oil. Based on cumulative production data for all Utah oil and gas fields, available on the DOGM website, 85% of Utah's actively producing fields are very small (6.3 to 62.8 million m^3 [1 to 10 million bbls] of oil or 0.3 to 2.8 billion m^3 [10 to 100 billion ft^3] of gas) in size; see Appendix B for field-size classification. Thus, on average new field discoveries in the CCPA can be generally expected to be very small in size. Very small fields are not likely to attract large oil companies, but may attract small or mid-sized petroleum companies.

One factor that could dampen future exploration would be the lack of availability of land for leasing in the CCPA. As of 2011, about 180,895 ha (447,000 ac; 17.5%) of the nearly 1.03 million ha (2.55 million ac) of federally managed mineral rights in the CCPA are leased for oil and gas. The existence of a substantial number of existing oil and gas leases indicates serious interest by the industry exists to pursue oil and gas exploration and development on the CCPA. However, new areas of interest may need to be open for leasing also. Another factor that could affect future oil and gas exploration is a recent inventory of lands with wilderness values; however, BLM has identified only minimal additional lands as having wilderness characteristics in the CCPA.

The resource occurrence and development potential rating system used in this study is presented in Appendix A at the end of this report. This occurrence rating system comes from the BLM Manual 3031 (illustration 3), and the low, moderate, and high development potential ratings were modified by the UGS from the BLM occurrence potential system, but development potential rating has no certaintly level of development assigned to it because future market developments area too hard to predict with any level of certainty. A discussion of the resource occurrence potential of the various petroleum plays defined in the CCPA follows.

Unconformity A Play (USGS play number 1901) Potential

Although sparsely drilled, this play has received the most exploration potential of the four plays in the CCPA, with 11 exploration test wells. Eight of the 11 wells were drilled in Iron County, with six wells in the Cedar Valley and the other two in the Escalante Desert part of the play. Two of the early wells in Cedar Valley reported oil shows at depths between 853 and 1244 m (2800 and 4080 ft), one in the Dakota Formation and the second in the Navajo Sandstone. Van Kooten (1988) and Hurlow (2002) show examples of various seismic lines crossing the Cedar Valley, so adequate data should be available to delineate drilling prospects there. Based on the fact that other areas of the play outside the CCPA have producing oil fields and that some oil shows have been reported from wells within the CCPA, this play has high (H) occurrence potential with a certainty level of B (H/B; figure 5.1.1.1). Not surprisingly, BLM records show that much of the federal land in the Cedar Valley is already under lease for oil and gas. For these reasons, the Cedar Valley area of play number 1901 is rated as moderate (M) for development potential (figure 5.1.1.2). The Cedar Valley part of the play is estimated to see four new wells drilled in the next 20 years.

The remaining three wells drilled in play number 1901 were in Beaver County; two were in the northern Pine Valley and the last one was north of Milford in the Beaver River Valley. None of these wells reported any oil or gas shows. The extent of seismic data for the play outside the Cedar Valley is not known, and the lack of such data would slow future exploration. The part of play number 1901 outside the Cedar Valley is rated a low (L) for development potential. The UGS expects the remainder of this play will also see four new wells, particularly in those areas already under lease. Thus, the total expected new drilling for play number 1901 is eight wells.

Late Paleozoic Play (UGS play number 1902-hypothetical) Potential

Only 7 of the 20 wells drilled have tested this stratigraphic interval in the CCPA, and one had a weak show of oil (Van Kooten, 1988). Since this hypothetical play has not seen any actual production, it has been rated as having moderate (M) occurrence potential with a certainty level of B (M/B; figure 5.1.1.1).

During the next 20 years, it is possible that companies may look to the frontier reservoirs and structures in the area as a wildcat play. The play is believed to have a low (L) development potential (figure 5.1.1.2) because of its remoteness, the difficulty of developing low-risk prospects cheaply, and the fact that there are other lower risk areas available elsewhere in Utah that will probably see exploration first. If leases continue to be available, this play could likely see limited exploration drilling at the level of four wells in the next 20 years.

Permo-Triassic Unconformity Play (USGS play number 2106) Potential

This play has had only one test in the CCPA, and has limited potential for hydrocarbon accumulations because of its proximity to potential carbon dioxide flushing as a result of extensive recent magmatism immediately to the north. To the east of the CCPA in southcentral Garfield County there is one medium-sized, producing oil field in this play, the Upper Valley oil field (discovered 1964), that has produced more than 3.1 million m^3 (26 million bbls) of oil from Permian and Triassic reservoirs. South of the CCPA in eastern Washington County, the abandoned Virgin field produced a 236 m^3 (2007 bbls) of oil from the Triassic Moenkopi Formation (Doelling and others, 1989). In spite of these nearby discoveries, this play is very lightly explored. Based on production from other parts of the play, the southeastern portion of the CCPA has high (H) occurrence potential for oil and gas in the Permo-Triassic play, with a B level of certainty (H/B; figure 5.1.1.1).

Until seismic data are collected, and all the source rock and timing questions are answered, the true petroleum occurrence potential of this part of the play is unclear. This play is therefore rated low (L) for the development potential for new oil and gas (figure 5.1.1.2) because of its unproven nature in the CCPA and due to the increased risk of flushing of any hydrocarbons by carbon dioxide expelled from the Tushar volcanic pile immediately to the north in eastern Beaver County. This play will probably see two new wells drilled in the next 20 years, provided adequate leases are available during the planning horizon.

Paleozoic Devonian-Pennsylvanian Play (UGS play number 2108) Potential

This play has not been tested in the CCPA, and has limited potential for hydrocarbon accumulations because of its proximity to potential carbon dioxide flushing as a result of extensive recent magmatism immediately to the north. To the east of the CCPA in southcentral Garfield County, the Upper Valley oil field (discovered 1964) had one well in section 12, T. 36 S., R. 1 E. that tested 17,000 barrels of oil from the Mississippian Redwall Limestone. South of the CCPA in eastern Washington County, the abandoned Virgin field had a well in section 13, T. 41 S., R. 12 W. with a significant show of oil in the Pennsylvanian Callville Limestone, but mechanical problems precluded successful drill stem tests and the well was abandoned (Doelling and others, 1989). Thus, there are indications that the lower Paleozoic section may be locally charged with petroleum, but the presence of petroleum in this play in the CCPA is still uncertain. Based on production from other parts of the play, the southeastern portion of the CCPA has moderate (M) occurrence potential for oil and gas in the Devonian-Pennsylvanian play, with a B level of certainty (M/B; figure 5.1.1.1).

Until seismic data are collected, and all the source rock and timing questions are answered, the true petroleum occurrence potential of this part of the play is unclear. This play is therefore rated low (L) for the development potential for new oil and gas (figure 5.1.1.2) because of its unproven nature in the CCPA and due to the increased risk of flushing of any hydrocarbons by carbon dioxide expelled from the Tushar volcanic pile immediately to the north in eastern Beaver County. This play will probably see two new wells drilled in the next 20 years, probably the same two wells drilled to test play number 2106, but extended deeper to test the lower Paleozoic section as well.

5.1.2 Coal-Bed Gas Play (UGS play number 2100) Potential

The Coal-Bed Gas Play has only been lightly explored within the CCPA. The portions of the play prospective for gas in the CCPA cover a small swath through the southeast part of the planning area. Through 2010, only one well was drilled in the CCPA that penetrated the Upper Cretaceous section. This well did not discover economic gas accumulations in the coal beds, and the limited testing to date in similar coals to the east has resulted in discouraging gas content and show results. This play is rated moderate (M) for the occurrence potential of gas, with a certainty level of B (M/B; figure 5.1.1.1).

The potential for development of the Coal-Bed Gas Play in the next 20 years is low (L) (figure 5.1.1.2). Dampening interest in this play is the questionable maturity of the source rocks to provide adequate gas generation for economic accumulations. Wells drilled to test deeper reservoirs would hopefully also test the shallower Cretaceous section where penetrated. This play is expected to see only a very limited number of wildcat wells during the 20-year planning horizon, estimated at two wells.

5.1.3 Coal Potential

The Kolob coalfield contains areas with coal beds that are sufficiently thick, under thin enough cover, and proven by adequate past coal-exploration drilling or mining to meet BLM requirements to delineate a Known Recoverable Coal Resource Area (KRCRA). The thick coal part of the Kolob coalfield (KRCRA) has been rated high (H) for occurrence potential with a D level of certainty (H/D; figure 5.1.3.1). The other coal-bearing parts of the CCPA, with less data, have been rated as moderate (M) for occurrence potential, but with a B level of certainty.

Even as the low-cost coal resources of the Emery, Book Cliffs, and Wasatch Plateau coalfields of central Utah become evermore depleted over the next 20 years, the UGS does not believe that the high-sulfur, low-rank, underground-minable resources of the Kolob coalfield will see any level of interest in domestic development. For this reason, the known thicker coal resource of the Kolob field has only been rated moderate (M) for development potential while the other coal-bearing areas are rated as low (L) for development potential (figure 5.1.3.2). However, rapid expansion of international markets and development of new clean coal technologies could provide presently unforeseen future development opportunities that could change the present forecast of no disturbance. In light of these unforeseen opportunities for future development, the known minable coal deposits in the KRCRA should be evaluated based on established unsuitability criteria by the BLM in this planning effort in case a lease application should arise in the next 20 years.

5.1.4 Geothermal

To promote the development of renewable energy resources, the 2008 Utah State Legislature passed and Governor Jon Huntsman, Jr., signed into law *The Energy Resource and Carbon Emission Reduction Initiative* (Utah Code 54-17-602). In support of this legislation the Governor commissioned the Utah Renewable Energy Zones (UREZ) Task Force to (1) identify areas in Utah where utility-scale renewable energy development could occur; (2) assess the electrical generation potential of wind, solar, and geothermal technologies; and (3) identify new and existing transmission needed to bring renewable energy generation sources to market.

UREZ Phase I was a screening-level study that identified geographical locations of renewable resources and estimated the theoretical potential of electrical energy capacity (Berry and others, 2009). The UREZ Task Force assessed geothermal resource potential in Utah, separating resources into categories of “identified” versus “undiscovered” resources. Identified resources were further classified into “explored” versus “unexplored” resources. All geothermal resource areas classified as “identified” and “explored” are within the Sevier thermal area (table 5.1.4.1). Moreover, nearly all of the identified/explored resource areas are also within the BLM

CCPA. (Only approximately the southern one-third of the Cove Fort-Sulphurdale area lies within the CCPA although resource values for Cove Fort in table 5.1.4.1 reflect the entire geothermal area.)

Table 5.1.4.1, modified from Berry and others (2009), presents the theoretical electrical potential of geothermal areas having development potential and compares certain resource parameters. It should be noted that distance to and availability of transmission lines, the development cost, and cost effectiveness were not factors included in this analysis. As earlier stated, this analysis was a screening-level study that identified geographical locations of geothermal resources and estimated the theoretical potential of electrical energy capacity. It was not an attempt to provide a project-level assessment of the geothermal energy resource quality or project development potential.

Table 5.1.4.1. Electrical generating potential of geothermal areas in the BLM Cedar City District. The area of the 100°C/km thermal anomaly (in square miles) is defined by the presence of thermal-gradient boreholes with gradients of 100°C per kilometer or greater (B). The area of the "defined" resource (in square miles) refers to the area evaluated within the context of a geothermal reservoir engineering study (C). Published megawatts-electric (D) refers to published resource values determined within the context of a geothermal reservoir engineering study. Possible megawatts-electric (E) refers to the potential of the total area of the thermal anomaly (B) minus the evaluated area (C) and the remainder assigned a potential of 2 megawatts per square mile. The last column (G) indicates the potential and certainty based upon the BLM Mineral Occurrence Potential Classification System. Modified from Berry and others (2009). Undiscovered geothermal resources for the Escalante Desert was estimated at 0.25 MWe per square mile after subtracting the known resource areas.

Geothermal Area	**County (A)**	**Anomaly 100°C/km (mi^2) (B)**	**Defined Resource (mi^2) (C)**	**Published MWe (D)**	**Possible MWe (E)**	**Total MWe (F)**	**Class (G)**
IDENTIFIED							
Roosevelt	BE	55	10	120	90	210	H/D
*Cove Fort-Sulphurdale**	BE, MI	94	7	102	174	276	H/D
Thermo	BE, IR	37	37	138	0	138	H/D
Newcastle	IR	2	2	10	0	10	M/C
Beryl	IR	2	2	0	10	10	M/B
SUBTOTAL				**370**	**274**	**644**	
UNDISCOVERED							
Escalante Desert (0.25 MWe/mi^2)	JU, BE, MI, IR	5154				1289	L/B
SUBTOTAL						**1289**	
TOTAL						***1933***	

**Only about one-third of the Cove Fort-Sulphurdale geothermal area is within the BLM Cedar City District.*

The estimates in Table 5.1.4.1 are based on a combination of published resource assessments for some areas and projections for areas having thermal gradients of 100°C per kilometer (5.49°F/100 ft) or greater. The total estimated potential from both identified and undiscovered geothermal systems in the CCPA is approximately 1900 MWe (e =electric). The last column of the table shows our interpreted classification of each of the geothermal areas (figure 5.1.4.1) described here based upon the BLM Mineral Occurrence Potential Classification System. The development potential of the various geothermal areas is shown on figure 5.1.4.2. The Cove Fort-Sulphurdale and Roosevelt KRGRAs and the Thermo area have high development potential, the Beryl and Newcastle thermal areas have moderate development potential, and the rest of the undiscovered geothermal resource in the Sevier thermal area has low development potential.

5.1.5 Potash (Alunite)

The potential for occurrence of potash deposits as alunite is rated as high with a certainty of D (H/D) at known mines and prospects in the CCPA. Alteration zones with reported alunite are rated as high (H) with a certainty of C (table 5.1.5.1, figure 5.1.5.1). Continued interest in the Blawn Wash (or NG) alunite deposit suggests that development of the resource is possible; therefore development potential is rated high (H) at Blawn Wash, and moderate (M) at other known alunite mines and prospects as well as known alteration zones containing alunite (figure 5.1.5.2). Exploration will almost certainly occur, but actual exploitation of alunite deposits is speculative, as the economics of processing an alunite resource are yet to be proven and potash prices would need to remain high.

Table 5.1.5.1. CCPA Potash (Alunite) Mineral Occurrence and Development Potential.

Commodity	Area	Classification	Development	Disturbance	Figures
LEASABLE					
Potash				25-160 ha	5.1.5.1; 5.1.5.2
	Known mines and prospects	H/D	H to M		
	Altered zones with reported alunite	H/C	H to M		
	Known deposits	H/D	L		

5.2 Locatable Minerals

5.2.1 Copper

Beaver Lake District, Beaver County

The significant Cu production, long history of mineral exploration and development, and presence of remaining resources assures the Beaver Lake district of continued interest from explorers and the likelihood of sporadic mine developments well into the future. As of October 2011, the most important of the district's resources are included in the Western Utah Copper Company bankruptcy; however, renewed exploration and development is assured following the conclusion of these legal proceedings. All mineral resources discussed here and reported in table 4.2.1.1 are classified as H/D using the BLM mineral occurrence potential classification system.

The Beaver Lake district is rated a high (H) for development potential (table 5.2.1.1, figure 5.2.1.1, figure 5.2.1.2).

Rocky Range, Beaver County

The Rocky Range mining district has been a productive Cu district and has seen considerable exploration and attempted development of its mineral resources over the last half century. As of October 2011, the majority of the district and its resources are tied up in the Western Utah Copper Company bankruptcy; however, renewed exploration and development activity is certain after the legal proceedings are concluded. All mineral resources discussed in this section and reported in table 4.2.1.1 are classified as H/D using the BLM mineral occurrence potential classification system. The Rocky Range is rated high (H) for development potential (table 5.2.1.1, figure 5.2.1.1, figure 5.2.1.2).

San Francisco District, Beaver County

The San Francisco district is one of the most productive districts in the CCPA and has a long history of mineral exploration. The large areas of hydrothermal alteration assure the district will continue to undergo considerable mineral exploration and possible development in the future. All of the mineral resources discussed in this section and reported in table 4.2.1.1 are classified as H/D using the BLM mineral occurrence potential classification system. The San Francisco district is rated high (H) for development potential (table 5.2.1.1, figure 5.2.1.1, figure 5.2.1.2).

Star District, Beaver County

The Star district is not as large a historic Cu producer as the other districts discussed in this section, has not had nearly as much exploration in the last 50 years, and has no drill-hole delineated Cu resources. The district is likely to have sporadic exploration efforts continuing into the future, but is far less likely to see development as a result. The Star district is classified as M/C for Cu using the BLM mineral occurrence potential classification system. The Star district is rated low (L) for development potential (table 5.2.1.1, figure 5.2.1.1, figure 5.2.1.2).

5.2.2 Gold-Silver

Antelope Range, Iron County

Although unpatented mining claims continue to blanket the Antelope Range mineralized area, the lack of past production and current exploration activity are not indicative of mineral development in the Antelope Range in the near future and the district is given an L/C using the BLM mineral occurrence potential classification system. The Antelope Range is rated low (L) for development potential (table 5.2.1.1, figure 5.2.2.1, figure 5.2.2.2).

Confidence District, Iron County

Unpatented mining claims currently cover most of the available land in the Confidence – Eagle Valley district; however no active exploration activity has been reported and the apparent

Table 5.2.1.1. CCPA Metallic Mineral Occurrence and Development Potential.

Commodity	District	Mine/Target	Occurrence	Development	Disturbance	Figures
Copper						5.2.1.1; 5.2.1.2
	Beaver Lake		H/D	H	200-300 ha	
	Rocky Range		H/D	H	200-500 ha	
	San Francisco		H/D	H	200-800 ha	
	Star		M/C	L	30 ha	
Gold-Silver						5.2.2.1; 5.2.2.2
	Antelope Range		L/C	L	25 ha	
	Blue Mountain		M/C	M	25 ha	
	Confidence		L/B	L	25 ha	
	Escalante		H/D	H	200 ha	
	Fortuna		M/C	M	50 ha	
	Gold Spring		M/C	M	50 ha	
	Modena		L/B	L	25 ha	
	Newton		M/C	M	50 ha	
	Stateline		M/C	M	50 ha	
	Pink Knolls			See Mercury		
	San Francisco			See Lead-Zinc		
Iron						5.2.3.1; 5.2.3.2
	Iron Springs	C-ML	H/D	H	270 ha	
	Iron Springs	Rex	H/D	H	440 ha	
	Iron Springs	Burke	H/D	H	25 ha	
	Iron Springs	Duncan	H/D	H	25 ha	
	Iron Springs	Homestake	H/D	H	150 ha	
	Iron Springs	A&B	H/D	M	25 ha	
	Iron Springs	McCahill	H/D	M	25 ha	
	Iron Springs	Section 2	H/D	M	25 ha	
	Iron Springs	Section 9	H/D	M	25 ha	
	Iron Springs	Tip Top/ Excelsior	H/D	H	150 ha	
	Iron Peak		L/B	L	None	
	Rocky Range			See Copper		
Lead-Zinc						5.2.4.1; 5.2.4.2
	Bradshaw		L/B	L	25 ha	
	Lincoln		L/B	L	25 ha	
	San Francisco		M/C	M	100 ha	
	Star		M/C	L	25 ha	
	Washington		L/B	L	25 ha	
Mercury						5.2.5.1; 5.2.5.2
	Pink Knolls		M/C	L	50 ha	
	Blue Mountain		L/B	L	None	
	Bradshaw		L/B	L	None	
	Brimstone		L/B	L	None	
	San Francisco		L/B	L	None	
Molybdenum						5.2.6.1; 5.2.6.2
	Broken Ridge		H/B	H	None	
	Newton			See Uranium		
	Star			See Lead-Zinc		
	Washington-Indian Pk		M/A	M	None	
Tungsten						5.2.7.1; 5.2.7.2
	Granite		M/C	M	25 ha	
	Bradshaw		L/B	L	None	
	Broken Ridge		L/B	L	None	
	Lincoln		L/B	L	None	
	Newton		L/B	L	None	
	Pine Grove			See Molybdenum		
	Rocky Range			See Copper		
	San Francisco			See Copper		
	Star			See Lead-Zinc		
Uranium						5.2.8.1; 5.2.8.2
	Blawn Mountain		L/B	L	None	
	Newton		L/C	L	None	
	Blue Mountain		L/A	L	None	
	Broken Ridge		L/A	L	None	
	Pink Knolls		L/A	L	None	
	Stateline		L/A	L	None	

lack of additional veins limits the likelihood of significant development in the foreseeable future. The Confidence district is classified as L/B using the BLM mineral occurrence potential classification system and is rated low (L) for development potential (table 5.2.1.1, figure 5.2.2.1, figure 5.2.2.2).

Escalante District, Iron County

The history of significant past Ag production in the Escalante district and the reported occurrence of Ag in the mine's wall rocks, at depth, and in the mill tailings suggesting that the district is likely to see future exploration and development activity. The Escalante district is classified as H/D using the BLM mineral occurrence potential classification system. The Escalante district is rated high (H) for development potential (table 5.2.1.1, figure 5.2.2.1, figure 5.2.2.2).

Fortuna District, Beaver County

The relatively modest history of exploration and production in the Fortuna district is not encouraging for future development; however, the intriguing vein showings are likely to continue to spur continued exploration of the district's mineral potential. The Fortuna district is classified as M/C using the BLM mineral occurrence potential classification system and moderate (M) for development potential (table 5.2.1.1, figure 5.2.2.1, figure 5.2.2.2).

Gold Springs District, Iron County

The modest production history and results of current exploration are not suggestive of any immediate mineral development in the Gold Springs district. However, the extensive exposed nature of the veins and the ongoing exploration may suggest that the district continues to host additional mineralization. The Gold Springs district is classified as M/C using the BLM mineral occurrence potential classification system and moderate (M) for development potential (table 5.2.1.1, figure 5.2.2.1, figure 5.2.2.2).

Modena Area, Iron County

While the Modena area has seen no production, the prospect area has seen sporadic mineral exploration efforts and is currently held under unpatented mining claims. The Modena area is given a classification of L/B using the BLM mineral occurrence potential classification system and low (L) for development potential (table 5.2.1.1, figure 5.2.2.1, figure 5.2.2.2).

Newton District, Beaver County

The modest production history and lack of significant current exploration (although the principal areas are held under unpatented mining claims) in the Newton district is not suggestive that mineral development is likely to occur in the near term. The district is classified as M/C using the BLM mineral occurrence potential classification system and moderate (M) for development potential (table 5.2.1.1, figure 5.2.2.1, figure 5.2.2.2).

Stateline District, Iron County

The modest production history and lack of extensive current exploration are not suggestive of any immediate mineral development in the Stateline district. However, the extensive nature of the exposed veins and the presence of some ongoing exploration indicate that the district may host additional mineralization and is likely to be subjected to ongoing exploration activities. The Stateline district is classified as M/C using the BLM mineral occurrence potential classification system and moderate (M) for development potential (table 5.2.1.1, figure 5.2.2.1, figure 5.2.2.2).

Other Gold-Silver Districts

The Blue Mountain, Pink Knolls, and San Francisco districts have all had significant Au-Ag exploration efforts in the past half century, are currently covered by unpatented mining claims, and are likely to continue see additional exploration/development activities over the next twenty years. These districts are all classified as M/C using the BLM mineral occurrence potential classification system and moderate (M) for development potential (table 5.2.1.1, figure 5.2.2.1, figure 5.2.2.2).

5.2.3 Iron

Iron Springs district, Iron County

The Iron Springs (Pinto) mining district is the most productive Fe district in the western United States (about 90 million t [100 million st] of Fe ore) and still hosts significant Fe resources. The C-ML open-pit is currently in operation, producing at a rate of approximately 166,000 t (183,000 st) of high-grade (+53% Fe) direct shipping ore per month. All mineral resources discussed in the Iron Springs section of this report and tabulated in table 4.2.3.1 are classified as H/D using the BLM mineral occurrence potential classification system and high (H) or moderate (M) for development potential (table 5.2.1.1, figure 5.2.3.1, figure 5.2.3.2).

Iron Peak Area, Iron County

The Iron Peak area has no recorded production, has seen very little exploration in the last half century, and has only a token known mineral resource. Iron Peak is classified as L/B in the BLM mineral potential classification, is unlikely to see any physical disturbance in the next 20 years, and is rated low (L) for development potential (table 5.2.1.1, figure 5.2.3.1, figure 5.2.3.2).

5.2.4 Lead-Zinc

Bradshaw District, Beaver County

The mineral exploration/development potential of the Bradshaw district is considered to be low given the low level of past Pb-Zn production and apparent lack of recent exploration activity. However, most of the district and the pediment to the west are currently under claim and an exploration notice of intent to drill eight exploration holes has been filed. The Bradshaw district is classified as L/B for Pb-Zn using the BLM mineral occurrence potential classification system and low (L) for development potential (table 5.2.1.1, figure 5.2.4.1, figure 5.2.4.2).

Lincoln District, Beaver County

The Lincoln district is classified as L/B for Pb-Zn using the BLM mineral occurrence potential classification system and low (L) for development potential (table 5.2.1.1, figure 5.2.4.1, figure 5.2.4.2).

San Francisco District, Beaver County

The San Francisco district has been a significant Pb-Ag producer and has had considerable exploration efforts directed toward Pb-Zn-Ag sporadically over the last century. Nonetheless, this exploration has reported little success so that the future of Pb-Zn development in the near term is believed to be low. Nonetheless, the San Francisco district is rated M/C for Pb-Zn using the BLM mineral occurrence potential classification system and moderate (M) for development potential for the next 20 year period (table 5.2.1.1, figure 5.2.4.1, figure 5.2.4.2).

Star District, Beaver County

The overall exploration potential for Pb-Zn in the Star district is thought to be low. The district is likely to have sporadic exploration efforts continuing into the future, but is unlikely to see development as a result. The Star district is classified as M/C for Pb-Zn using the BLM mineral occurrence potential classification system and low (L) for development potential (table 5.2.1.1, figure 5.2.4.1, figure 5.2.4.2).

Washington District, Beaver and Washington Counties

The overall exploration potential for the Washington district is thought to be very low. The district may have sporadic exploration efforts continuing into the future, but is very unlikely to see development as a result. The Washington district is classified as L/B for Pb-Zn using the BLM mineral occurrence potential classification system and low (L) for development potential (table 5.2.1.1, figure 5.2.4.1, figure 5.2.4.2).

5.2.5 Mercury

Pink Knolls Area, Beaver and Iron Counties

The mineral exploration/development potential of the Cina Hg-S mine is considered to be moderate given the low level of past Hg production and apparent lack of current Hg exploration activity, but presence of a reported Hg resource. The Pink Knolls area is classified as M/C for Hg using the BLM mineral occurrence potential classification system and low (L) for development potential (table 5.2.1.1, figure 5.2.5.1, figure 5.2.5.2).

Other Mercury Districts

None of the other known Hg occurrences in the CCPA have apparent significant exploration/development potential. Mercury prospects or weak anomalies in the Blue Mountain district (Tar Claims), San Francisco district (Golden Reef mine), Bradshaw district (Cave mine), and Brimstone (Sulfur Knoll) are seen as unlikely targets for future Hg developments. The other Hg districts in the CCPA are all classified as L/B using the BLM mineral occurrence potential classification system and low (L) for development potential (table 5.2.1.1, figure 5.2.5.1, figure 5.2.5.2).

5.2.6 Molybdenum

Pine Grove District, Beaver County

The presence of a significant Mo resource in the Pine Grove district suggests the potential for development at some point in the future. However, there is no exploration in the district at present (September 2011) and the likelihood of development is deemed low in the near future, but high in the long term. The Pine Grove mineral resource is classified as H/D using the BLM mineral occurrence potential classification system and high (H) for development potential (table 5.2.1.1, figure 5.2.6.1, figure 5.2.6.2).

Broken Ridge Area, Iron County

The Broken Ridge breccia and the Mountain Spring Peak areas were not recognized until the late 1970s when a large, strong Mo-Sn-W anomaly in both rocks and stream sediment samples was discovered. However, no deep porphyry Mo exploration has been done on this target so the Broken Ridge area is given an H/B rating for mineral occurrence potential and high (H) for development potential (table 5.2.1.1, figure 5.2.6.1, figure 5.2.6.2).

Other Molybdenum Districts

The Blawn Wash, Newton, and Star districts are thought to have the potential for future porphyry Mo exploration, but the results of such work are considered too speculative to rate higher than M/A using the BLM mineral occurrence potential classification system and moderate (M) for development potential (table 5.2.1.1, figure 5.2.6.1, figure 5.2.6.2).

5.2.7 Tungsten

Granite District, Beaver County

The mineral exploration/development potential of the Granite district is considered to be moderate given the low level of past W production and apparent lack of current exploration activity, but presence of an inferred resource. The Granite district is classified as M/C for W using the BLM mineral occurrence potential classification system and moderate (M) for development potential (table 5.2.1.1, figure 5.2.7.1, figure 5.2.7.2).

Other Tungsten Districts

The Bradshaw, Broken Ridge, Lincoln, Newton, Pine Grove, Rocky Range, San Francisco, and Star districts all have known W minerals or geochemical anomalies. The mineral exploration/development potential of these other W districts is considered to be low given the very low level of past W production and apparent lack of current W exploration activity. These districts are classified as L/B for W using the BLM mineral occurrence potential classification system and low (L) for development potential (table 5.2.1.1, figure 5.2.7.1, figure 5.2.7.2).

5.2.8 Uranium

Blawn Mountain, Beaver County

The modest production history and lack of significant recent exploration (although the principal areas are held under unpatented mining claims) in the Blawn Mountain district is not suggestive that U mineral development is likely to occur in the near term. The district is classified as L/B for U using the BLM mineral occurrence potential classification system and low (L) for development potential (table 5.2.1.1, figure 5.2.8.1, figure 5.2.8.2).

Newton District, Beaver County

The modest production history and lack of significant recent exploration (although the principal areas are held under unpatented mining claims) in the Newton district is not suggestive that mineral development is likely to occur in the near term. The district is classified as L/C for U using the BLM mineral occurrence potential classification system and low (L) for development potential (table 5.2.1.1, figure 5.2.8.1, figure 5.2.8.2).

Other Uranium Districts

The other U districts discussed earlier include the Stateline, Broken Ridge, Pink Knolls, and Blue Mountain districts. None of these U districts have any recorded production and the likelihood of renewed U exploration and/or development in these districts is considered minimal. These districts are classified as low, with certainty level A using the BLM mineral occurrence potential classification system (L/A) and low (L) for development potential (table 5.2.1.1, figure 5.2.8.1, figure 5.2.8.2).

5.3 Salable Minerals[8]

5.3.1 Barite

The potential for occurrence of barite is rated as high with a certainty of D (H/D) at known localities. Mining districts where barite has been identified are rated as high with a certainty level of B (H/B) (table 5.3.1.1, figure 5.3.1.1).

Essentially no potential for development of barite exists in the CCPA, unless it is produced as a byproduct from a mine that is exploiting other commodities. Development potential for barite at known deposits and mining districts is rated as low (L) (figure 5.3.1.2).

5.3.2 Building Stone

Potential for occurrence is rated high with a certainty of D (H/D) at known building stone quarries. Potential for occurrence is rated as high with certainty level C (H/C) for host formations that have been mined within or near the CCPA (table 5.3.1.1, figure 5.3.2.1).

Continued development of building stone quarries is likely in the CCPA at similar levels to current development, therefore development potential is high (H) at known quarries. Development potential is moderate (M) at known host units (figure 5.3.2.2), except where limited by land use restirictions. Rapid urban growth of Cedar City or other cities to the south could potentially increase building stone demand and quarry development in the CCPA.

5.3.3 Common Clay

The potential for occurrence of common clay at known pits is high with a certainty of D (H/D). The potential for the occurrence of clays is high (H) in shale-bearing and lacustrine units in the CCPA. The certainty of occurrence is rated as B, as no known investigation of suitability of the units for any applications has occurred in the area (table 5.3.1.1, figure 5.3.3.1). The lack of historical exploration and minimal production in or near the CCPA indicates that development potential of common clay resources within the CCPA is low (L) (figure 5.3.3.2). Any development would likely be for local purposes and at a small scale.

5.3.4 Crushed Stone and Ballast

The potential for the occurrence of crushed stone and ballast deposits is rated as high with a certainty level of D (H/D) at known mines and prospects. Elsewhere in the CCPA where the proper host formations are present the potential for occurrence is rated high with a certainty level of C (H/C) (table 5.3.1.1, figure 5.3.4.1).

[8]Some of the commodities discussed under Salable Commodities maybe subject to location under the 1872 Mining Law or the “Common Vanities” Act of 1955. See Introduction, 1.2 Lands Involved, p. 23, for general discussion.

Consistent production at the Milford Quarry 1 indicates continued potential for development of crushed stone and ballast in the CCPA, and development potential is rated high (H) at known quarries. However, limited historical development elsewhere in the CCPA suggests future development will likely not expand significantly beyond current levels of development. Development potential is considered low (L) at proper host formations elsewhere in the CCPA for crushed stone (figure 5.3.4.2).

5.3.5 Fluorspar/Fluorite

The potential for occurrence of fluorite at the known mines and prospects is high with a certainty of D (H/D). The Washington and Blawn Mountain mining districts are rated high with a certainty of C (H/C), due to levels of past productivity. The mining districts containing fluorite occurrences, but with lower historical production levels, are considered moderate for potential of occurrence with a certainty of B (M/B) (table 5.3.1.1, figure 5.3.5.1).

The relatively small size and remoteness of the deposits in the CCPA will likely limit future development of fluorite resources. Lack of significant fluorite activity in the CCPA since the 1940s also suggests limited future development. However, if fluorspar prices remain high and continue to rise, exploration within the Washington and Blawn Mountain mining districts may occur. Stockpiles at the J.B. mine may also be recovered at some point in the future. Development potential within the Washington and Blawn Mountain mining districts is rated as moderate (M), and potential within other known fluorite districts is low (L) (figure 5.3.5.2). In areas, particularly in the Washington district, where there is overlap with restricted lands, development potential is low (L).

5.3.6 Gemstones

The potential for occurrence of gemstones is rated high with a certainty of D (H/D) at known mines and prospects (table 5.3.1.1, figure 5.3.6.1).

Given red beryl's rarity, additional development at the Ruby Violet mine is likely and development potential is rated as high (H). Small scale development of the Ruby Violet will continue to occur, and larger scale development is possible. Small scale development of Picasso marble and other gemstones will also continue to occur, likely intermittently. Development potential of the area around the Sliver mines is also rated as high (H). Development potential at other known gemstone mines or prospects is rated as moderate (M) (figure 5.3.6.2).

5.3.7 Gypsum

The potential for occurrence of gypsum is rated high with a certainty level of D (H/D) at past and current mines and prospects. Elsewhere within the Jurassic Carmel Formation (J1), the occurrence potential is also rated high but with a certainty of C (H/C). Potential for occurrence of gypsum in the Permian Toroweap Formation (P2) is rated moderate with a certainty level of B (M/B) (table 5.3.1.1, figure 5.3.7.1).

The development potential for gypsum deposits is mostly low (L) for a number of reasons: little historical extraction of gypsum has occurred in the CCPA, larger and better defined deposits occur elsewhere in Utah, and transportation from the better deposits in the CCPA would be difficult. Any development that occurs will likely be from the Carmel Formation (J1) in the Cedar Canyon area. However, production will probably be limited to local uses. Development potential of gypsum at known mines or prospects in the Cedar Canyon area is considered moderate (M), and development elsewhere is considered low (L) (figure 5.3.7.2).

5.3.8 High-Calcium Limestone and High-Magnesium Dolomite

The potential of occurrence for hical limestone and himag dolomite is rated as high with a certainty level of B (H/B) on host formations that are known to have hical limestone or himag dolomite elsewhere. Units with reported intervals of massive dolomite that have not produced from elsewhere are ranked as moderate with a certainty of A (M/A) (table 5.3.1.1, figure 5.3.8.1).

Development potential of hical limestone or himag dolomite is low (L) given the limited exploration and development in the past, and established, large-volume production to the north of the CCPA in the Cricket Mountains (figure 5.3.8.2). Any development would likely only be economic if production served local, small-scale end uses.

5.3.9 Kaolinite

The potential of occurrence for kaolinite deposits is rated as high with a certainty of D (H/D) at known mines and prospects. Altered areas with known kaolinite are rated as high with a certainty of C (H/C) (table 5.3.1.1, figure 5.3.9.1).

Kaolinite development will continue to occur within the CCPA. However, levels of development and production will be dependent upon current markets and development of new markets. Development potential at known mines and prospects is high (H), and is moderate (M) at alteration zones with known kaolinite (figure 5.3.9.2).

