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**GEOTHERMAL MANAGEMENT COMPANY, INC.**

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**GEOTHERMAL RECONNAISSANCE SURVEY IN THE VICINITY  
OF STEAMBOAT SPRINGS, COLORADO – A REPORT OF  
FINDINGS WITH RECOMMENDATIONS FOR FUTURE WORK**

By

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For

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# **GEOHERMAL RECONNAISSANCE SURVEY IN THE VICINITY OF STEAMBOAT SPRINGS, COLORADO – A REPORT OF FINDINGS WITH RECOMMENDATIONS FOR FUTURE WORK**

## **Introduction**

This report is submitted to Wenk Associates Planners and Landscape Architects (“Wenk”) by Gerald Hutterer, President of Geothermal Management Company, Inc. (“GMC”). It is written with regard to the conduct, from 14-17 August 2006, of *activities whose purpose is the eventual discovery and preliminary characterization of new sources of subsurface geothermal fluids suitable for snow melting as part of the planned Steamboat Springs Base Area Redevelopment Project “the Project” or “Project”*. The scope of these activities was essentially as proposed in my letter to Wenk dated 2 August 2006.

The report first describes the various activities undertaken by Mr. Hutterer. It then summarizes findings, presents a geothermal exploration rationale, recommendations for future work, and estimates of the cost and time required to implement the recommended next work steps to achieve the geothermal objectives. A geologic map, geologic cross-sections, and a topographic map of the area investigated are included to facilitate identification of features referenced in the text.

## **Activities Undertaken**

- I. On Monday, 14 August, Mr. Hutterer traveled from the GMC Frisco, CO offices to Denver, Lakewood, and Golden where the following activities were conducted:
  1. At the Colorado Geologic Survey, Mr. Hutterer met with James Cappa, Chief, Mineral and Mineral Fuels Section, and Fred Berthold, Contract Geologist working under Mr. Cappa’s direction, on geothermally-related projects. Though neither of these men was personally familiar with the Steamboat Springs geothermal environment, they did suggest several relevant publications.
  2. At the Colorado Division of Water Resources, Mr. Hutterer met with Mr. Michael Schaub, Water Conservation Specialist. Mr. Schaub allowed access to the computerized Division water well records. Of special interest were maps of the Project area showing the locations of permitted and drilled wells and the drilling records for some of these wells. A few of the records inspected included meaningful descriptions of the geologic formations penetrated (“Browns Park, granite, limestone, etc”), but most just mentioned color changes with depth (red rock, tan rock, grey-white rock, etc). Unfortunately, the Division forms lack a

space in which to enter temperatures, thus no temperatures were shown on any of the records examined.

3. Mr. Hutterer next drove the Lakewood U.S. Geological Survey Publications Center where he purchased two full color maps showing bedrock and surficial geology of the Steamboat Springs Quadrangle, one publication concerning the Precambrian bedrocks of the Park Range northeast of Steamboat Springs, and two recent (2000) Steamboat Springs Quadrangle 1:24,000 scale topographic maps.
4. Finally, Mr. Hutterer went to the Arthur Lakes Library at the Colorado School of Mines in Golden. There he perused the computer files to find literature and/or maps of potential relevance to the Project. A long, careful search produced only two sketch maps and one full color, small scale map, both of which were found, reviewed, and partially copied.

It should be noted that surprisingly little geoscientific literature specifically related to the Steamboat Springs area has been published. With regard to the geothermal phenomena per se, there are less than 10 documents!

- II. With the informational materials referenced above and several other documents gleaned from the GMC office files in hand, Mr. Hutterer traveled to Steamboat Springs on Tuesday, 15 August.

The purpose of this investigation is to find out if there are any other thermal waters in or near Steamboat Springs; specifically, in the vicinity of the planned Project. The activities described above were designed to answer this question.

