EXPLAINING THE UNEVEN DISTRIBUTION OF THE EARTH'S **NATURAL RESOURCES**

STUDENT HANDOUT

Utah SEEd Standard 8.4.1
Next Generation Science Standard: MS-ESS3-1
Grade and Topic: 6th-grade Integrated Science
Middle School Physical Science

THE UNIVERSITY OF UTAH
College of Education

UTAHFORGE

GeoSights Exploration

Name _____

Background Information:

- Utah has some amazing geological locations. GeoSights highlights some of the lesser-known geologic wonders.
- Utah is divided into 3 different geological provinces, Basin and Range, Rocky Mountains, and Colorado Plateau, these regions are shown on this map.

Do this:

- Using your internet browser go to the web page https://geology.utah.gov/apps/geosights/index.htm
- Visit at least 5 sites in each geological region.
- Read the information about each site you visit.

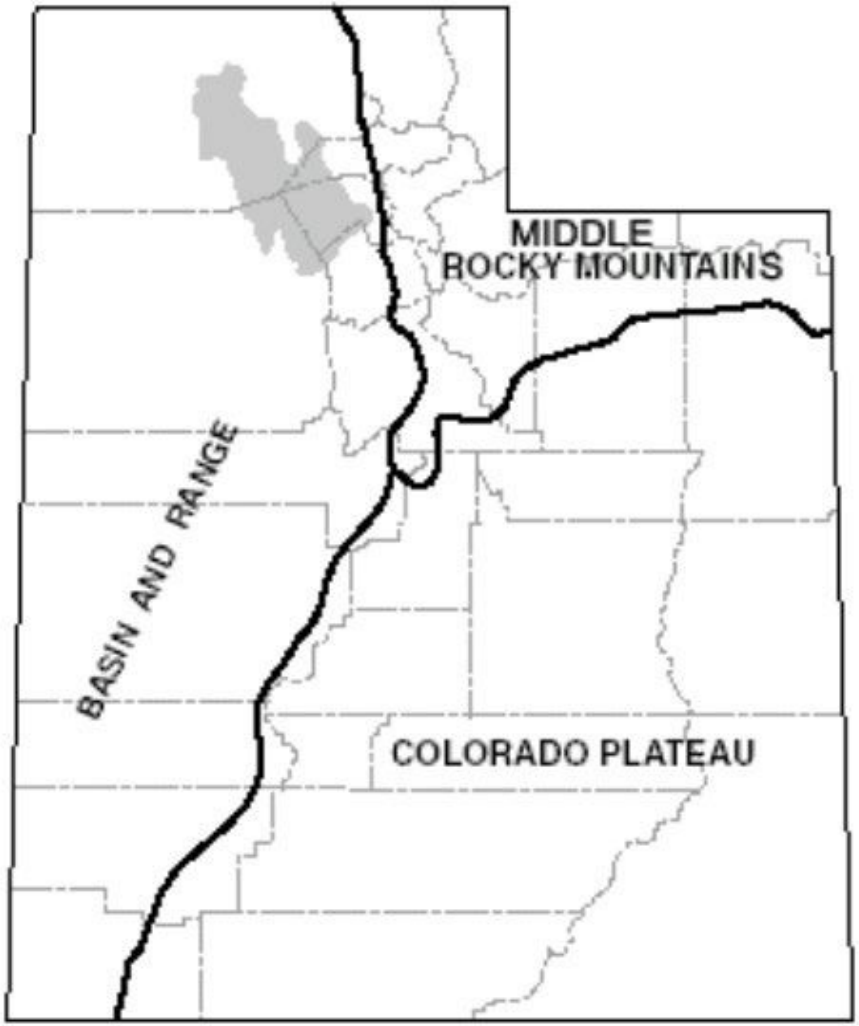
Write this:

- On the map label the sites you visited with the site name.

Think about this:

- Which places did you think were most interesting?
- Have you ever visited any of these locations?
- Did you notice any patterns?