5.3.10 Lapidary Material

The potential for occurrence of lapidary material is high with a certainty of D (H/D) at known pits and prospects. Potential for occurrence of obsidian at Quaternary rhyolite flows is high with a certainty of C (H/C) (table 5.3.1.1, figure 5.3.10.1). Development potential is considered high (H) at known pits and prospects, and moderate (M) in Quaternary rhyolite (Qr) (figure 5.3.10.2). As in the past, development will continue only on a small scale, and will probably be intermittent.

5.3.11 Lightweight Aggregate

Potential for occurrence of known perlite and pumice quarries and prospects is rated as high with a certainty of D (H/D). Quarternary rhyolite (Qr) deposits, which host the majority of perlite and pumice quarries, are rated as high with a certainty of C (H/C). Occurrence potential for other volcanic units is rated as moderate with a certainty of B (M/B) (table 5.3.1.1, figure 5.3.11.1).

Some potential for development of lightweight aggregate exists in the CCPA, given recent activity. If development occurs, it would likely occur at the well-defined, large perlite resource at the North Pearl Queen mine. Development potential of lightweight aggregate is high (H) within the Quaternary rhyolite (Qr) at the Mineral Mountains, particularly at existing mines and prospects located there. At mines or prospects outside of Qr, development potential is moderate (M). At other areas of potential occurrence in the CCPA, development potential is low (L) (figure 5.3.11.2).

5.3.12 Sand and Gravel

The potential for occurrence of sand and gravel in the CCPA is rated as high with a certainty level of D (H/D) at known sand and gravel pits and prospects. Elsewhere in the CCPA where the proper host deposits are present, including the Bonneville and Provo shorelines, the occurrence potential is rated high with a certainty of C (H/C) (table 5.3.1.1, figure 5.3.12.1).

Development potential of sand and gravel is high (H) in the CCPA at existing pits and prospects, as well as in proper host deposits within 5 km (3.1 mi) of major transportation routes. Elsewhere, where proper host deposits are present, development potential is moderate (M) (figure 5.3.12.2), except where limited by land use restirictions.

5.3.13 Silica

The potential of occurrence for high-purity silica is rated as high with a certainty of D (H/D) where known quarries and prospects are located. Formations with known production in the CCPA, the Grand Castle Formation (K3), are rated as high with a certainty of C (H/C). The other formation with known purity elsewhere, the Eureka Quartzite (O) is rated as high with a certainty of B (H/B). Other formations hosting quartzite or sandstone are rated as moderate with certainty level A (M/A) (table 5.3.1.1, figure 5.3.13.1).

Development potential of silica is low (L) given lack of historical development and production (figure 5.3.13.2). Development will likely be limited to small volumes extracted from existing quarries.

5.3.14 Sulfur

The potential for occurrence of sulfur deposits in the CCPA is rated as high with a certainty of D (H/D) where deposits are known (table 5.3.1.1, figure 5.3.14.1). Although the Sulphurdale deposit represents a significant deposit of native sulfur, development potential is low (L) as the vast majority of currently produced sulfur is derived as a byproduct from other extractive industries (figure 5.3.14.2).

Table 5.3.1.1. CCPA Salable Mineral Occurrence and Development Potential.

Commodity	Area	Classification	Development	Disturbance	Figures
Barite				0 ha	5.3.1.1; 5.3.1.2
	Known occurrences	H/D	L		
	Mining districts with reported barite	H/B	L		
Building Stone				130 ha	5.3.2.1; 5.3.2.2
	Known quarries	H/D	H		
	Known host units	H/C	M		
Common Clay				20 ha	5.3.3.1; 5.3.3.2
	Known pits	H/D	L		
	Potential host units	H/B	L		
Crushed Stone and Ballast				120-160 ha	5.3.4.1; 5.3.4.2
	Known quarries and prospects	H/D	H		
	Potential host units	H/C	L		
Fluorite				25-50 ha	5.3.5.1; 5.3.5.2
	Known mines and prospects	H/D	M to L		
	Washington, Blawn Mtn districts	H/C	M		
	Other dist. w/ known fluor. occurrences	M/B	L		
Gemstones				25-40 ha	5.3.6.1; 5.3.6.2
	Known mines and prospects	H/D	H to M		
Gypsum				25 ha	5.3.7.1; 5.3.7.2
	Known mines and prospects	H/D	M to L		
	Unit J1 (known producer)	H/C	L		
	Unit P2	M/B	L		
High-Calcium Limestone and High-Magnesium Dolomite				20 ha	5.3.8.1; 5.3.8.2
	Known host units	H/B	L		
	Potential host units	M/A	L		
Kaolinite				25-100 ha	5.3.9.1; 5.3.9.2
	Known mines and prospects	H/D	H		
	Altered zones with reported kaolinite	H/C	M		
Lapidary Material				25 ha	5.3.10.1; 5.3.10.2
	Known pits and prospects	H/D	H		
	Quaternary Rhyolite (Qr)	H/C	M		
Lightweight Aggregate (Perlite, Pumice)				20-80 ha	5.3.11.1; 5.3.11.2
	Known mines and prospects	H/D	H to M		
	Quaternary Rhyolite (Qr)	H/C	H		
	Other volcanic units	M/B	L		
Sand and Gravel				250 ha	5.3.12.1; 5.3.12.2
	Known pits and prospects	H/D	H		
	Known and potential host units	H/C	M		
Silica				20 ha	5.3.13.1; 5.3.13.2
	Known quarries and prospects	H/D	L		
	Unit K3 (known producer in CCPA)	H/C	L		
	Unit O (known producer elsewhere)	H/B	L		
	Other potential host units	M/A	L		
Sulfur				20 ha	5.2.14.1; 5.2.14.2
	Known deposits	H/D	L		

6.0 REASONABLY FORESEEABLE DEVELOPMENT SCENARIO

6.1 Leasable Minerals

6.1.1 Oil, Gas, and Coal-bed Gas

Coal-bed gas is lumped together with conventional oil and gas since they are all essentially petroleum plays. Except for a small part of play number 1901 (Unconformity A), where there have been oil shows, seismic exploration, and oil and gas leasing (rated moderate), the rest of the play areas in the CCPA are rated as low for development potential in the next 20 years. Historical exploration in the CCPA area has been low, with only 20 exploration wells drilled in the past. Due to improvements in the understanding of petroleum systems, drilling practices, geophsical techniques for finding petroleum, and increases in demand and price for petroleum, the UGS anticipates that the next 20 years will see the drilling of approximately 16 new wildcat petroleum exploration wells in the CCPA. Play number 1901 is expected to see about eight of the new wells, play number 1902 (Late Paleozoic) will see roughly four new wells, and play numbers 2100 (Coal-bed Gas), 2106 (Permo-Triassic), and 2108 (Devonian-Pennsylvanian) will have a combined total of an estimated four new wells. Each well will require a pad and associated road involving 8.9 ha (22 ac) of disturbance, for a total disturbance of 142.4 ha (352 ac). Additional seismic exploration is anticipated to entail 2414 linear km (1500 mi), with an estimated disturbance level of 0.2 ha per km (0.8 ac per mi) for a total seismic disturbance of 487 ha (1204 ac). Combined, the petroleum exploration drilling and seismic activity will disturb 636 ha (1572 ac) of federal land in the CCPA. We expect that all of that disturbance, except for one well pad and associated road (8.9 ha [22 ac]), will be reclaimed during the planning period. That one well will be left open for further testing and evaluation at the end of the 20-year planning period.

6.1.2 Coal

There are various reasons the UGS does not anticipate any coal exploration or development activities in the CCPA within the 20-year planning horizon. First, the coal in the Kolob field of the CCPA has a high sulfur content (> 5%) compared to coal already produced in Utah or nearby states (≤ 1%). Also, the expected lack of any new coal-fired power plant construction in the region in the next 20 years will not require development of new coal resources in this field to supplement the adequate coal reserves of the Alton or central Utah coalfields for the next 20 years. However, coal exports are increasing off the west coast of the United States and Canada, and very high demand from Asian markets could lead to some unexpected interest in development of coal in the CCPA.

6.1.3 Geothermal

Table 5.1.4.1, after Berry and others (2009), presents estimates of the geothermal electrical generating potential for selected areas in the BLM's CCPA, including as yet undiscovered resource areas within the Escalante Desert. The potential estimates are based upon a number of underlying assumptions and qualifications and are meant to serve only as a planning tool. So much of future renewable energy development is dependent on the energy marketplace that it is difficult to predict development scenarios. However, based on announced plans, current exploration levels and interest in geothermal development, it is possible that over the next 20 years the identified geothermal areas within the CCPA will experience expansion of geothermal generating capacity by as much as 90 MW. Along with this would include the drilling of 25 to 42 new production/injection wells. Below is a summary of these development projections:

- PacifiCorp/Rocky Mountain Power have indicated plans to eventually double the size of their existing facility (37 MW gross) at **Roosevelt Hot Springs** to about 75 MW gross capacity. Such expansion may require seven additional production and injection wells (assumes 7.5 MW per production well), plus additional roads and distribution lines.

- Enel North America has indicated that they plan to initially develop a binary geothermal power facility at **Cove Fort-Sulphurdale** geothermal area somewhere between 15 to 20 MW in generating capacity with exact expansion plans yet to be determined. Enel is reported to have dismantled the old plant with the intent to build a new binary generation facilities in roughly 17 MW increments. Possibly as many as six additional production/injection wells have been completed since Enel acquired the property and facilities. It is expected that an additional six to 12 wells may be required to expand to 35 MW gross capacity (assumes 3 MW per production well), plus additional roads and distribution lines.

- Although no plans have been made public for expansion at **Thermo** geothermal area from the currently installed 10 MW gross capacity, several companies now have land positions there. In April of 2011, Raser Technologies filed Chapter 11 documents in U.S. Bankruptcy Court seeking protection through a restructuring agreement with bondholders and secured creditors. The company has reportedly re-emerged as Cyrq Energy. It does not seem unreasonable, though, to expect the gross capacity at Thermo to expand to 25 MW within the next 20 years, given that other developers also have land positions in the area . An additional five to eight production/injection wells may be required for an expansion (assumes 3 MW per production well), plus additional roads and distribution lines.

- Although the resource is still somewhat undefined at **Newcastle** geothermal area, and no geothermal power generation is currently installed, the resource may eventually be developed for power generation in the future. It does not seem unreasonable to estimate a binary power facility of 5 to 10 MW gross installed generation capacity within the next 20 years. A well field of five to 10 exploration/production/injection wells may be required (assumes 2 MW per production well), plus additional roads and distribution lines.

- Geothermal power generation possibilities in the **Beryl** area are only a guess at this stage as more drilling information will be required. An exploratory drilling program here may consist of two to five wells over the next 20 years, however most land in the Beryl-Enterprise area is privately held, so development here would probably take place on private parcels.

Thus, for all the areas mentioned above there would be a maximum total of 42 new wells, plus access road and distribution line, each with an estimated disturbance of about 1.6 ha (4 ac) for a total disturbance of 67.2 ha (168 ac). New power plant or plant additions are estimated at the Roosevelt, Cove Fort-Sulphurdale, Thermo, and Newcastle areas with an estimated disturbance per plant of 21.2 ha (53 ac) for a total plant disturbance of 84.8 ha (212 ac) in the next 20 years in the CCPA. Total disturbance from geothermal drilling and plant construction is estimated to be 153 ha (380 ac).

6.1.5 Potash (Alunite)

Any potash-related disturbance will be from alunite extraction. Exploration for alunite will certainly occur in the next 20 years, and the possibility of alunite mining exists. Any mining would likely take place at the Blawn Wash deposit. Development may occur at many levels, and a rough estimate of disturbance is 25 to 160 ha (62 to 400 ac; table 5.1.5.1).

6.2 Locatable Minerals

6.2.1 Copper

Beaver Lake District, Beaver County

The Beaver Lake mining district currently has the permitted, open-pit, OK Cu mine and an adjoining flotation mill, but as of October 2011, both are in bankruptcy and idle. The area of disturbance associated with Cu exploration, development, and extraction in the Beaver Lake district is likely to range from 200 to 300 ha (490 to 740 ac), depending on the type (underground or open pit) of future mineral development (table 5.2.1.1).

Rocky Range, Beaver County

As of October 2011, the Rocky Range has a permitted, open-pit, Cu mine at Hidden Treasure, which is in bankruptcy and idle. The extent of the future Cu development in the Rocky Range is broadly estimated at between 200 and 500 ha (490 to 1240 ac) depending on which of the known deposits are developed and whether the mining is by open-pit or underground methods (table 5.2.1.1).

San Francisco District, Beaver County

The anticipated future area of disturbance associated with Cu mineral exploration, development, and extraction in the San Francisco district could range from 200 to 800 ha (490 to 1980 ac) depending on the size and style (underground or open-pit) of development (table 5.2.1.1).

Star District, Beaver County

The anticipated disturbance in the Star district for Cu exploration is likely to be approximately 30 ha (74 acres) in the next 20 years (table 5.2.1.1).

6.2.2 Gold-Silver

Antelope Range, Iron County

A nominal future disturbance in the Antelope Range for Au-Ag is estimated at 25 ha (62 ac) or less, primarily based on a continuing series of Au-Ag exploration programs over the next 20 years (table 5.2.1.1).

Confidence District, Iron County

A nominal estimated disturbance in the Confidence – Eagle Valley district for Au-Ag is likely to be 25 ha (62 ac) or less in the next 20 years based principally on repeated Au-Ag exploration programs (table 5.2.1.1).

Escalante District, Iron County

The total estimated disturbance for a mine and mill operation at the Escalante Ag mine in the next 20 years would be approximately 200 ha (490 ac) based on the potential exploration and development of new resources and/or reworking the existing mine tailings (table 5.2.1.1).

Fortuna District, Beaver County

The estimated disturbance for Au-Ag in the Fortuna district is approximately 50 ha (124 ac) in the next 20 years, primarily based on a series of Au-Ag exploration programs over the next two decades, but also on the possible development or some new Au-Ag resources (table 5.2.1.1).

Gold Springs District, Iron County

A crude forecast of future disturbance for Au-Ag in the Gold Springs district is likely to be roughly 50 ha (124 ac). This estimate is based primarily on a series of exploration programs over the next 20 years, but also on the possible development or some new Au-Ag resources (table 5.2.1.1).

Modena Area, Iron County

Nominal disturbance in the Modena area is estimated for Au-Ag at about 25 ha (62 ac) or less in the next 20 years, based principally on limited new Au-Ag exploration programs (table 5.2.1.1).

Newton District, Beaver County

A crude forecast for future Au-Ag exploration and development disturbance in the Newton district is approximately 50 ha (124 acres). This estimate is primarily based on a series of Au-Ag exploration programs over the next two decades, but also on the possible development or some new Au-Ag resources (table 5.2.1.1).

Stateline District, Iron County

The crudely forecast disturbance for Au-Ag in the Stateline district is likely to be about 50 ha (124 ac) in the next 20 years, based on a series of exploration programs and some nominal development activity (table 5.2.1.1).

6.2.3 Iron

Iron Springs District, Iron County

The surface disturbance at the C-ML open-pit Fe operation is very roughly 70 ha (173 acres) for the open-pit mine itself, with a total area of disturbance of 200 ha (490 ac) for the mine, dumps, milling, ancillary facilities, and tailings in the next 20 years (table 5.2.1.1).

The surface disturbance anticipated in the next two decades for an open-pit operation at the Rex Fe deposit is very roughly estimated at 120 ha (300 ac) for the mine itself, and a total area disturbed of 300 ha (740 ac) for mine, dumps, and associated facilities. A new mill and tailings pond would impact an additional estimated 140 ha (350 ac).

The future surface disturbances in the next 20 years for the other known Fe resources in the Iron Springs district are estimated at 25 ha (62 ac) at the Burke, 25 ha (62 ac) at the Duncan, 150 ha (370 ac) at the Homestake, 25 ha (62 ac) at the A&B, 25 ha (62 ac) at the McCahill, 25 ha (62 ac) at the Section 2, 25 ha (62 ac) at the Section 9, and 50 ha (124 ac) at the Tip Top and Excelsior mines. Much of this development is expected to occur on private land, e.g. patented mining claims.

Iron Peak Area, Iron County

The Iron Peak resources are not large enough for steel industry use and no surface disturbance is anticipated (0 ha/ac) in the next two decades.

6.2.4 Lead-Zinc

Bradshaw District, Beaver County

A nominal future disturbance in the Bradshaw district for Pb-Zn is estimated at 25 ha (62 ac) or less, predicated on a series of exploration programs in the next two decades (table 5.2.1.1).

Lincoln District, Beaver County

A nominal disturbance in the Lincoln district for Pb-Zn is estimated to be 25 ha (62 ac) or less in the next 20 years, based on the likelihood of a series of exploration programs.

San Francisco District, Beaver County

The future disturbance for Pb-Zn in the San Francisco district is crudely estimated at about 100 ha (250 ac) based on a combination of exploration programs and some mineral development activity in the next 20 years.

Star District, Beaver County

Estimated disturbance in the Star district for Pb-Zn exploration and development is likely to be 25 ha (62 ac) or less in the next 20 years, largely as a result of minor exploration programs.

Washington District, Beaver and Washington Counties

A nominal amount of disturbance in the Star district for two decades of Pb-Zn exploration and development is estimated at about 25 ha (62 acres) or less resulting primarily from a series of minor exploration programs.

6.2.5 Mercury

Pink Knolls Area, Beaver and Iron Counties

The crude forecast of disturbance for Hg exploration and development in the Pink Knolls area is likely to be about 50 ha (124 ac) in the next 20 years. Some of this work is likely to occur in conjunction with Au-Ag programs (table 5.2.1.1).

6.2.6 Molybdenum

Pine Grove District, Beaver County

The future area of disturbance associated with Mo exploration, development, and extraction in the Pine Grove district in the next 20 years could range from 200 to 400 ha (490 to 990 ac). Since no work is currently being done on the property, this disturbance is not likely to occur in the near term (table 5.2.1.1).

Broken Ridge Area, Iron County

The complete lack of historic production and deep porphyry exploration in the area does not suggest a high likelihood for development in the near term. However, these factors are offset by the favorable exploration potential for a deep, Climax porphyry Mo deposit. Further future exploration and drilling on this target are seen as inevitable so the Broken Ridge area is given an estimated area of disturbance of 100 ha (250 ac) in the next two decades.

Other Molydenum Districts

Several other districts in the CCPA have recognized Mo mineralization, like the Star Range, or have potential deep, underlying porphyry Mo systems, including the Blawn Wash and Newton mining districts. However, none of these areas have realized previous Mo production. Many of these other possible Mo districts are given an area of disturbance under another commodity, but none are expected here to have disturbance for Mo alone in the next 20 years (0 ha [0 ac]).

6.2.7 Tungsten

Granite District, Beaver County

A nominal disturbance area in the Granite district for W exploration and development is estimated at 25 ha (62 ac) or less in the next 20 years based primarily on a series of drilling campaigns (table 5.2.1.1).

Other Tungsten Districts

The Bradshaw, Broken Ridge, Lincoln, Pine Grove, Rocky Range, San Francisco, and Star mining districts all have known W occurrences. However, none of these districts have any significant recognized W mineral resources. Some of these other W districts are given an area of disturbance under another commodity, but none are given an estimated area of disturbance in the next two decades for W here (0 ha/ac).

6.2.8 Uranium

Blawn Mountain, Beaver County

There is no anticipated disturbance in the Blawn Mountain district for U exploration or development (0 ha/ac) in the next 20 years (table 5.2.1.1).

Newton District, Beaver County

There is no anticipated future disturbance in the Newton district for U exploration or development (0 ha/ac) in the next two decades.

Other Uranium Districts

Several other districts in the CCPA have U prospects or occurrences, including the Blue Mountain, Broken Ridge, Pink Knolls, and Stateline districts; however, none of these other districts have any recorded U production or resources. Some of these other U-bearing districts are given an area of disturbance under another commodity, but none is given a separate area here for U (0 ha/ac) in the next 20 years.

6.3 Salable Minerals[9]

6.3.1 Barite

Any future barite production will only be as a byproduct in conjunction with production of another mineral, and therefore no disturbance is projected related to barite (table 5.1.5.1).

6.3.2 Building Stone

Development of building stone within the CCPA will continue at current or increased levels over the next 20 years. Disturbance is roughly estimated to be from 5 to 8 ha (12 to 20 ac) per year for a total of about 130 ha (320 ac) over the next 20 years (table 5.1.5.1).

6.3.3 Common Clay

Little common clay exploration or development activity is expected in the CCPA in the next 20 years. Minor extraction is possible for local purposes, but disturbance will likely not exceed 20 ha (49 ac; table 5.1.5.1).

6.3.4 Crushed Stone and Ballast

Crushed stone and ballast development and production are expected to continue at current or slightly increased levels over the next 20 years. Approximately 6 to 8 ha (15 to 20 ac) of disturbance are expected to occur each year for a 20-year total of 120 to 160 ha (300 to 400 ac; table 5.1.5.1). Much, if not all, of the disturbance will likely come from continued ballast production in the Rocky Range.

6.3.5 Fluorite/Fluorspar

Significant development of fluorite in the next 20 years is unlikely in the CCPA. Minimal activity has occurred in the CCPA since the 1940s, and the small size and remoteness of the deposits will likely limit any future development. However, if fluorspar prices continue to rise, exploration may occur within the mining districts where there are known fluorite occurrences, particularly the Washington and Blawn Mountain districts. Also, stockpiles at the J.B. mine may be recovered in the near future. Estimated disturbance for the CCPA is from 25 to 50 ha (62 to 124 ac; table 5.1.5.1).

6.3.6 Gemstones

Historically and presently, red beryl and Picasso marble are the most well-known gem materials within the CCPA, and future development will likely involve both red beryl and marble. Small-scale development will continue to occur for each gem material, and larger-scale

[9]Some of the commodities discussed under Salable Commodities maybe subject to location under the 1872 Mining Law or the "Common Vanities" Act of 1955. See Introduction, 1.2 Lands Involved, p. 23, for general discussion.

development is possible for red beryl in and around the Ruby Violet mine. Disturbance is estimated to range from 25 to 40 ha (62 to 99 ac) over the next 20 years (table 5.1.5.1).

6.3.7 Gypsum

Small-scale gypsum exploration and development is likely over the next 20 years. Any gypsum activity will focus on the Jurassic Carmel Formation (J1), and any extraction will likely be from the Cedar Canyon area for local uses. Disturbance will likely not exceed 25 ha (62 ac; table 5.1.5.1).

6.3.8 High-Calcium Limestone and High-Magnesium Dolomite

Little hical limestone or himag dolomite exploration or development is expected for the CCPA over the next 20 years. Any development of hical limestone or himag dolomite would likely be small amounts for local use, and any disturbance is estimated to be less than 20 ha (49 ac; table 5.1.5.1).

6.3.9 Kaolinite

Continued development of kaolinite is likely to occur in the CCPA over the next 20 years. Existing quarries are likely to continue at the same level of production should existing markets remain and there is no development of new markets. Production of kaolinite as cement raw material from the Sandy Wash 4 quarry may be limited due to unacceptable levels of mercury in the rock, which is problematic for the cement industry. Disturbance activities might range from 25 to 100 ha (62 to 250 ac; table 5.1.5.1).

6.3.10 Lapidary Material

Limited development is likely for lapidary material within the CCPA. While large volumes of material will not be mined, small amounts will be taken intermittently from known and, perhaps, new locations. Disturbance is estimated to be about 25 ha (62 ac) over the next 20 years (table 5.1.5.1).

6.3.11 Lightweight Aggregate

Potential for development of perlite and pumice exists in the CCPA. The well-defined and large resource at the North Pearl Queen mine would be an obvious target for potential developers if perlite demand increases as the construction industry recovers. Depending upon future demand, exploration and development disturbance for the next 20 years could be between 20 and 80 ha (49 to 198 ac; table 5.1.5.1).

6.3.12 Sand and Gravel

Sand and gravel development will likely continue at current or slightly increased levels within the CCPA for the next 20 years. An estimated 10 ha (15 ac) per year for the first 10 years and 15 ha (37 ac) per year for the last 10 years will be disturbed, for a total of 250 ha (620 ac;

table 5.1.5.1). Development will continue to be focused around major transportation corridors, particularly near Interstate 15, county roads, and Cedar City.

6.3.13 Silica

Development of high-purity silica deposits will be limited in the CCPA, as it was in the past. The remoteness of the many potential deposits and the lack of local demand will limit future development. Disturbance is not expected to exceed 20 ha (49 acres) over the next 20 years (table 5.1.5.1).

6.3.14 Sulfur

Development potential in the CCPA is low because the vast majority of the world's sulfur is produced as a low-cost byproduct, production of sulfur as a primary commodity is unlikely. Any exploration likely to occur would be at the Sulphurdale deposit, and disturbance is expected to be less than 20 ha (49 ac; table 5.1.5.1) in the next 20 years; however, such efforts would have to compete with geothermal development in the same area.

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APPENDIX A. BLM MINERAL OCCURRENCE POTENTIAL AND UGS DEVELOPMENT POTENTIAL CLASSIFICATION SYSTEMS
(from BLM Manual 3031)

BLM Potential for Occurrence Rating Scheme

H: The geologic environment, the inferred geologic process, the reported mineral occurrences and/or valid geochemical/geophysical anomaly, and the known mines or deposits indicate high potential for accumulation of mineral resources. The known mines and deposits do not have to be within the area that is being classified, but have to be within the same type of geologic environment.

M: The geologic environment, the inferred geologic process, the reported mineral occurrences or valid geochemical/geophysical anomaly indicates moderate potential for accumulation of mineral resources.

L: The geologic environment and the inferred geologic process indicate low potential for accumulation of mineral resources.

O: The geologic environment, the inferred geologic process, and the lack of mineral occurrences do not indicate potential for accumulation of mineral resources.

ND: Mineral potential is not determined due to the lack of useful data. This notation does not require a level of certainty qualifier.

BLM Certainty of Occurrence Rating Scheme

A: The available data are insufficient and/or cannot be considered as direct or indirect evidence to support or refute the possible existence of mineral resources within the respective area.

B: The available data provide indirect evidence to support or refute the possible existence of mineral resources.

C: The available data provide direct evidence but are quantitatively minimal to support or refute the possible existence of mineral resources.

D: The available data provide abundant direct evidence and indirect evidence to support or refute the possible existence of mineral resources.

NONE: No data exist to prove or disprove the existence of economic deposits of petroleum or carbon dioxide in the play area reservoirs.

(Note: the determination of “no potential (O)” for specific commodities implies O/D.)

BLM Mineral Occurrence Potential Classification System.

			Certainty of Occurrence			
		High	←			None
		D	C	B	A	None
Potential for Occurrence	High	H	**H/D**	H/C	H/B	H/A	None
	Medium	M	M/D	M/C	M/B	M/A	None
	Low	L	L/D	L/C	L/B	L/A	None
	None	O	O/D	O/D	O/D	O/D	None
	ND*	ND	ND	ND	ND	ND	ND

* Not determined

UGS Potential for Development Rating Scheme

High (H): The geologic environment, the inferred geologic process, the reported mineral occurrences and/or valid geochemical/geophysical anomaly, the known mines or deposits, and market factors indicate high potential for development of mineral resources. The known mines and deposits do not have to be within the area that is being classified, but have to be within the same type of geologic environment.

Moderate (M): The geologic environment, the inferred geologic process, the reported mineral occurrences or valid geochemical/geophysical anomaly, and market factors indicate moderate potential for development of mineral resources.

Low (L): The geologic environment, the inferred geologic process, and market factors indicate low potential for accumulation of mineral resources.

None (O): The geologic environment, the inferred geologic process, the lack of mineral occurrences, and lack of positive market factors do not indicate potential for development of mineral resources.

Not Determined (ND): Mineral development potential is not determined due to the lack of useful data.

Although the dvelopment potential ratings are made on the basis of reasonable market assupmptions at the time of their formulation, none of the above development potential ratings are given a level of certainty qualifier because future development potential is subject to too much market uncertaiinty beyond a few years time from the date of prediction.

APPENDIX B. OIL AND GAS FIELD-SIZE CLASSIFICATION

Field Size	Gas, trillion cubic ft (ultimate recovery)	Oil, millions of bbls (ultimate recovery)
Giant	>5 to 50	>500 to 5,000
Major	>1 to 5	>100 to 500
Large	>0.5 to 1	>50 to 100
Medium	>0.25 to 0.5	>25 to 50
Small	>0.1 to 0.25	>10 to 25
Very Small	>0.01 to 0.1	>1 to 10
Tiny	>0.001 to 0.01	>0.1 to 1
Insignificant	≤ 0.001	≤ 0.1

BLM Mineral Occurrence Potential Classification System.

			Certainty of Occurrence				
			High ←				None
			D	C	B	A	None
Potential for Occurrence	High	H	**H/D**	H/C	H/B	H/A	None
	Medium	M	M/D	M/C	M/B	M/A	None
	Low	L	L/D	L/C	L/B	L/A	None
	None	O	O/D	O/D	O/D	O/D	None
	ND*	ND	ND	ND	ND	ND	ND

* Not determined

UGS Potential for Development Rating Scheme

High (H): The geologic environment, the inferred geologic process, the reported mineral occurrences and/or valid geochemical/geophysical anomaly, the known mines or deposits, and market factors indicate high potential for development of mineral resources. The known mines and deposits do not have to be within the area that is being classified, but have to be within the same type of geologic environment.

Moderate (M): The geologic environment, the inferred geologic process, the reported mineral occurrences or valid geochemical/geophysical anomaly, and market factors indicate moderate potential for development of mineral resources.

Low (L): The geologic environment, the inferred geologic process, and market factors indicate low potential for accumulation of mineral resources.

None (O): The geologic environment, the inferred geologic process, the lack of mineral occurrences, and lack of positive market factors do not indicate potential for development of mineral resources.

Not Determined (ND): Mineral development potential is not determined due to the lack of useful data.

Although the dvelopment potential ratings are made on the basis of reasonable market assupmptions at the time of their formulation, none of the above development potential ratings are given a level of certainty qualifier because future development potential is subject to too much market uncertaiinty beyond a few years time from the date of prediction.

APPENDIX B. OIL AND GAS FIELD-SIZE CLASSIFICATION

Field Size	Gas, trillion cubic ft (ULTIMATE RECOVERY)	Oil, millions of bbls (ULTIMATE RECOVERY)
Giant	>5 to 50	>500 to 5,000
Major	>1 to 5	>100 to 500
Large	>0.5 to 1	>50 to 100
Medium	>0.25 to 0.5	>25 to 50
Small	>0.1 to 0.25	>10 to 25
Very Small	>0.01 to 0.1	>1 to 10
Tiny	>0.001 to 0.01	>0.1 to 1
Insignificant	$\leq$ 0.001	$\leq$ 0.1

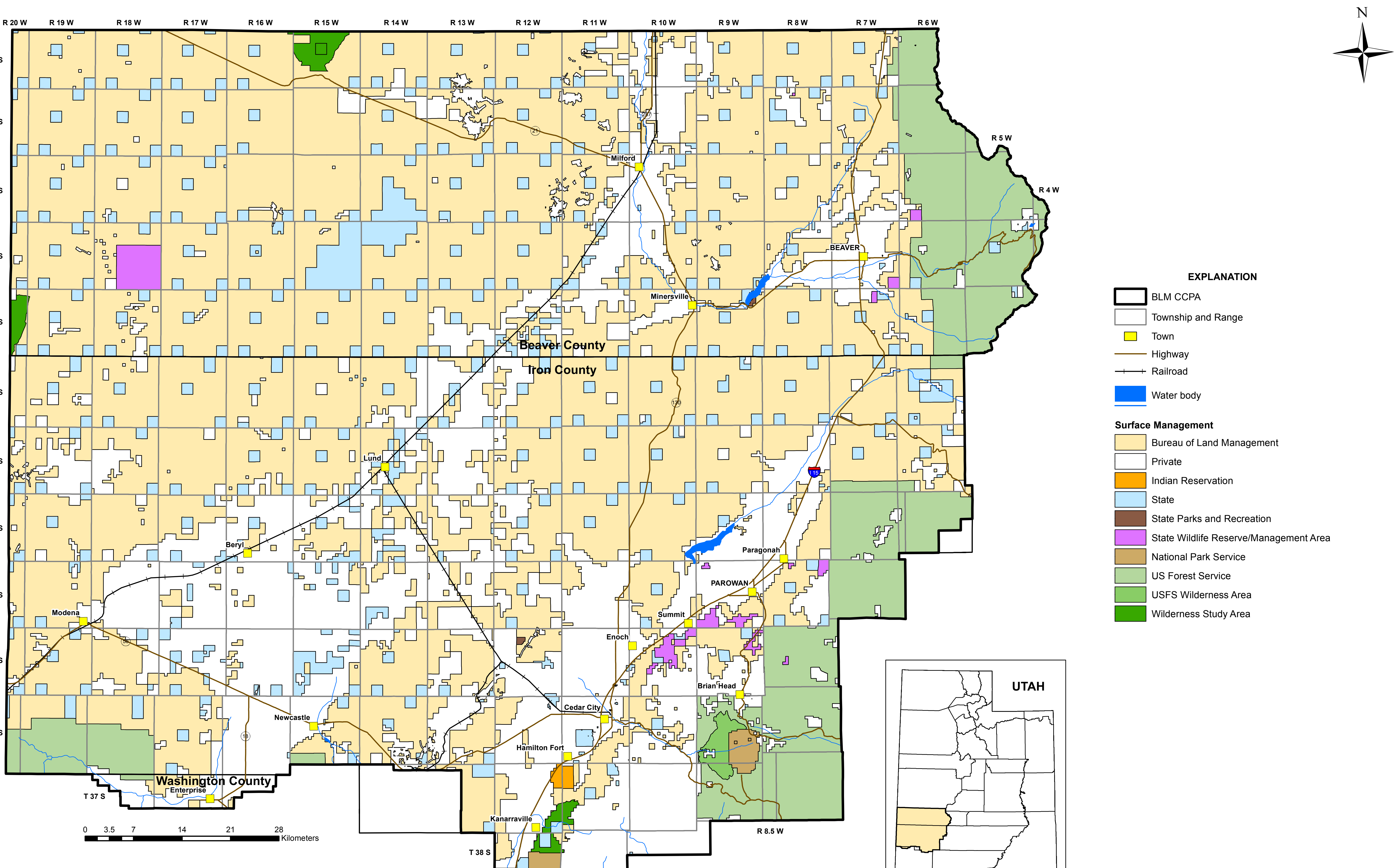


Figure 1.2.1. BLM Cedar City planning area surface management status.

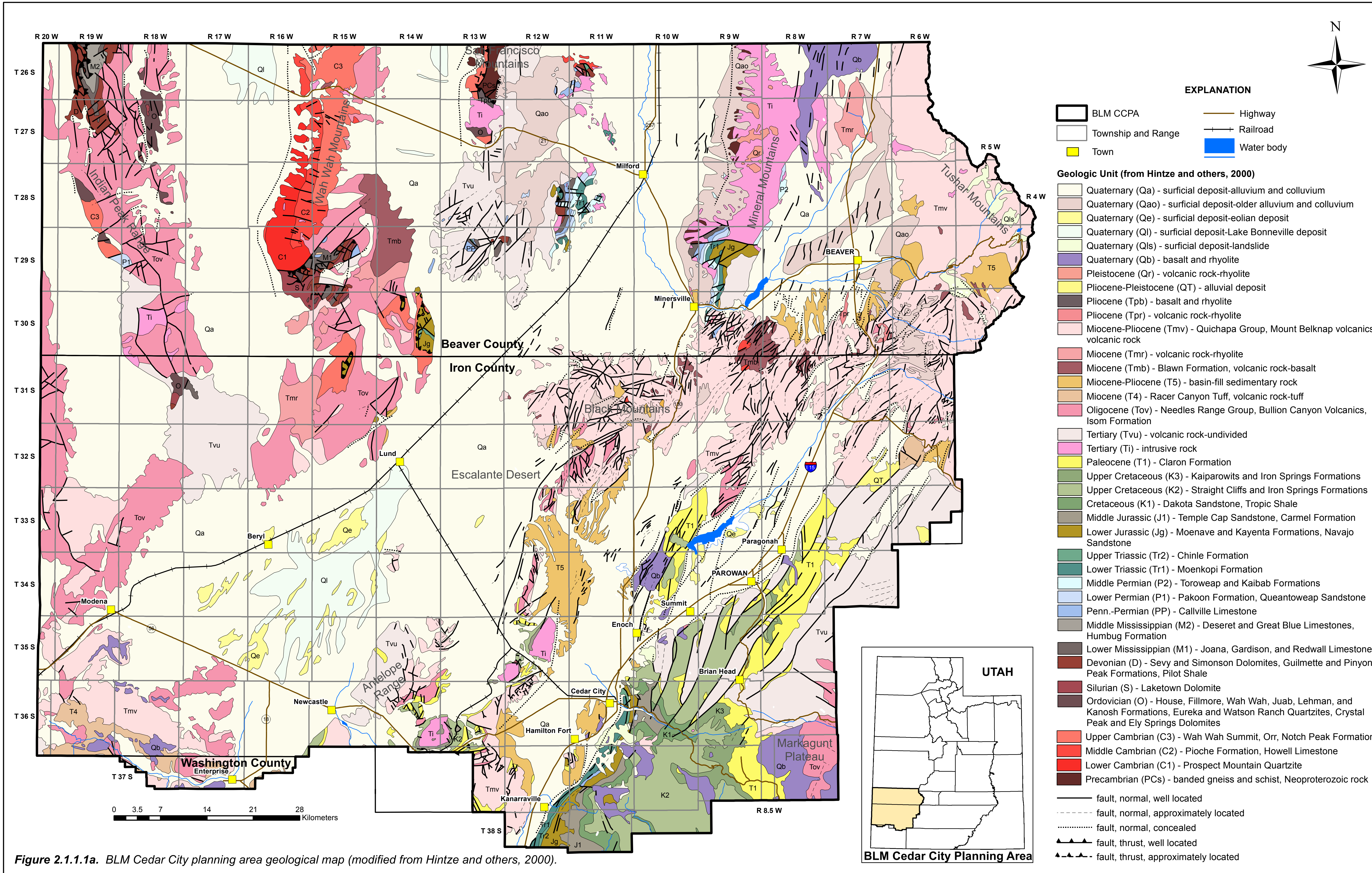


Figure 2.1.1.1a. BLM Cedar City planning area geological map (modified from Hintze and others, 2000).