1. He met with Susan Bott and Joe Kracum at the City Planning Department and was given a brief overview of the project scope, two Project planning documents to review, and was shown sketches of the planned facilities.
2. Ms Bott, Mr. Kracum, and Mr. Hutterer then drove to the site of the Stockbridge Multi-Modal project. Mr. Hutterer was asked to meet there on 17 August with Rocky Mountain Geothermal Company (RMGC) drillers who were to spud a thermal conductivity hole in connection with a planned ground-source geothermal space conditioning installation. The purpose of this suggested interaction was for Mr. Hutterer to be able to obtain new geologic information from the drill cuttings. Unfortunately, RMGC was not able to arrive on schedule, so Mr. Hutterer was not able to meet with them during his stay in Steamboat Springs.

3. Ms Bott, Mr. Kracum, and Mr. Hutterer then went to the Project site and walked along the planned snow melting areas. The group met with Jim Schneider, V.P. Skier Services for the Steamboat Ski & Resort Corporation, who volunteered the services of Mr. Lance Miles, Snowmaking Manager, to drive Mr. Hutterer around the ski area to help identify spring locations, fracture-related stream drainages, and subtle geothermal indicia such as elk-bedding grounds and altered rock areas.
4. After leaving Ms Bott and Mr. Kracum, Mr. Hutterer explored the fault-controlled Burgess Creek drainage on foot in search of subtle thermal indicia.
5. Mr. Hutterer then met with Mr. Bill Bowes, a long time Steamboat resident and experienced mineral and geothermal geologist. Mr. Bowes was generous with his time and was very willing to talk about his work, but unfortunately, he could contribute little new about thermal features or indicia in the interest area.
6. After leaving Mr. Bowes, Mr. Hutterer met with Rod Branstetter of Aztec Drilling Company. He was asked if he or his employees had ever found elevated temperatures in any of the wells that they had drilled in the past 20 years. No such information came to mind. Mr. Branstetter did tell of hot wells drilled in the vicinity of Routt (Strawberry) Hot Springs, ~ 5 miles north of Steamboat Springs, and about some 70°F springs near the Sidney railway station ~ 5 miles south of town, but neither of these data have real relevance to the Project.
7. On Wednesday 16 August, Mr. Hutterer hiked up Howelsen Hill and then southward along several cross country trails in order to find the limits of the travertine deposits (created by paleo-hot springs) and the trace of the regionally important fault from which these ancient springs flowed.
8. Mr. Hutterer then returned to the City Hall where he carefully examined several wall-mounted air photographs of the Steamboat Region so as to help identify large scale linear features transecting the interest area. While there, he also queried two civil engineers from the firm of Drexel Barrell regarding any geothermal evidence that they might recall from their years of work in the region.

9. For about three hours on 16 August, Mr. Hutterer met with Lance Miles, reviewed computerized GIS images of Mt. Werner ski area, and rode with him over most of the service roads that traverse Mt. Werner. Mr. Miles was able to point out many springs, wet areas, bogs, wetlands, and perennial ponds that could be related to fractures in the PreCambrian crystalline rocks that underlie most of the ski area..
10. The morning of Thursday, 17 August was spent synthesizing the information gathered into coherent notes and planning final office and field work. Accordingly, Mr. Hutterer then revisited the travertine bench south of Howelsen Hill, the Aztec Drilling Company, the offices of City officials Ms Bott, Ms Anne Small, and Ms Wendy DuBord, and finished with a trip to the Steamboat Springs field office of the Division of Water Resources to obtain records of wells in and near the significant fracture systems previously identified.
11. In the late afternoon, Mr. Hutterer returned to the Frisco GMC offices.

### **A Summary of Findings**

First of all it should be noted that none of the activities conducted during the three day geothermal reconnaissance revealed any thermal features (or evidence of hidden phenomena) of any kind, other than the four described below, in the vicinity of Steamboat Springs or the Project. The interviews with a driller, a geologist, two engineers, some long-time residents, and three veteran ski area employees, failed to identify any clues as to new thermal waters and field traverses, covering many tens of miles by car and several miles on foot, unfortunately yielded the same results.

