CHECKLIST FOR ANALYZING POTENTIAL EFFECTS ON SIGNIFICANT THERMAL FEATURES

(REF: Geothermal Steam Act Amendment, 1998, P.L. 100-143)

Utah BLM and Forest Service,
Proposed May 2015 Competitive Geothermal Lease Sale

Utah Power's Blundell geothermal power plant at Roosevelt Hot Springs geothermal area, Beaver County, Utah (from, Blackett, 2008)

LEASE APPLICTATION AND PARCEL NUMBERS

<u>Bureau of Land Management Parcels</u>

UT0515 – 7954 - 001
(Serial #: UTU90273)
T. 19 S., R. 7 W., Salt Lake
Sec. 26: W2SW, NESE, S2SE;
Sec. 27: SENE, E2SE;
Sec. 34: E2E2;
Sec. 35: All;
T. 20 S., R. 7 W., Salt Lake
Sec. 3: Lot 1;
Sec. 4: SWNE, SE.
1,366.15 Acres
Millard County, Utah
Fillmore Field Office
Nearest Geothermal Area: North of Meadow Hatton Spring, Black Rock Desert area

UT0515 – 7955 - 002
(Serial #: UTU90271)
T. 13 S., R. 8 W., Salt Lake
Sec. 3: All;
Sec. 10: N2NE, SWNE, E2W2, W2SE, SESE;
Sec. 15: W2NE, E2NW, S2.
1,533.64 Acres
Juab County, Utah
Richfield Field Office
Nearest Geothermal Area: Crater Springs

UT0515 – 7956 - 003
(Serial #: UTU86143)
T. 26 S., R. 9 W., Salt Lake
Secs. 26, 27, 28 and 33: All;
Sec. 34: W2W2;
Sec. 35: E2, E2NW, NESW.
3,160.00 Acres
Beaver County, Utah
Cedar City Field Office
Nearest Geothermal Area: Roosevelt Hot Springs

LEASE APPLICTATION AND PARCEL NUMBERS (cont.)

Bureau of Land Management Parcels (cont.)

UT0515 – 7957 - 004
(Serial #: UTU86142)
T. 27 S., R. 9 W., Salt Lake
Sec. 1: All;
Sec. 4: SW, N2SE, SWSE;
Sec. 9: W2NE, W2, NWSE;
Sec. 11: NE, NENW, S2NW, S2;
Sec. 14: All;
Sec. 15: E2E2, SWSE.
2,841.40 Acres
Beaver County, Utah
Cedar City Field Office
Nearest Geothermal Area: Roosevelt Hot Springs

UT0515 – 7958 - 005
(Serial #: UTU90483)
T. 15 S., R. 12 W., Salt Lake
Secs. 22, 23, 24, 25, 26, 27, 34 and 35: All.
5,120.00 Acres
Millard County, Utah
Fillmore Field Office
Nearest Geothermal Area: Drum Mountain

UT0515 – 7959 - 006
(Serial #: UTU90200)
T. 30 S., R. 12 W., Salt Lake
Sec. 21: N2NE, SWNE, NW, N2SW, SESW, NWSE;
Sec. 27: All;
Sec. 28: N2S2;
Sec. 29: N2, NESW, SE.
1,760.79 Acres
Beaver County, Utah
Cedar City Field Office
Nearest Geothermal Area: Thermo Hot Springs II

LEASE APPLICTATION AND PARCEL NUMBERS (cont.)

US Forest Service Parcels

UT0515 – 7960 - 007
(Serial #: UTU86298)
T. 24 S., R. 6 W., Salt Lake
Sec. 32: Lots 1-4, N2N2, N2S2, SESE;
Sec. 33: All.
1,180.20 Acres
Millard County, Utah
Fillmore Field Office
Nearest Geothermal Area: Monroe-Joseph area

UT0515 – 7961 - 008
(Serial #: UTU86295)
T. 25 S., R. 6 W., Salt Lake
Protraction Block 38: unsurveyed;
Secs. 5 and 8: All.
1,864.99 Acres
Millard County, Utah
Fillmore Field Office
Nearest Geothermal Area: Monroe-Red Hill Joseph Hot Springs area

POTENTIALLY AFFECTED FEATURE: **Lake Mead National Recreation Area (NRA)**

- Distance: Approximately 100 miles to southwest of nearest 2015 Utah geothermal parcels offerings.
- Type Feature: Hot Springs
- National Park Service Unit: Western Region

SUMMARY ANALYSIS

The parcels to be offered for lease at the proposed May 2015 competitive lease sale are located in the eastern Basin and Range geologic province (Fig.1,2). The parcels are also located in a region of Utah called the "Sevier Thermal Area" (Fig. 1,2,3), an area where known high temperature geothermal systems occur covering a region from Juab County south to Iron County. Surface conditions that express the geothermal systems in this area include: hot springs, sulphur deposits, altered zones, and surface venting of gases at fumaroles. The nearest potentially affected feature is the Lake Mead National Recreation Area (NRA) (Fig. 9) which is located over 100 miles southwest of the closest 2015 offered geothermal lease parcel near the the Thermo Hot Springs II geothermal area (Figs. 2,3).

The nearest "Significant Thermal Feature" is the Lake Mead National Recreation Area (see Fig-9), located 100 miles to the southwest of the nearest 2015 geothermal lease parcel offering. The Lake Mead National Recreation area also lies in the same geological province (Basin and Range) and has hot springs and igneous activity related to the crustal extension of the Basin and Range province. However, it has two unique and major structural elements not found in the Sevier Thermal Area, the Las Vegas Shear zone and the Lake Mead shear zone (Fig.9).

From current information the Lake Mead National Recreation area hydrothermal, lithological, and structural features are not interconnected to those geothermal areas in the "Sevier Thermal Area" where parcels are being offered for this 2015 competitive geothermal lease sale. Therefore, it is unlikely that adverse effects on the thermal features (hot springs) of the Lake Mead National Recreation area will occur from any geothermal exploration or development in any of the offered parcels in the Sevier Thermal Area.

The basis for this conclusion is discussed below in the content of the main document.

The remaining National Park thermal features listed in 43 CRFR 3206.11 (b) are located in National Parks at great distance from the 2015 Geothermal lease offerings and are not considered further.

CONCLUSION

___X___ There is no scientific information indicating geologic or hydrologic interconnection between the offered parcels under lease application and parklands, and exploration, development or utilization of the lands in the parcels is not reasonably likely to have any effects on any significant thermal feature.

________ The scientific evidence indicates there may be a geologic or hydrologic interconnection between the lands within the parcels under lease application and parklands. The type, extent, and magnitude of possible effects on significant thermal features will require additional analysis.

GEOLOGIST: /s/ Tim H. Ingwell DATE: September 8, 2014

MANAGEMENT: /s/ Becky J. Hammond DATE: September 8, 2014

Quaternary volcanic flows and cone in the Sevier Thermal Area: Tabernacle Hill crater, Black Rock Desert, Millard County (after Utah Geological Survey, 2014b).

GEOLOGIC FACTORS REVIEWED

- General Factors

The parcels to be offered for lease at the 2015 competitive geothermal lease sale and the Lake Mead National Recreation Area (NRA) are located in the eastern Basin and Range geologic province (Fig-1, 2). The parcels are also located in a region of Utah called the "Sevier Thermal Area" (Fig-1, 2, 3), an area where known high temperature geothermal systems occur covering a region from Juab county south to Iron county, Utah. Surface conditions that express the geothermal systems in this area include: hot springs, sulphur deposits, and surface venting of gases at fumaroles. The nearest potentially affected feature is the Lake Mead National Recreation Area (Fig. 9) over 100 miles to the southwest of the closest 2015 offered geothermal lease parcel in southwestern Utah near the Thermo Hot springs II geothermal area (Fig 2,3).