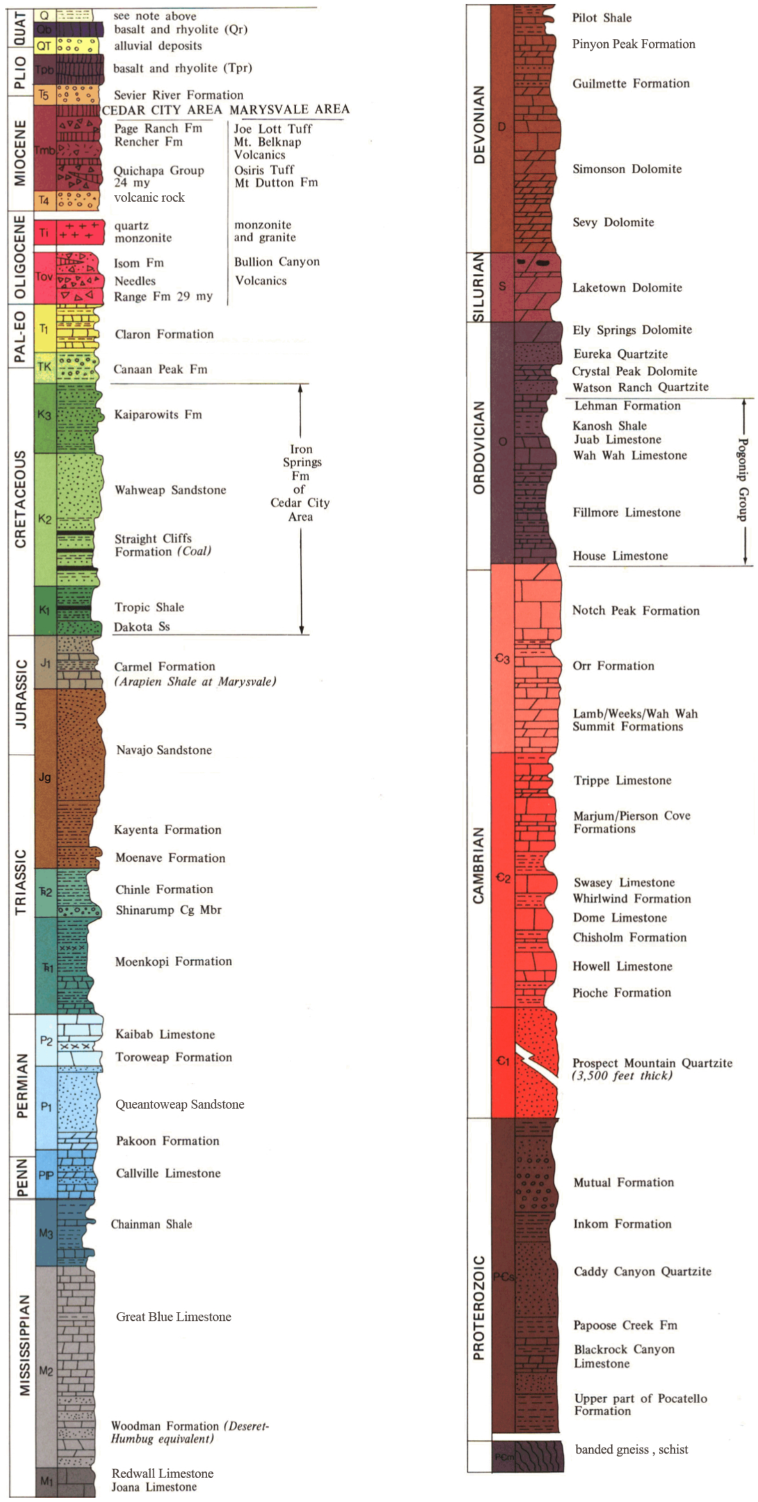


Figure 2.1.1.1b. *BLM Cedar City planning area stratigraphic column (modified from Hintze and others, 2000).*

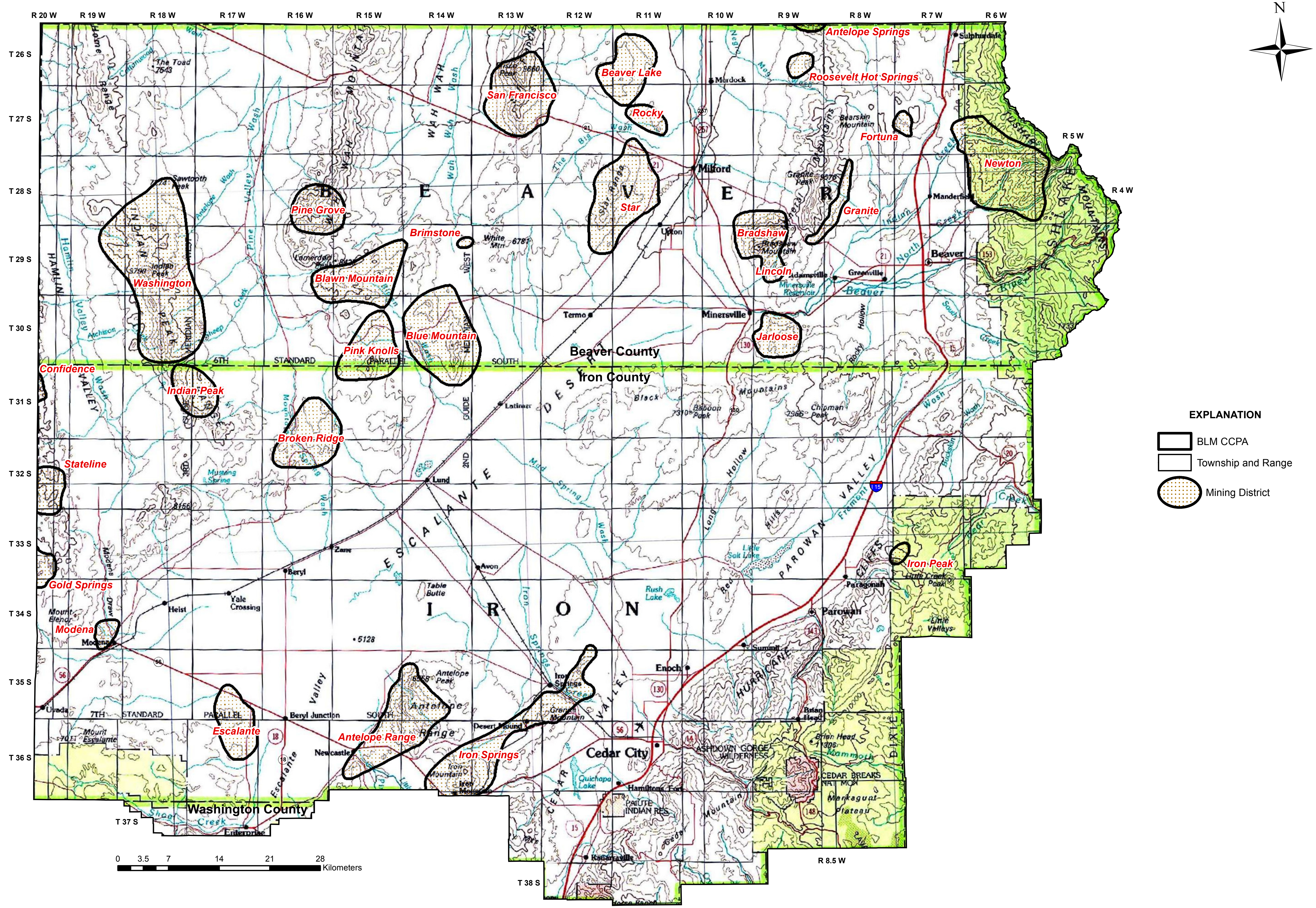


Figure 2.1.12.1. *BLM Cedar City planning area mining districts.*

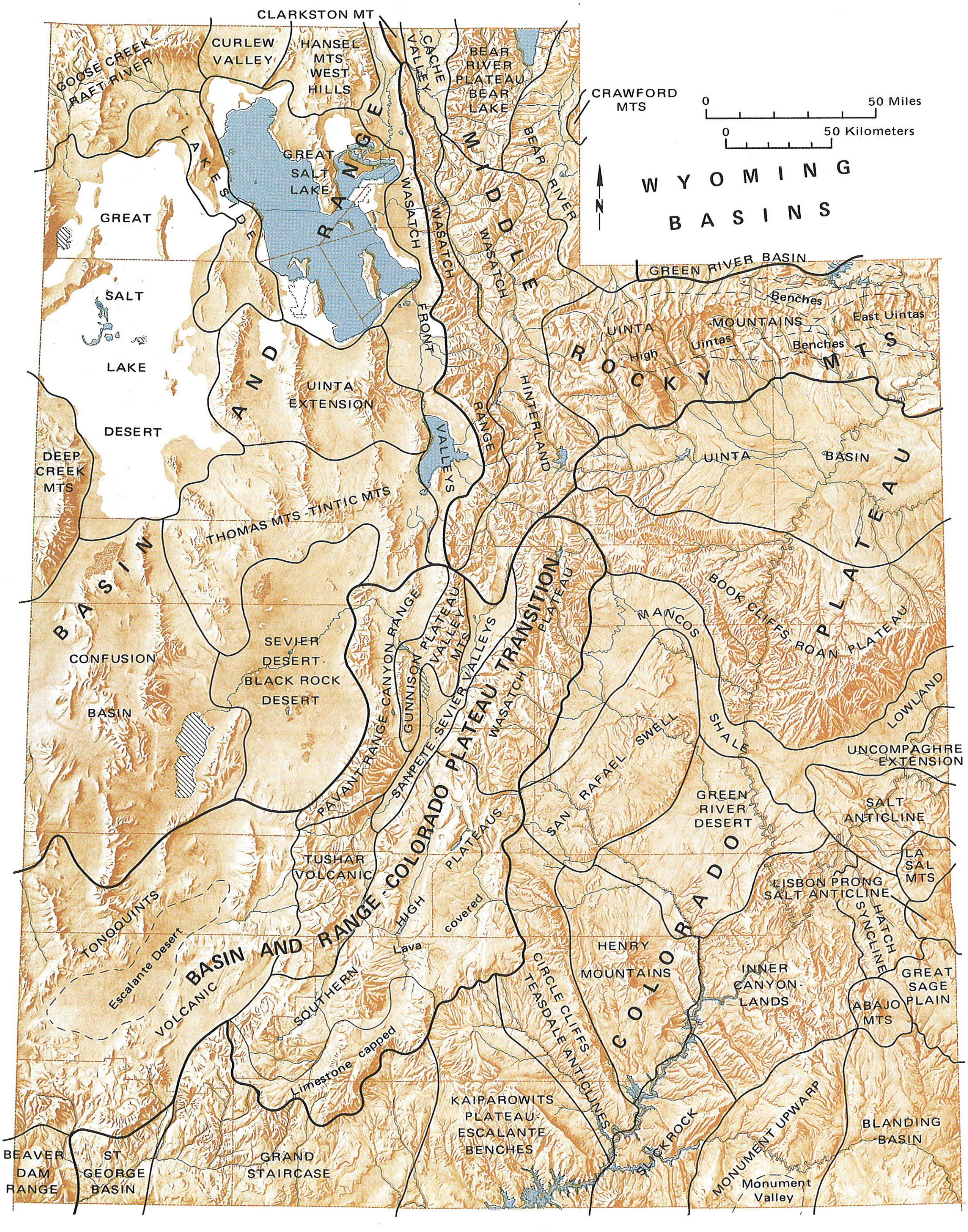


Figure 2.2.1. *Physiographic province setting of the BLM Cedar City planning area.*

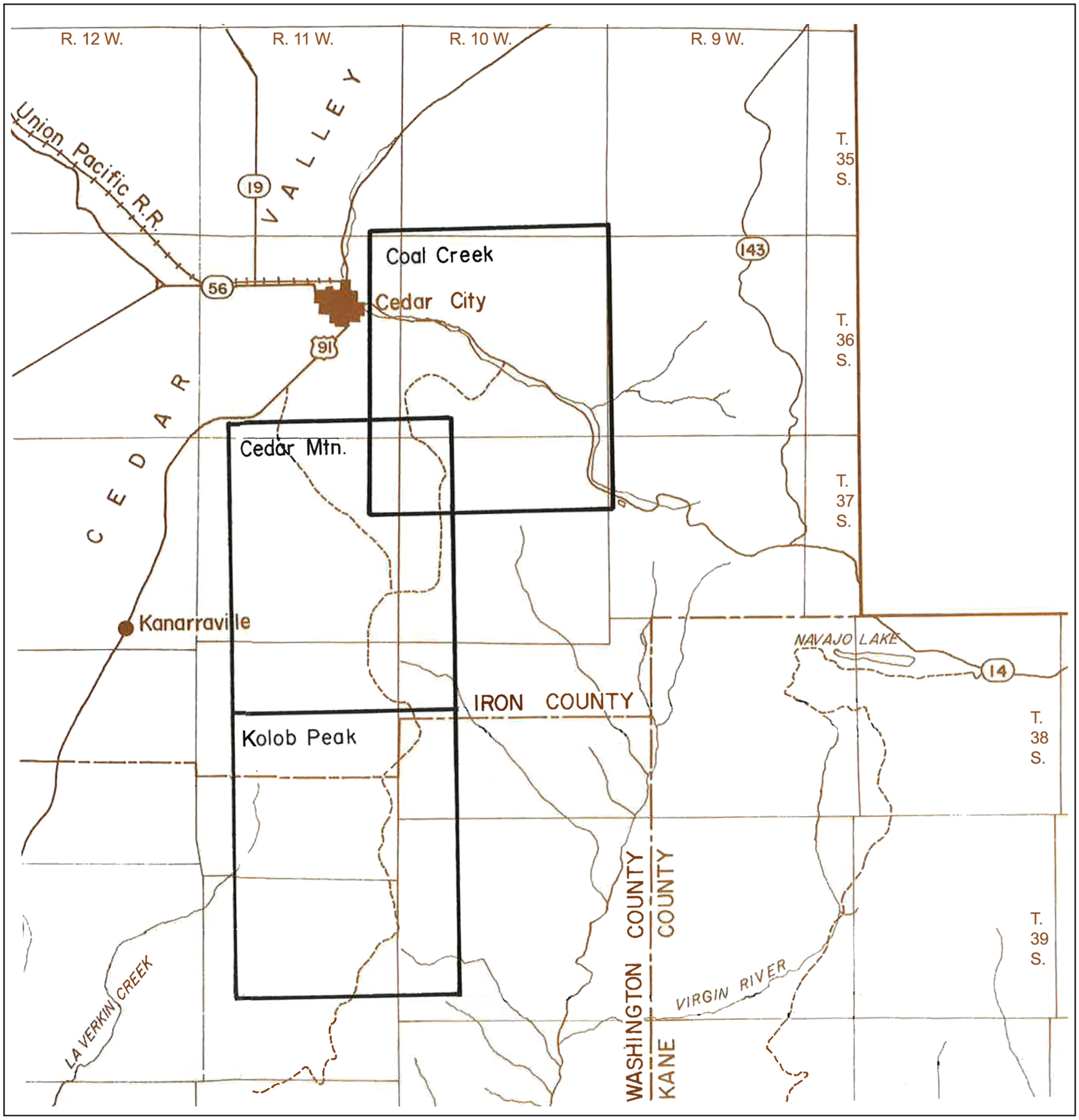


Figure 3.1.3.1. *Location of coal quadrangles studied by Doelling and Graham (1972).*

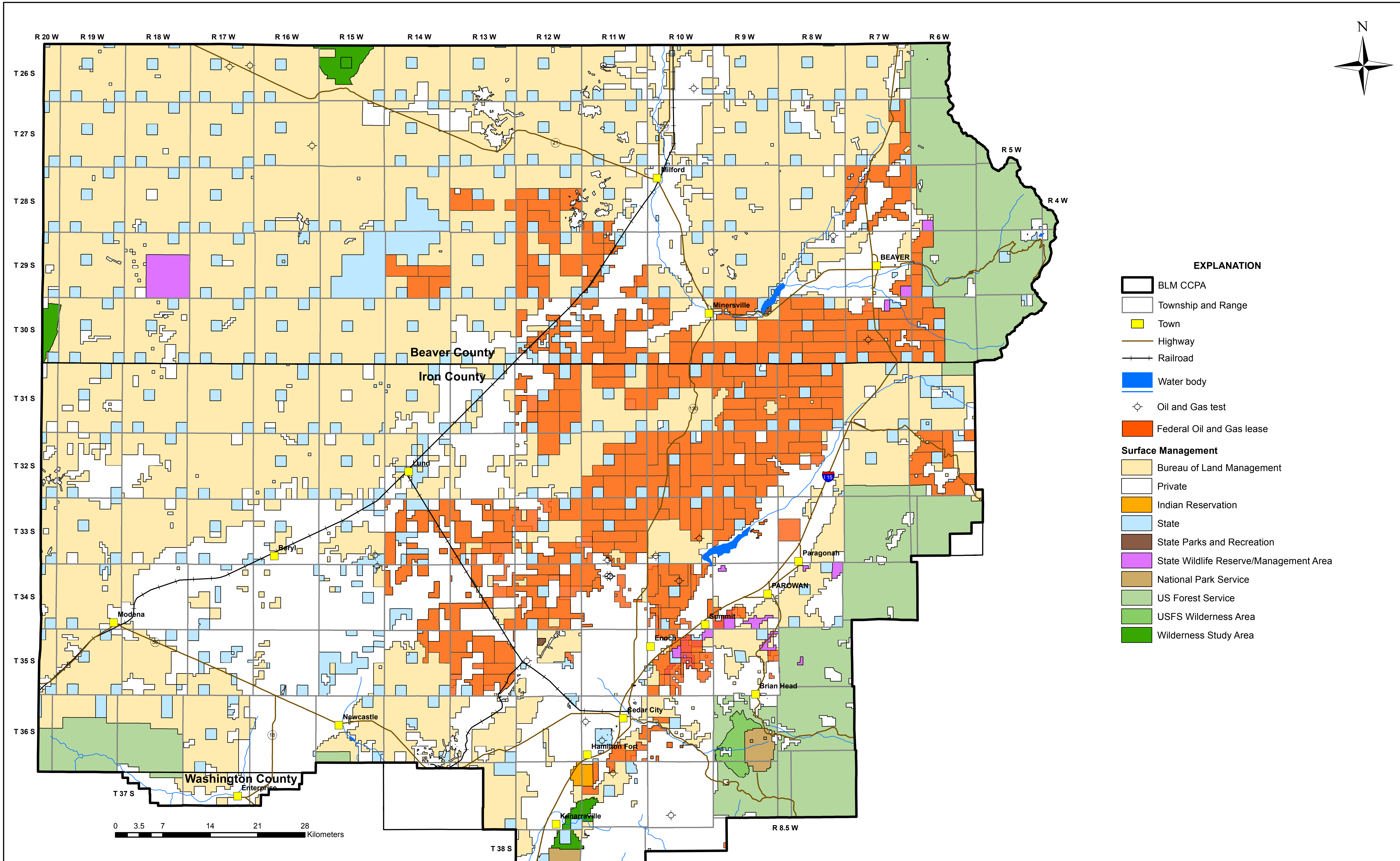


Figure 4.1.1.1. *BLM Cedar City planning area federal oil and gas leases.*

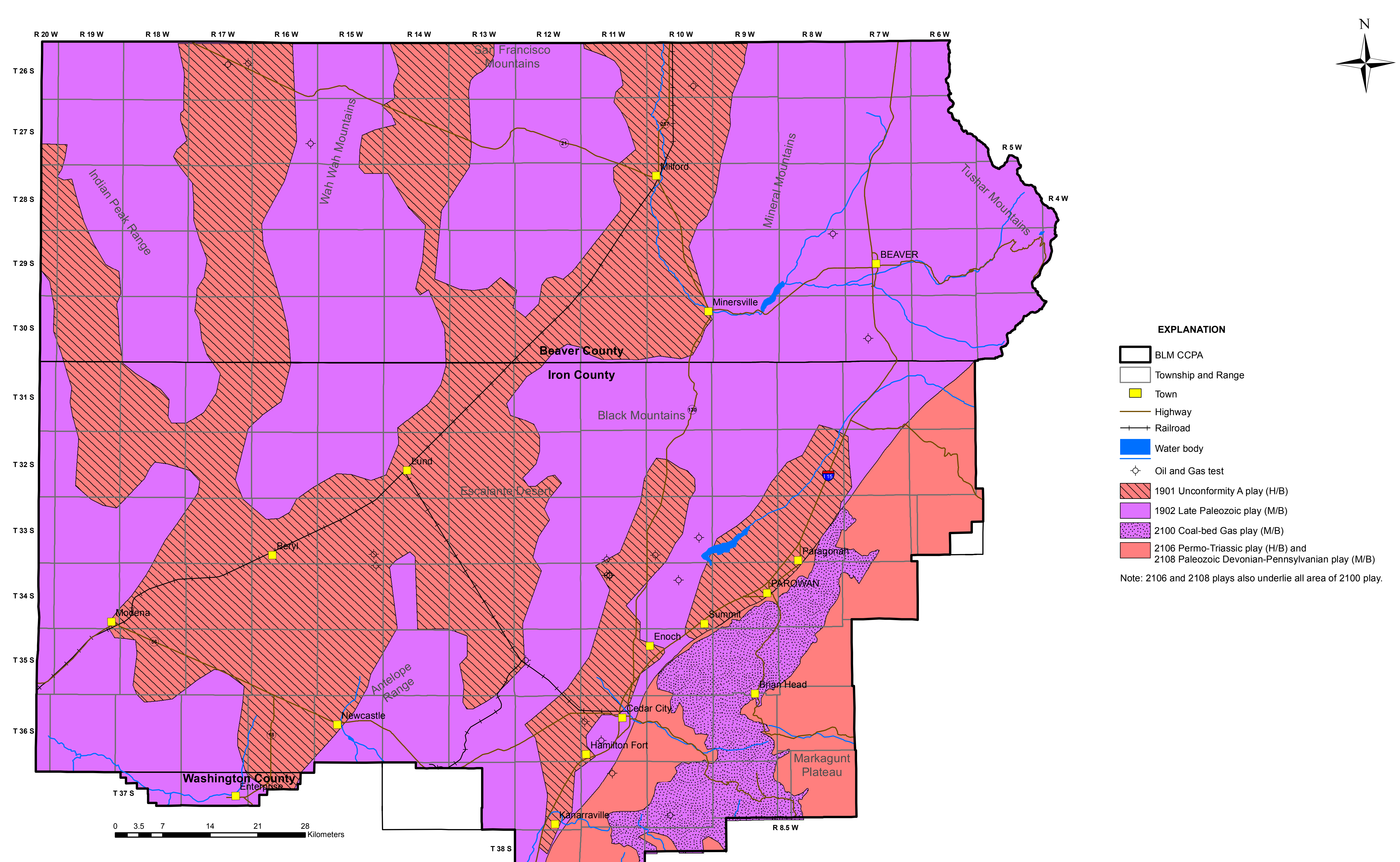


Figure 5.1.1.1. *BLM Cedar City planning area oil and gas occurrence potential.*

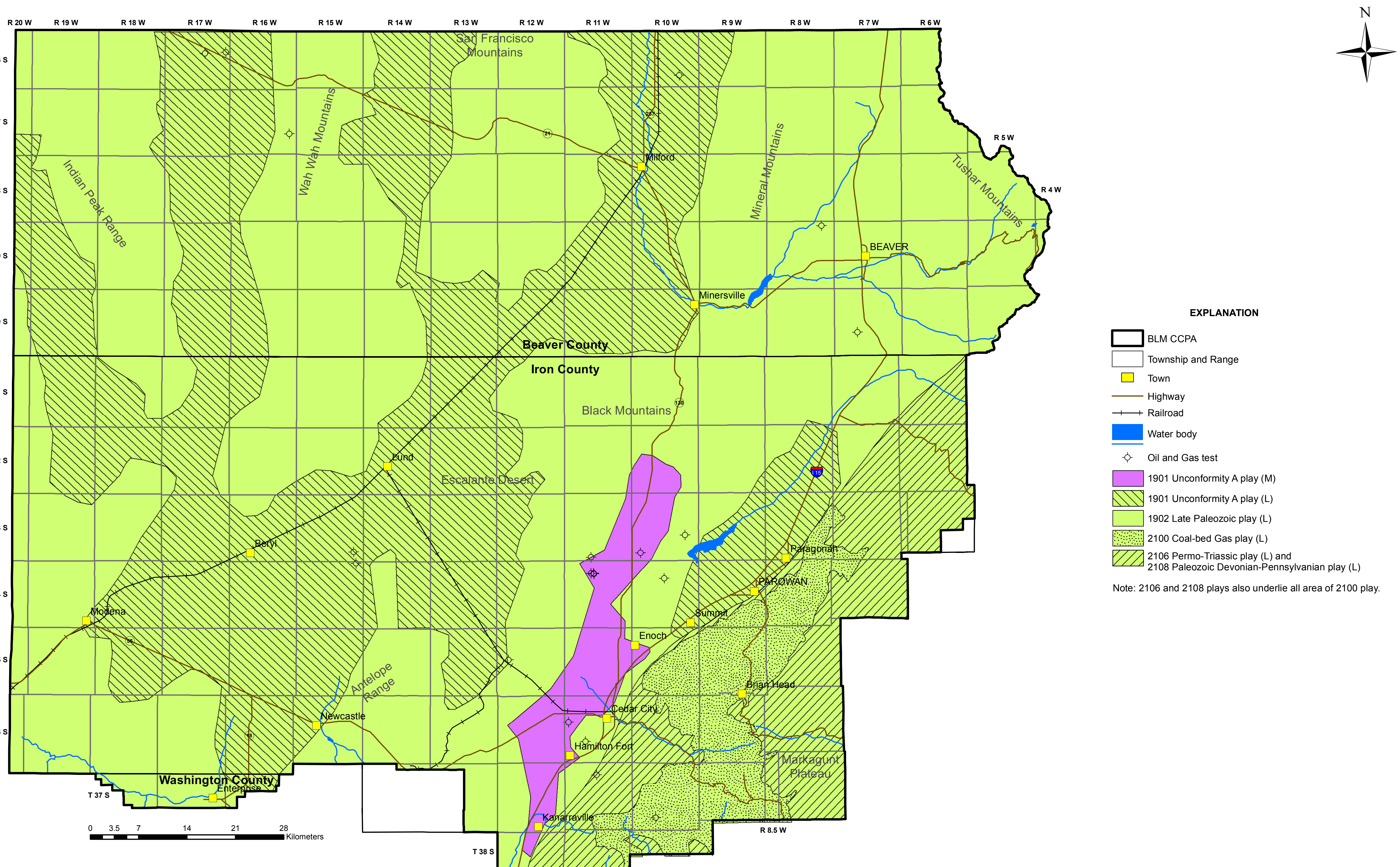


Figure 5.1.1.2. *BLM Cedar City planning area oil and gas development potential.*

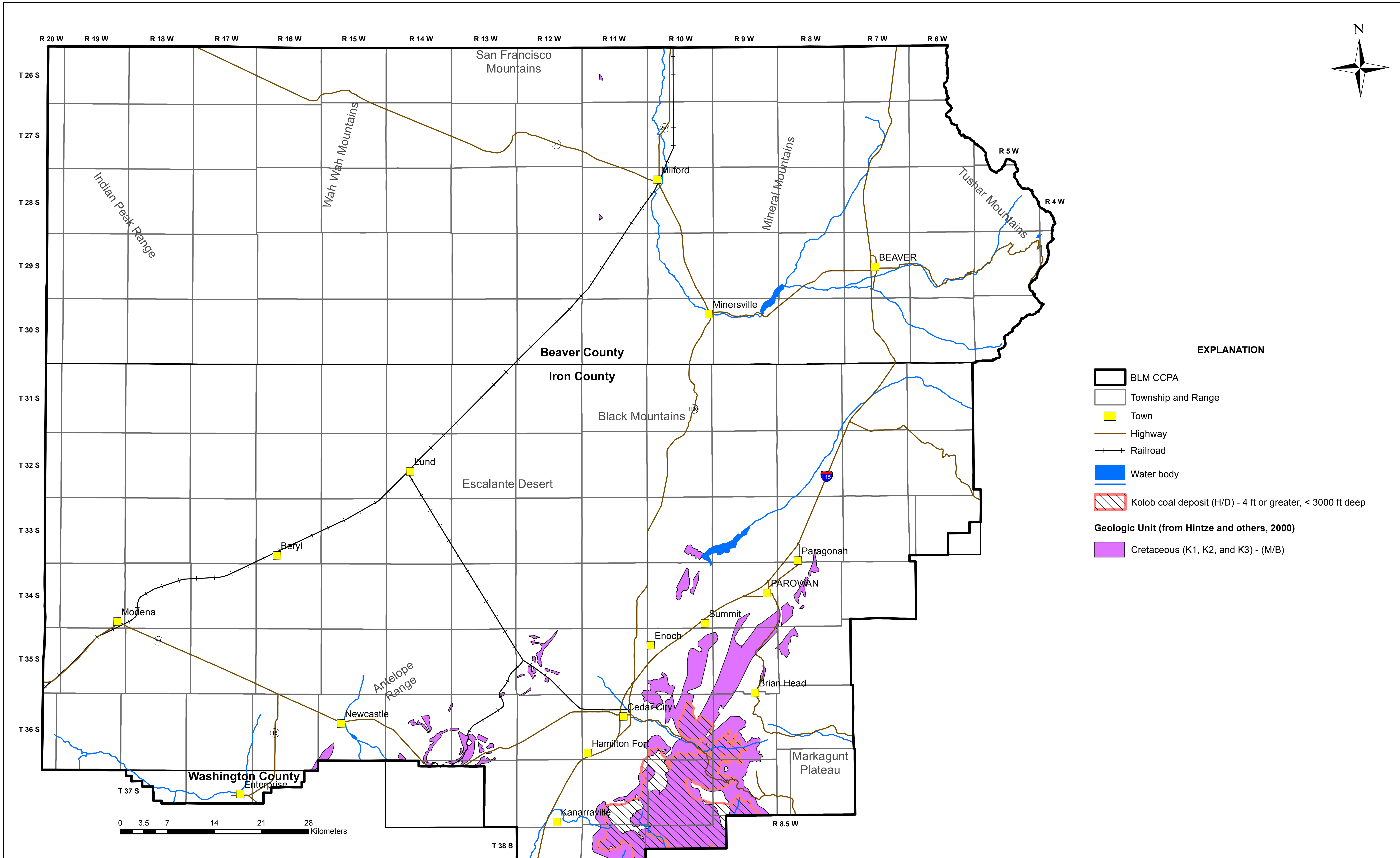


__Figure 5.1.3.1.__ BLM Cedar City planning area coal occurrence potential.

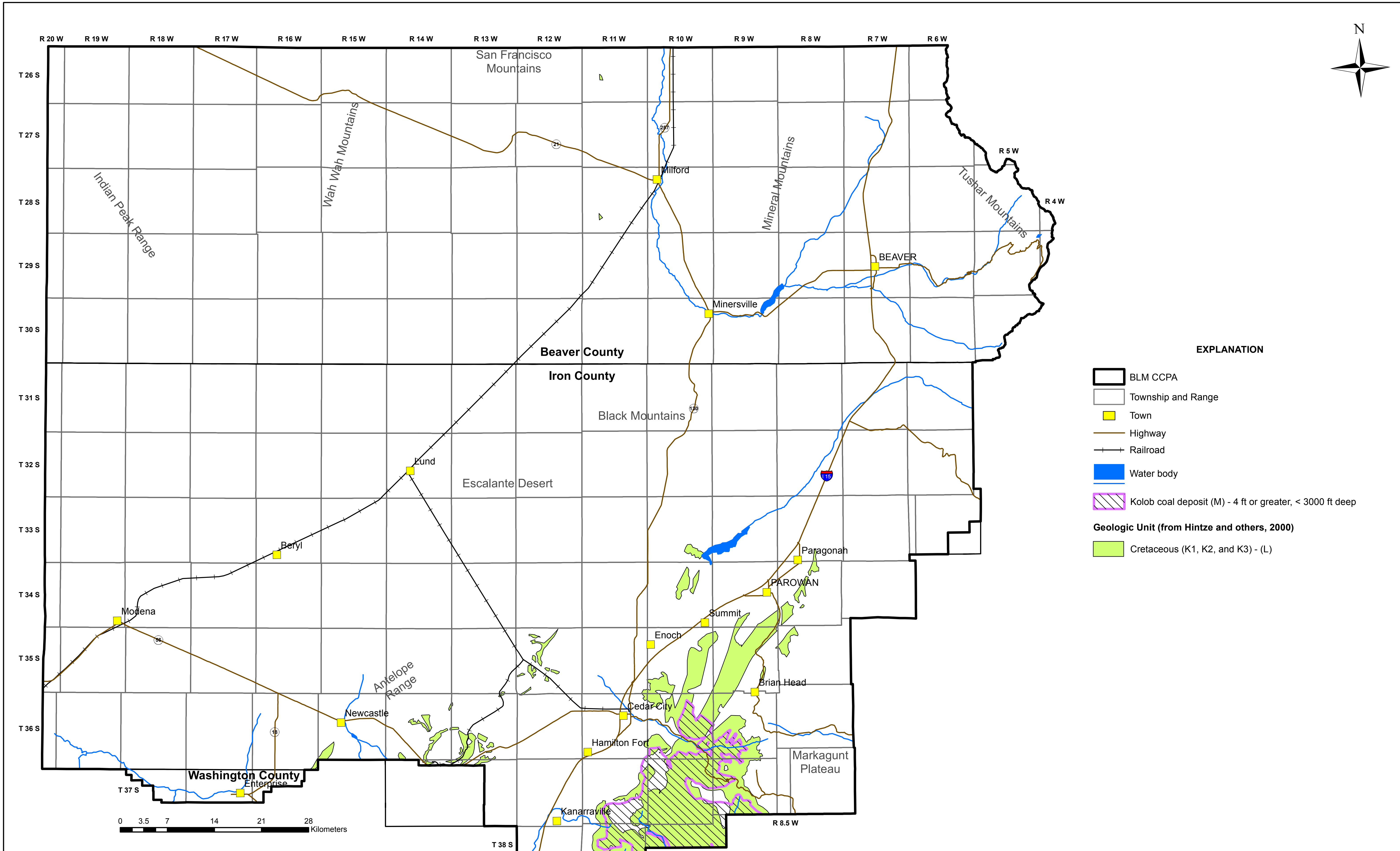


Figure 5.1.3.2. BLM Cedar City planning area coal development potential.