#### **Known Geothermal Phenomena**

There are three well known active geothermal features in and near Steamboat Springs and one site that flowed pre-historically. They are:

1. Steamboat Springs Hot Springs – This group comprises several orifices from which flow tepid (68-78°F), highly mineralized, slightly sulphurous waters. The thermal springs are on both sides of the Yampa River, opposite 12<sup>th</sup> Street in “Old Town”. These features are on or very near the trace of a regionally important northerly-trending fault system to be discussed further below.

2. Heart Springs – This spring feeds the Town swimming pool that is near the corner of 3rd and Lincoln streets. It flows about 140 gallons per minute at ~102°F and may be situated on an intersection of northerly and northeast trending fractures.
3. Routt (Strawberry) Hot Springs – This group of 5 springs, about 5 miles north of town, flows from a northwest trending fracture near its intersection with the northerly striking fault that also localizes Steamboat Hot Springs. The aggregate flow rate is greater than 85 gallons per minute, the temperatures range from 124 – 147°F, and the waters are now used for a nicely developed spa.
4. There is also a thick, areally extensive travertine deposit located south of Howelsen Hill, along the west bank of the Yampa River. The travertine (calcium carbonate) was precipitated from warm to hot springs that probably flowed from the northerly-trending fault zone that has been mapped from north of the Routt Hot Springs, southward to and far beyond the Project interest area.

#### New Exploration Targets

Notwithstanding the disappointing results of interviews and field studies, there is still considerable merit in identifying and planning to drill thermal gradient holes on two of the following significant fracture systems near Steamboat Springs in search of a deep, “cryptic” geothermal system.

There are three such fracture systems that transect the Steamboat Springs area (Figure 1). The first strikes approximately N10E to N10W and appears to extend from at least as far north as Routt (Strawberry) Hot Springs to and beyond Howelsen Hill and then further south. This feature may actually comprise a zone up to 2,500 feet wide (near Routt Springs; Christopherson, 1979) that includes several strands of both thrust and normal faults of different ages (Figure 2). This zone transects rocks of Precambrian through Oligocene ages and localizes the several thermal features collectively called “Steamboat Hot Springs”. This is also the fracture zone that leaked the warm waters from which were deposited the thick and extensive travertine deposits outcropping south of Howelsen Hill. It may be that the travertine deposits sealed off the warm water flow over time and that the thermal waters can still be tapped by drilling through the travertine and into or near the fracture zone that was once their conduit to the surface.

The second important fracture system comprises at least 5 sub-parallel, N45-62E striking structures located southeast and east of town (Figure 1). These fractures transect the granitic and metamorphic Precambrian rocks underlying the Park Range, but their traces are covered by glacial, landslide, and alluvial deposits along the western front of the mountains and near their mouths in the Yampa River Valley. The very straight course of

Fish Creek is the most striking evidence of one of these faults, but there are several other similar, if slightly less dramatic, fracture-controlled valleys mapped to the northwest of Fish Creek. It seems possible that one of the latter fractures may conduct the Heart Spring waters.

The third sets of fractures identified during this study are those that appear to control the courses of Priest and Beaver Creeks south of the Project area. These also trend about N50E, and could extend to significant depth, but they may be too far away and downhill from the project to be considered economically viable sources of thermal waters. It is possible that the warm waters, reported (Mr. Rod Branstetter, Aztec Drilling Company, personal communication) to exist in the Yampa River Valley near the Sydney railroad stop, may be flowing southwestward along the buried traces of one or both these fractures.

In addition to these major fracture systems, there is evidence (springs, seeps, prominent scarps, straight valleys), on Mt. Werner, of an extensive network of faults within the underlying Precambrian age crystalline rocks. It is conceivable therefore, that there may be thermal waters at depth beneath Mt. Werner. However logistical, legal, and economic considerations suggest that these potential targets be given lower exploration priorities, at least for the time being.