Localized geologic and geohydrologic features, including geologic, lithologic, structural (faults/fracture zones), young Quaternary extrusive or intrusive silicic igneous bodies, hydrologic systems of recharge and circulation of groundwater through fractures (fracture flow) and high subsurface temperatures or heat flow define unique narrow geothermal systems (Figs-4,5,6).

In each of the geothermal areas of the Sevier Thermal Area (from north to south) are: Crater Springs, Drum Mountains, Cove Fort-Sulphurdale, Roosevelt Hot Springs, Monroe-Red Hill, Joseph Hot Springs, and Thermo Hot Springs II, (Fig-1,2,3) where the parcels are being offered for geothermal competitive lease sale in 2015.

Geothermal systems are classified as high temperature if the reservoir temperatures exceed 150 degrees C (302 F) and moderate temperature systems if their reservoir temperatures range between 100-150 degrees C (212-302 F). Known high temperature systems include the Roosevelt Hot Springs II and the Cove Fort-Sulphurdale known geothermal resource areas (KGRAs). Other areas with potential high temperature systems include the Thermo Hot Springs II, Joseph Hot Springs, and Monroe-Red Hill areas.

Much larger stratigraphic reservoirs in the Blackrock Desert are being studied (Allis and others, 2011, 2012, 2013) for their geothermal potential. These deeper basin geothermal systems may exist over large areas and are associated with Paleozoic sub-horizontal carbonate reservoir beds in downfaulted blocks of the Basin and Range geologic province. New exploration and drilling is necessary to verify the potential and viability of this geothermal concept. Horizontal drilling with multi stage hydraulic fracturing technology would seem ideal to develop these subhorizontal geothermal reservoirs (Allis, et.al, 2011, 2013).

The University of Utah Energy and Geoscience Institute, the Utah Geologic Survey and the Department of Energy (DOE) are currently developing a "Frontier Observatory for Research in Geothermal Energy" or (FORGE) (http://energy.gov/eere/forge/forge-home) project proposal 5 miles west of the Roosevelt Hot Springs II geothermal area (Blundell power plant) north of Milford in Beaver County, Utah in a 10 square mile area. The goal of the project is to develop new technologies for geothermal energy extraction. The intent of the project is to drill several wellbores into low permeability, hot (175-225 C) intrusive crystalline rocks (Tertiary quartz monzonite) to create a network of hydraulically created fractures and then produce circulation of water through one or more injection and production wells (Figure-7). This would be an Enhanced Geothermal System (EGS) or a manmade geothermal reservoir, created where there is hot rock,

GEOLOGIC FACTORS REVIEWED

- General Factors (cont.)

but insufficient or little natural permeability or fluid saturation. The goal of this FORGE EGS project then is to create man-made geothermal reservoirs by creating or re-opening pre-existing fractures creating permeability and fluid saturation in the hot crystalline rock (Tertiary quartz monzonite).

The topics in Utah was compiled by S. Earls and R.E. Blackett, 2011, "Geothermal Bibliography of Utah", Utah Geological Survey, 87 p. Additional literature searches were conducted to evaluate the most recent research and development of geothermal resources in Utah for the 2015 competitive lease sale area (see References).

Blakett, and others (2004) divided the geothermal resources of Utah into three tiers:

1) Tier I: Resource undergoing active development, well defined.
    a. Roosevelt hot springs KGRA (Known Geothermal Resource Area)
    b. Cove Fort-Sulphurdale KGRA
2) Tier II: Resource explored, but not defined.
    a. Thermo hot springs, KGRA
    b. Drum mountains
3) Tier CNA: Geothermal Areas Considered but not Analyzed: because temperatures appear too low and reservoirs undefined
    a. Crater Springs, KGRA
    b. Meadow and Hatton Hot Springs
    c. Monroe-Red Hill Area Joseph Hot Springs

The parcels offered for this competitive lease sale are located, from north to south, in the following studied geothermal areas: 1) Crater Springs (Tier CNA), 2) Drum Mountains (Tier II), 3) Cove Fort-Sulphurdale (Tier I), 4) Roosevelt Hot Springs (Tier I), Monroe-Red Hill Joseph Hot Springs (Tier CNA) and 5) Thermo Hot Springs (Tier II).

The Roosevelt and the Cove Fort-Sulphurdale geothermal areas have the highest potential for future and continued geothermal exploration development and are currently the most studied of the geothermal areas in Utah. The parcels offered in the 2015 competitive lease sale are located in a region of Utah referred to as the "Sevier Thermal Area", an area where known high heat flow and high temperature geothermal systems occur (Fig. 1,2,3).

Currently there are three geothermal power plants in southwestern Utah: 1) Roosevelt Hot Springs, Beaver County, 2) Thermo Hot Springs (Hatch geothermal power plant), Beaver County, and 3) Cove Fort-Sulphurdale, Beaver County (source, Utah Geological Survey, 2014b). New research (Allis et.al., 2011, 2013) suggest that deeper basin geothermal systems may exist associated with Paleozoic sub-horizontal carbonate reservoir beds covering larger areas in down faulted blocks of the Basin and Range geologic province in the Blackrock Desert area (Fig. 2,3). New exploration and drilling, however, is necessary to verify the potential and viability of this geothermal concept. Horizontal drilling with multi stage hydrofracturing is technology that would seem ideal to develop these sub-horizontal geothermal reservoirs

GEOLOGIC FACTORS REVIEWED

- General Factors (cont.)

(Allis, et.al, 2011, 2013). Magnetotelluric (MT) surveys and modeling, as well as, gravity surveys exhibiting gravity anomalies in the Black Rock Desert area suggest hot saline fluids in basement rock (Hardwick and Chapman, 2012). This geophysical work supports the concept of a deeper basin geothermal system previously suggested (Allis, 2012, 2013). Factors which that may limit the viability of this concept are higher drilling costs for deeper targets in basin centers and the lack of laterally extensive permeability in host rocks (Paleozoic carbonates) where fluids could circulate creating a geothermal system.

The University of Utah Energy and Geoscience Institute, the Utah Geologic Survey and the Department of Energy (DOE) is currently developing a FORGE (http://energy.gov/eere/forge/forge-home) project 5 miles west of the Roosevelt Hot geothermal area (Blundell power plant) north of Milford, Beaver County, Utah in a 10 mile square area. The goal of the project is to develop new technologies for geothermal energy extraction. The intent of the project is to drill several wellbores into low permeability, hot (175-225 C) intrusive crystalline rocks (Tertiary quartz monzonite) and create a network of hydraulically created fractures and then produce circulation of water through one or more injection and production wells (Figure-7). This would be an Enhanced Geothermal System (EGS) or a man-made geothermal reservoir, created where there is hot rock, but insufficient or little natural permeability or fluid saturation. The goal of this FORGE EGS project then is to create manmade geothermal reservoirs by creating or re-opening pre-existing fractures creating permeability and fluid saturation in the hot crystalline rock (Tertiary quartz monzonite).

- Extent of Volcanism/Magmatism

In the Sevier Thermal Area where 2015 geothermal lease parcels are being offered Quaternary volcanism provides local, high level heat sources for geothermal systems in southwestern Utah (Fig. 1, 2, 3).

Young volcanic rocks (<2Ma) extend from southwestern Utah to west-central Utah and are comprised of basalt flows and less commonly rhyolite flows (bimodal occurrence). High silica volcanic and intrusive rocks of Quaternary age have been suggested (Rush, 1983) to localize hydrothermal convective systems. Silicic intrusive and extrusive rocks are believed to have been emplaced at the same time (Whelan, 1970).

In southwest-central Utah (an area, from south to north), including the northern part of the Escalante Desert, the Black Rock Desert, and the southern part of the Sevier Desert lie clusters of young Quaternary basaltic rocks with lesser amounts of rhyolite (See Fig-2). These clusters occur along the eastern margin of the Basin and Range geologic province and formed in: 1) an intra-graben area between the Pavant and Tusher mountains on the east and the Mineral and Cricket mountains on the west (Cove Fort-Sulphurdale geothermal area) and 2) in downfaulted blocks to the west of the Mineral mountains (Roosevelt Hot Springs geothermal area).