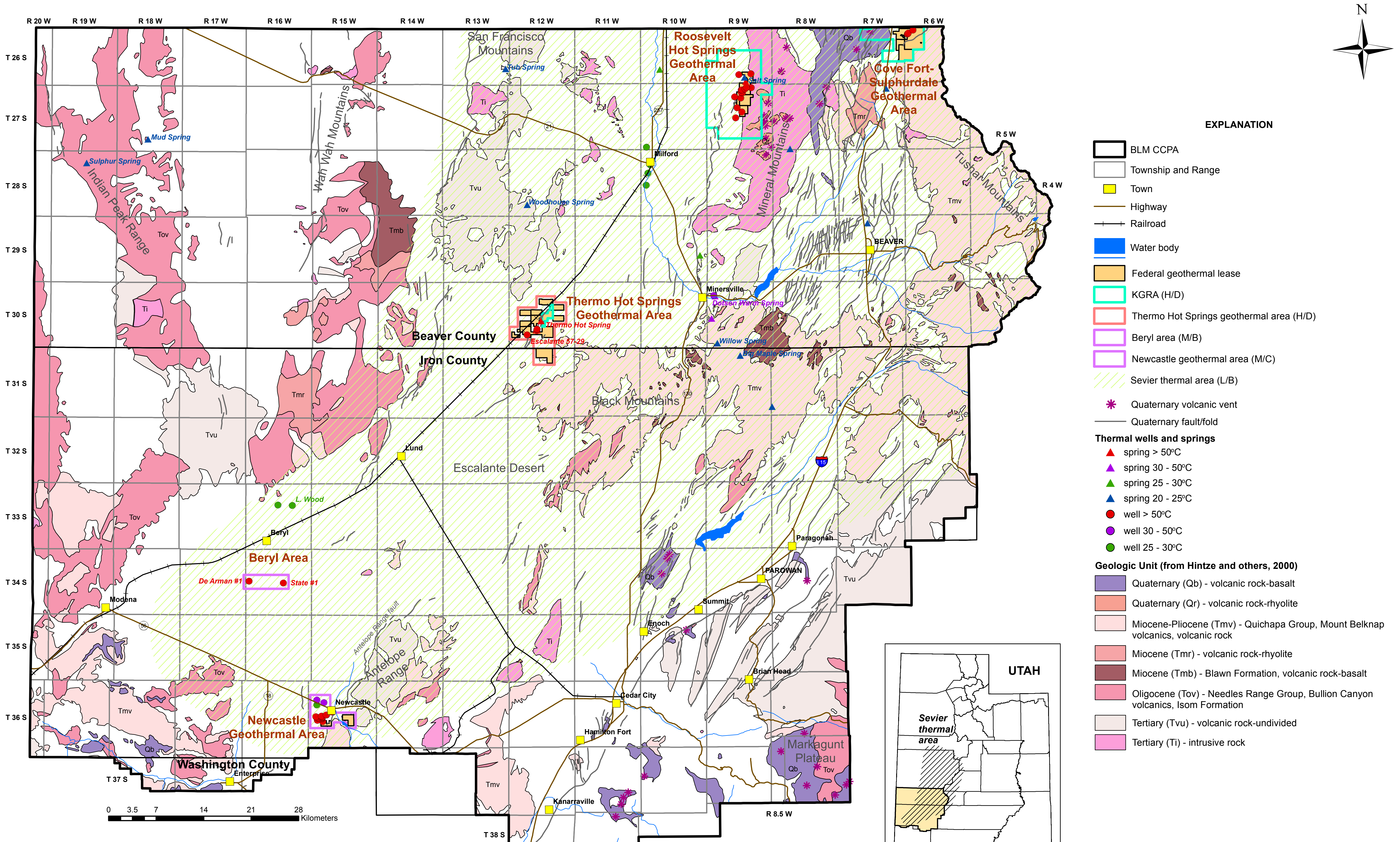


Figure 5.1.4.1. BLM Cedar City planning area geothermal occurrence potential.

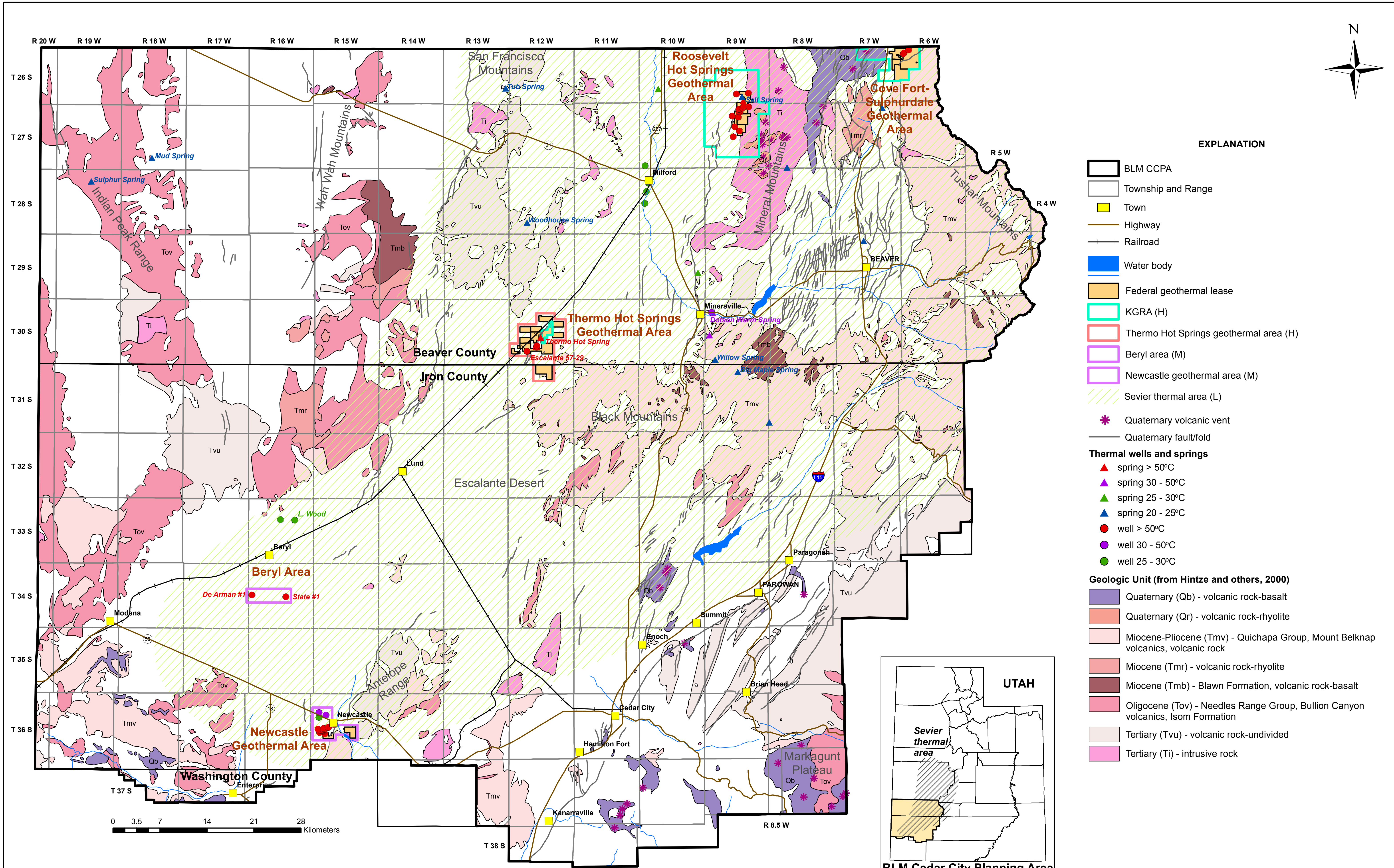


Figure 5.1.4.2. BLM Cedar City planning area geothermal development potential.

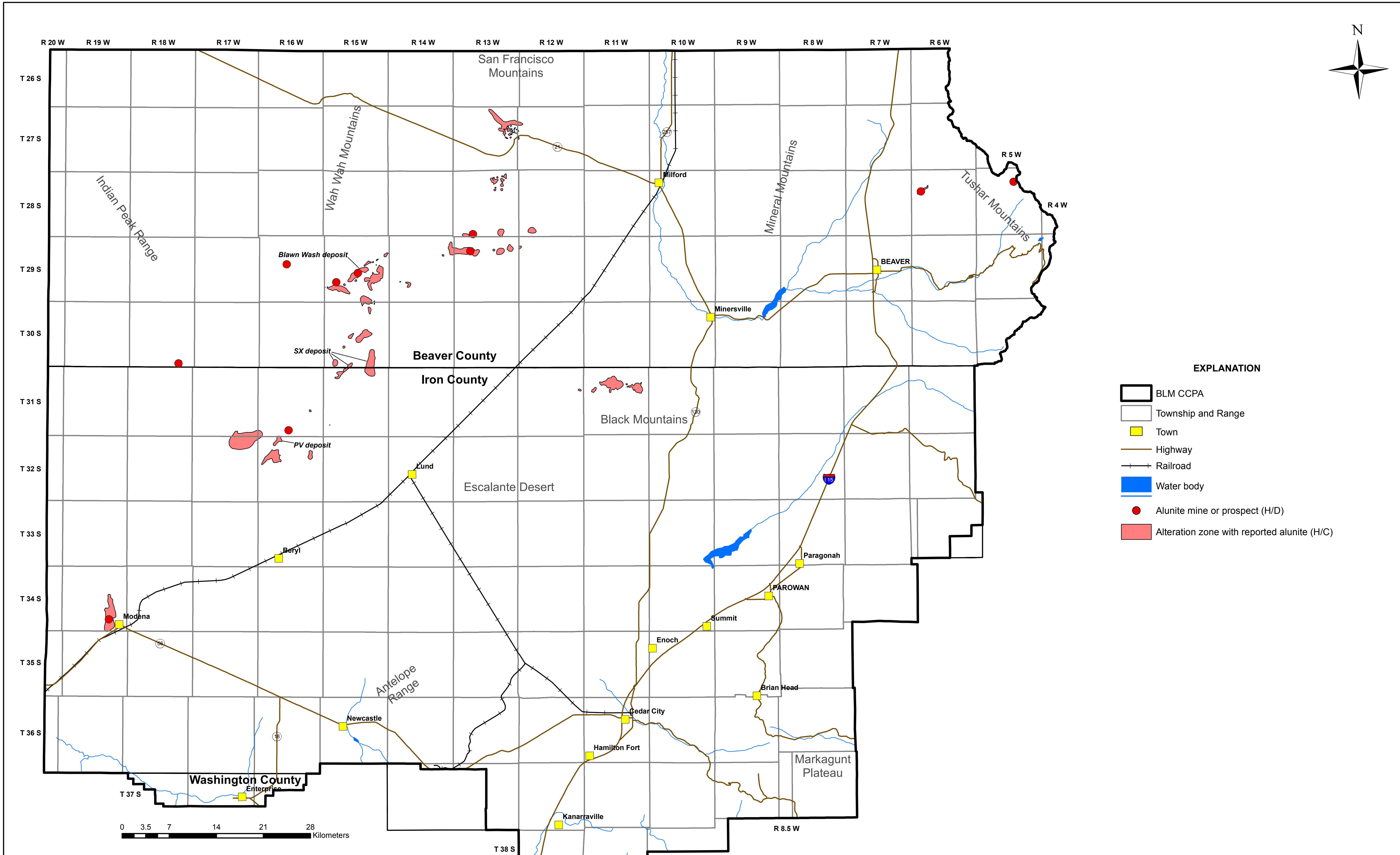


Figure 5.1.5.1. *BLM Cedar City planning area alunite occurrence potential.*

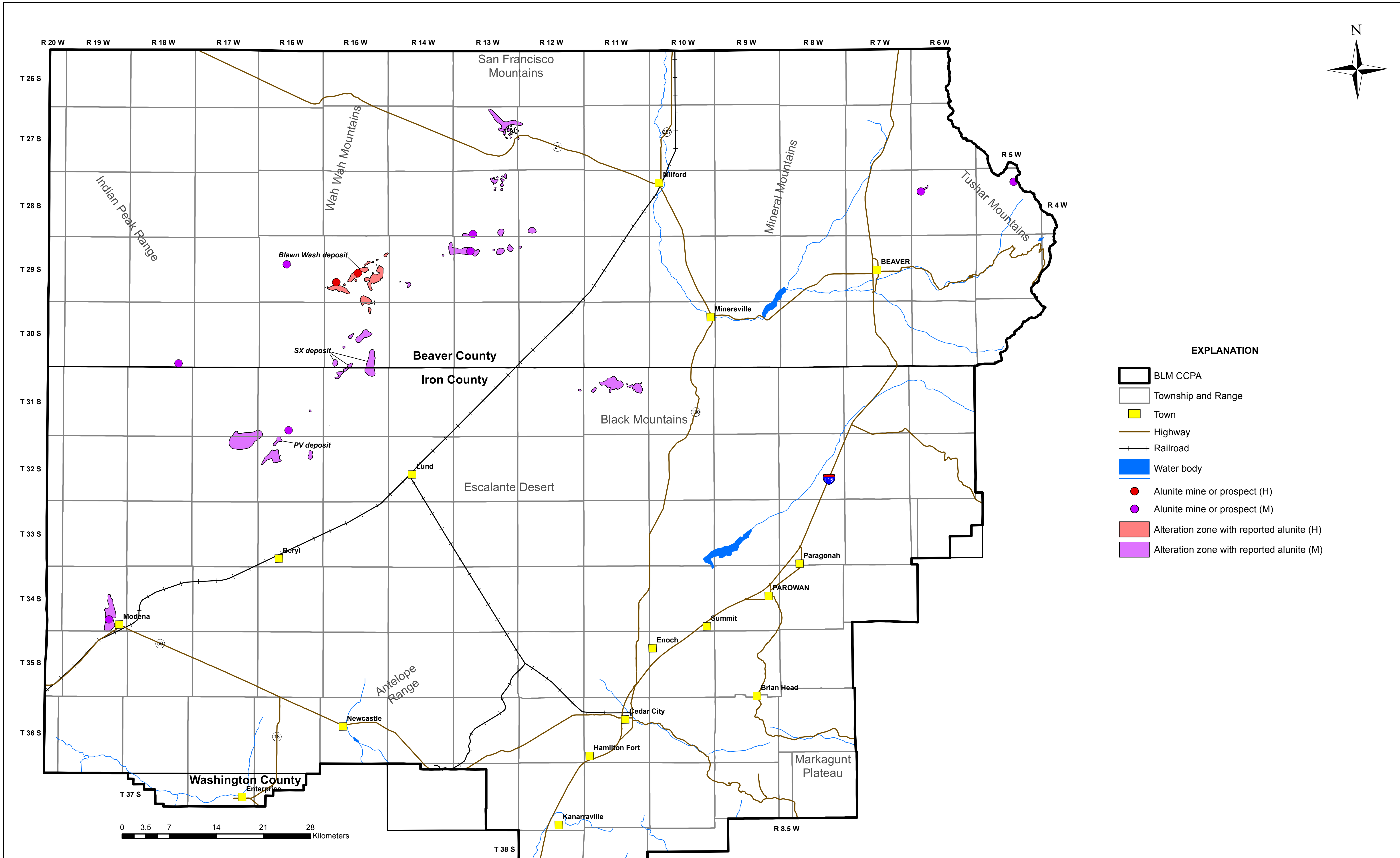


Figure 5.1.5.2. *BLM Cedar City planning area alunite development potential.*

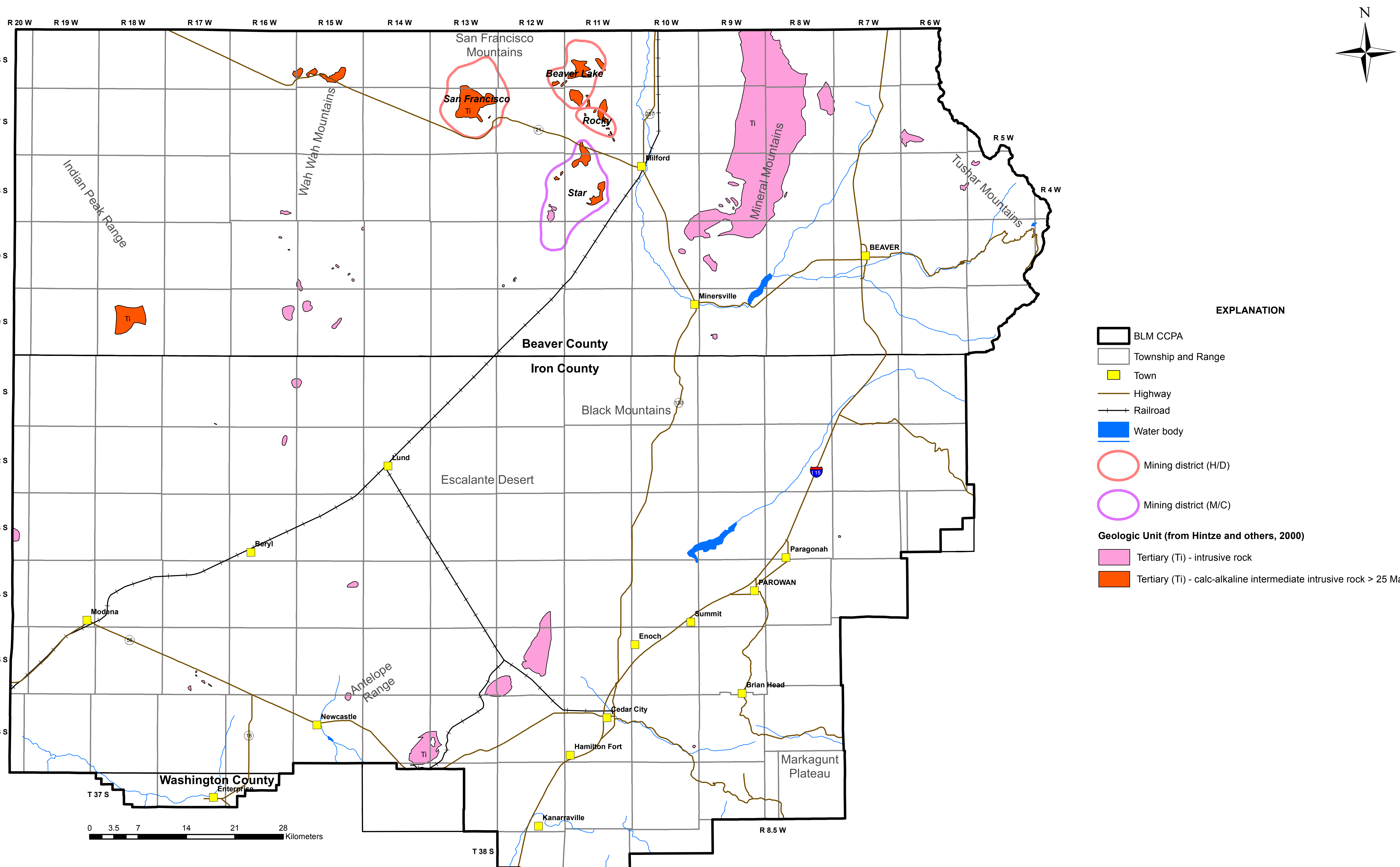


Figure 5.2.1.1. *BLM Cedar City planning area copper occurrence potential.*

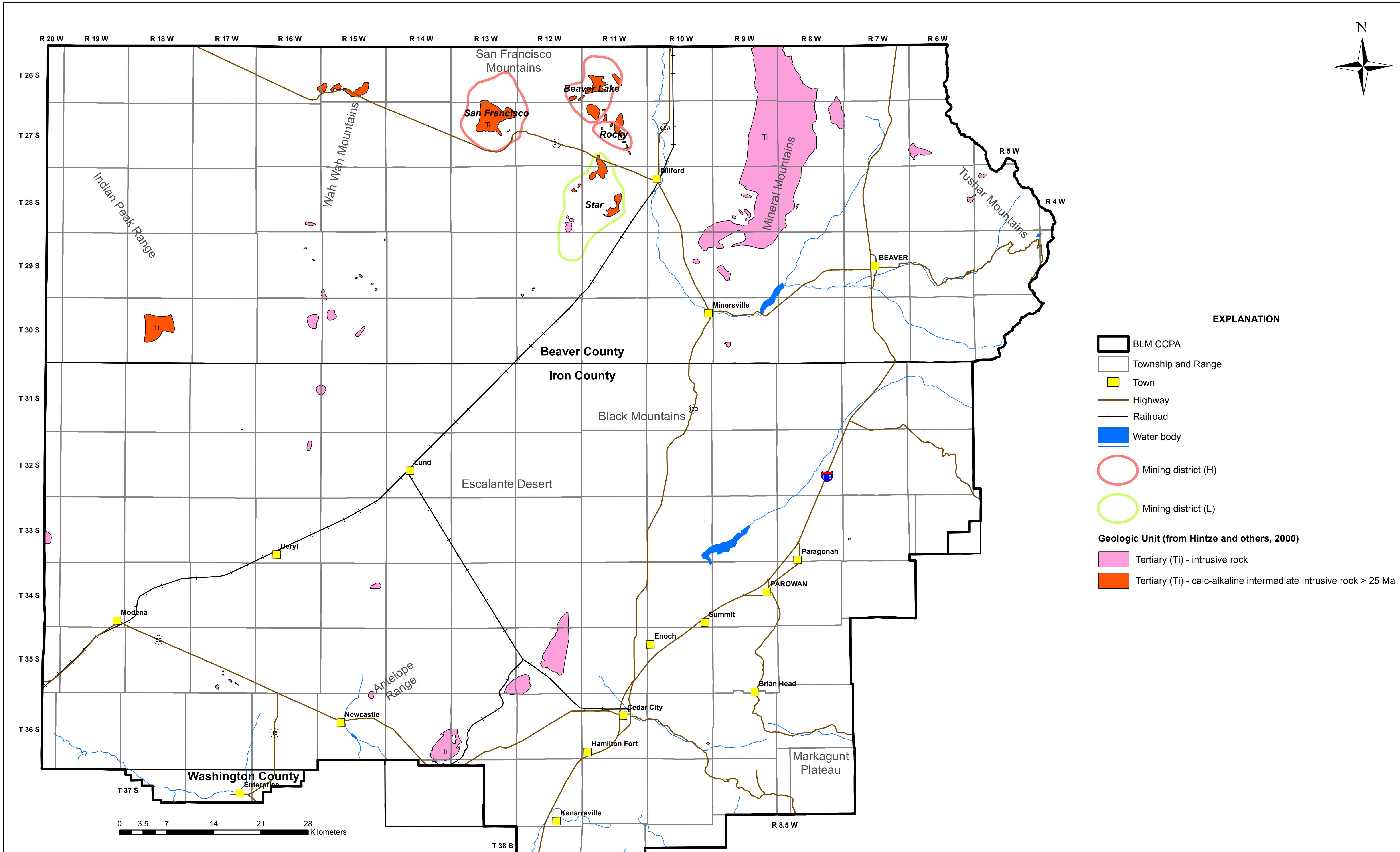


Figure 5.2.1.2. BLM Cedar City planning area copper development potential.

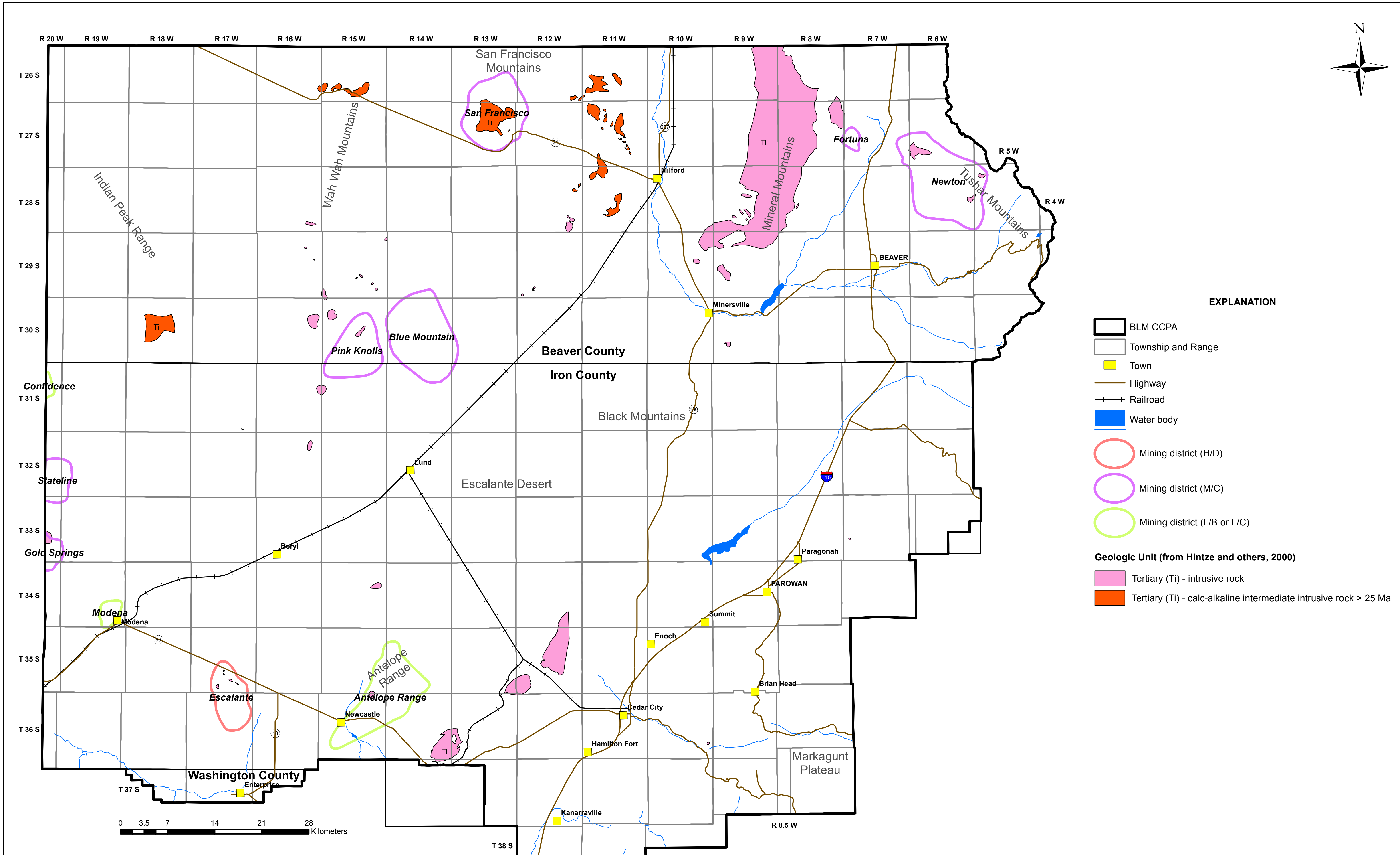


Figure 5.2.2.1. *BLM Cedar City planning area gold and silver occurrence potential.*

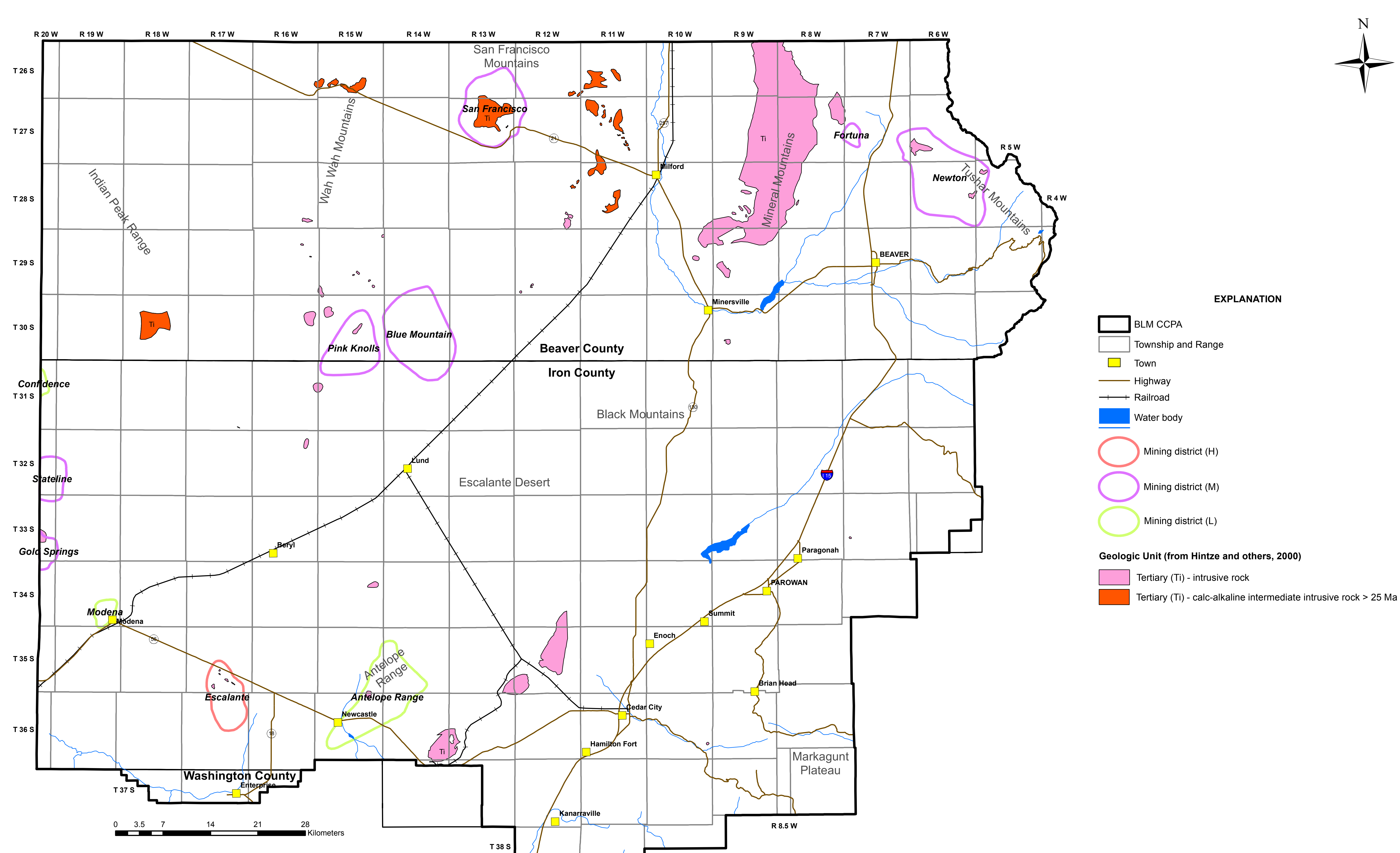


Figure 5.2.2.2. BLM Cedar City planning area gold and silver development potential.

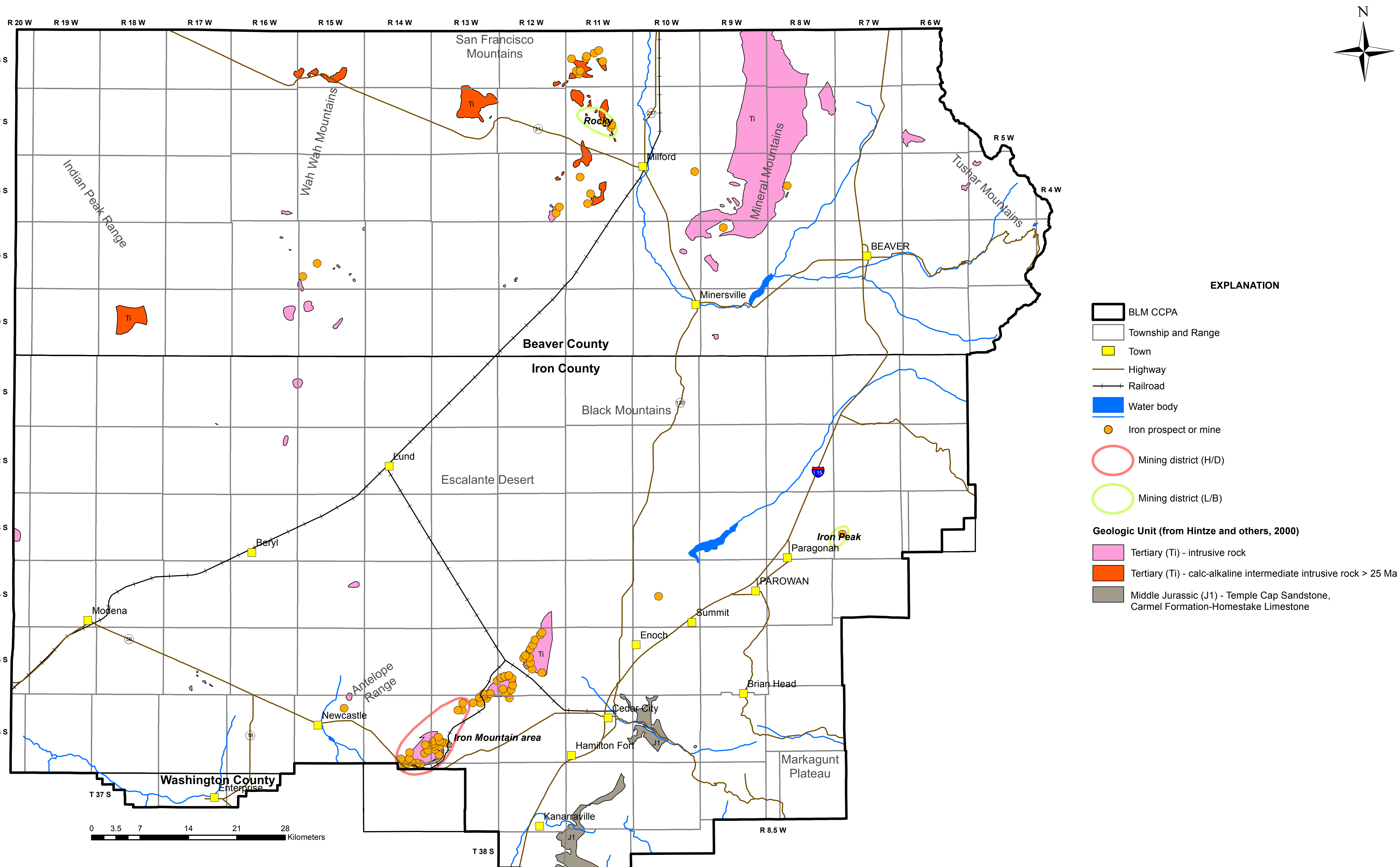
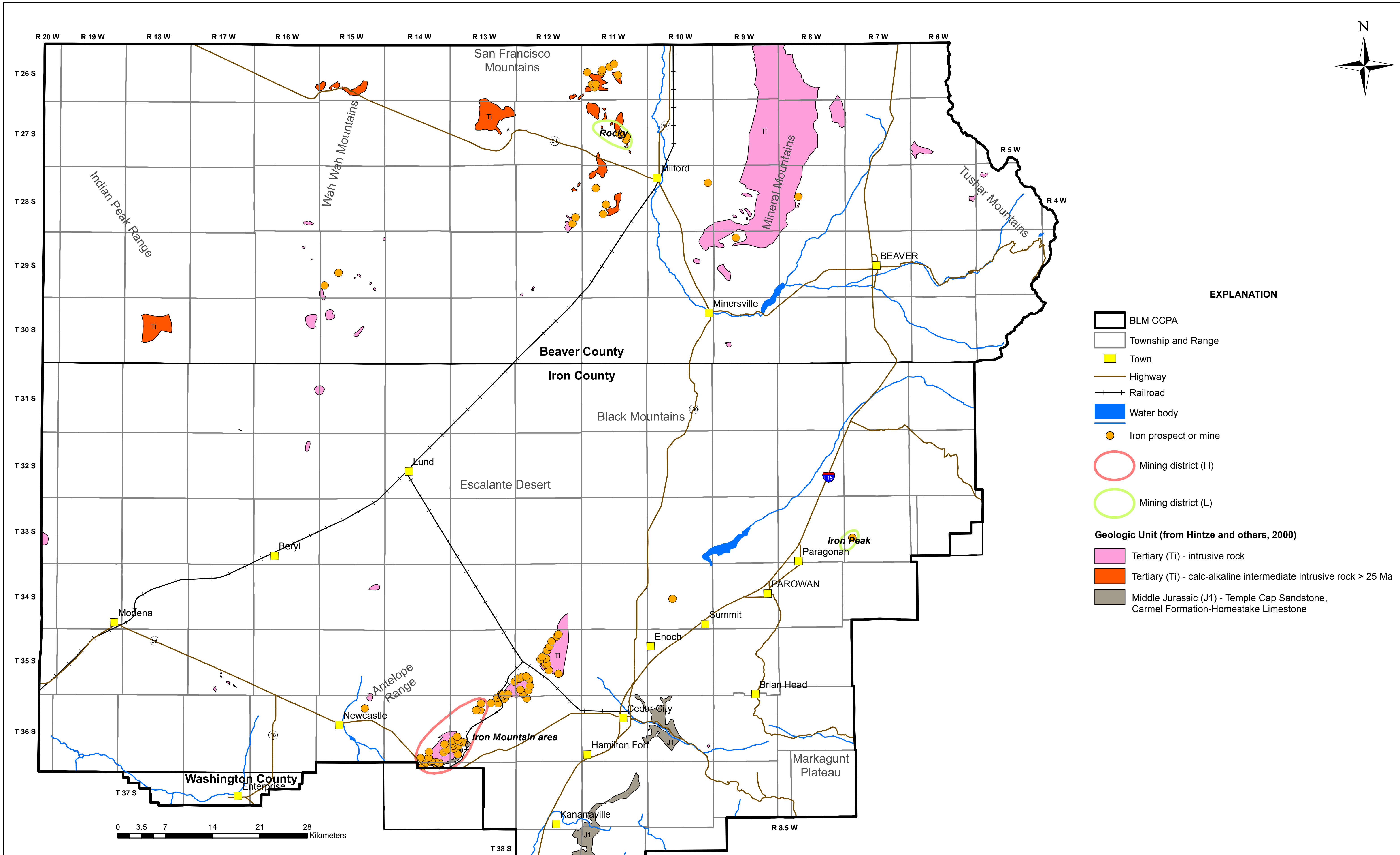