### **The Geothermal Exploration Rationale**

In order to have a viable geothermal system there must exist the following:

1. A Heat Source - In the Steamboat Springs region, in the absence of young volcanic activity, it is likely that the thermal waters are heated by circulation of meteoric waters to depths of 12,000 to 15,000 feet (Christopherson, 1979). At these depths, the waters are conductively heated by the surrounding rocks (these derive their elevated temperature due to radiogenesis, exothermic mineral reactions, and the earth's natural thermal gradient) after which the heated waters ascend to the surface due to their lowered density.
2. A Reservoir - The geothermal reservoir beneath Steamboat Springs likely comprises zones of highly fractured rock within the sedimentary and/or crystalline basement formations. It is considered unlikely that the reservoir depends on the limited natural intergranular porosity and permeability of the local formations.
3. A Conduit System - The conduit system for Steamboat Springs vicinity thermal waters is believed to comprise the sub-parallel and orthogonal networks of faults

and fractures that transect the region. In some cases, these fractures are evidenced by linear stream drainages (as is the case with Fish Creek, Burgess Creek, Priest Creek, and Beaver Creek) and/or by major changes in lithology (as is seen adjacent to the travertine deposits located south of Howelsen Hill).

During a search for high temperature geothermal resources to be used for generation of electric power, the exploration studies typically start with detailed geologic and geochemical surveys that cover ground progressively further away from the known geothermal phenomena. If encouraging geologic structures, rock alteration, and chemistry are recorded, geophysical investigations comprising gravity, magnetic, and/or electrical resistivity techniques are usually conducted. This work is then followed by the drilling of multiple thermal gradient holes in areas determined to be prospective on the basis of the results of the preceding studies.

The current geothermal reconnaissance study is not focused on high temperature resources and its scope is somewhat limited by time and budget constraints. *Accordingly, the detailed, expensive, and time-consuming geoscientific studies are being foregone, and the plan is to: 1) identify one or more fracture systems that might conduct thermal waters at depth and 2) drill shallow (~500 feet deep) thermal gradient holes designed to transect these fractures and to measure temperature changes with depth in these bores.* If encouraging temperatures are found in one or more holes, the drilling of a deeper exploratory well may be recommended at the best site.

### **Recommendations for Future Work**

As time and money are of the essence, the conduct of gravity, magnetic and/or electrical resistivity geophysical studies is not recommended. These investigations could help identify the precise locations of the major faults in areas covered by sediments, but they would be expensive to run, face major challenges due to the widespread cultural impediments (roads, power lines, traffic noise, etc.), and therefore their successful completion would not be certain.

Recommendations are as follows:

1. The drilling of **one thermal gradient hole**, ~500 feet deep, designed to penetrate the travertine bench and, if possible, to intersect the suspected northerly trending fault zone. It would be located at the southern end of the cross country ski trails, approximately due west of the Yampa Botanical Park, and near the east-west trending “fire break” that leads to the top of Quarry Mountain (Figure 3). If anomalous temperatures, and eventually thermal waters, were to be found at this

location, they could be piped about 1.5 miles to the Project site using existing bridges, tunnels, and road right-of-ways at a relatively reasonable cost.

2. The drilling of **at least one, and preferably three thermal gradient holes**, ~ 500 feet deep, with the first hole located near where the projected extension of the “Fish Creek fault” passes between North Mt. Werner Circle and Rockies Way (near the sign advertising “The Porches” development) (Figure 3). If more than one hole is drilled, the second and third bores should be situated so as to create a “fence” oriented perpendicular to the fault trace. In this way, it may be possible to most accurately locate the actual fault trace and any thermal waters associated with it. **Alternatively**, the fourth hole might be drilled near the City Water Treatment Plant on Fish Creek (Figure 3). This hole would definitely test the fault zone, but is slightly further from the project than might be desirable.
3. The budgeting of a second short trip to Steamboat Springs by Mr. Hutterer in order to precisely identify the optimum locations for the **four** recommended thermal gradient holes.