A group of known high silica rhyolite flows and domes occur along the crest and western flank of the Mineral Mountains in Beaver County (800-500 ka). One of the youngest rhyolite flows (400 ka) is located in the Black Rock Desert (Fig 2,3). In general the youngest igneous rocks have the best potential as heat

GEOLOGIC FACTORS REVIEWED (cont.)

- Extent of Volcanism/Magmatism (cont.)

sources. The high silica intrusive and volcanic rocks are thought to localize hydrothermal resources (Rush, 1983) (Fig. 4) since silicic magmas are always erupted from high level storage chambers and high temperature convection systems may be sustained for many thousands of years (White and Williams, 1975).

Older Tertiary volcanic deposits occur in the Lake Mead National Recreation area (Fig. 9). The deposits are related to crustal thinning and extension in the Basin and Range Province and from extension caused by the Lake Mead Shear zone. Justet and Beard (2010) through structural geologic and kinematic studies indicated that faults that formed by the interaction of E-W extension related to the Lake Mead shear zone were the main controls of groundwater flow and occurrence of hot springs in the vicinity of Hoover Dam and the Boulder City Pluton.

The plutons responsible for the volcanic deposits of the Lake Mead area and those formed in the Sevier Thermal area are not interconnected, but localized due to unique structural and volcanic/magmatic conditions of each area. Therefore, exploration and development of the 2015 offered geothermal lease parcels will not affect the geothermal features in the Lake Mead National Recreation area.

- Structural Continuity

Geothermal resources in west central and southwestern Utah occur primarily in the eastern Basin and Range geologic province (see Figure 1, 2) that has undergone Tertiary crustal extension and crustal thinning during the last 17 million years. The Basin and Range geologic province is characterized by north-south uplifted normal fault block mountain ranges with associated down dropped sediment filled basins. Most thermal springs and wells commonly occur in valleys near the margins of uplifted mountains. North-south normal faulting occurs in the northern Sevier Thermal area and northeast-southwest normal faulting occurs in the southern Sevier Thermal area (Figure 2, 3). Tectonically active regions are known to have abundant active geothermal systems. Quaternary faulting (Figure 3) described by Heckler (1993) is also related Quaternary intrusive igneous activity and volcanic rocks which provide the high level heat sources necessary for the convective geothermal systems to develop.

Several of the geothermal areas are near major E-W lineaments or “transverse zones” (Rowley, 1978) associated with high silica rhyolites that accompanied eruption of basalts (bimodal, basalt and rhyolite) (Fig-3). Lineaments and their associated geothermal systems are (Fig. 3): 1) Black Rock lineament associated with the Roosevelt Hot Springs and Cove Fort-Sulphurdale geothermal areas, 2) Blue Ribbon lineament associated with the Thermo Hot Springs, and 3) Timpahute associated with the Newcastle geothermal area.

Conceptual models for the geothermal systems in the Sevier Thermal area were developed by Rush (1983) (Fig 4), by Faulder (1991) (Fig 5) for the Roosevelt Hot Springs hydrothermal system, by DOE (2006) (Fig. 6) for the Cove Fort-Sulphurdale geothermal area, and by Shannon, et.al. (1983) for the Department of Energy FORGE project (Fig. 7).

GEOLOGIC FACTORS REVIEWED (cont.)

- Conceptual Models

The conceptual models of Rush (1983), Faulder (1991), and DOE (2006) involves the down flow and recharge of cold water along normal faults forming the basin and the adjacent mountain range. This recharged groundwater encounters the heat source of the intrusive igneous body and forms the hydrothermal reservoir. Convective flow brings some water back to the surface along other faults to form hot springs, sulphur deposits, alteration zones, and fumaroles.

The main tectonic elements of the Lake Mead Recreational area are Basin and Range faulting, the NW-SE trending Las Vegas shear zone and the NE-SW trending Lake Mead shear zone (Fig. 9). The E-W extension related to the Arizona extensional corridor and the NW-SE trans-tension related to the Lake Mead shear zone are the main controls on the groundwater flow in the vicinity of Hoover Dam (Justet and Beard, 2010). Interconnection of the regional carbonate aquifer and the Boulder City Pluton was concluded to be unlikely and the hot springs are derived relatively locally being controlled by these main structural controls of groundwater flow (Justet and Beard, 2010).

This supports that the structural trends of the Lake Mead National Recreation area are unique to that area and not connected to the 2015 offered geothermal parcels in the Sevier Thermal area.

- Lithologic Continuity

The Basin and Range geologic province is characterized by uplift along normal faults of rocks of various geologic ages and down dropped basins filled with Quaternary valley fill deposits of various environments of deposition (alluvial, eolian, playa, lacustrine, etc.).

Numerous Tertiary igneous basalt flows occur in the Sevier Thermal Area. However, it is the Quaternary igneous intrusive and extrusive rocks that are the key factors (Fig-3) for the development of the geothermal resources in the Sevier Thermal Area. Intrusive upper level silicic plutons in many are the heat source for the many of the convective geothermal systems (Rush, 1983) which occur in the shallower unconsolidated Quaternary valley fill in the Sevier Thermal Area (Fig. 4). The Black Rock Desert field contains Utah's youngest rhyolite dome (400 ka) and its youngest eruptive vent producing the 660 year old Ice Springs basalt flows.

In the DOE FORGE project area west of the Roosevelt Hot Springs, the hot intrusive crystalline rocks are described as Tertiary quartz monzonite (Shannon et.al, 1983) (Fig. 7). The intent of this DOE project is to create a network of hydraulically created fractures and then produce circulation of water through one or more injection and production wells (Fig.7).. This would be an Enhanced Geothermal System (EGS) or a

Man-made geothermal reservoir, created where there is hot rock, but insufficient or little natural permeability or fluid saturation. The goal of this FORGE EGS project then is to create manmade geothermal reservoirs by creating or re-opening pre-existing fractures creating permeability and fluid saturation in the hot crystalline rock (Tertiary quartz monzonite).

GEOLOGICAL FACTORS REVIEWED (cont.)

- Lithologic Continuity (cont)

While Tertiary intrusive and volcanic rocks and sedimentary deposits occur in the Lake Mead Recreation Area (Fig. 9), younger Quaternary igneous rocks have not been mapped as they have been in southwestern and west central Utah (Fig 2,3). This suggests a lack of continuity between the younger igneous activity and rocks exposed in or near the 2015 geothermal lease parcels and the Lake Mead Recreation area.

HYDROLOGIC FACTORS REVIEWED

The geothermal parcels offered in this 2015 competitive lease sale occur in the Great Basin and the Sevier Lake-Escalante sub-basin, whereas the Lake Mead National Recreation Area occurs in a different hydrologic basin and sub-basin, the Lower Colorado Basin and the Lower Colorado-Lake Mead sub-basin (Fig. 8).

Groundwater systems in the Sevier Thermal area generally involve recharge areas to groundwater in uplifted range fault blocks and discharge in adjacent basin discharge areas of the Basin and Range geologic province. Localized occurrence of high heat flow, Quaternary igneous extrusive and intrusive activity, and complex faulting in the adjacent basins allow for the development of localized geothermal systems to occur, in addition to the normal recharge-discharge of water resources (Figs. 4,5,6). Examples of geothermal resources adjacent to recharge-discharge in adjacent uplifted ranges include the Cove Fort-Sulphurdale and Roosevelt Hot Springs geothermal areas (Figs. 5,6).

The Lake Mead Recreational area surface and groundwater systems are not related or connected to those surface or groundwater systems developed in the Sevier Thermal Area.