Figure 5.2.3.1. *BLM Cedar City planning area iron occurrence potential.*



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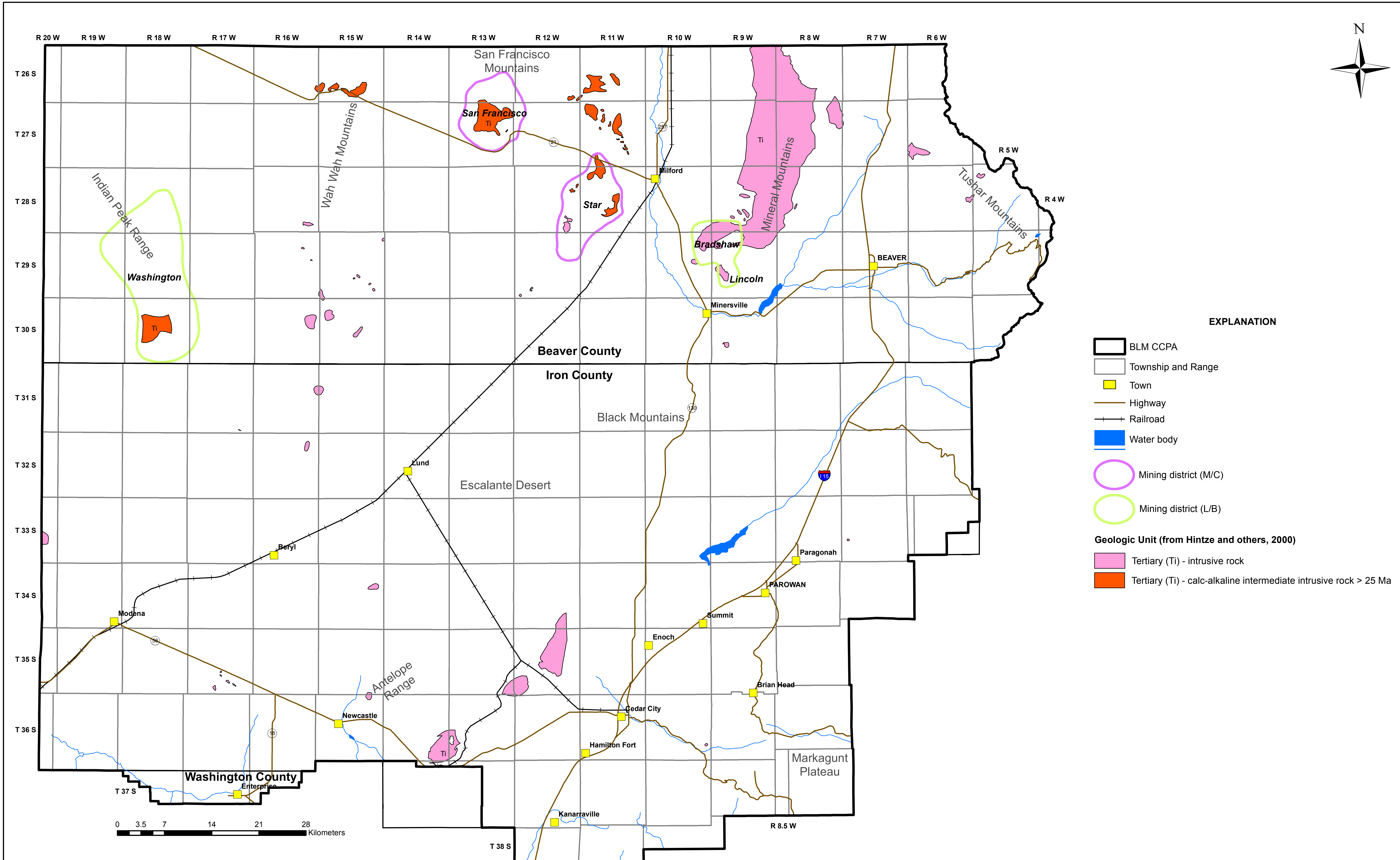

Figure 5.2.4.1. *BLM Cedar City planning area lead and zinc occurrence potential.*

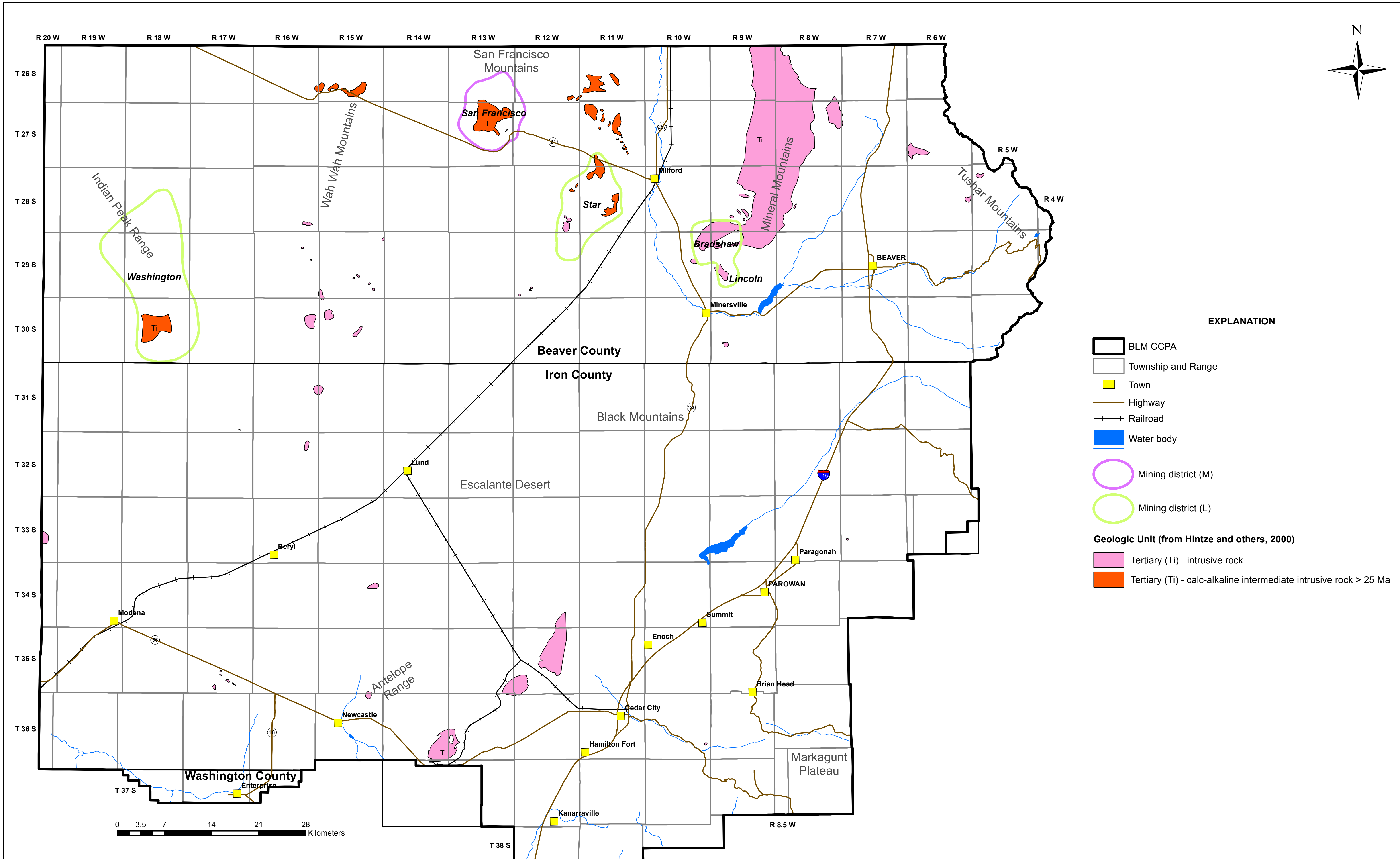

Figure 5.2.4.2. BLM Cedar City planning area lead and zinc development potential.

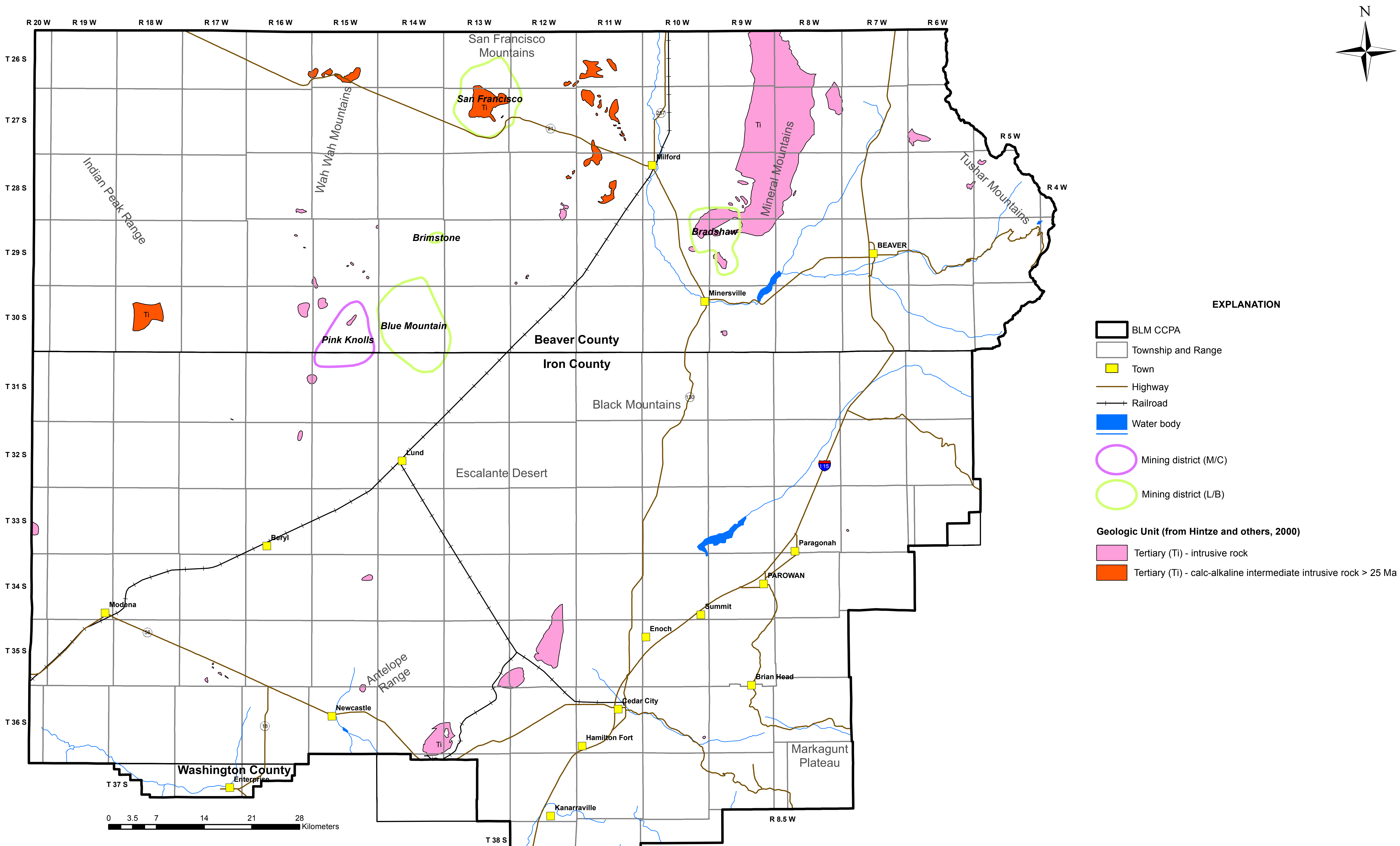

Figure 5.2.5.1. BLM Cedar City planning area mercury occurrence potential.

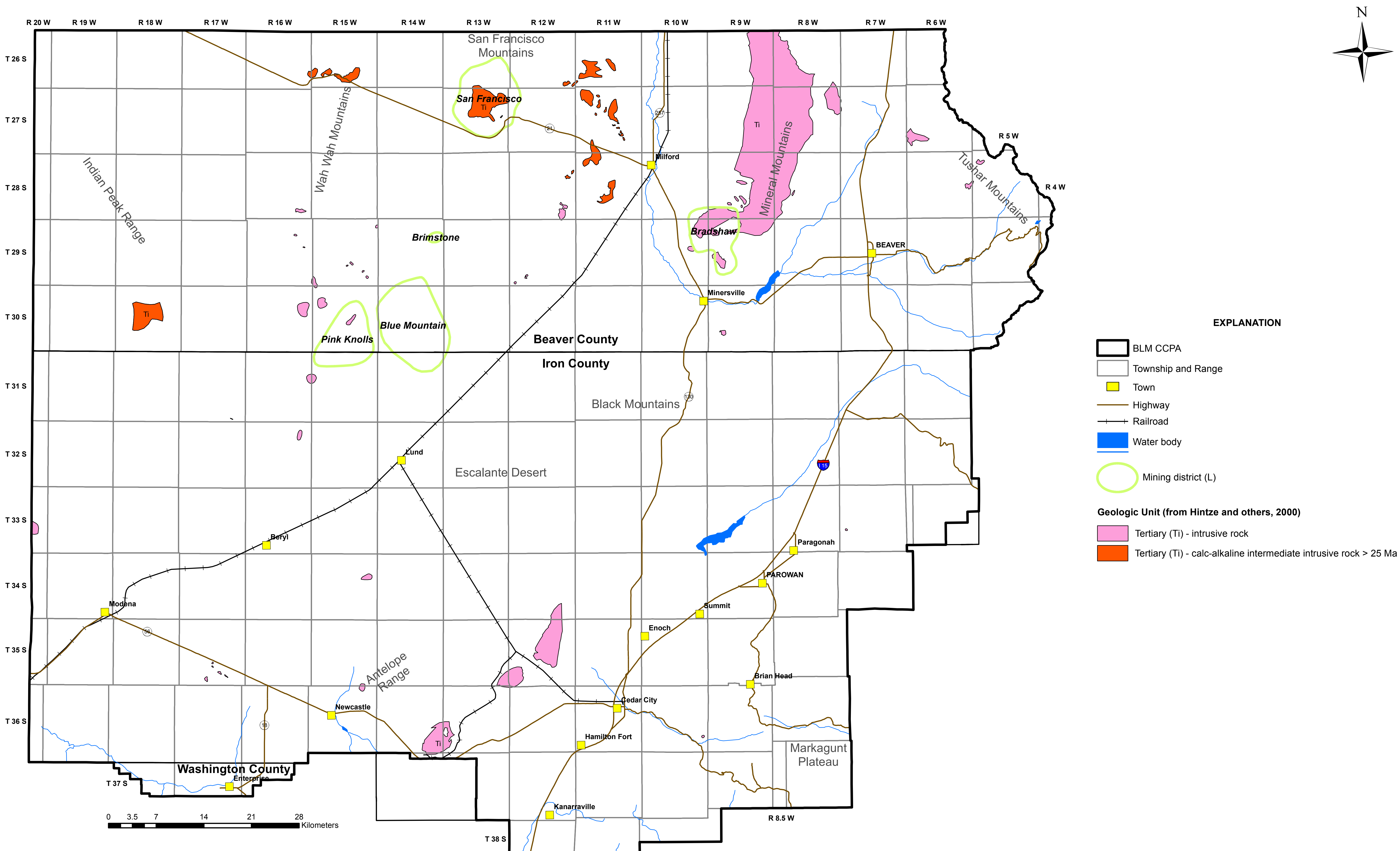

Figure 5.2.5.2. BLM Cedar City planning area mercury development potential.

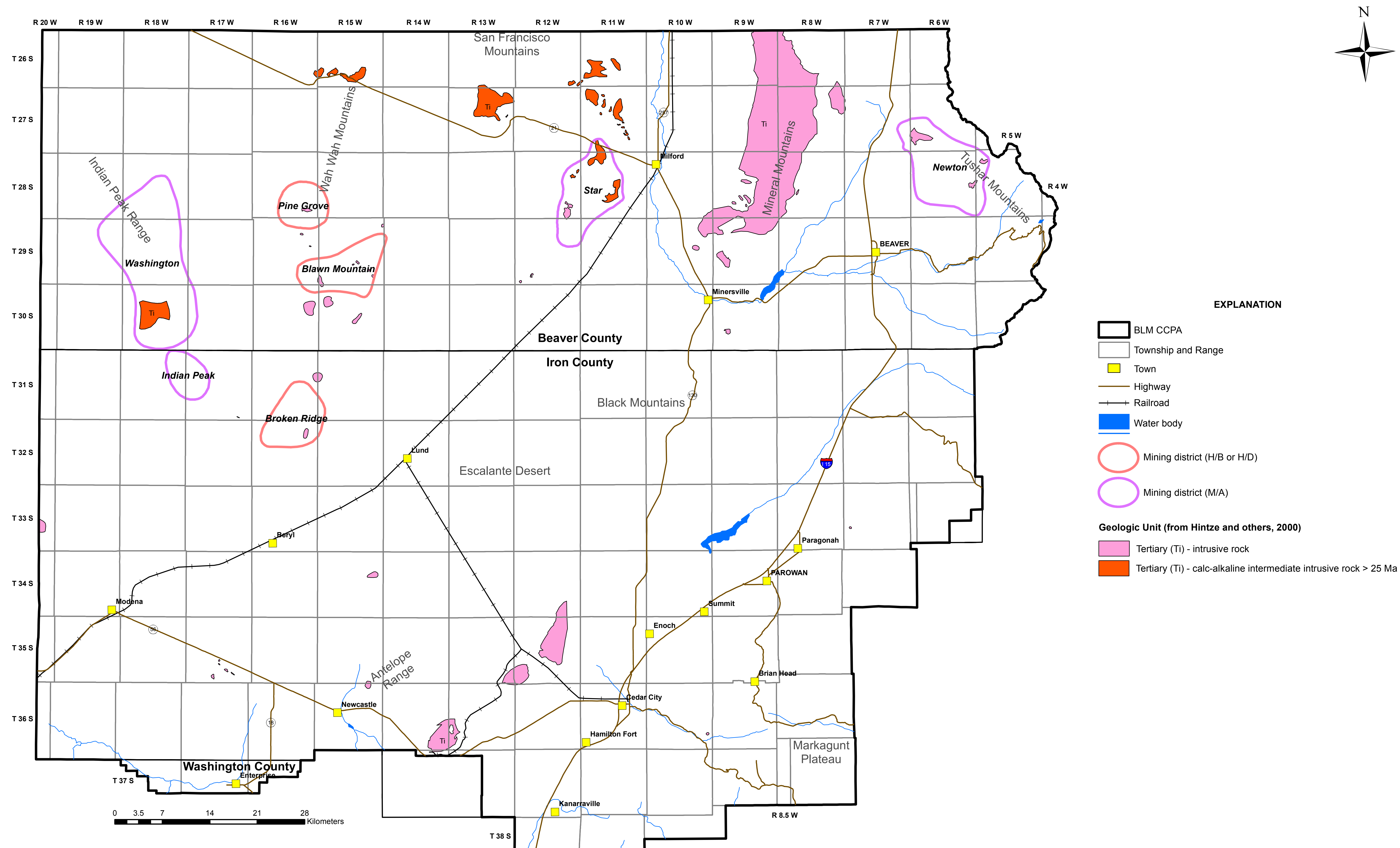

Figure 5.2.6.1. *BLM Cedar City planning area molybdenum occurrence potential.*

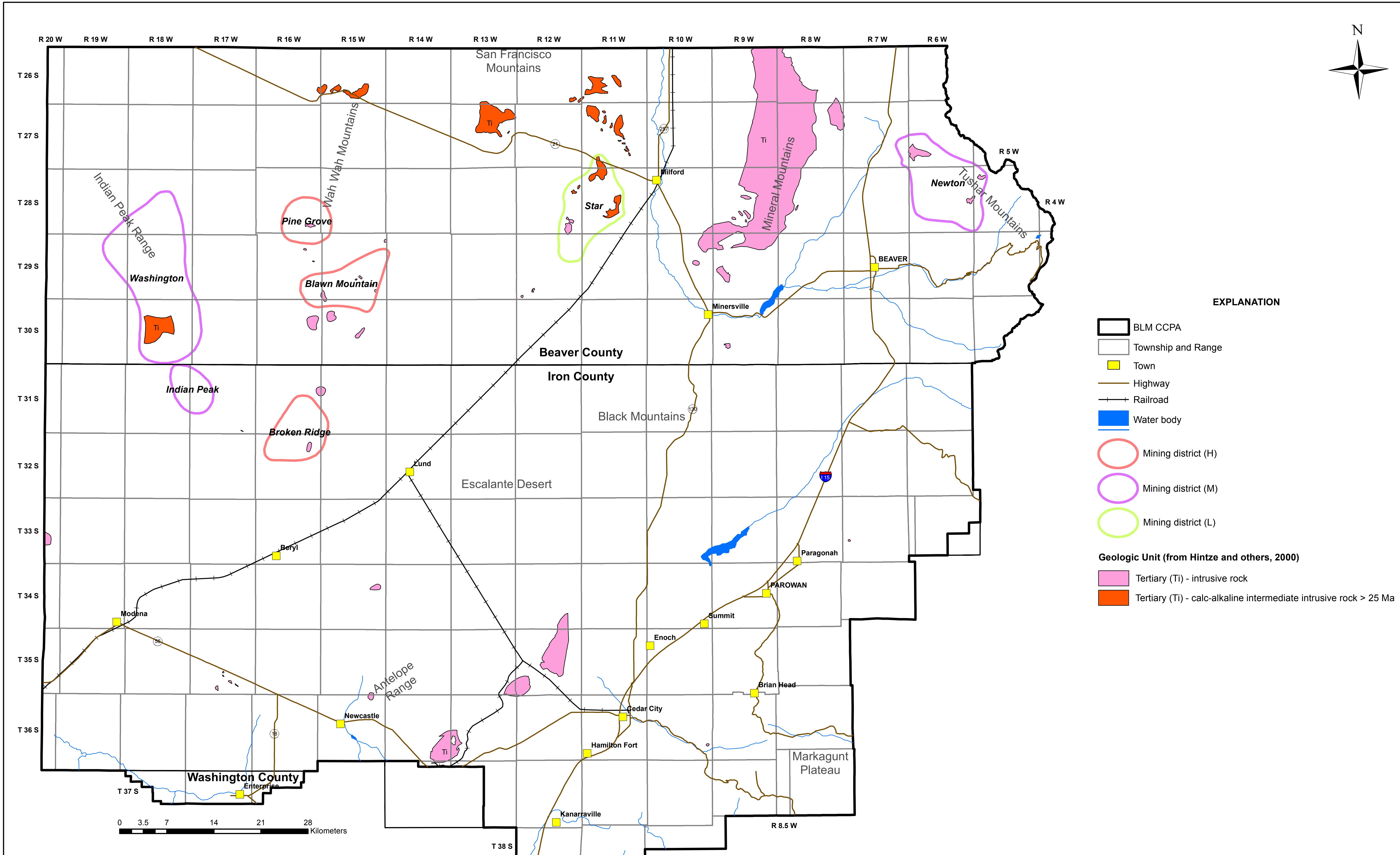

Figure 5.2.6.2. BLM Cedar City planning area molybdenum development potential.

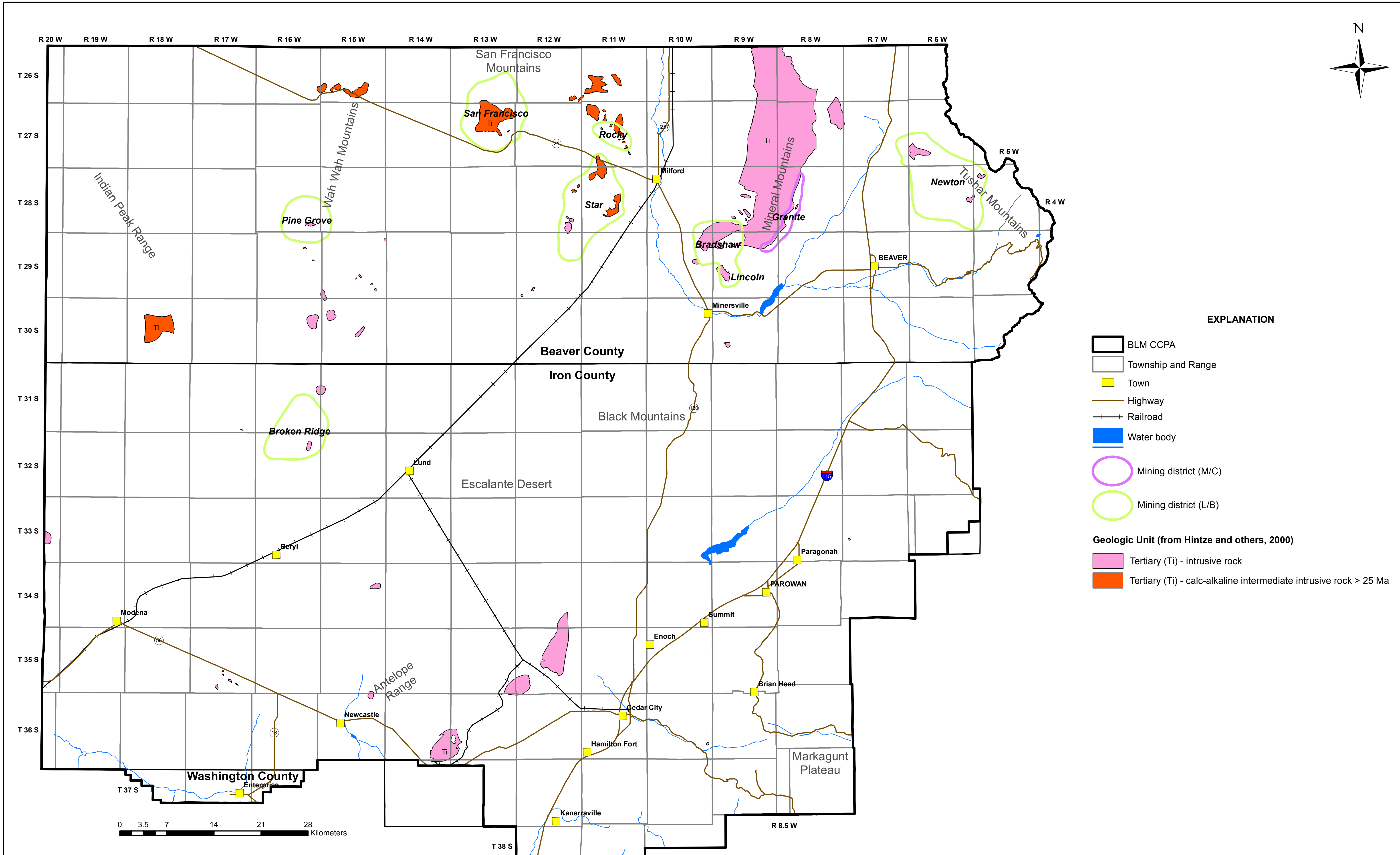

Figure 5.2.7.1. BLM Cedar City planning area tungsten occurrence potential.