After the thermal gradient holes are drilled, 1 inch diameter black iron pipe, capped at the bottom, will be installed. It will be filled with water, and the hole will be allowed to thermally equilibrate for at least as long as was required for drilling (about 3 days). Then, using a thermometer or thermistor, temperatures will be recorded at 10 foot intervals while going into as well as coming out of the hole. The temperature readings will be plotted against depth on a graph to determine the gradient profile. It would be encouraging to see: a) temperatures above those attributable to the normal earth gradient of ~1.7 degrees F per 100 feet, and b) a line graph that shows temperatures still increasing at the bottom of the hole (a “conductive gradient”).

Gradient curves will be drawn for each of the holes and then the thermal and logistical attributes will be compared for each location. The site having the highest temperature combined with a conductive gradient and its proximity to the Project site will determine where a deep geothermal production well should be drilled.

### **Estimated Costs and Time Required to Drill the Recommended Holes Including Geologic Supervision, Data synthesis, and Report Writing**

#### Gradient Hole Drilling

The thermal gradient holes will have to be collared with a diameter of about 9 inches in order to accommodate up to 150 feet of 7 inch surface casing. This upper part of each hole will cost about \$50 per foot including casing and cementing. The remaining 350 feet

of each hole can be drilled “open hole” (uncased) using a 4.5 inch bit. This will cost about \$25 per foot. There will be a mobilization/demobilization charge of about \$1,000 and per diem charges for a three man crew of \$200 per man per day. It is anticipated that the set-up, drilling, moves, and tear-down will take about 3 days per hole.

Accordingly the following costs are estimated:

Mobilization/Demobilization .....	\$ 1,000
Drill 150 ft. x 4 holes, case with 7”, and cement @ \$50/ft. ....	30,000
Drill 350 ft. x 4 holes, open hole @\$25/ft. ....	35,000
Furnish and install 2,000 ft. of 1.5” black iron pipe & couplings ..	6,740
Per Diem – 3 men x 12 days @ \$200/day .....	<u>7,200</u>
Subtotal .....	\$79,940

Prudence would suggest that a 10% contingency (~\$8,000) also be budgeted as the drilling business is very commonly challenged by unforeseen, unavoidable, time-consuming problems.

### Geologic Services

It would be advisable to have a geologist on site while the holes are drilled. This will enable the accurate logging of the subsurface conditions and will allow the measurement of temperatures in the first holes while the next holes are still being drilled. This would mean that the geologist would be on site for about 16 days at a cost of \$800 per day (regardless of how many hours are worked per day) plus living expenses (at cost) and vehicle mileage charges at \$0.44/mile. In addition, two office days would be required to analyze the temperature data and write a report regarding survey results, conclusions, and recommendations. Finally, it will be necessary to rent a suitable temperature measuring tool designed to be used in moderately deep geothermal holes. The cost of this is estimated at \$100 per day.

Geologist Professional Field Services – 16 days @ \$800/day .....	\$ 12,800
Geologist Professional Office Services – 2 days @ \$800/day .....	1,600
Vehicle miles – 250 @ \$0.44/mile .....	110
Temperature tool rental – 18 days @ \$150/day (incl. 5% tax & ck out fee) ..	2,700
Lodging - 14 nights @ \$75/night (est.) .....	1050
Meals - 15 days @ \$40/day .....	<u>600</u>
Subtotal .....	\$ 18,860

Estimated Cost and Schedule Summary

1. Gradient Hole Drilling .....	\$ 79,940
2. Contingency @ 10% .....	8,000
3. Geologic Services (Field and Office) .....	<u>18,860</u>
Estimated Total .....	\$ 106,800

Drilling time is estimated at 12 days; geologist field time is estimated at 16 days, and time for data analysis and report writing will be 2 days. **Allow three calendar weeks for the work.**

**Please note that the recommended program is of ideal scope. If fewer holes were to be drilled, most costs would be proportionately decreased.**

Selected Bibliography

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U.S. Geologic Survey, 2000, "Rocky Peak Quadrangle, 7.5 minute series (topographic), 1:24,000 scale.

U.S. Geologic Survey, 2000, "Steamboat Springs Quadrangle, 7.5 minute series (topographic), 1:24,000 scale.