GEOPHYSICAL FACTORS REVIEWED

Geophysical methods used to characterize the geothermal systems in general have been summarized by the Department of Energy (DOE, 2006: A History of Geothermal Energy Research and Development in the United States, 1976-2007). The methods reviewed included: seismic methods, aeromagnetic methods, gravity methods, thermal methods, geophysical well log interpretations/high temperature tools, electrical methods, and borehole geophysical methods.

New geophysical methods are proposed to be tested at by the DOE at the Frontier Observatory for Research in Geothermal Energy or FORGE project area (Fig. 7).

Geophysical studies have been conducted at Crater Lake (Hardwick and Chapman, 2011), Roosevelt Hot Springs II (Ross and others, 1982: Ward et.al., 1978), Cove Fort-Sulphurdale (Cook et.al., 1980; Ross and Moore, 1985), and Thermo Hot Springs II (Sawyer and Cook, 1977)

At Cove Fort-Sulpurdale and Roosevelt Hot springs detailed aeromagnetic surveys helped identify faults, fracture zones, intrusive rock, silicic domes, and major alteration zones (DOE, 2006). Aeromagnetic studies also helped define the relationship between faulting and the geothermal systems at Roosevelt Hot springs and Cove Fort-Sulphurdale (Ross and others, 1982: Wright, et.al., 1985).

GEOLOGICAL FACTORS REVIEWED (cont.)

Magnetotelluric (MT) surveys and modeling, as well as, gravity surveys exhibiting gravity anomalies in the Black Rock Desert area suggest hot saline fluids in basement rock (Hardwick and Chapman, 2012). This geophysical work supports the concept of a deeper basin geothermal system previously suggested (Allis, 2012, 2013). Factors which that may limit the viability of this concept are higher drilling costs for deeper targets in basin centers and the lack of laterally extensive permeability in host rocks (Paleozoic carbonates) where fluids could circulate creating a geothermal system. Detailed geophysical surveys for the Lake Mead area could not be located in detailed literature searches. Generally, however, it is hypothesized that geophysical surveys would not support a connection or correlation between the Sevier Thermal area and the Lake Mead National Recreation area hot springs.

GEOCHEMICAL SIMILARITY

A detailed compilation of chemical data on water samples in the Sevier Thermal area with temperatures was compiled and published by Maybe and Budding (1987). They summarized water samples for all the geothermal areas in the Sevier Thermal area. Most water samples collected in geothermal areas had high Total Dissolved Solids or TDS (1,000-7,000ppm), while those samples in non-geothermal areas had lower TDS values ranging from 200-600ppm. The Roosevelt Hot Springs had the most specific geochemical studies reported (Moore and Nielson, 1994; Atkinson, 1981; and Ward, et.al., 1978).

Justet and Beard (2010) studied the geochemistry of hot springs and seeps discharging into Black Canyon (Fig-9) of the Lake Mead National Recreation area in order to determine if groundwater development in southern Nevada and northwestern Arizona may impact those resources. The results of their studies indicated that the sources of the hot springs and seeps were local. Structural geologic and kinematic studies further indicated that faults that formed by the interaction of E-W extension related to the Lake Mead shear zone are the main controls of groundwater flow in the vicinity of Hoover Dam and the Boulder City Pluton. Other geochemical data for the Lake Mead Recreation area is limited.

Because of these localized structural elements (Lake Mead shear zone), local plutons (Boulder City Pluton), and hot springs at the Lake Mead National Recreational Area, data does not in general support a geochemical similarity or similar sources of the hot springs to those 2015 offered geothermal parcels in the Sevier Thermal area of Utah.

After, Berry, J., Hurlbut, D., Simon, R., Moore, J., and Blackett, R., 2009, Utah Renewable Energy Task Force: Phase I Report, Miscellaneous Publication 09-1, Utah Geological Survey

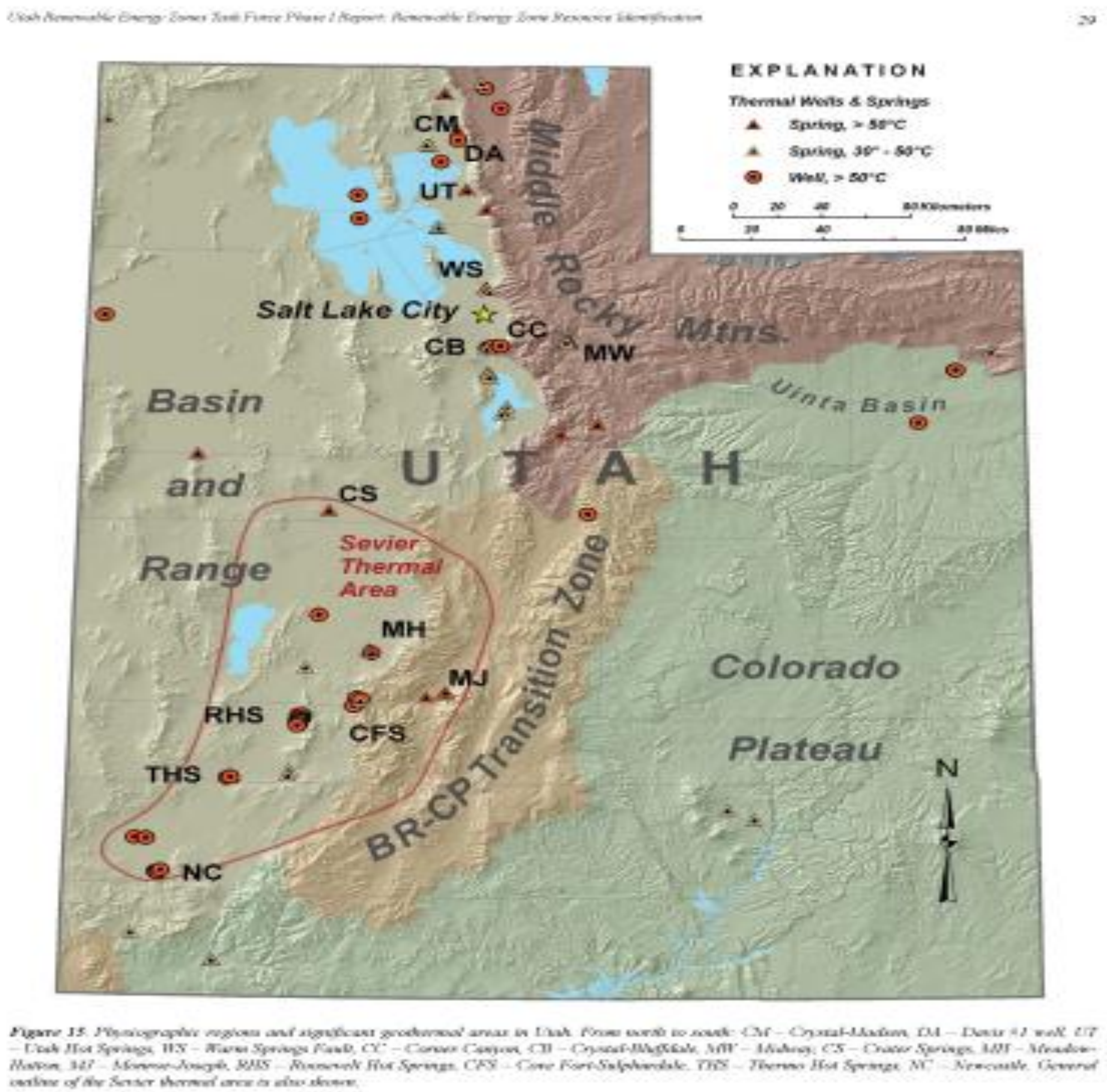

FIG-1: Geothermal areas (after Berry, 2009) in central to southern Utah occur mainly in the Basin and Range geologic province and to a lesser extent in the Transition Zone. These geothermal areas have been grouped together to form an area referred to as the Sevier Thermal Area (Maybe and Budding, 1987). Geothermal areas where parcels are offered in the 2015 Competitive Lease sale occur in the Sevier Thermal Area and include: CS-Crater Springs, MJ-Monroe Joseph, RHS-Roosevelt Hot Springs, CFS-Cove Fort-Sulphurdale, and THS-Thermo Hot Springs. The most southerly parcels offered in the 2015 competitive lease sale in the Thermo Hot Springs geothermal area are approximately 100 miles to the northeast of the Lake Mead National Recreation Area.