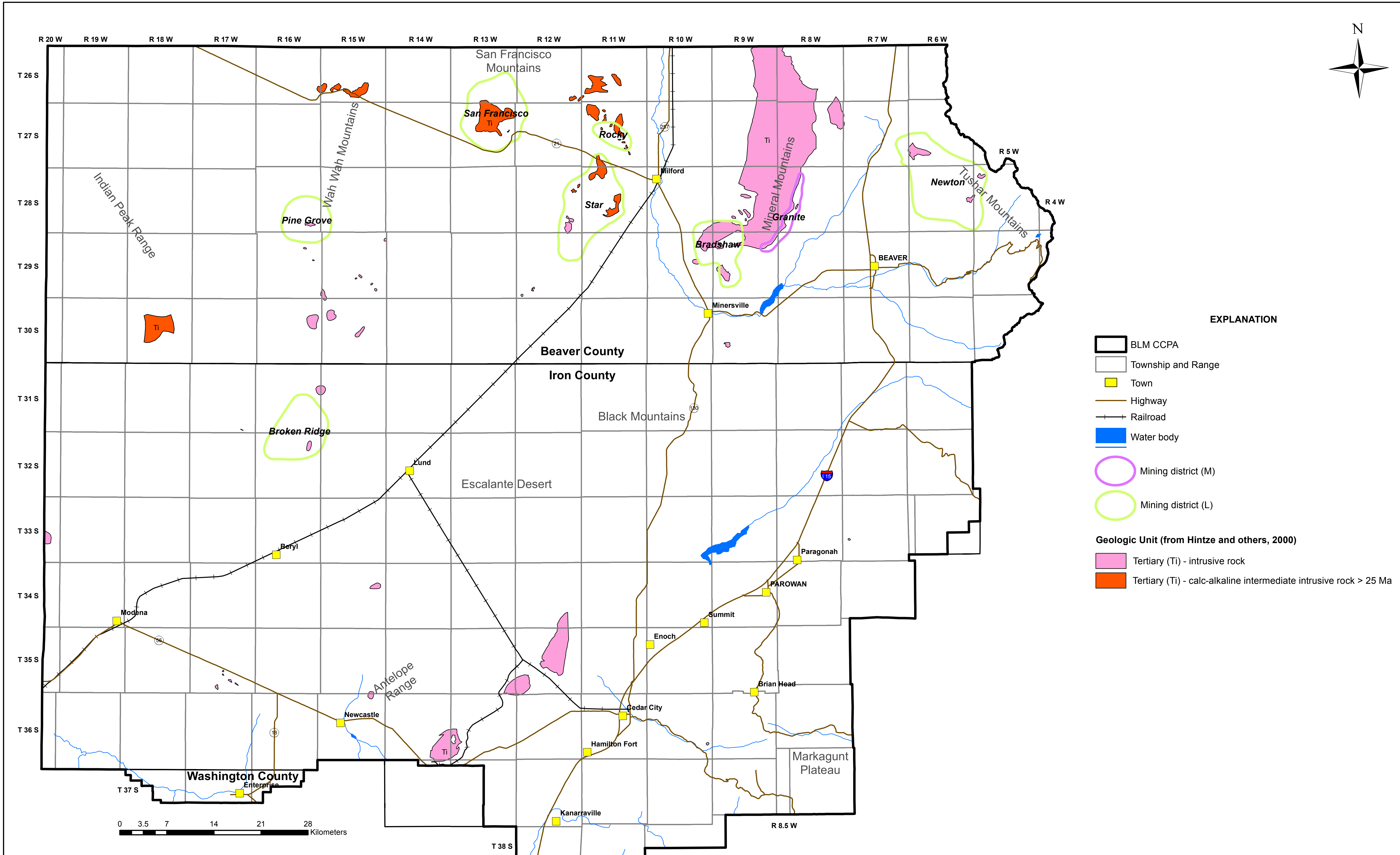

Figure 5.2.7.2. *BLM Cedar City planning area tungsten development potential.*

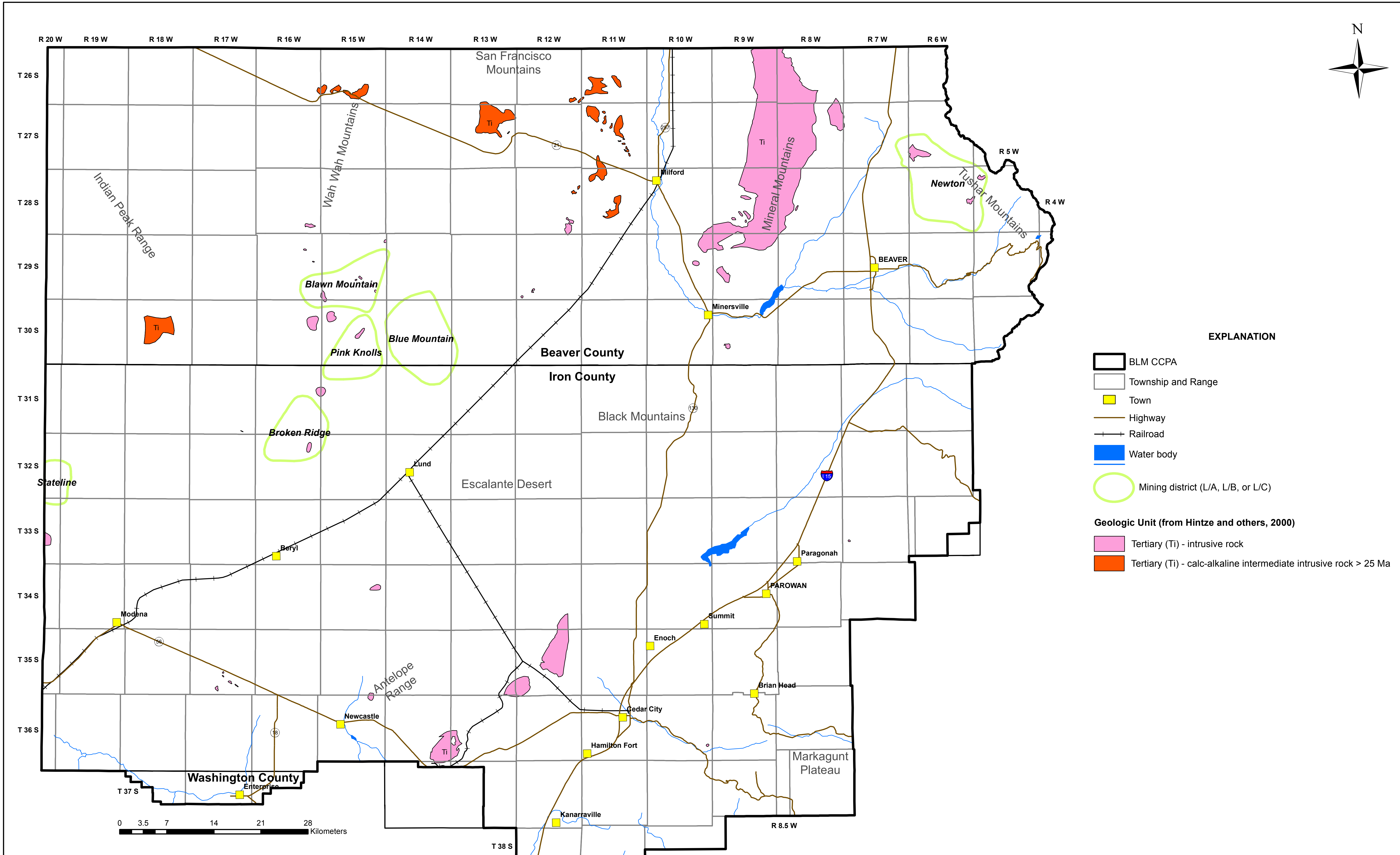

Figure 5.2.8.1. *BLM Cedar City planning area uranium occurrence potential.*

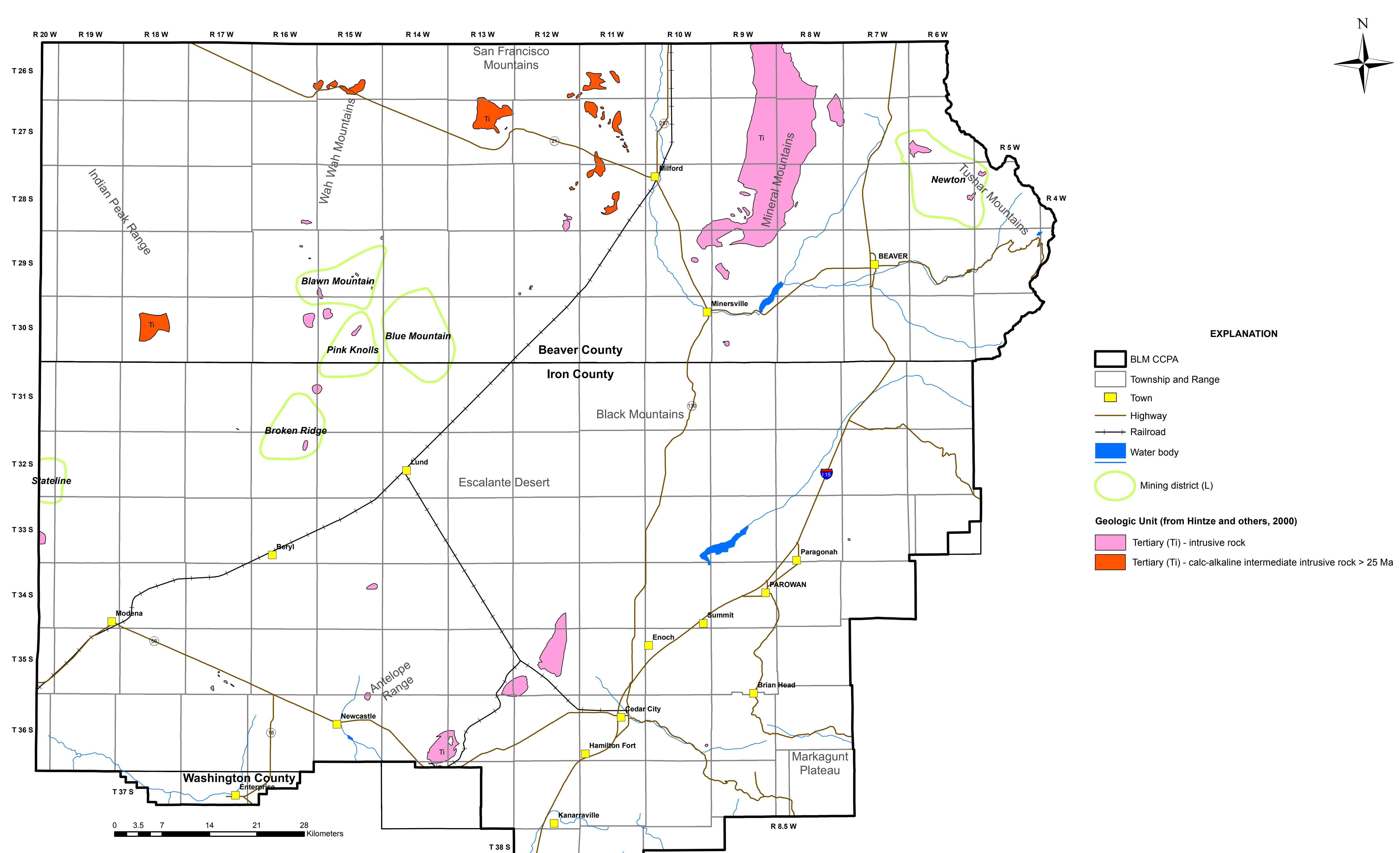

Figure 5.2.8.2. *BLM Cedar City planning area uranium development potential.*

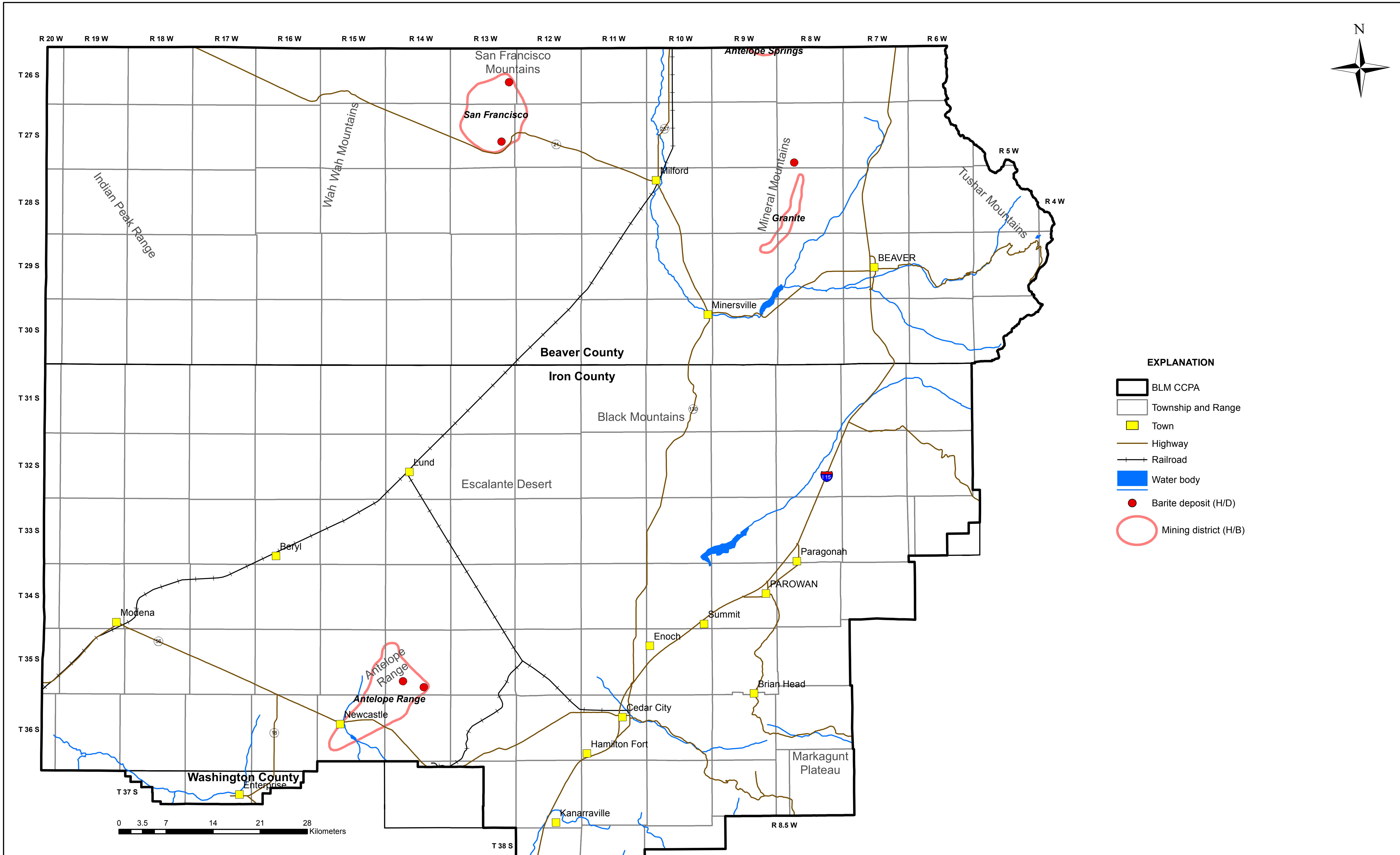

Figure 5.3.1.1. *BLM Cedar City planning area barite occurrence potential.*

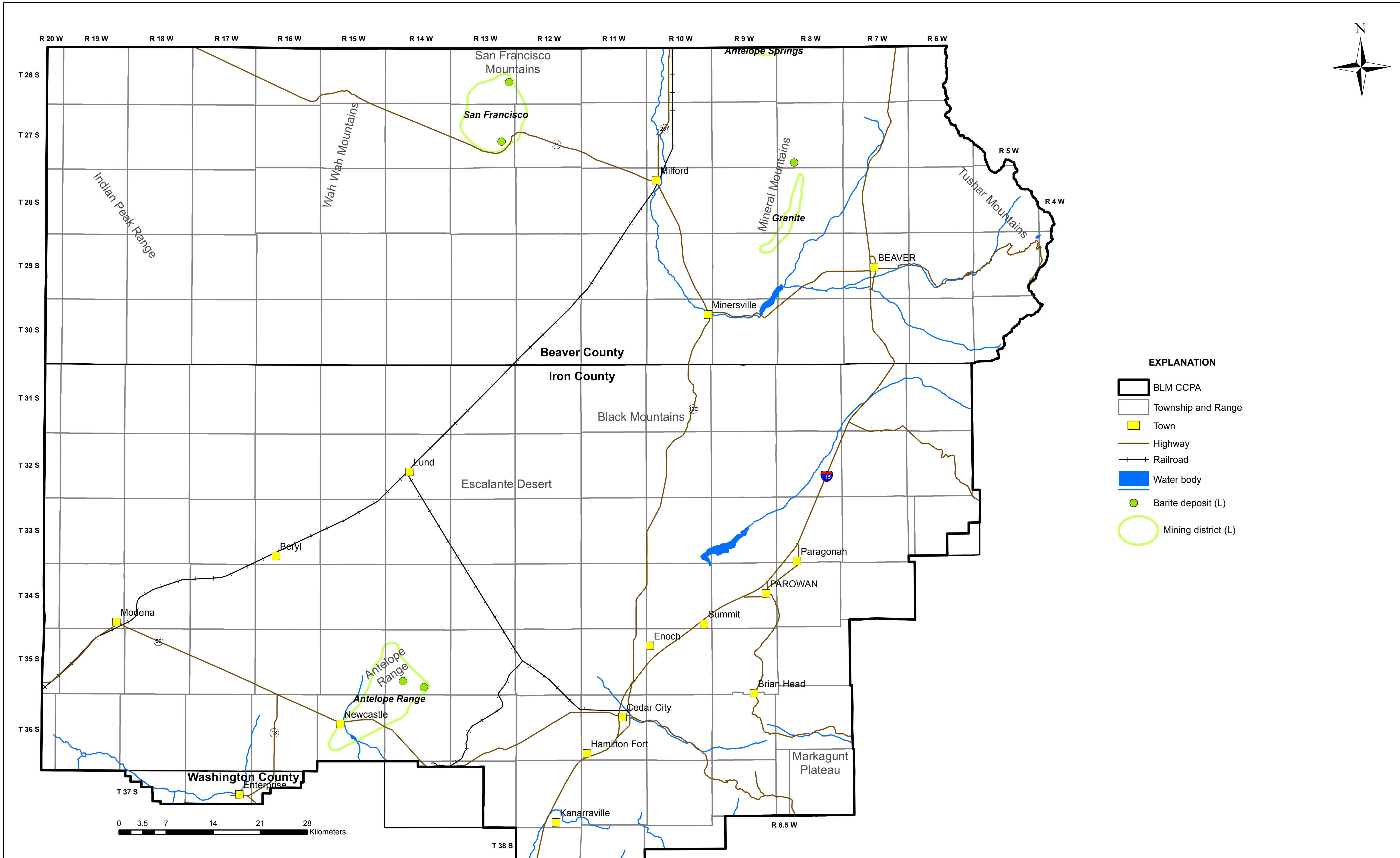

Figure 5.3.1.2. *BLM Cedar City planning area barite development potential.*

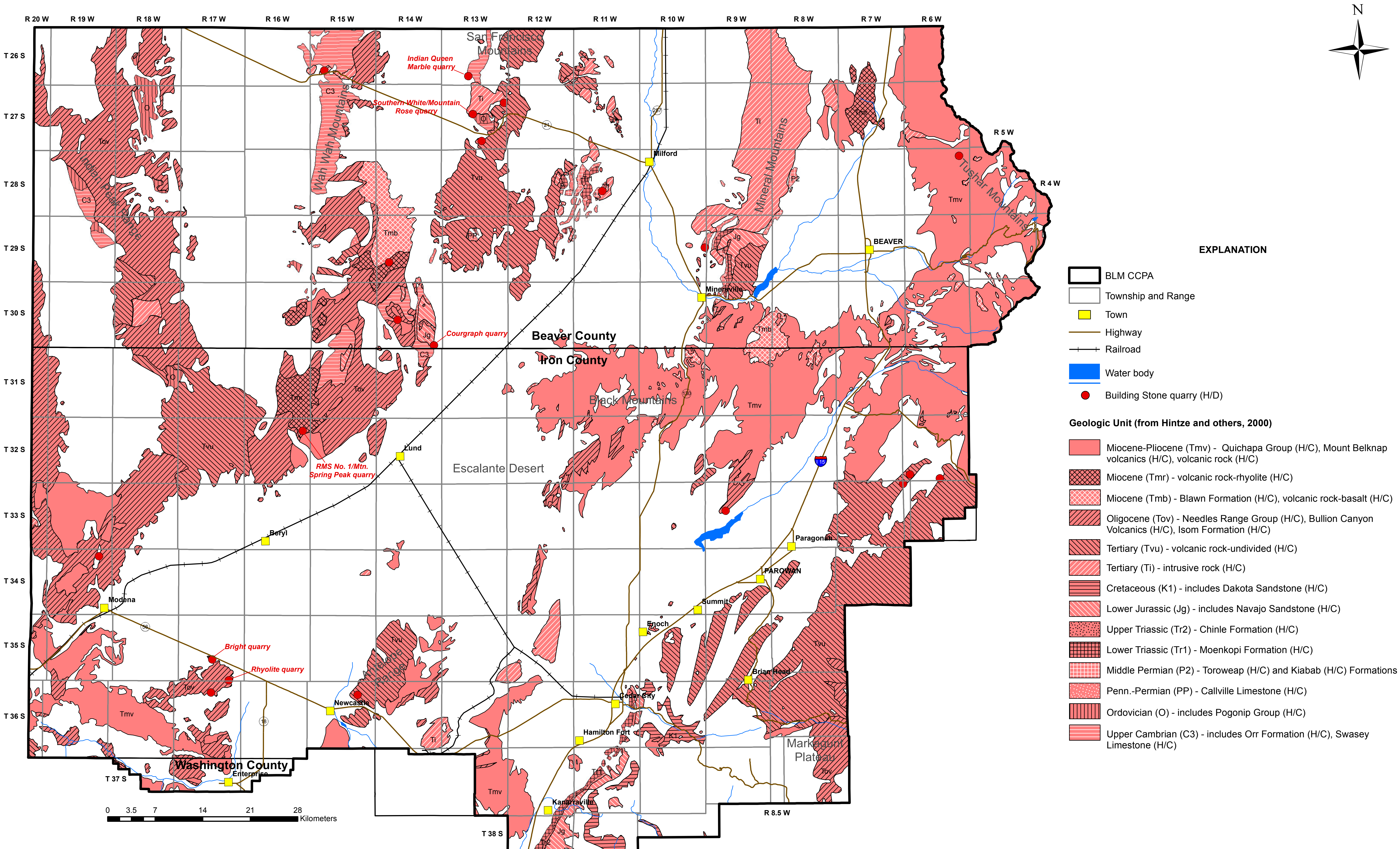

Figure 5.3.2.1. *BLM Cedar City planning area building stone occurrence potential.*

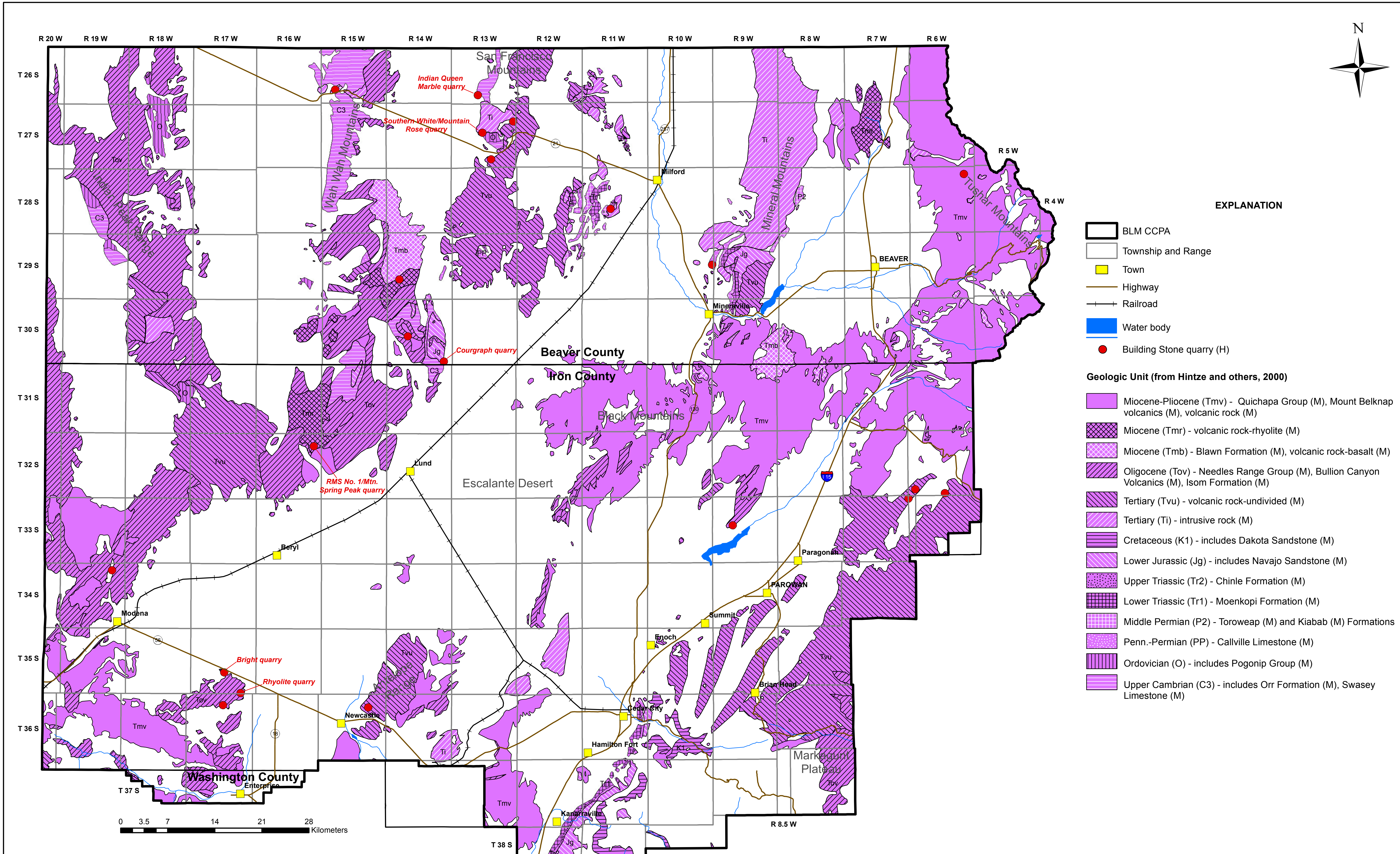

Figure 5.3.2.2. BLM Cedar City planning area building stone development potential.

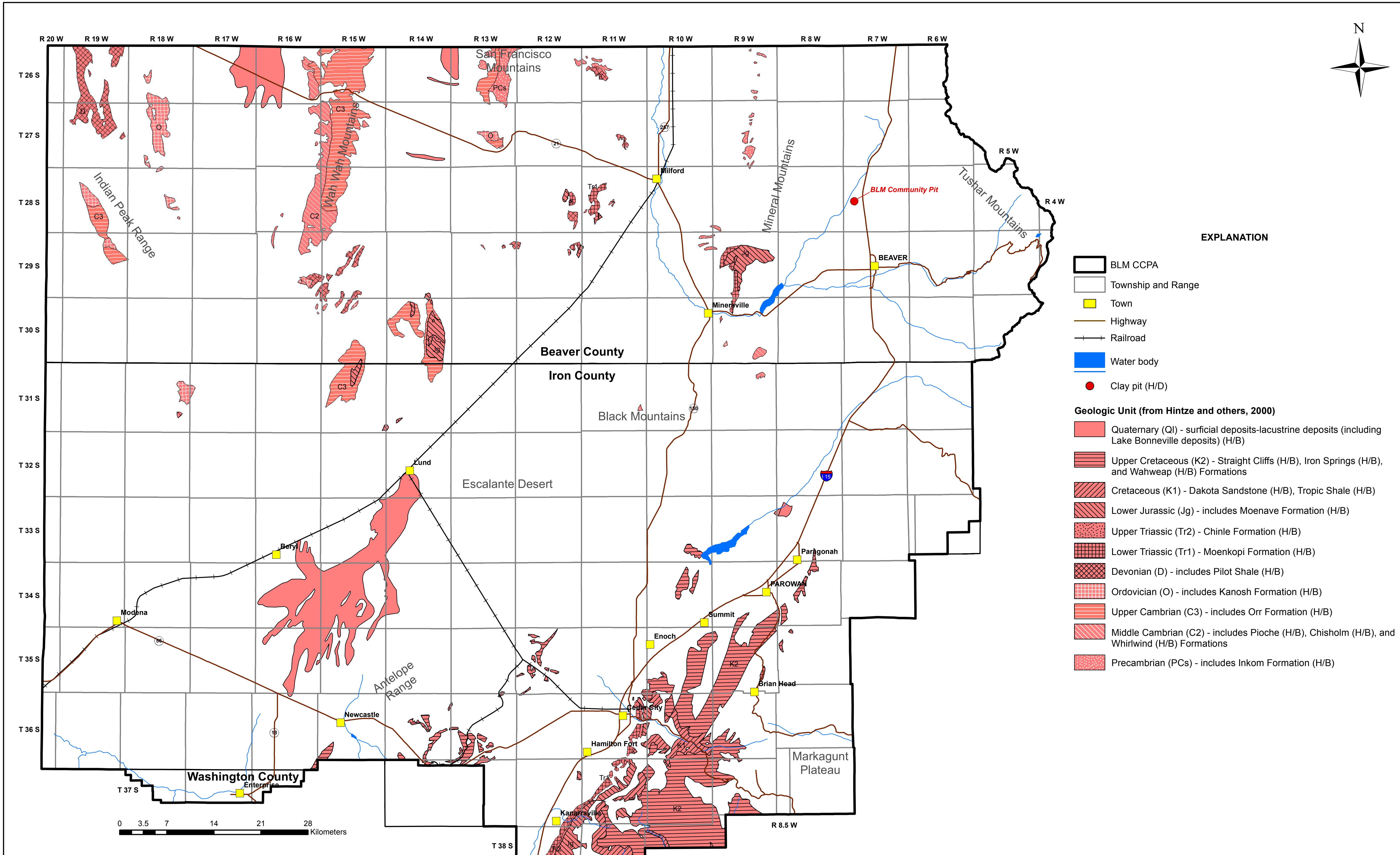

Figure 5.3.3.1. *BLM Cedar City planning area common clay occurrence potential.*

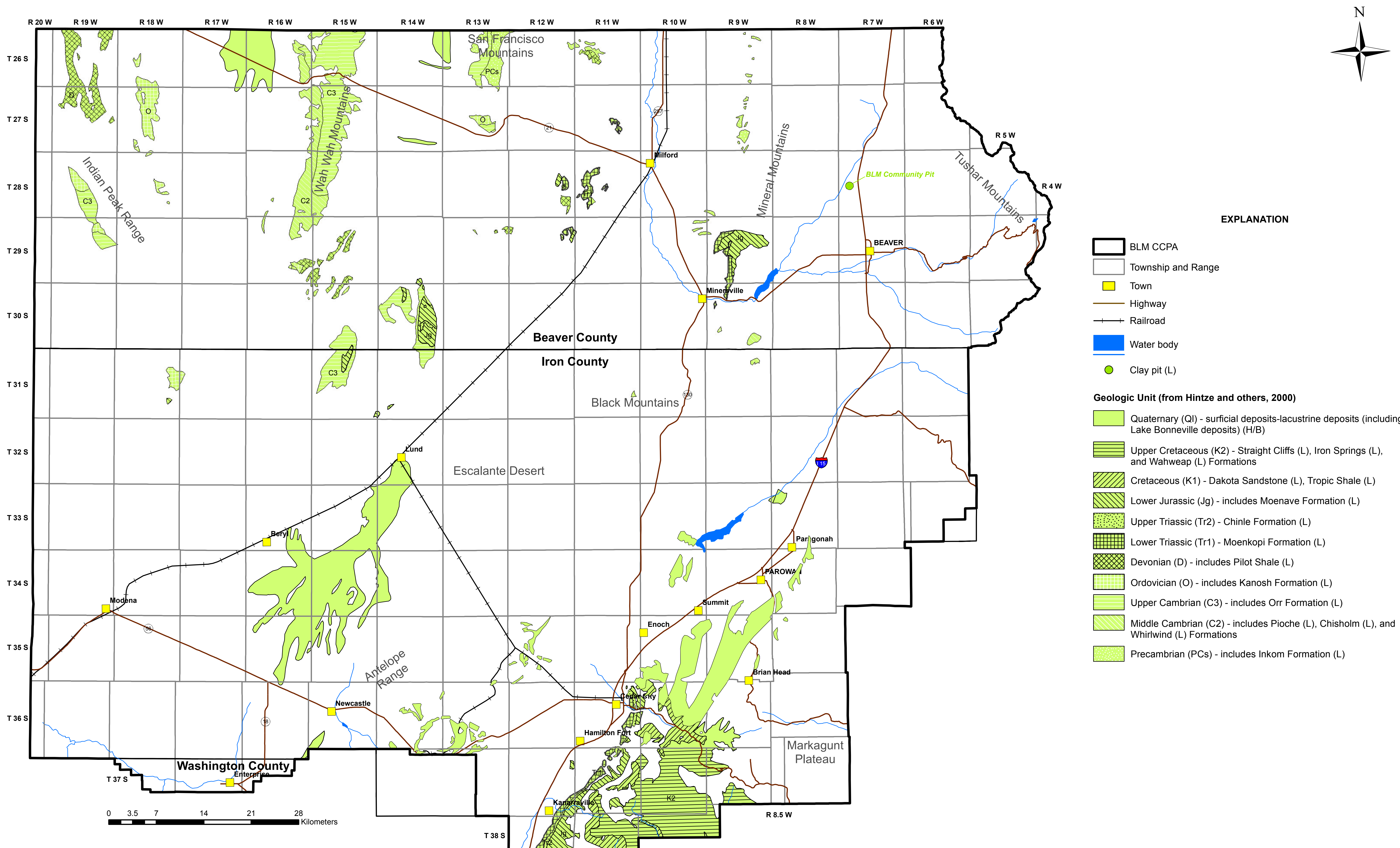

Figure 5.3.3.2. BLM Cedar City planning area common clay development potential.

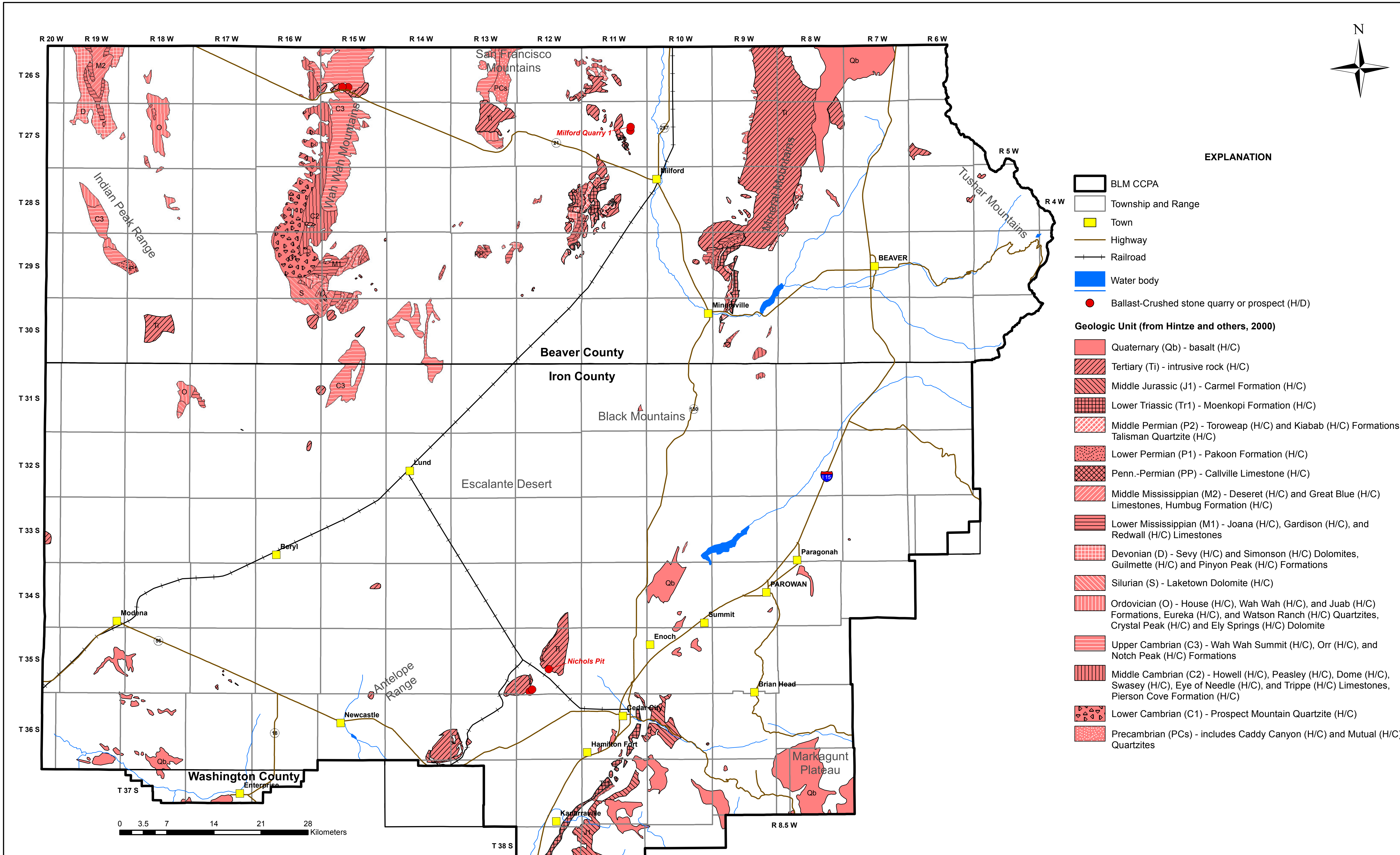

Figure 5.3.4.1. *BLM Cedar City planning area crushed stone and ballast occurrence potential.*

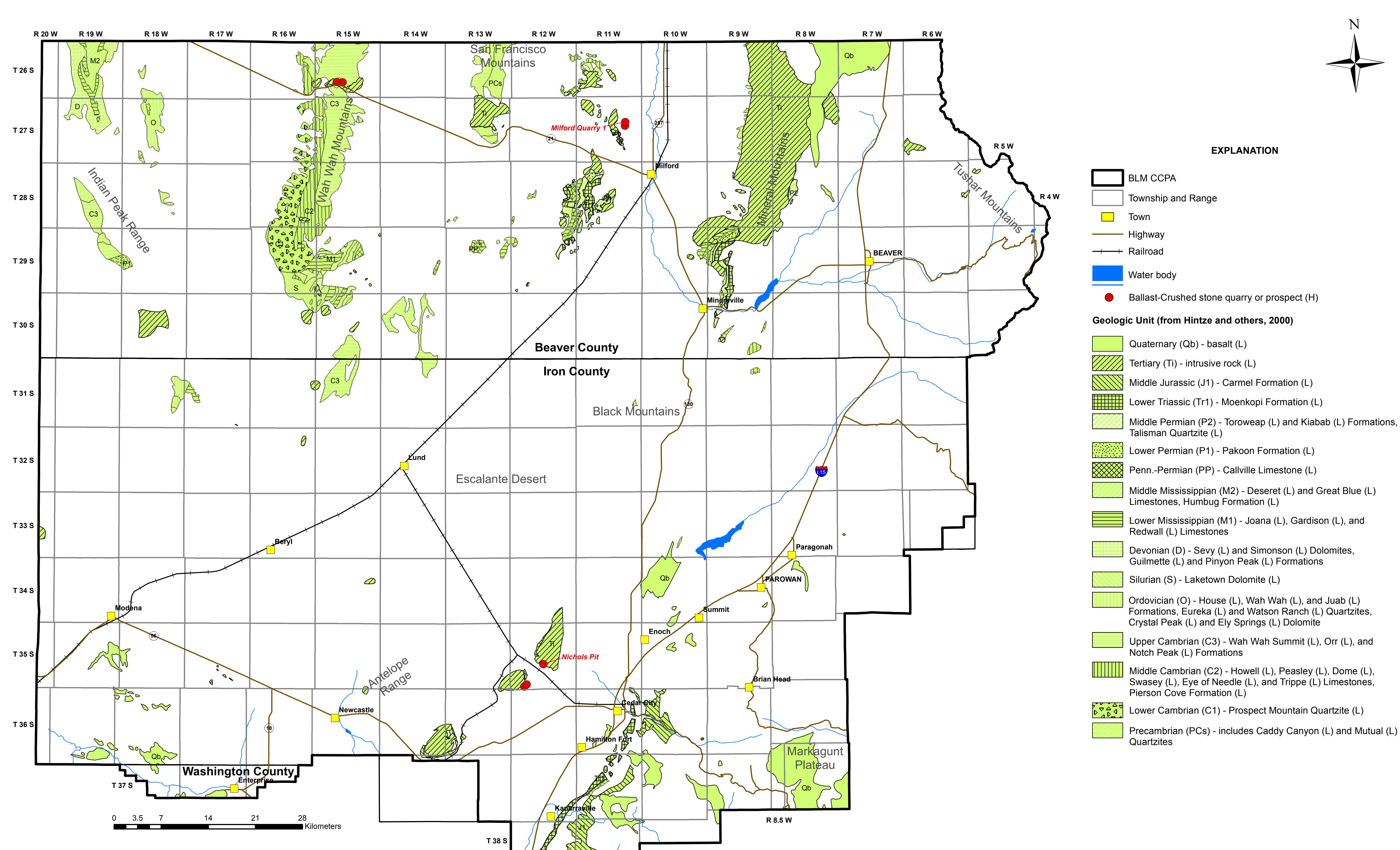

Figure 5.3.4.2. *BLM Cedar City planning area crushed stone and ballast development potential.*

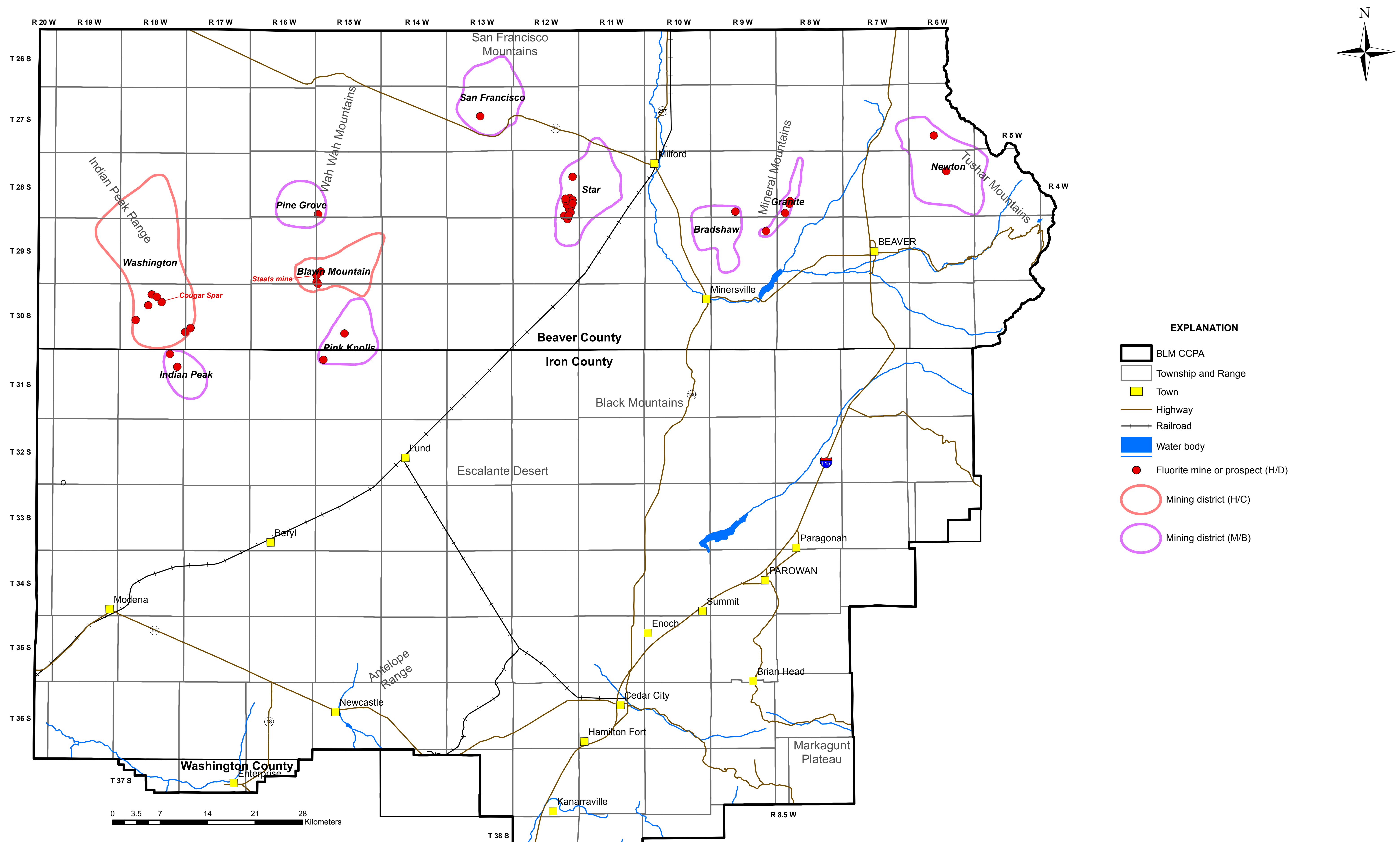

Figure 5.3.5.1. BLM Cedar City planning area fluorite occurrence potential.