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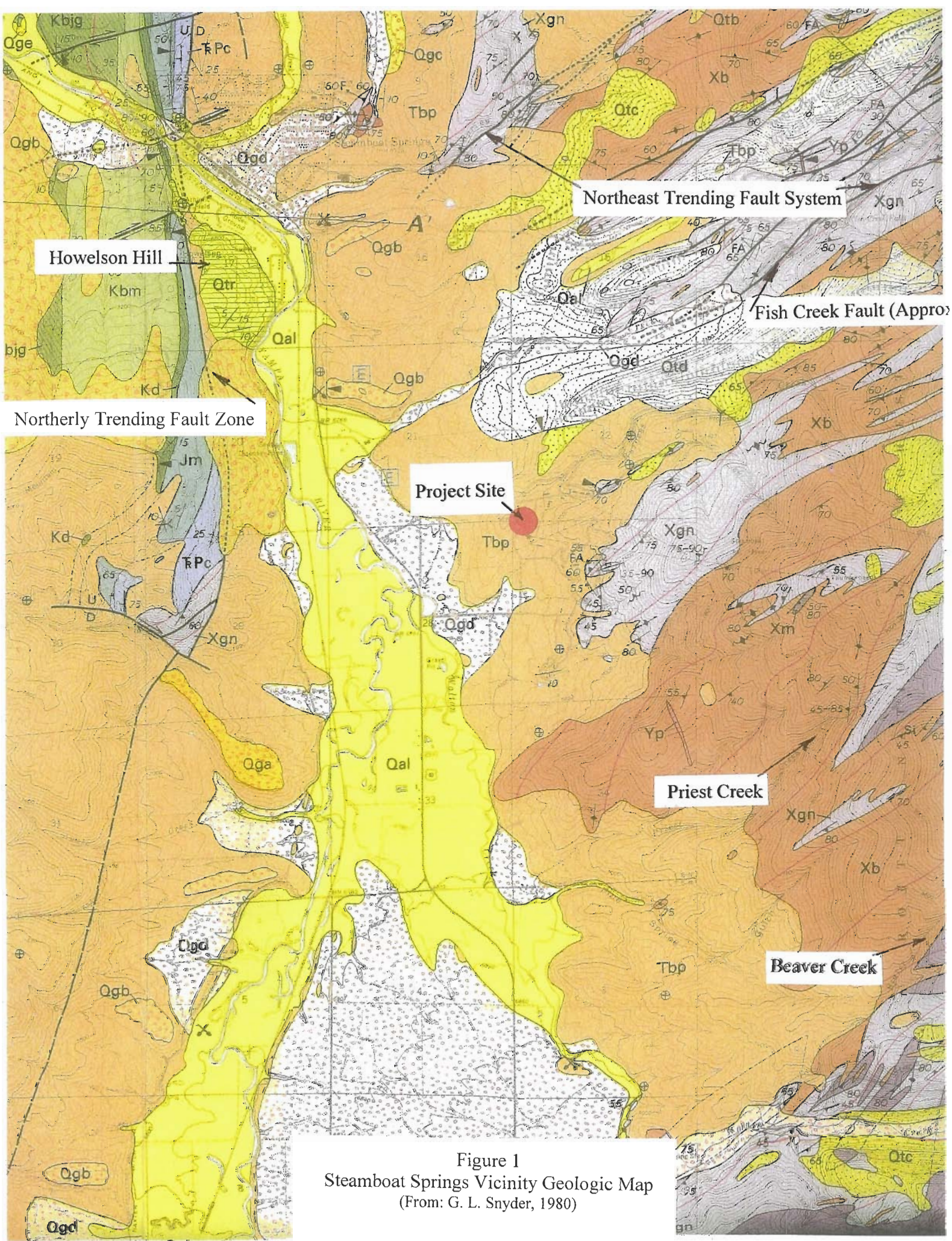


Figure 1  
 Steamboat Springs Vicinity Geologic Map  
 (From: G. L. Snyder, 1980)