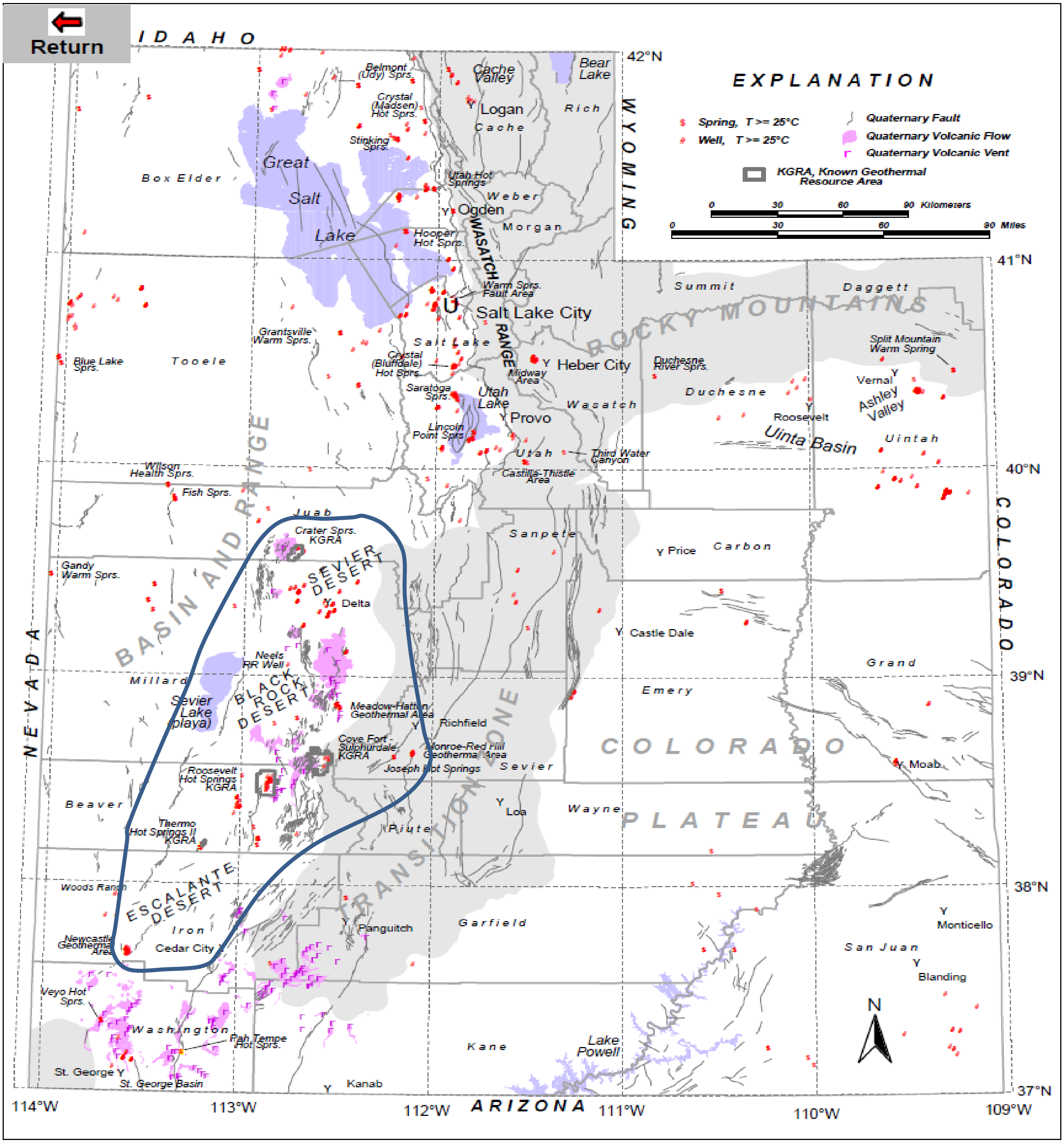

Figure 4. Geothermal resources of Utah showing thermal wells and springs, Quaternary tectonic and volcanic features, and major physiographic regions.

Figure 2 (after Blackett and Wakefield, 2002): Geothermal resources of Utah. Map shows thermal wells and springs, Quaternary tectonic and volcanic features, and major physiographic regions. Sevier Thermal Area (approximate) is shown by blue outline and extends from Juab County to Iron County, Utah a distance of approximately 150 miles. The most southerly 2015 offered parcels are in the Thermo Springs II geothermal area. The most northerly 2015 offered parcels are in the Crater Springs geothermal area.

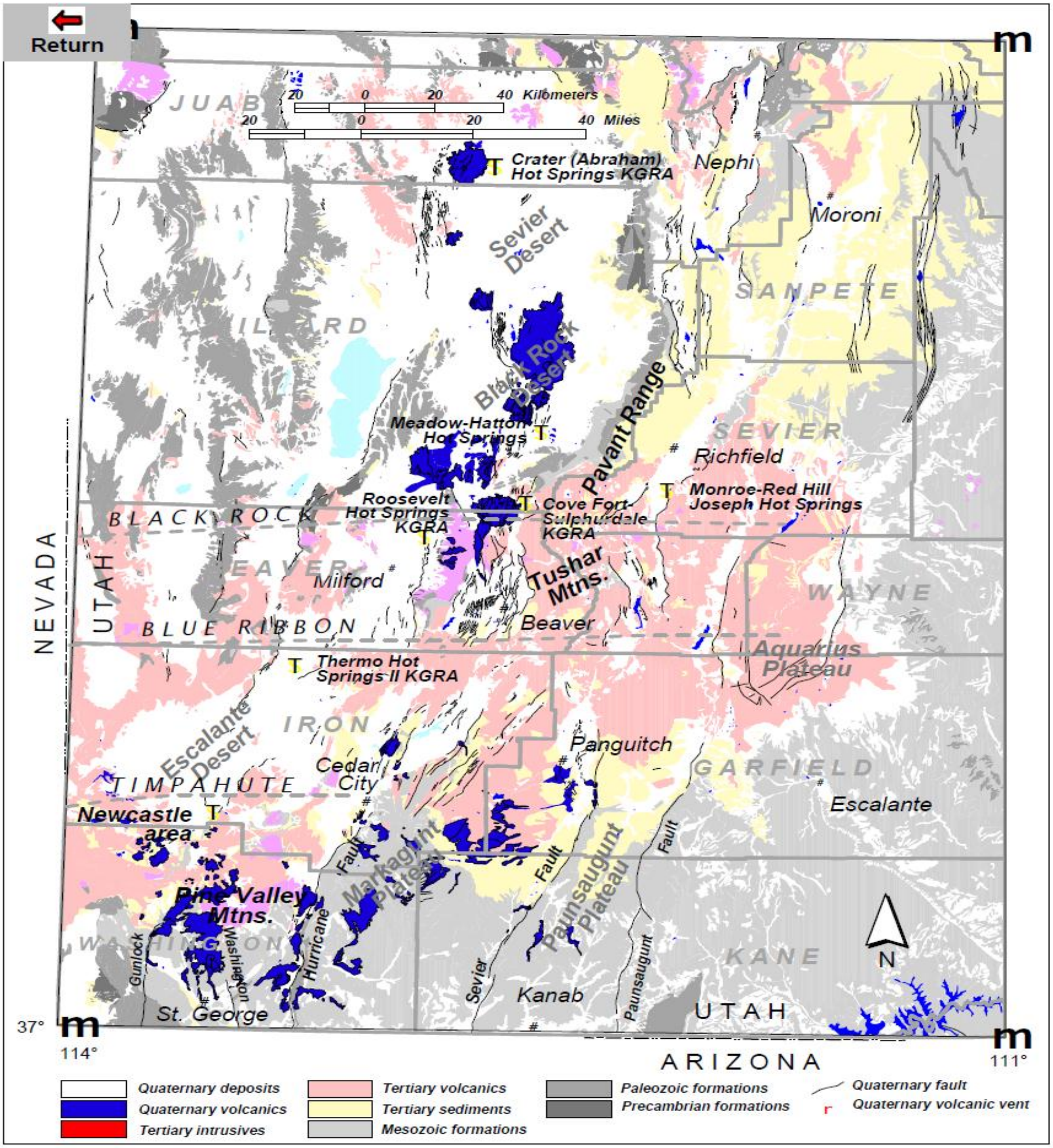

Figure 5. Southwestern Utah's "Sevier thermal area" showing locations of principal geothermal areas, general geology, Quaternary faults, and Quaternary volcanic features. East-west dashed lines approximate the trends of (from north to south) the Black Rock, Blue Ribbon, and Timpahute lineaments (modified from Magey and Budding, 1987; Hecker, 1993; Black and others, 2000; and Hintze and others, 2000).