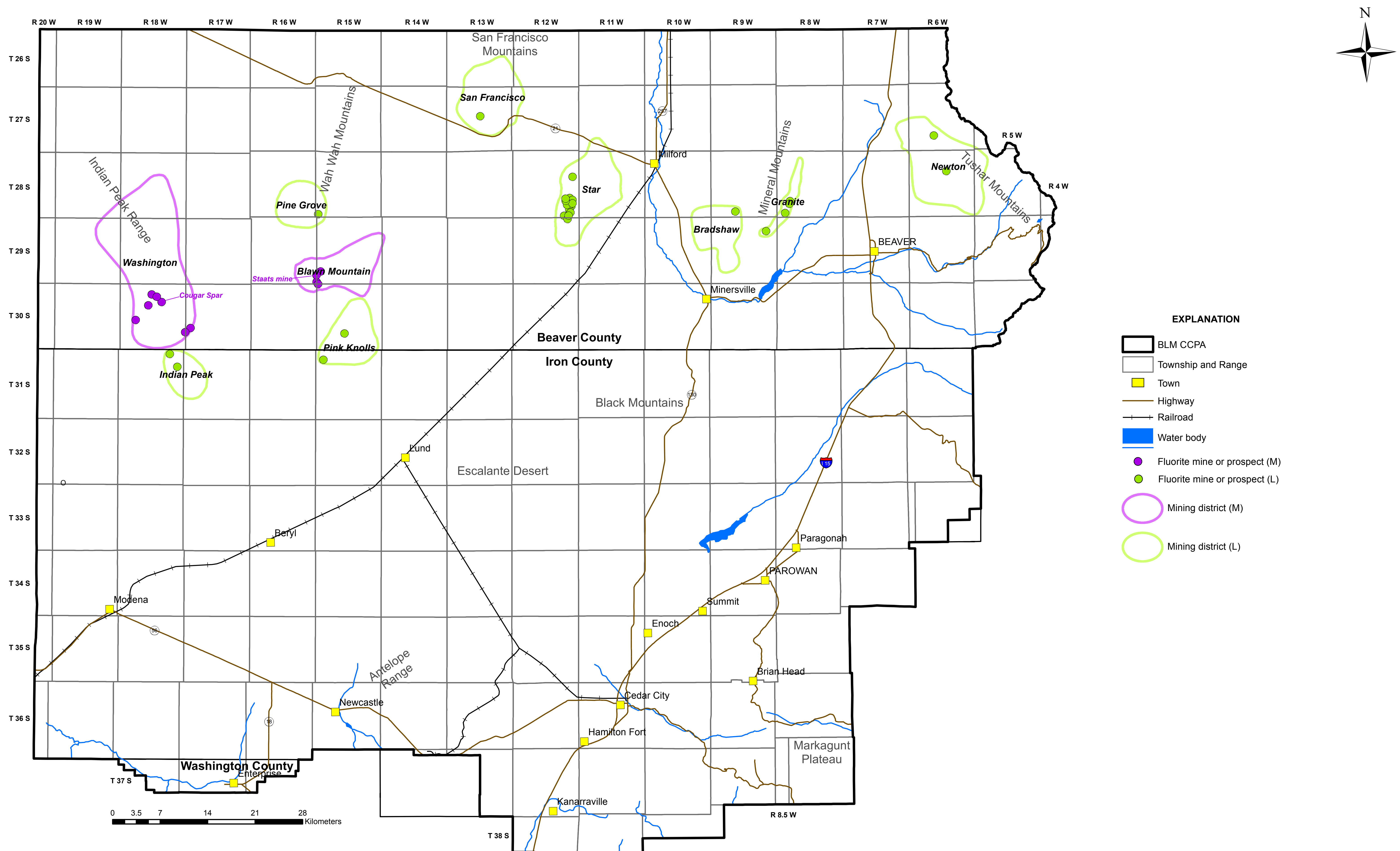

Figure 5.3.5.2. BLM Cedar City planning area fluorite development potential.

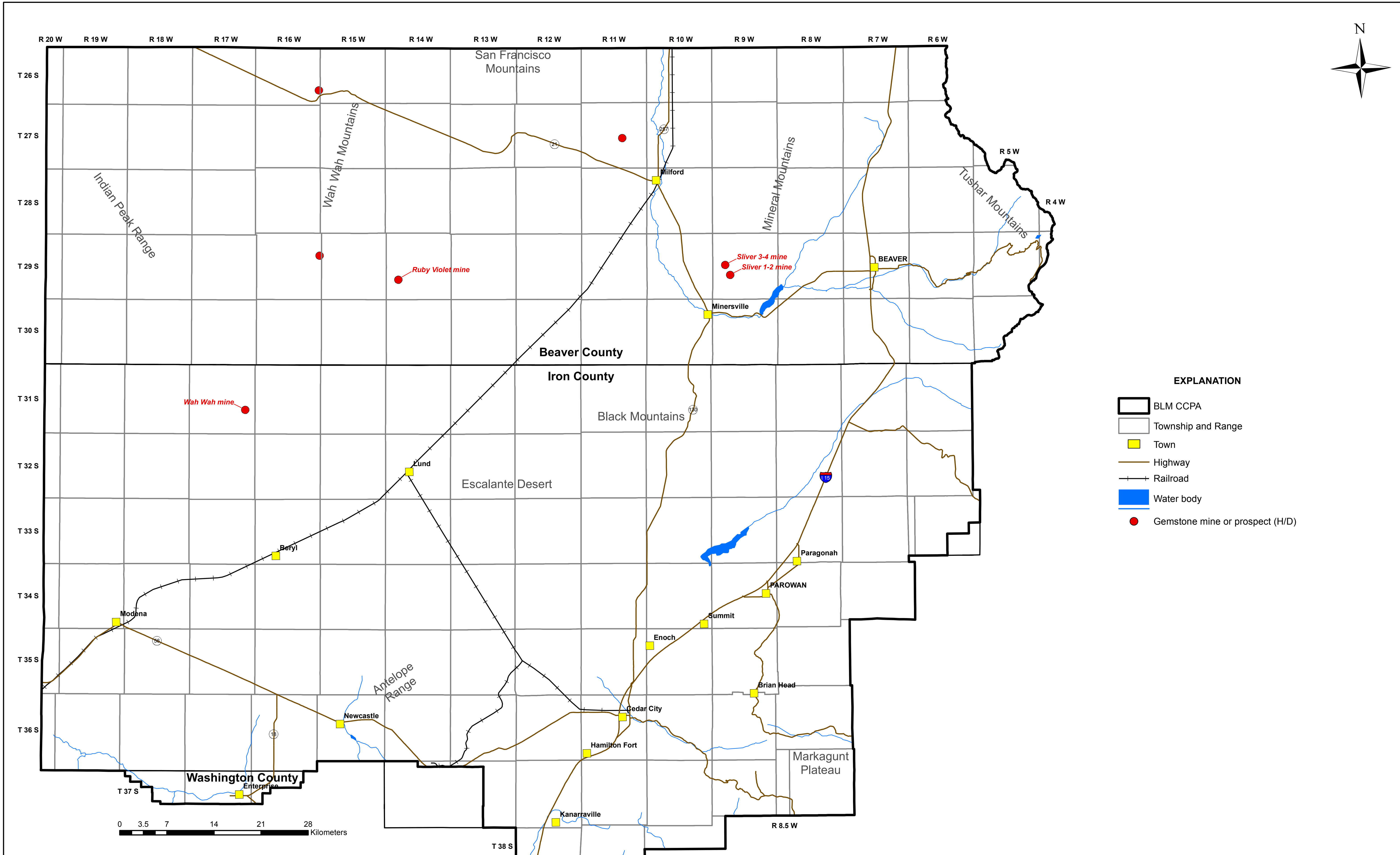

Figure 5.3.6.1. *BLM Cedar City planning area gemstone occurrence potential.*

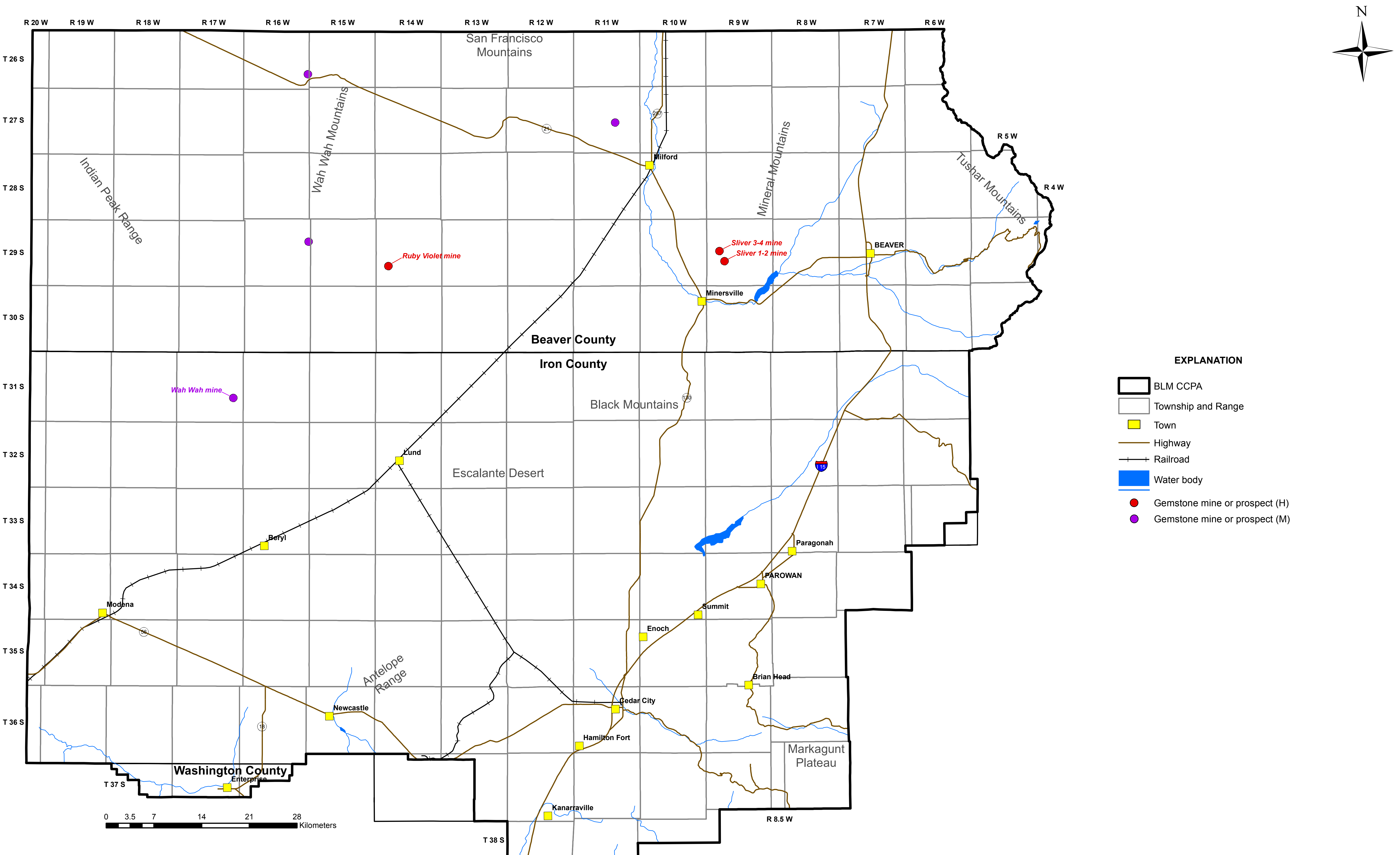

Figure 5.3.6.2. BLM Cedar City planning area gemstone development potential.

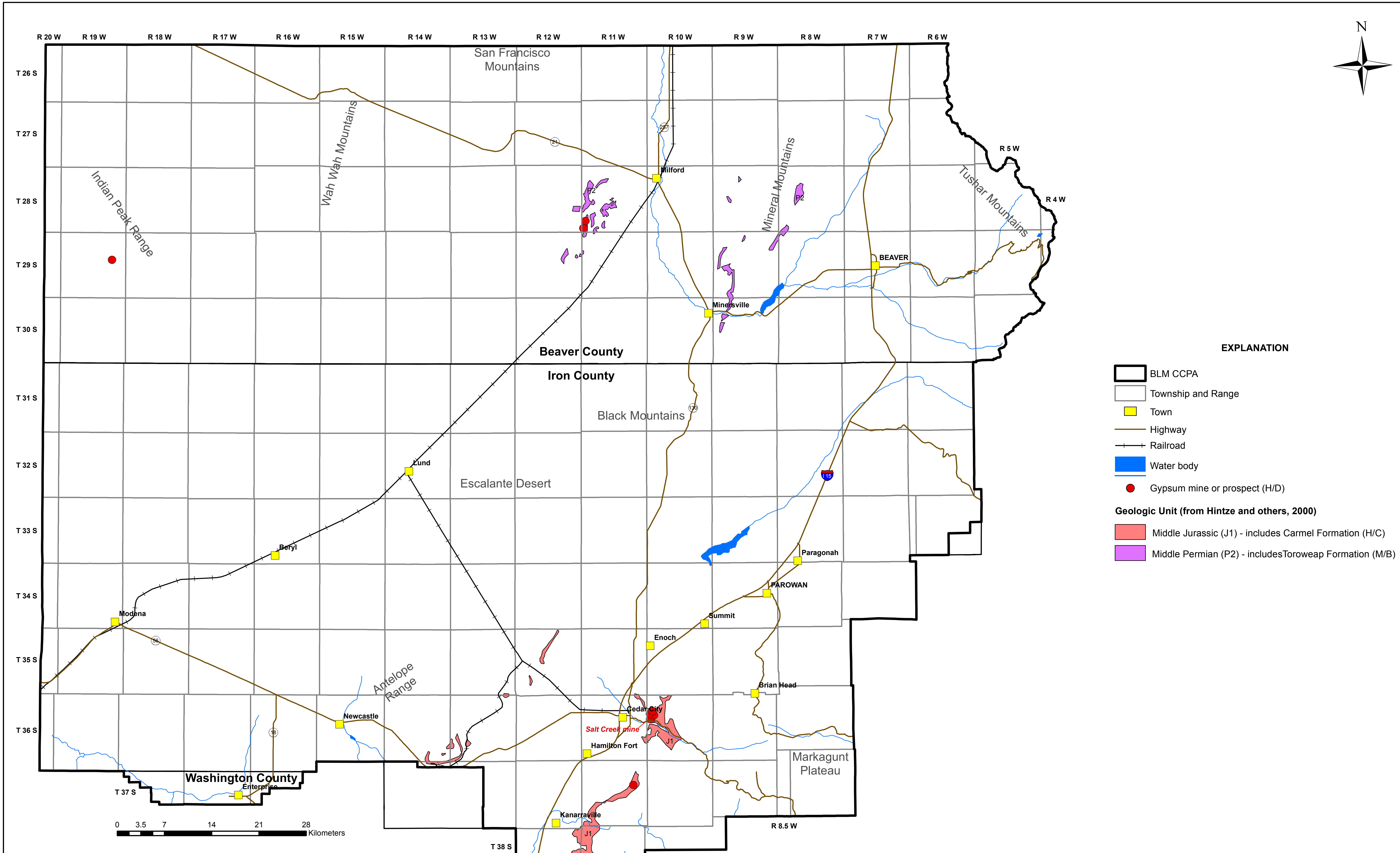

Figure 5.3.7.1. BLM Cedar City planning area gypsum occurrence potential.

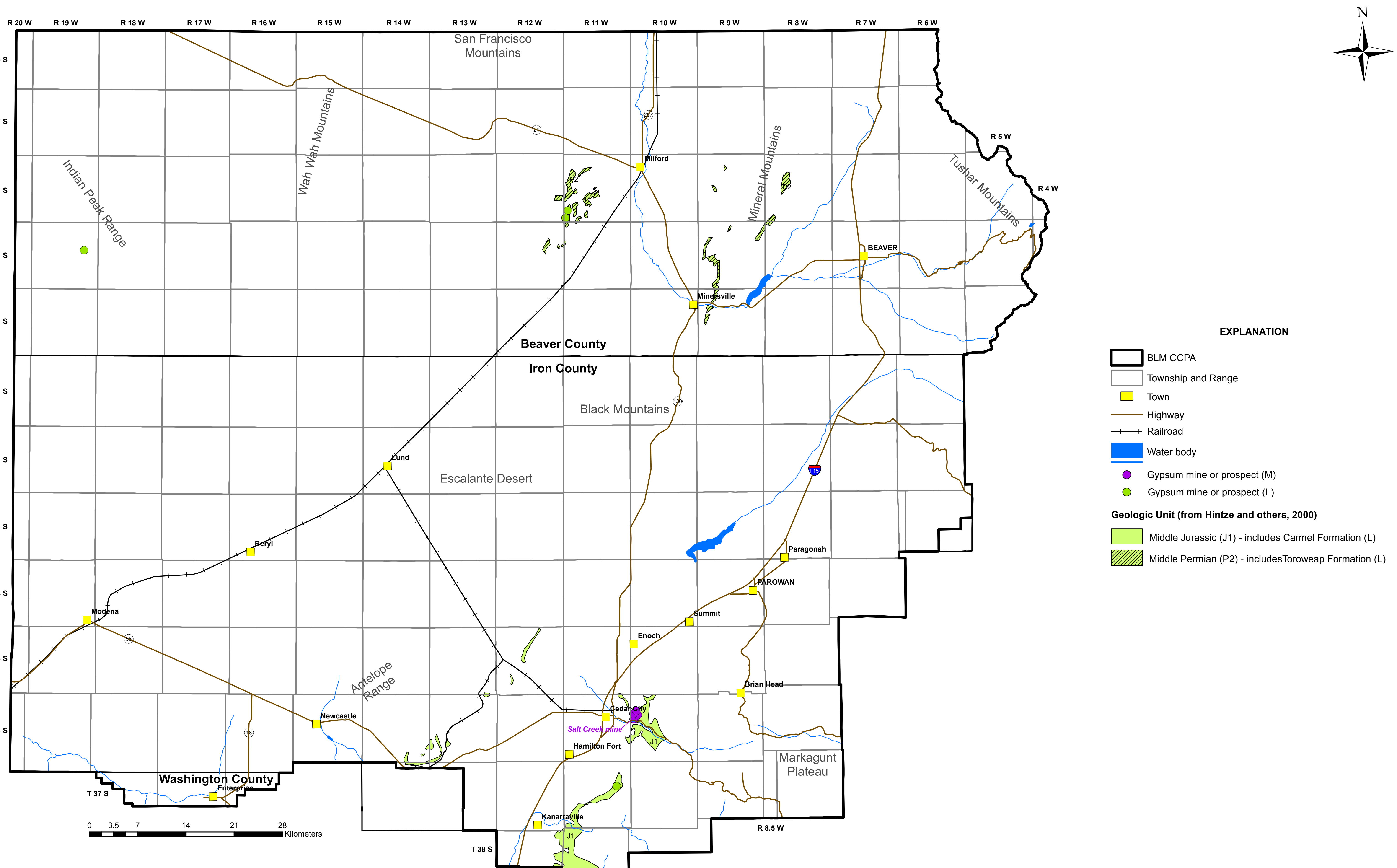

Figure 5.3.7.2. BLM Cedar City planning area gypsum development potential.

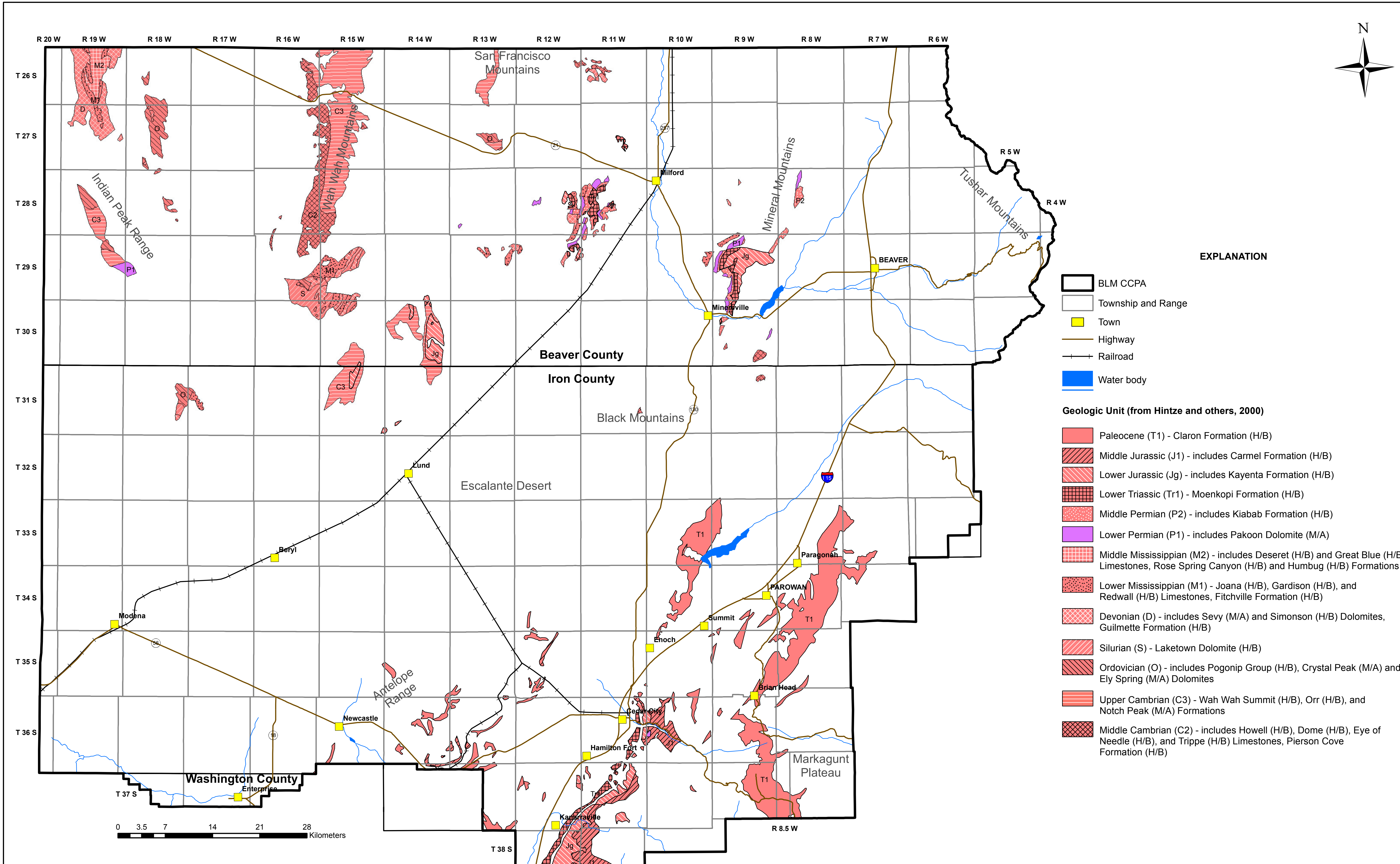

Figure 5.3.8.1. *BLM Cedar City planning area high-calcium limestone and high-magnesium dolomite occurrence potential.*

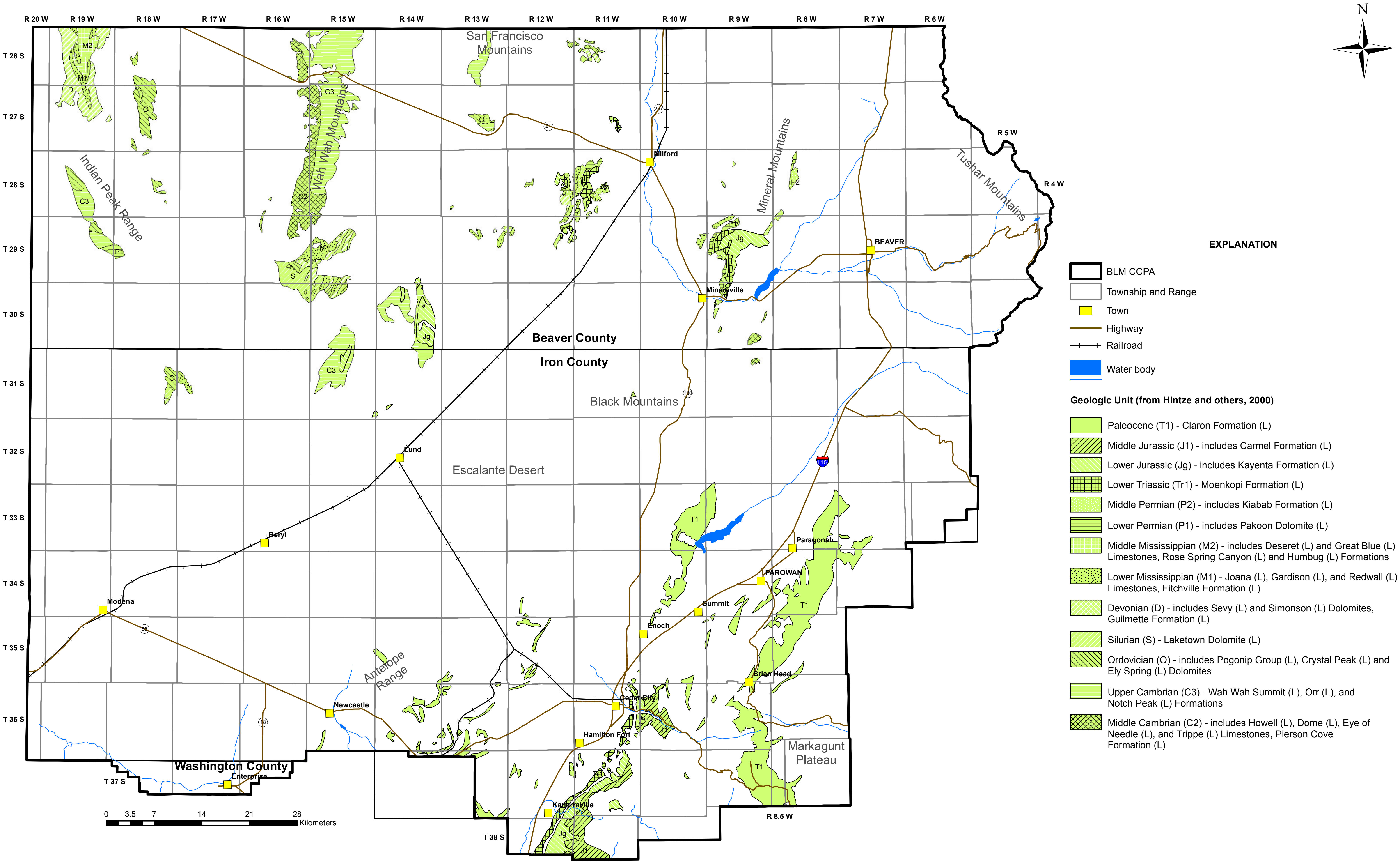

Figure 5.3.8.2. BLM Cedar City planning area high-calcium limestone and high-magnesium dolomite development potential.

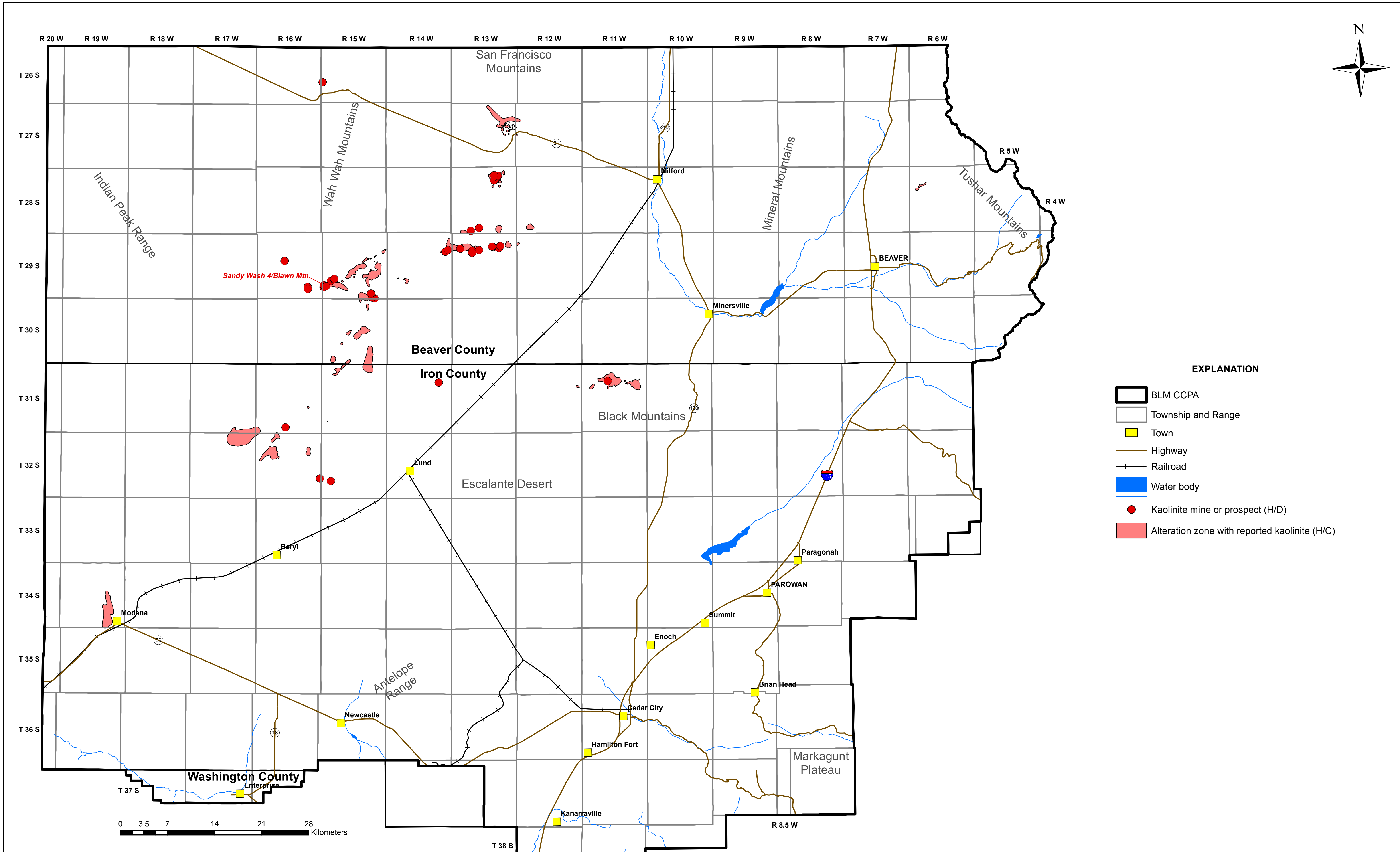

Figure 5.3.9.1. BLM Cedar City planning area kaolinite occurrence potential.

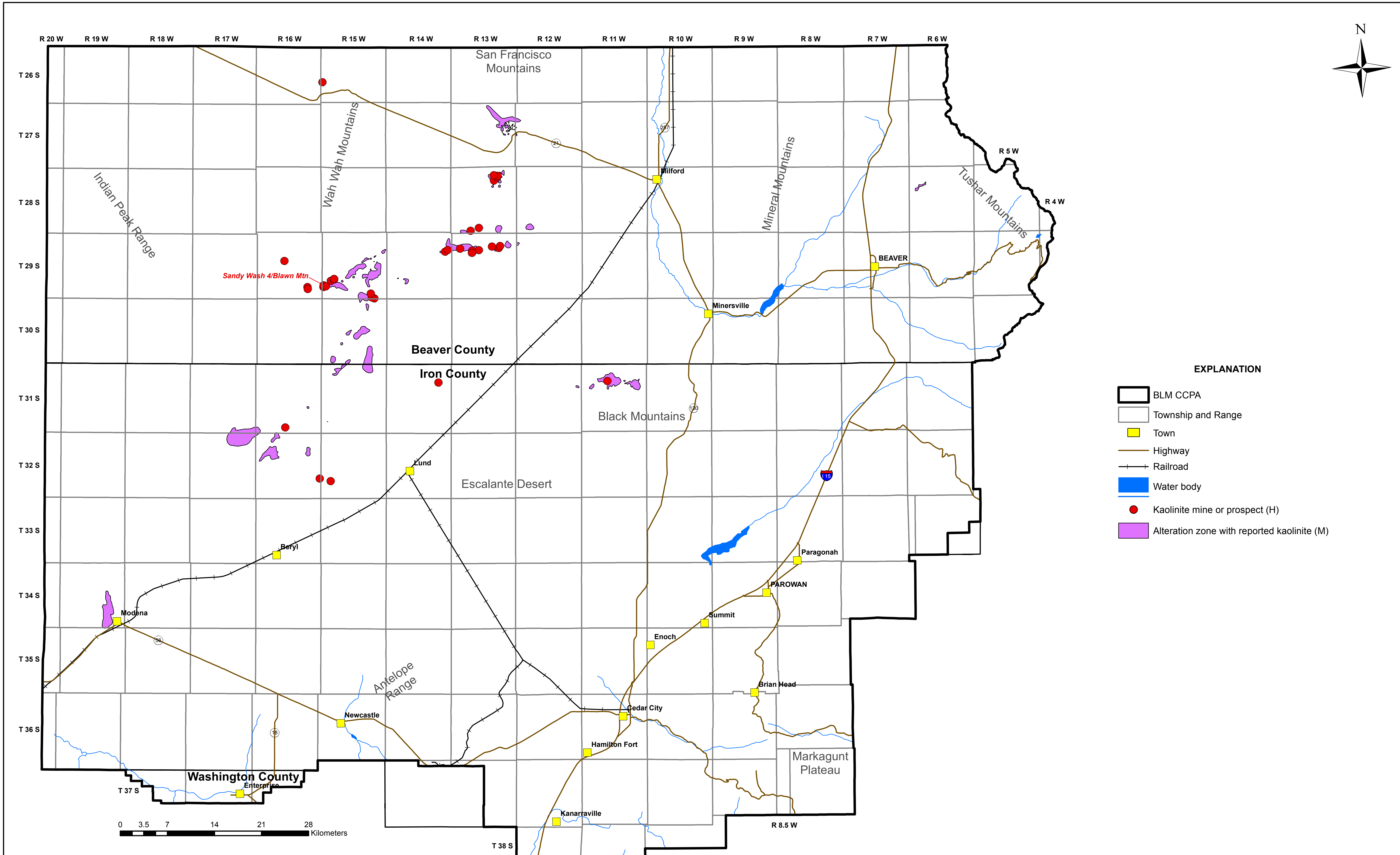

Figure 5.3.9.2. *BLM Cedar City planning area kaolinite development potential.*

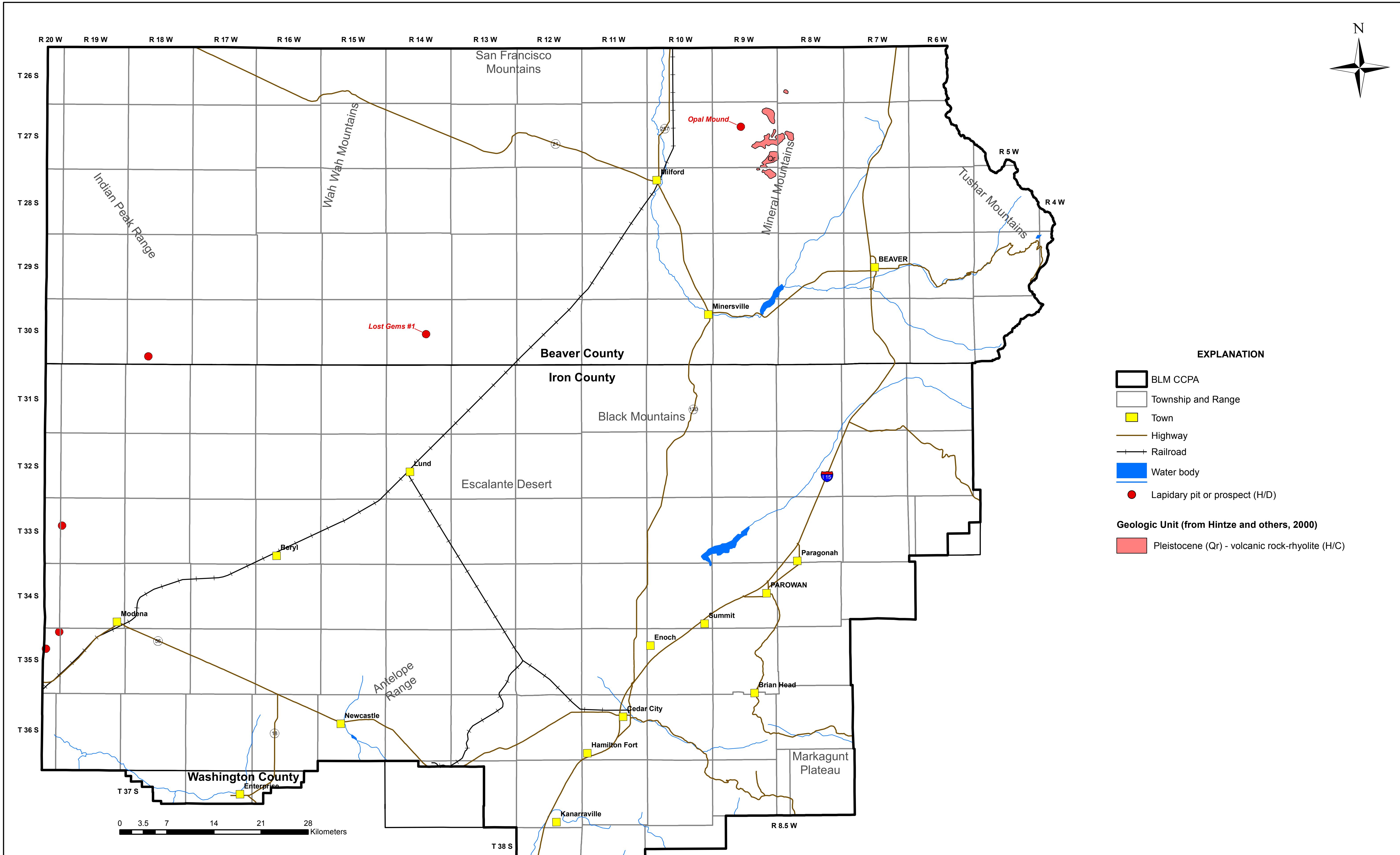

Figure 5.3.10.1. BLM Cedar City planning area lapidary material occurrence potential.