(you can write notes here)



Distribution of Natural Resources in Utah – Group roles

For the next couple of class periods, you will be exploring the distribution of geological resources in your small groups. At each station, you will be asked to read background information and explore a map of how this resource is distributed in Utah.

There are several roles for the group members, the roles will rotate as you go through the stations. Your teacher will let you know which role you have at each station.

- **Group Leader:** Your task is to make sure that your group stays on task. Keep track of the time spent on each item and make sure that your group is progressing. You also need to help chose the roles of reader and scribe. These are volunteer positions, but you need to make sure that everyone who wants to read gets to read, and that everyone who wants to be the scribe gets the opportunity. If necessary, the group leader or discussion leader could be the reader. It is better if the scribe is a group member.
- **Discussion Leader:** Your task is to lead the discussion. You can use the talk moves to make sure that each of the members in your group is able to contribute to the discussion and have their voice heard. If necessary, you could also volunteer to be the reader. You cannot be the scribe and also lead the discussion.
- **Group Member:** Your task is to contribute to the discussion. You can use the talk moves to help you express your ideas and check your understanding of your group members' ideas.
  - **Reader:** If you are assigned the role of group member, you can also choose to be the reader. The reader will read the background information to the full group. This is a volunteer position. When volunteering, make sure that everyone who wants to read has the chance to read.
  - **Scribe:** The scribe is also a volunteer position. The scribe's job is to take notes on the group discussions. Your teacher will let you know if you need to submit your notes, or if you just need to keep them as references. As with the reader, when volunteering for this position, make sure that everyone who wants to be the scribe gets the chance. You might also be asked to write the group answers for the questions if your teacher tells you to submit one set of answers for each group.

Distribution of Natural Resources in Utah – Talk Moves

Sometimes people get stuck when asked to contribute to group discussions. Having sentence stems can help make it easier. Here are some talk moves that you can use to help with your conversation. You can always contribute a new idea, agree with a group member and build on their ideas, disagree with a group member and give evidence for why you disagree, or ask a question about something a group member said.

One thing I noticed from the reading is _____.

I think the reading said this _____. Is that what you understood it to mean?

I was confused when the reading said _____. What do you think that meant?

When reading the map, I notice that the color _____ represents _____ and the color _____ represents _____.

There appears to be more of the resource in _____province.

There appears to be less of the resource in _____province.

I agree with what you said and I also want to add that _____.

I disagree with what you said, and my reason is _____.

I think you said _____ is that what you meant?

Can you clarify what you meant by _____?