Figure 3 (after Blackett and Wakefield, 2002): Southwestern Utah's "Sevier Thermal Area" showing locations of principal geothermal areas (in Juab, Millard, Beaver, and Iron counties), general geology, Quaternary faults and Quaternary volcanic features (purple). East West lineament trends shown as dashed lines, from north to south are Black Rock, Blue Ribbon, and Timpahute. Location of geothermal areas indicated by a **T.** The Lake Mead Recreational Area is approximately 100 miles to the southwest of the most southerly offered geothermal parcels near the Thermo Hot Springs II KGRA.

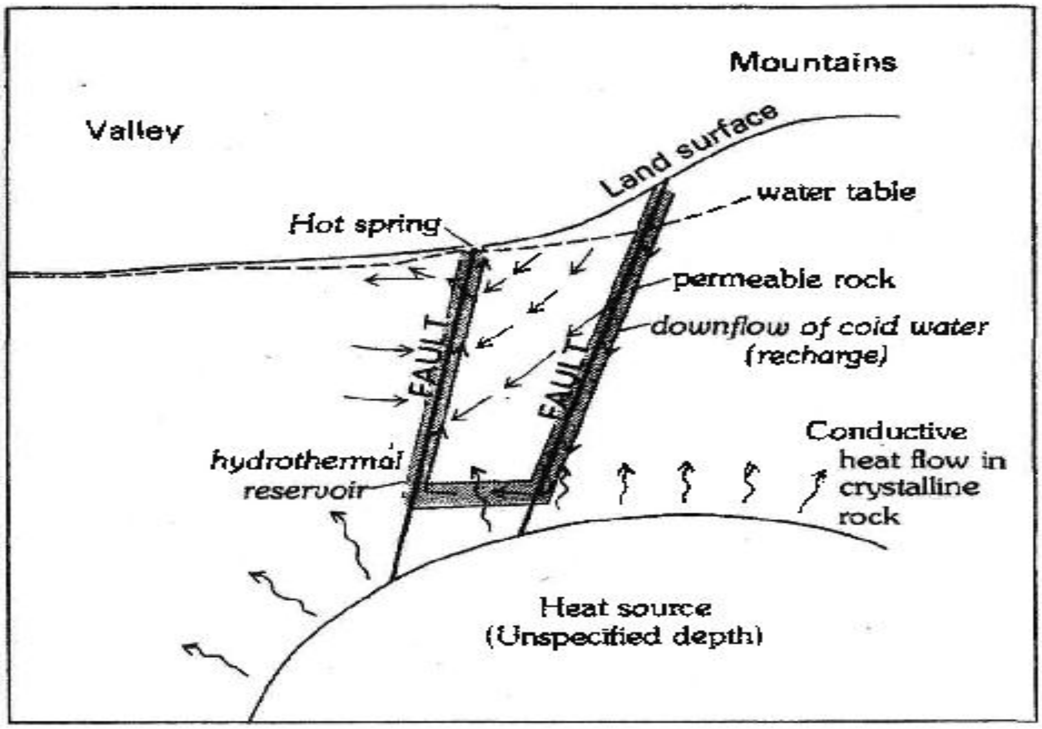

FIGURE 4.—Conceptual model of a hydrothermal convection cell.

Figure 4 (after Rush, 1983): Conceptual model for a hydrothermal cell in the Sevier Thermal Area which depicts the interaction of Basin-Range tectonics, uplifted mountains, adjacent, groundwater recharge and downflow in permeable rock in and near fault zones, heat source (upper level silicic igneous plutons),the hydrothermal reservoir in fractured rock, the downfaulted basins and surface expression of hot springs.

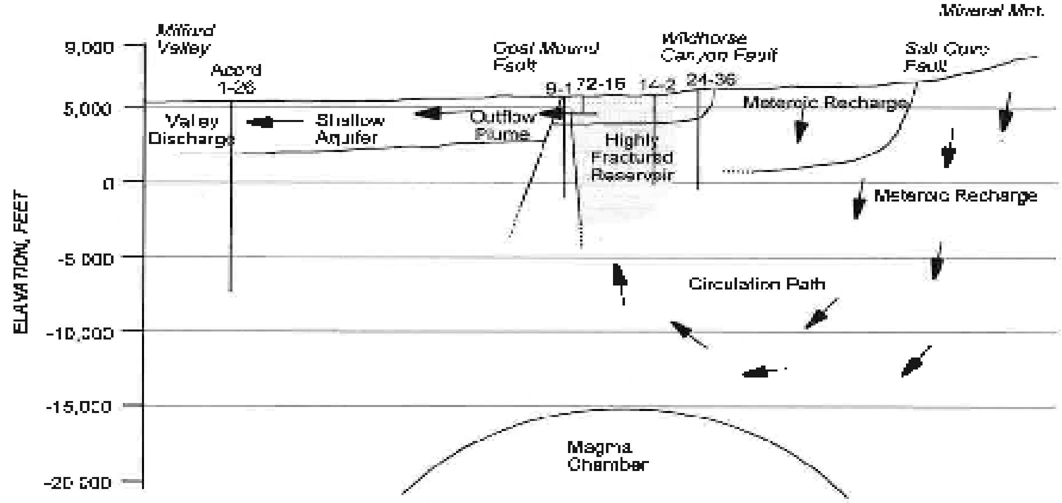

Figure 2. *Conceptual geologic model of the Roosevelt Hot Springs hydrothermal system after Faulder (1991).*

Figure 5: Conceptual geologic model of the Roosevelt Springs hydrothermal system (after Fendler, 1991). This model is similar to that previously proposed by Rush, 1983.

Note the meteoric recharge, the circulation path, magma chamber (heat source), and the highly fractured reservoir of the Roosevelt Springs hydrothermal system.