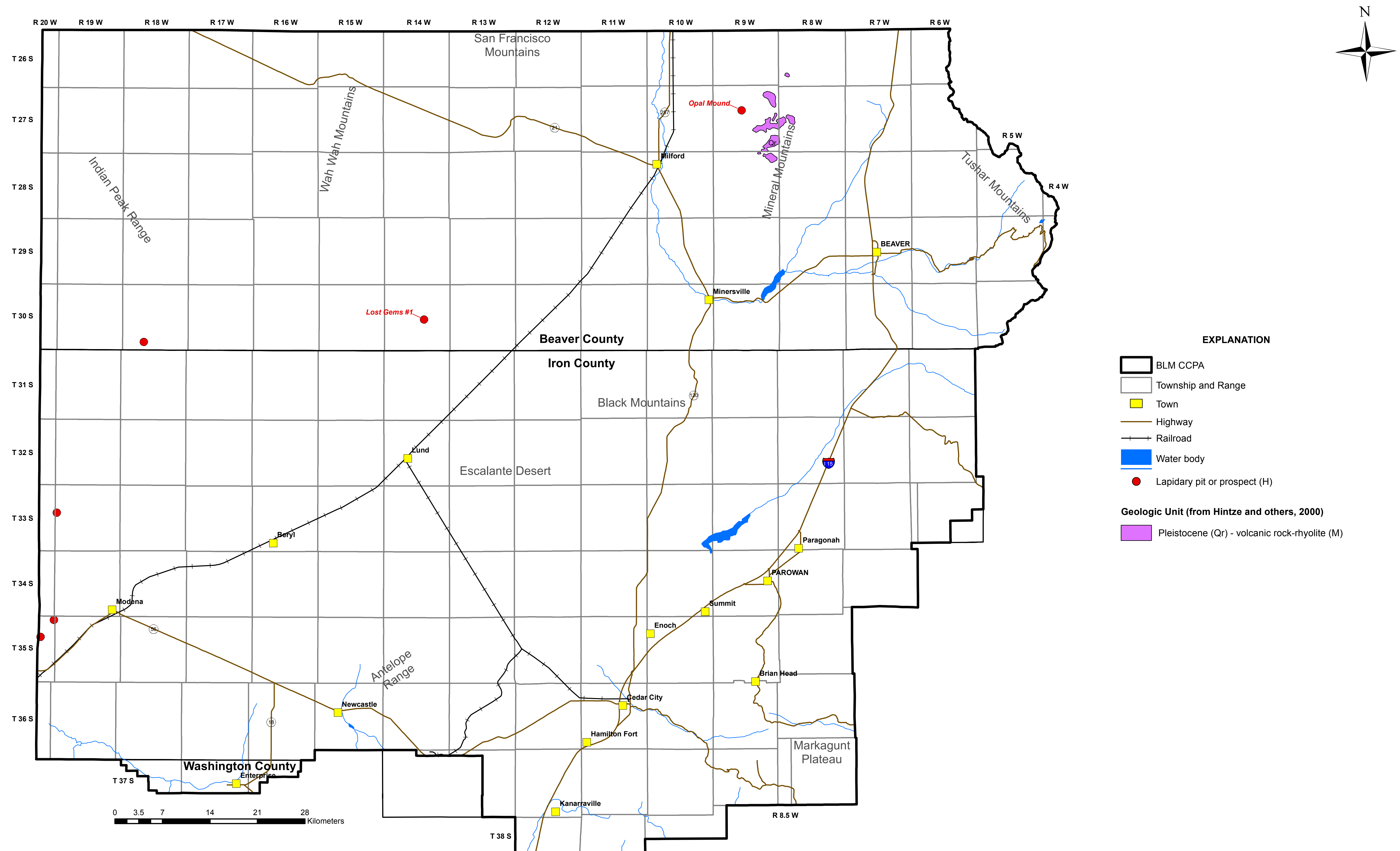

Figure 5.3.10.2. BLM Cedar City planning area lapidary material development potential.

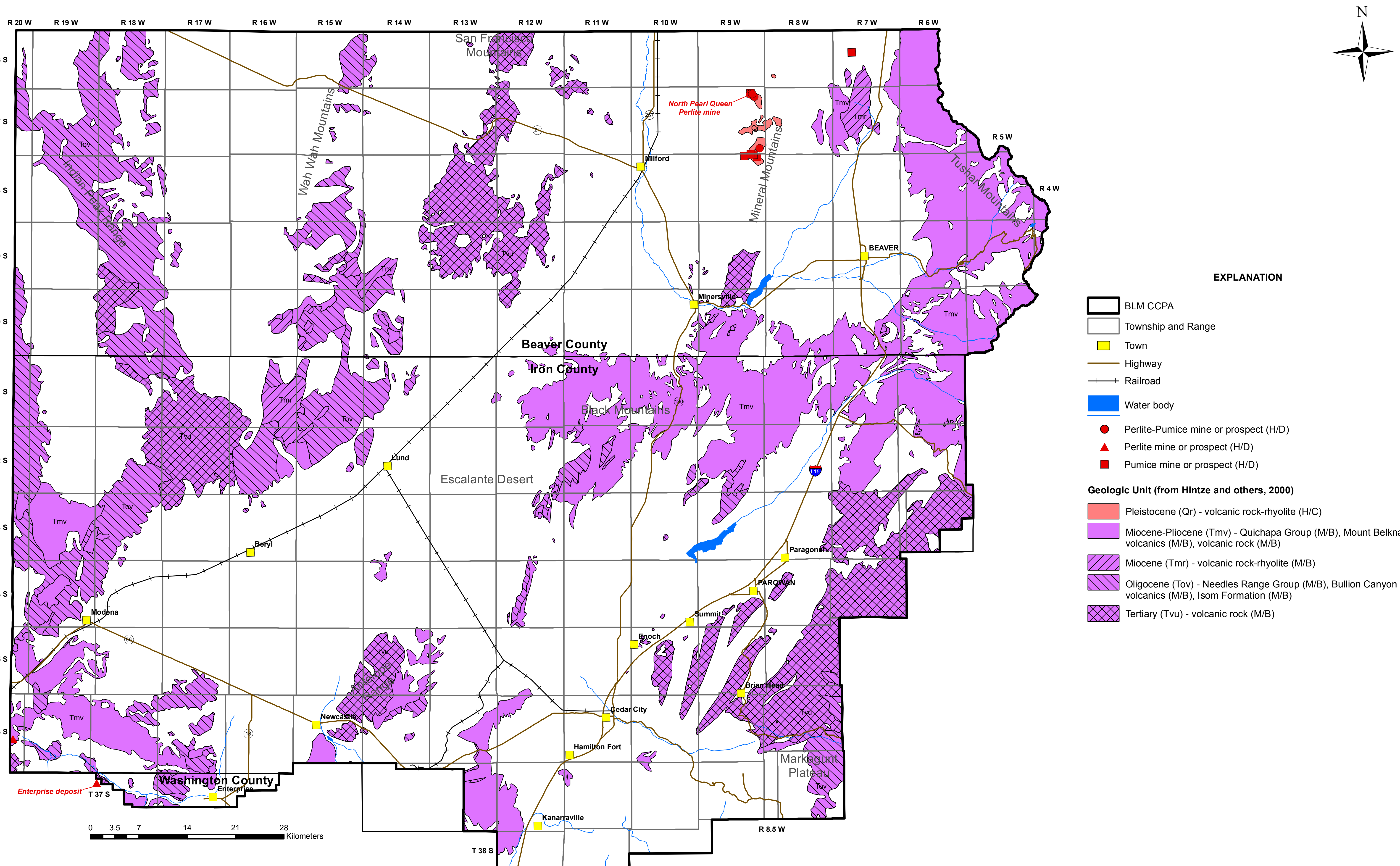

Figure 5.3.11.1. *BLM Cedar City planning area light weight aggregate occurrence potential.*

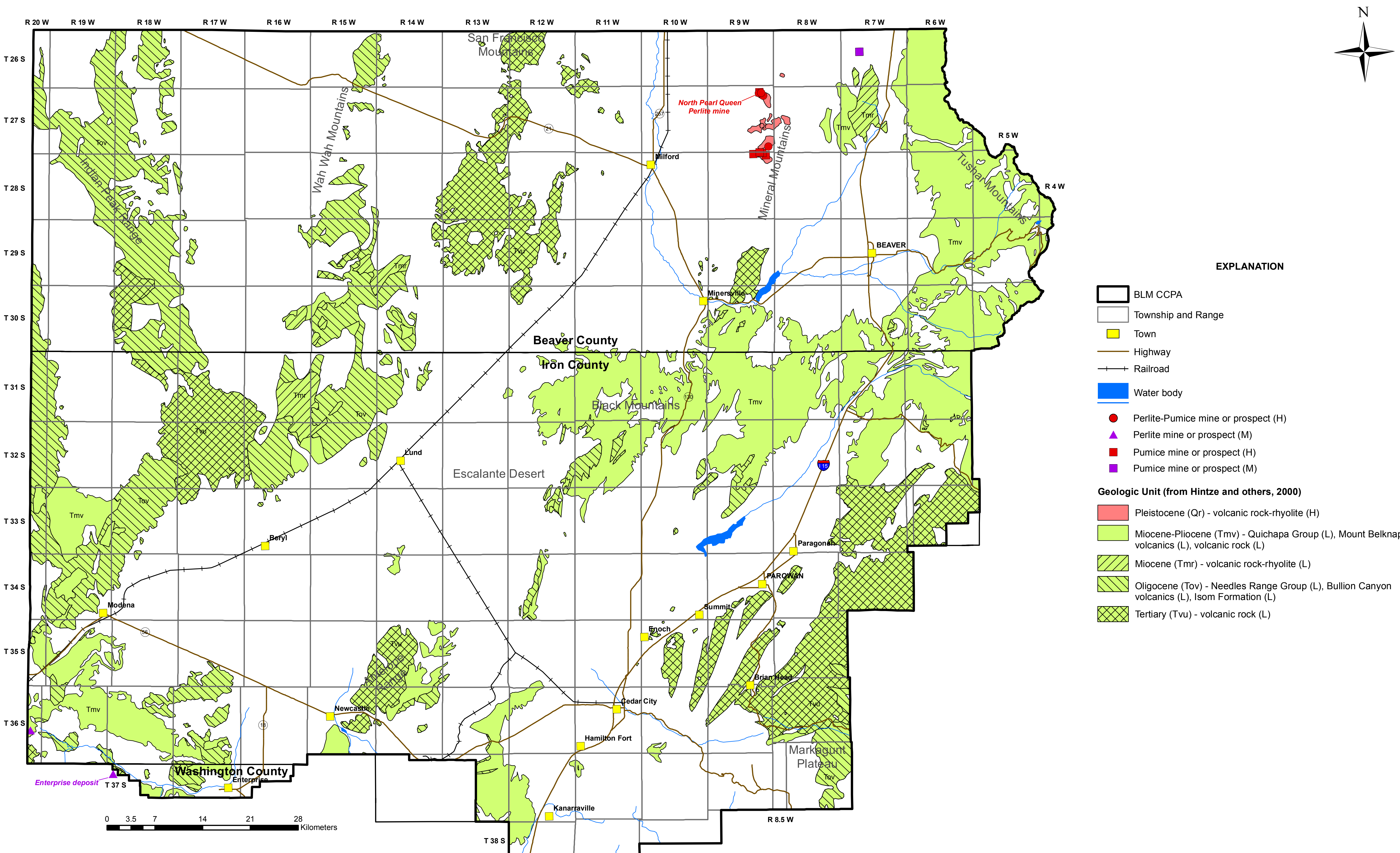

Figure 5.3.11.2. BLM Cedar City planning area light weight aggregate development potential.

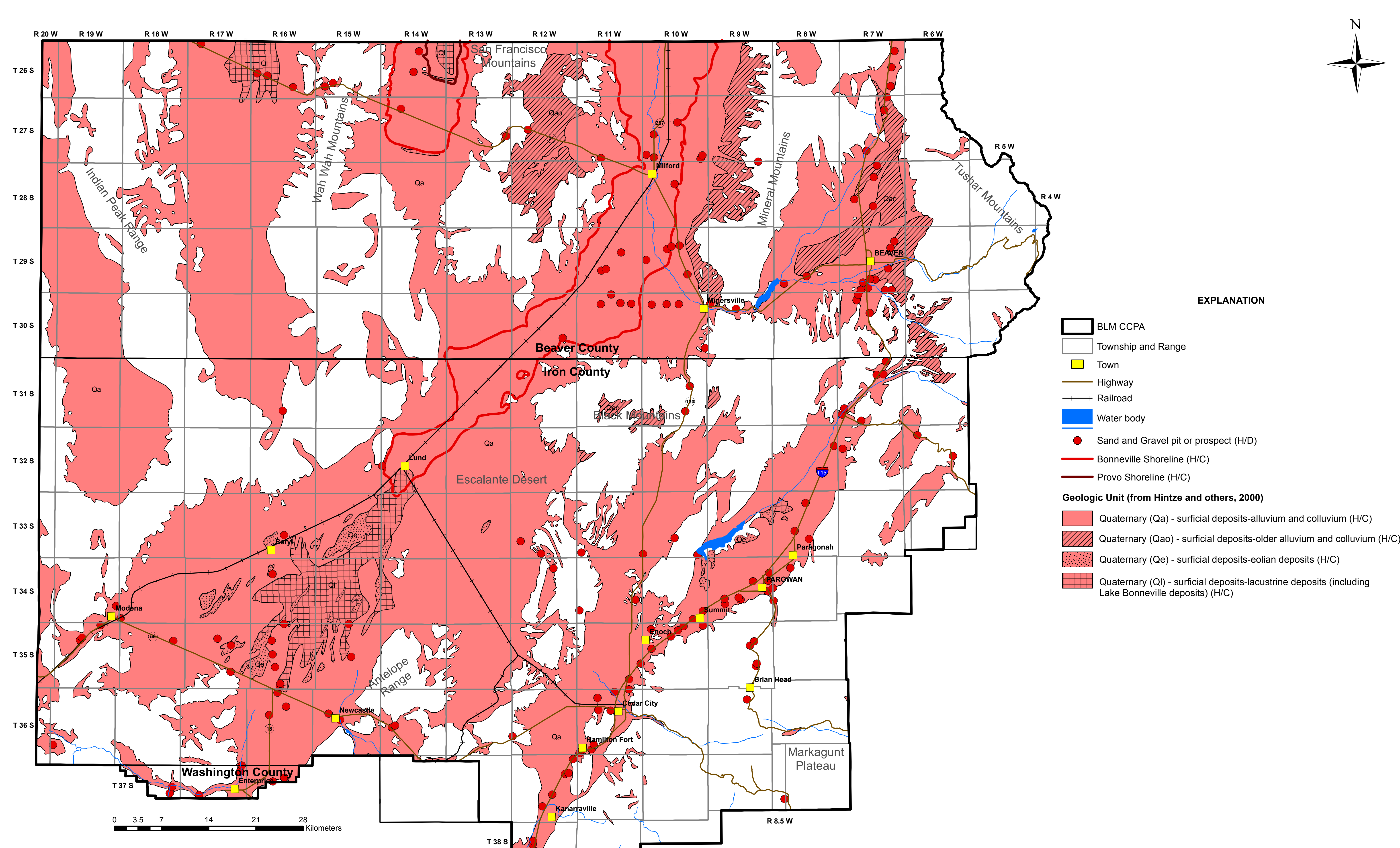

***Figure 5.3.12.1.** BLM Cedar City planning area sand and gravel occurrence potential.*

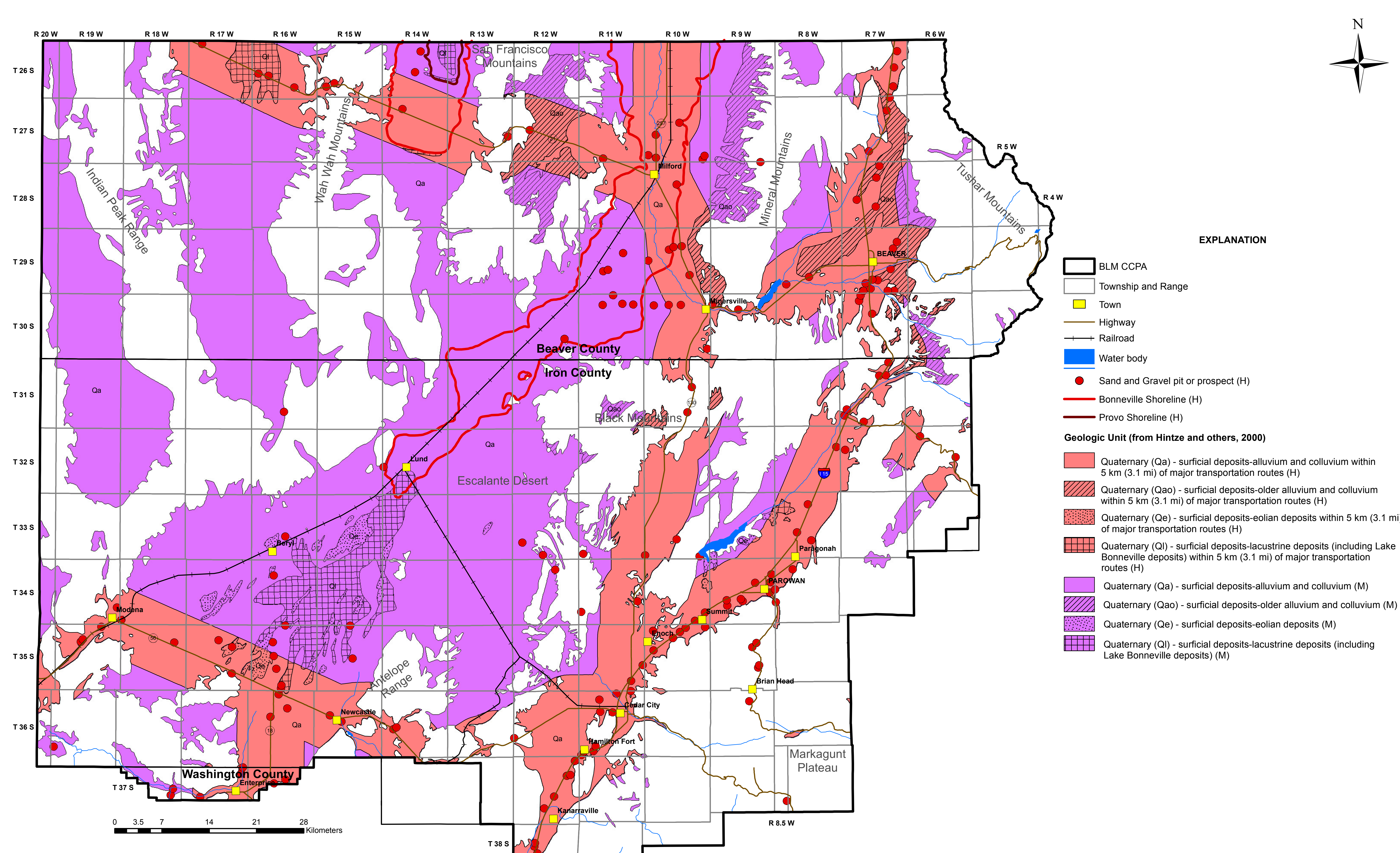

Figure 5.3.12.2. *BLM Cedar City planning area sand and gravel development potential.*

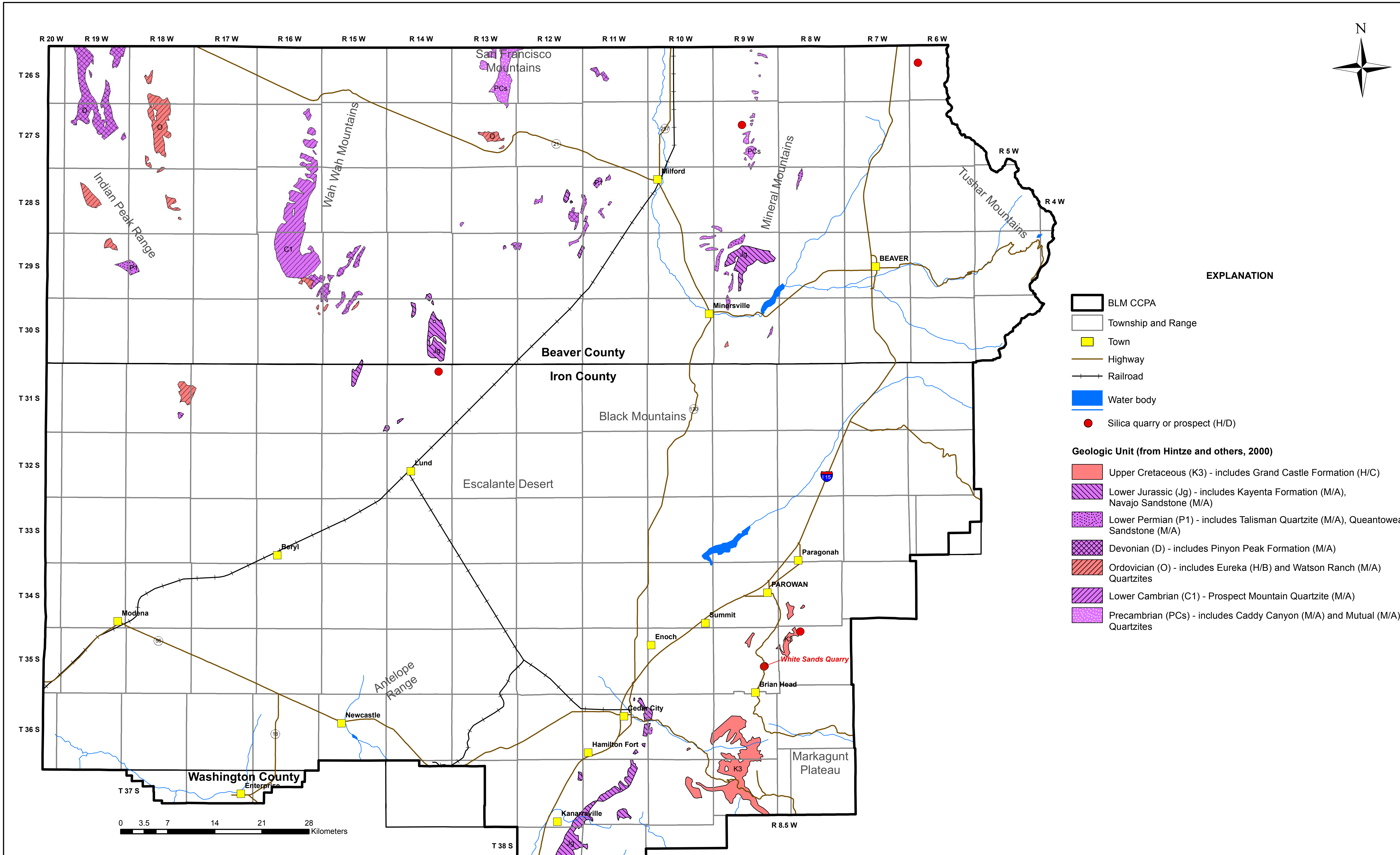

***Figure 5.3.13.1.** BLM Cedar City planning area silica occurrence potential.*

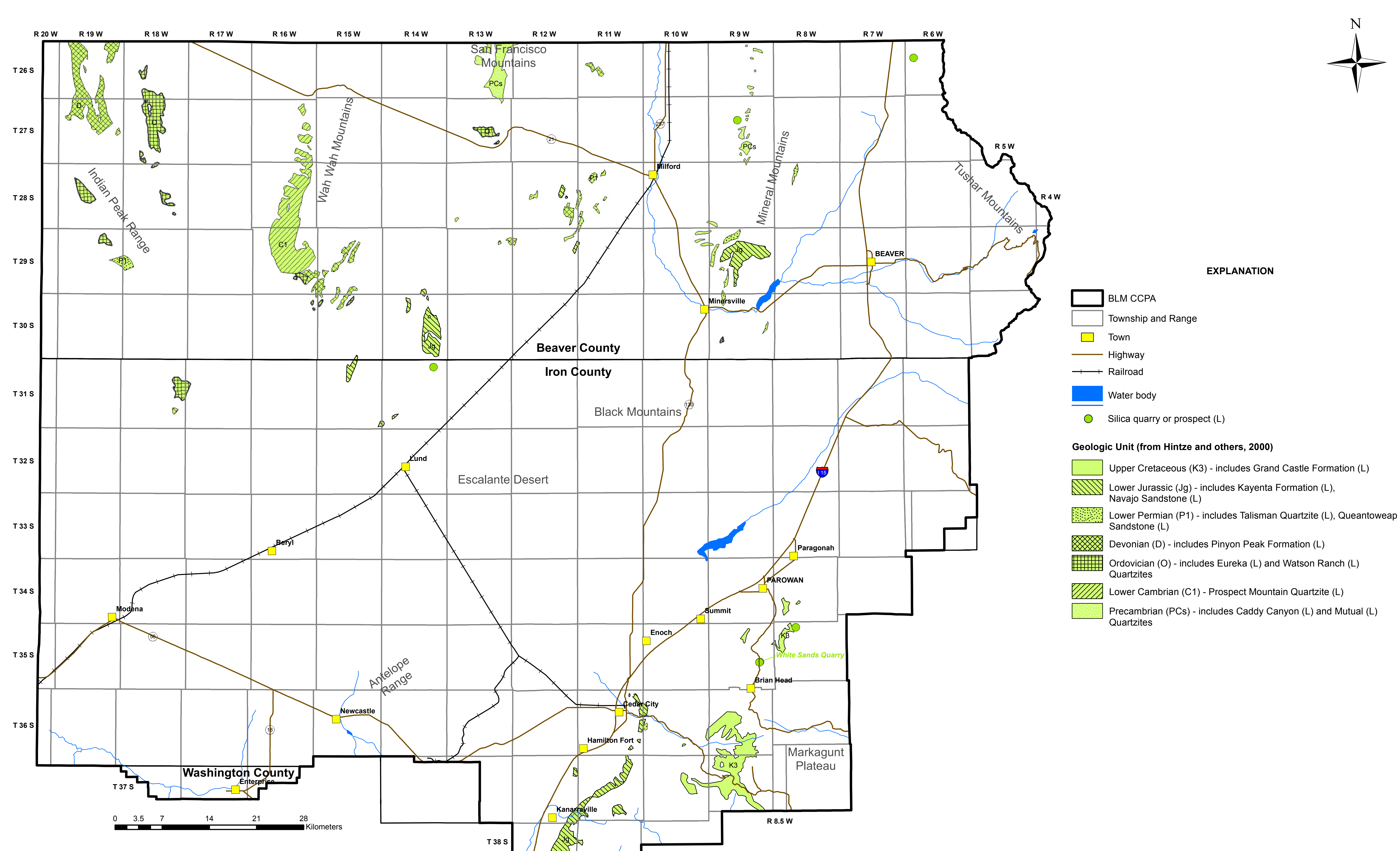

Figure 5.3.13.2. BLM Cedar City planning area silica development potential.

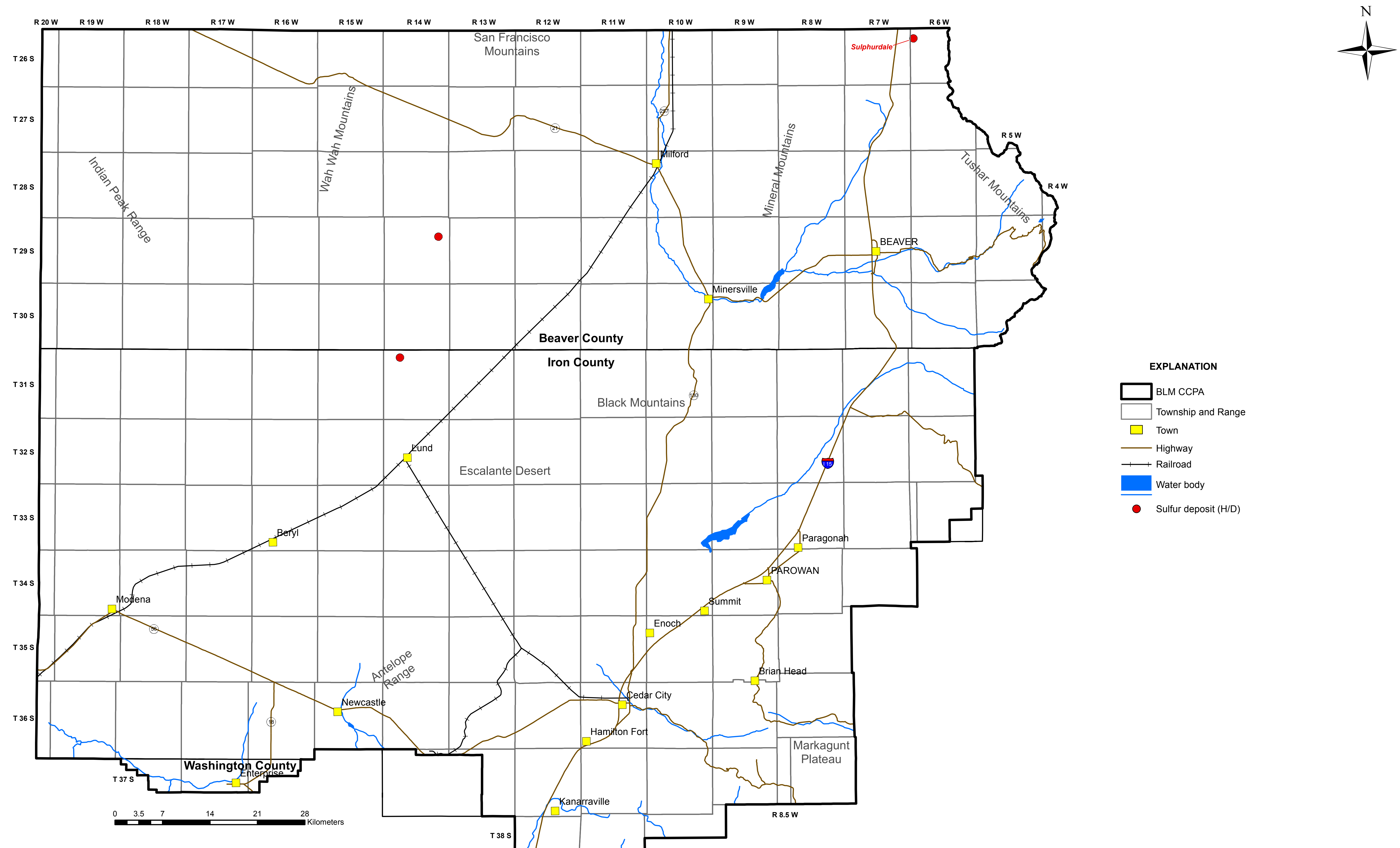

Figure 5.3.14.1. *BLM Cedar City planning area sulfur occurrence potential.*

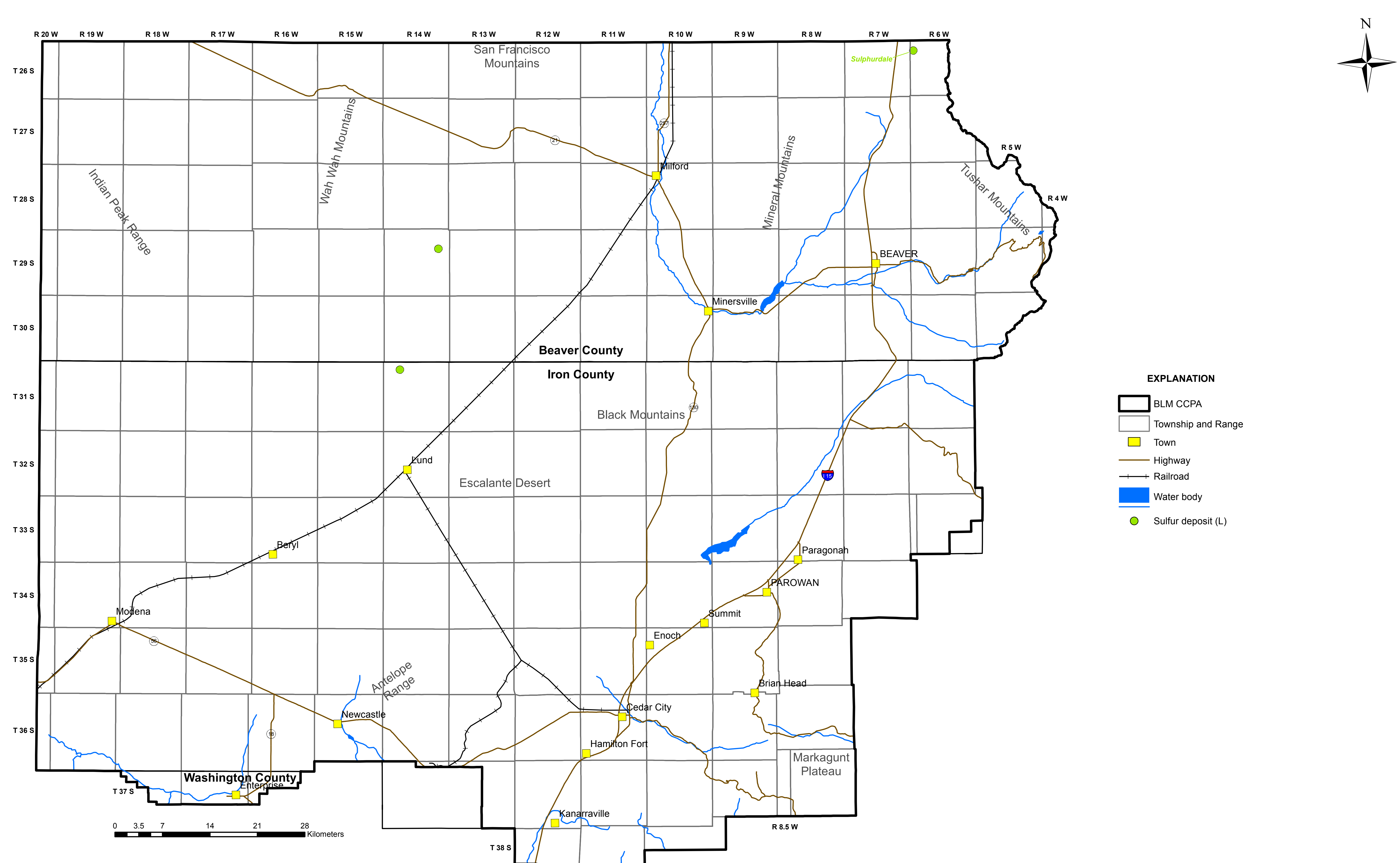

Figure 5.3.14.2. BLM Cedar City planning area sulfur development potential.