## **GEOLOGIC FORMATIONS**

(Youngest to Oldest)

### **Map Symbol**

### **Formation Age, Name, and Brief Description**

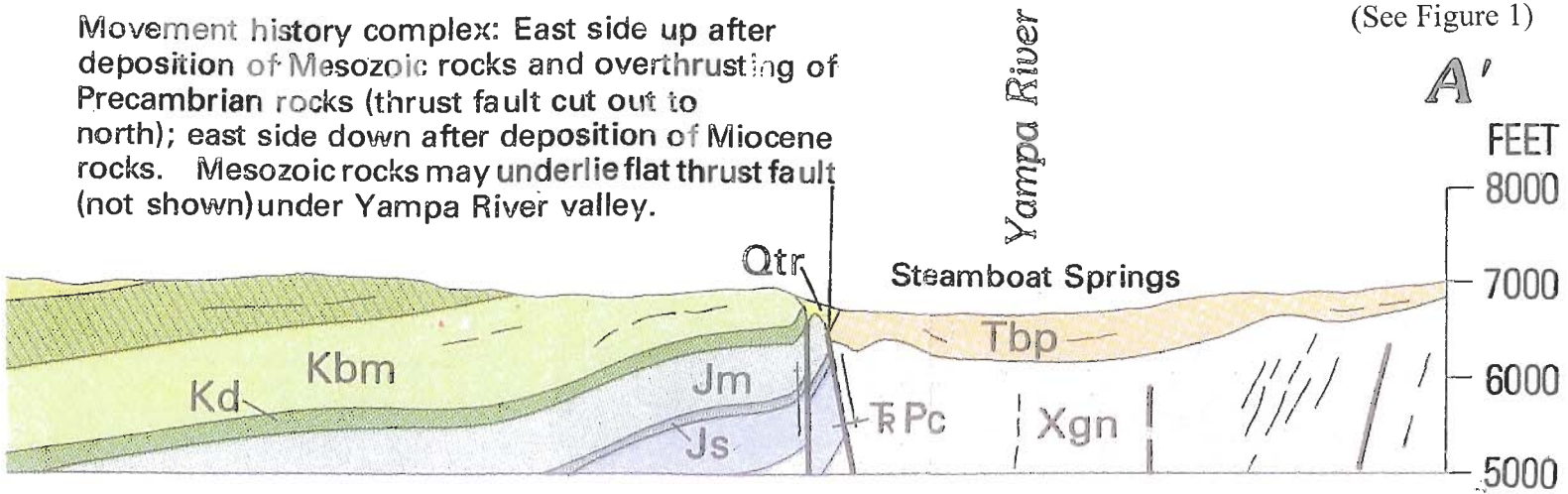
Qal	Quaternary fluvial alluvium
Ql	Quaternary landslide debris
Qtr	Quaternary travertine (layered limestone deposited by hot springs)
Qgd	Quaternary terrace gravels 3-18 mtrs. above modern flood plain
Qtd	Quaternary bouldery glacial till
Qgc	Quaternary terrace gravels 19-30 mtrs. above modern flood plain
Qtc	Quaternary glacial till remnants of lateral and terminal moraines
Qgb	Quaternary terrace gravels 31-76 mtrs. above modern flood plain
Qga	Quaternary terrace gravels 77-110 mtrs. above modern flood plain
Tbp	Tertiary Browns Park fm. Primarily silt and siltstones
Kbjg	Upper and Lower Cretaceous Greenhorn limestone
Kbm	Lower Cretaceous Mowry black shale
Kd	Lower Cretaceous Dakota sandstone
Jm	Upper Jurassic Morrison fm. Shales and claystones
TrPc	Triassic and Permian Chugwater fm. and older sediments
Yp	PreCambrian porphyritic fine grained dikes
Xb	PreCambrian quartz monzonite
Xgn	PreCambrian felsic gneiss and metavolcanic units