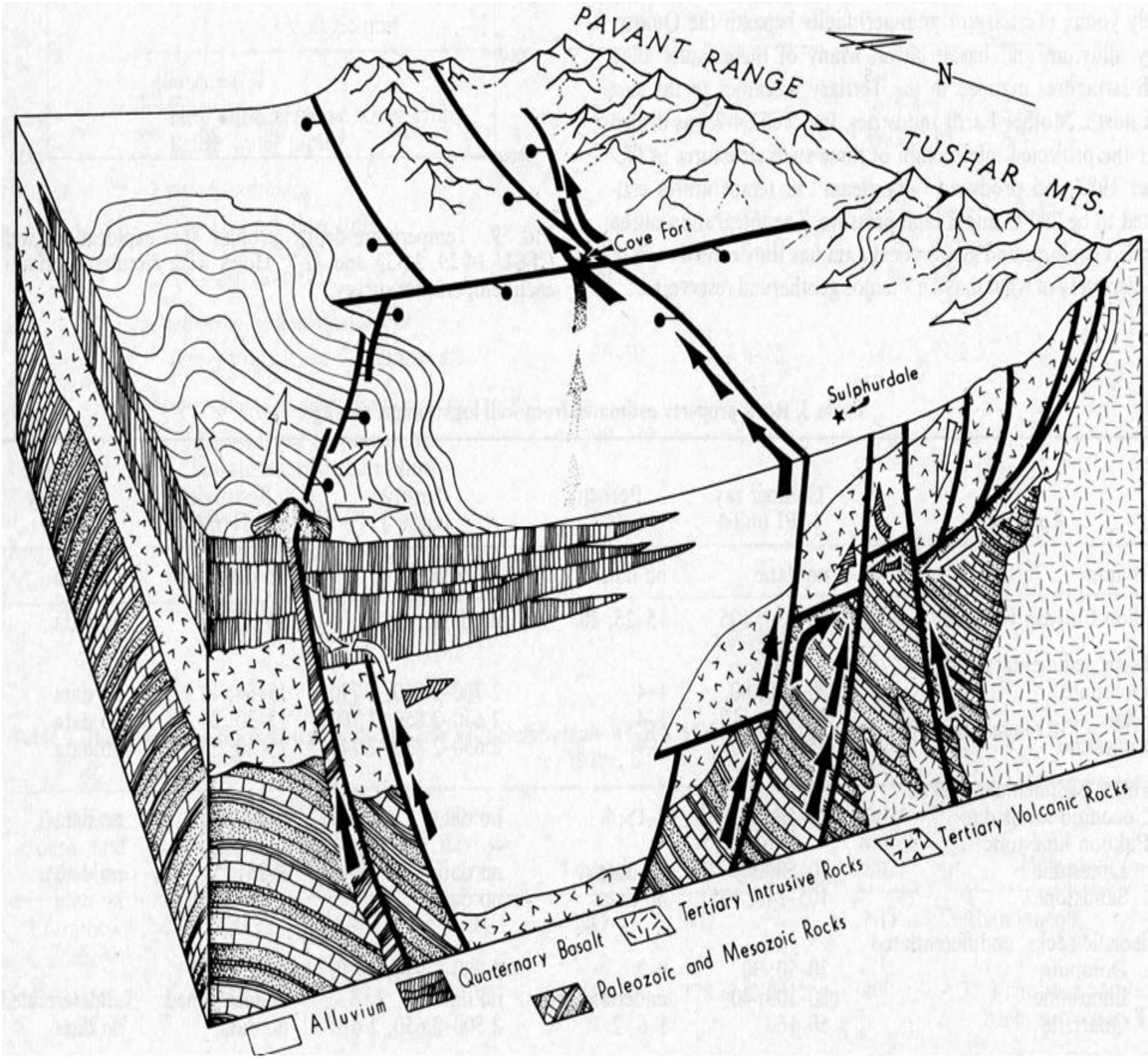

Figure 6: Conceptual model of the Cove Fort-Sulphurdale geothermal area (after DOE, 2006). Note the interaction between surface (clear arrows) and groundwater flow (solid arrows), volcanic and intrusive igneous rocks, and Basin and Range faulting. Note the upward groundwater flow from a deeper magmatic intrusive source in the basin center (not pictured).

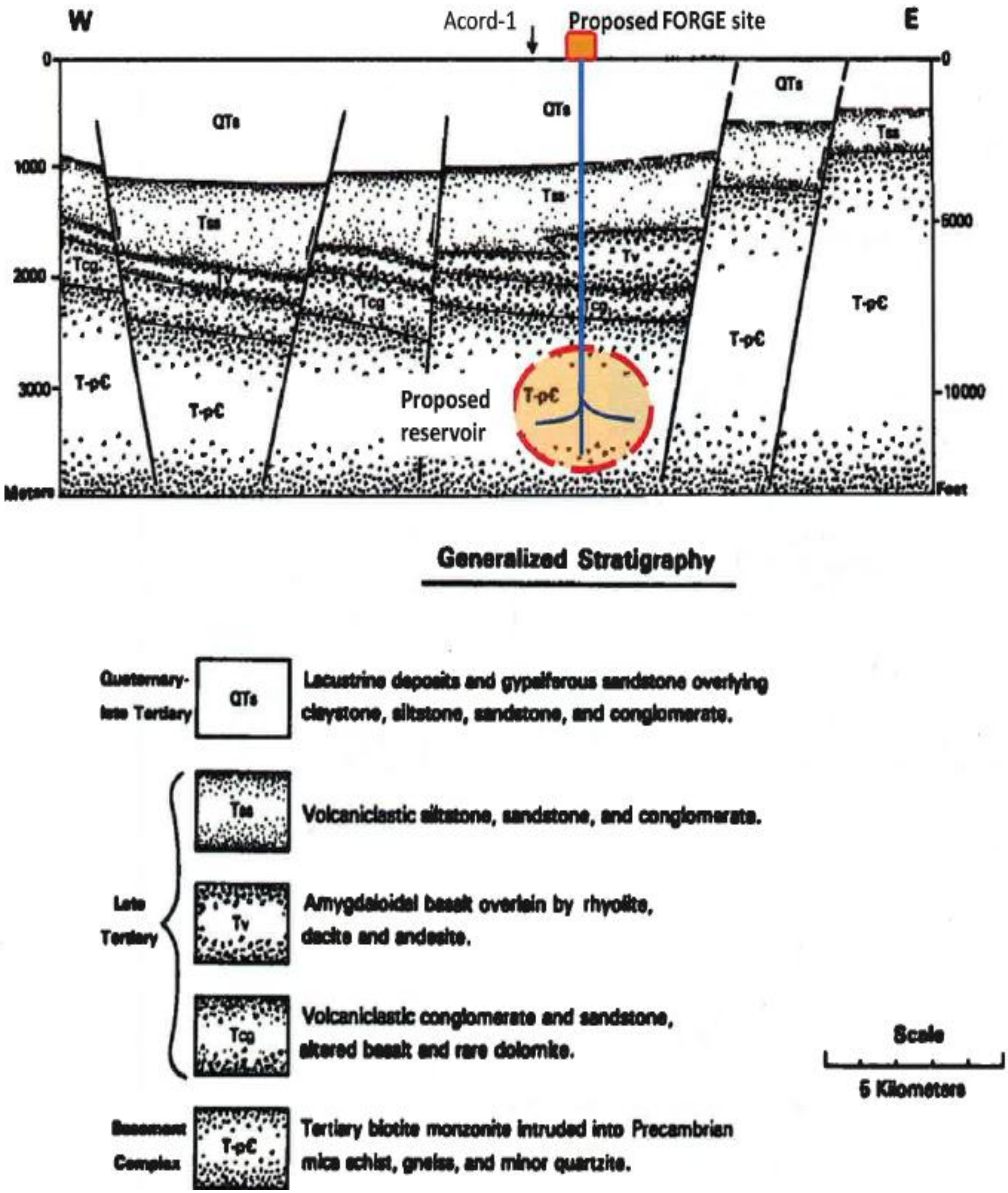

Figure-7: Proposed Department of Energy (DOE) FORGE project well to develop Enhanced Geothermal Systems (EGS) by drilling several wellbores into low permeability, hot intrusive crystalline rocks (Tertiary quartz monzonite) and create a network of hydraulically created fractures and then produce circulation of water through one or more injection and production wells in the man-made geothermal reservoir(after Shannon, et.al., 1983).

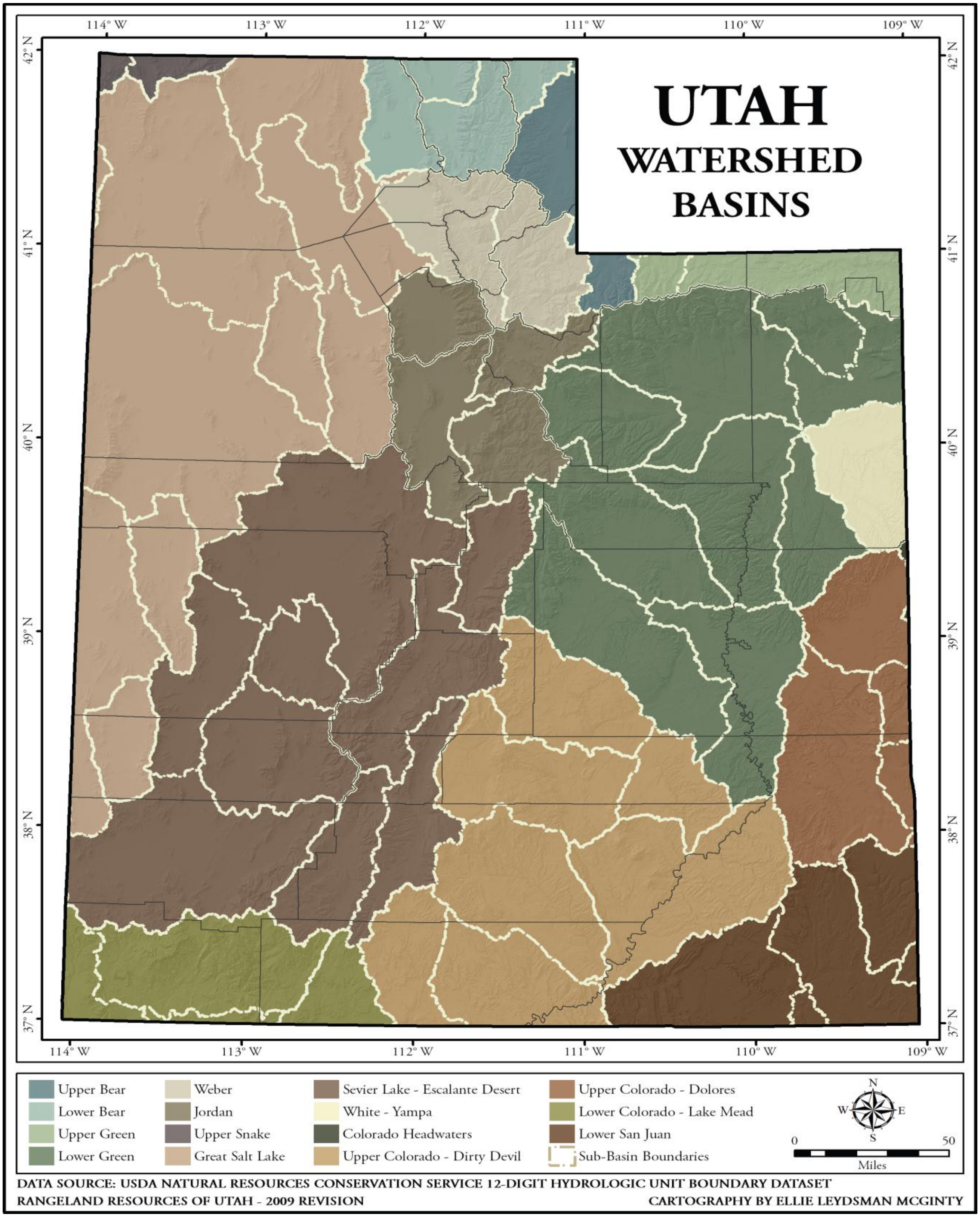

FIGURE 8- Geothermal Parcels offered in 2015 occur in the Sevier Lake-Escalante sub-basin (dark brown) of the Great Basin, whereas the Lake Mead National Recreation Area occurs in the Lower Colorado-Lake Mead sub-basins of the Lower Colorado Basin (olive green).

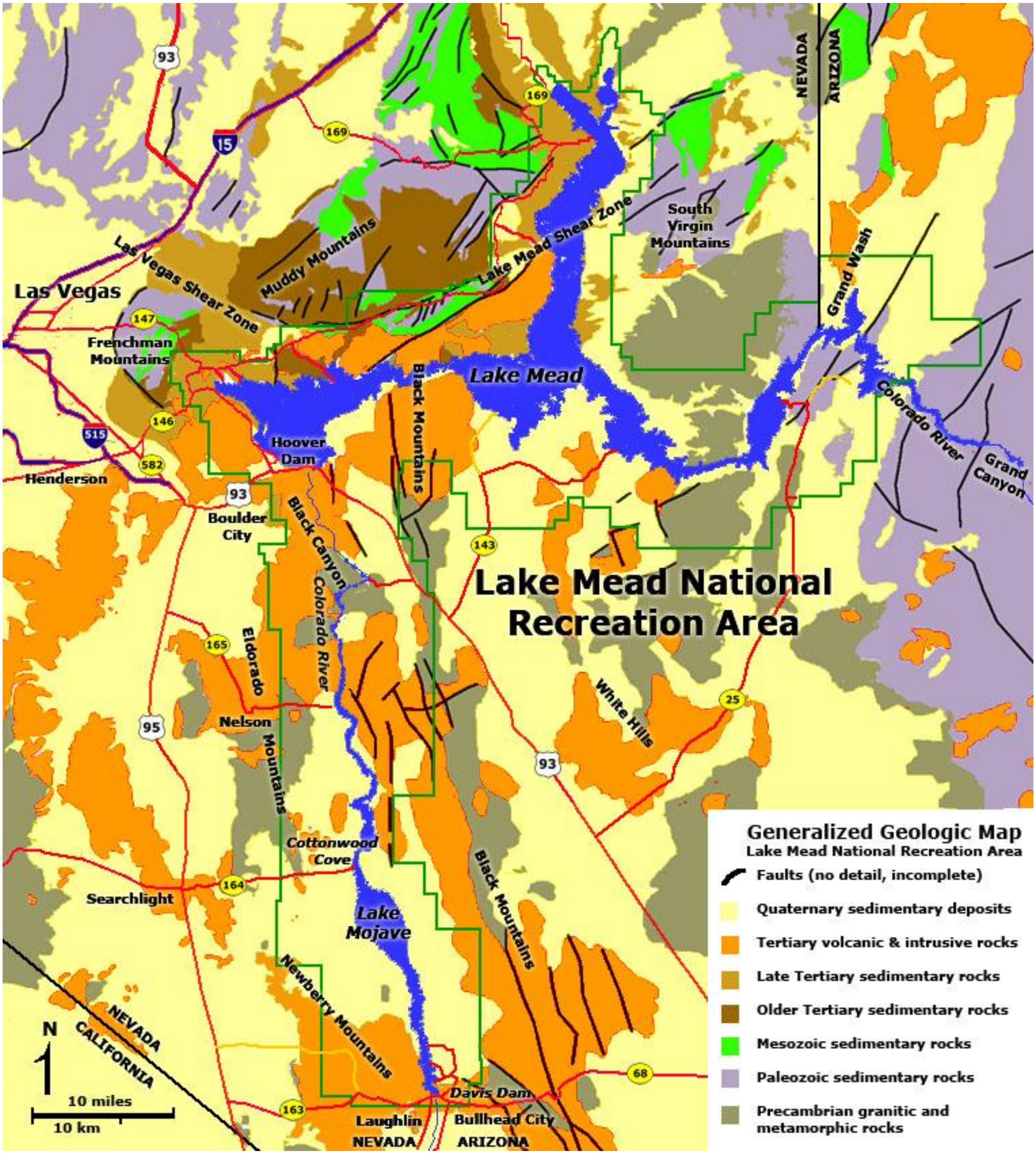

Figure-9: This generalized regional geologic map of the Lake Mead National Recreation Area was compiled for the National Park Service by the USGS from the state geologic maps for Nevada and Arizona (see Arizona Geological Survey, 2000; Crafford, 2007). The seven rock-unit colors represent general subdivisions based on geologic origin and geologic age. For a detailed geologic map of the northern part of this map area, see Beard and others (2007).

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