From: G.L. Snyder, USGS Map I-1114, 1980

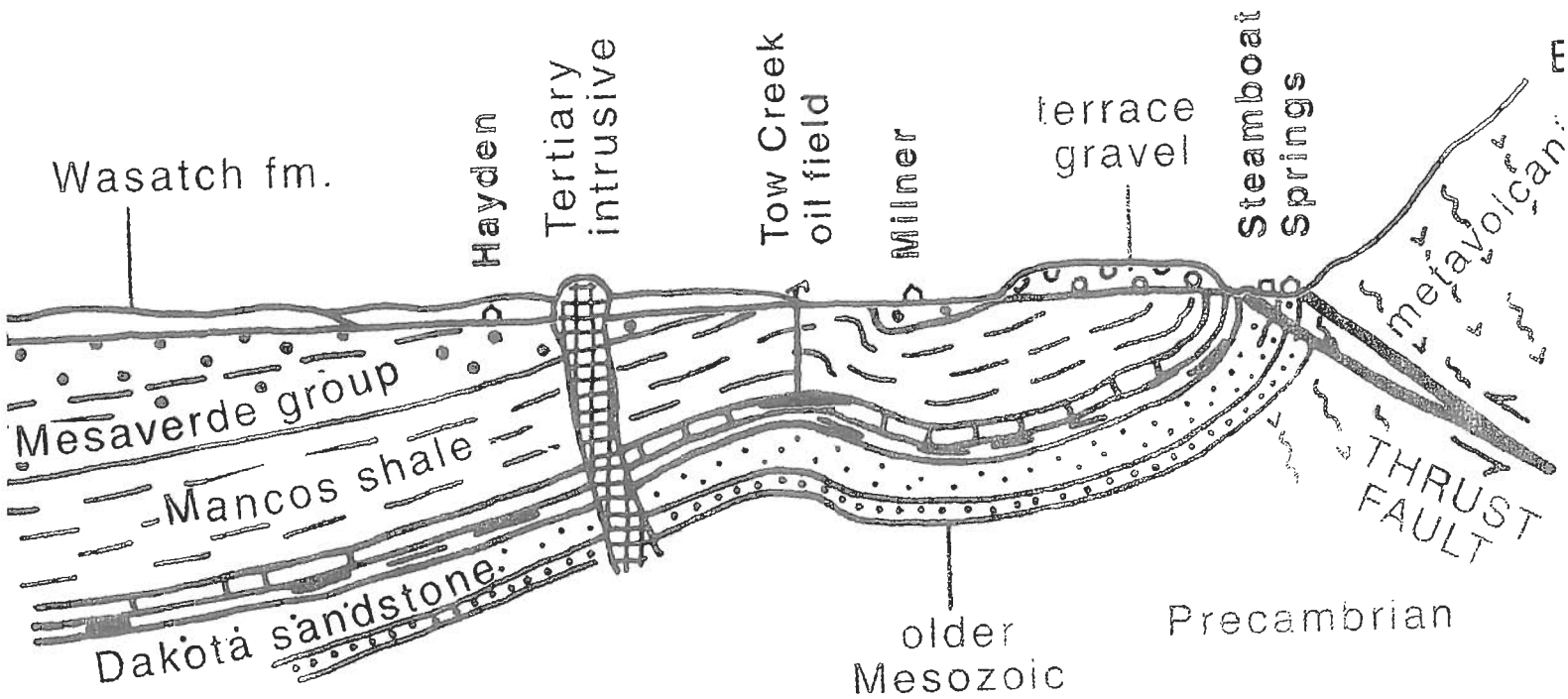
steamboat@colmaplegend

Movement history complex: East side up after deposition of Mesozoic rocks and overthrusting of Precambrian rocks (thrust fault cut out to north); east side down after deposition of Miocene rocks. Mesozoic rocks may underlie flat thrust fault (not shown) under Yampa River valley.

(See Figure 1)



From: G. L. Snyder, 1980



Section along U.S. 40 between Steamboat Springs and Craig.

From: H. Chronic and F. Williams, 2002

Figure 2  
Geologic Cross Sections