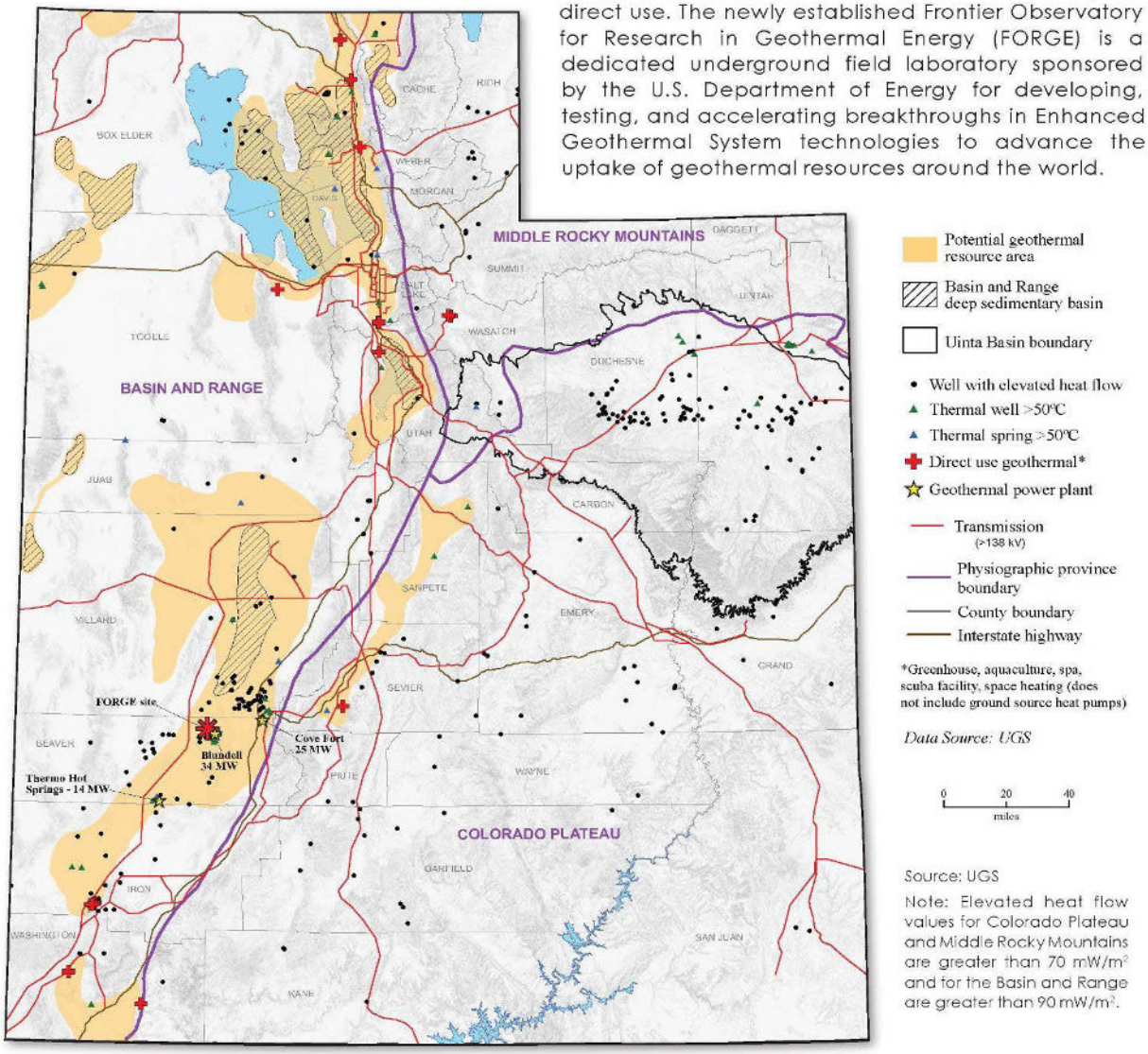
Station 1: Energy Resources

Directions:

1. Selecting roles: (<1 min)
   a. The group leader will help choose volunteers to fill the roles of reader and scribe.
   b. Record the group members' names next to their assigned/self-selected roles.
2. Background reading: (~5 min)
   a. The reader will read the background information for each map to the group.
   b. Group members will listen and/or read along, pay particular attention to information about how to read the map and the locations of resources on the map.
3. Map Exploration: (5 min)
   a. Each group member needs to take 5 minutes, without talking, to look at the maps. What are the maps showing? How do you read the maps? Is there anything about the maps you do not understand? What patterns do you see? What information do you think is important or interesting? Write down some of your ideas about the maps to prepare for the group discussion.
4. Discussion: (5-10 min)
   a. The discussion leader will lead a discussion on the information from the map.
   b. Each group member will contribute both new ideas and active listening responses.
   c. Use the talk moves to facilitate and contribute to the discussion.
   d. The scribe will take notes on important ideas.
   e. Here are some questions to help facilitate the discussion:
      i. How do you read each map?
      ii. Where do you find areas with many resources? Are there areas with few resources?
      iii. Are the resources all located in the same place? Or are different resources located in different places?
      iv. What patterns do you see? Using the information: (5-10 min)
   f. Either as a group or individually, answer the questions about the distribution of energy resources in Utah.
5. Rotate to the next station.

geothermal

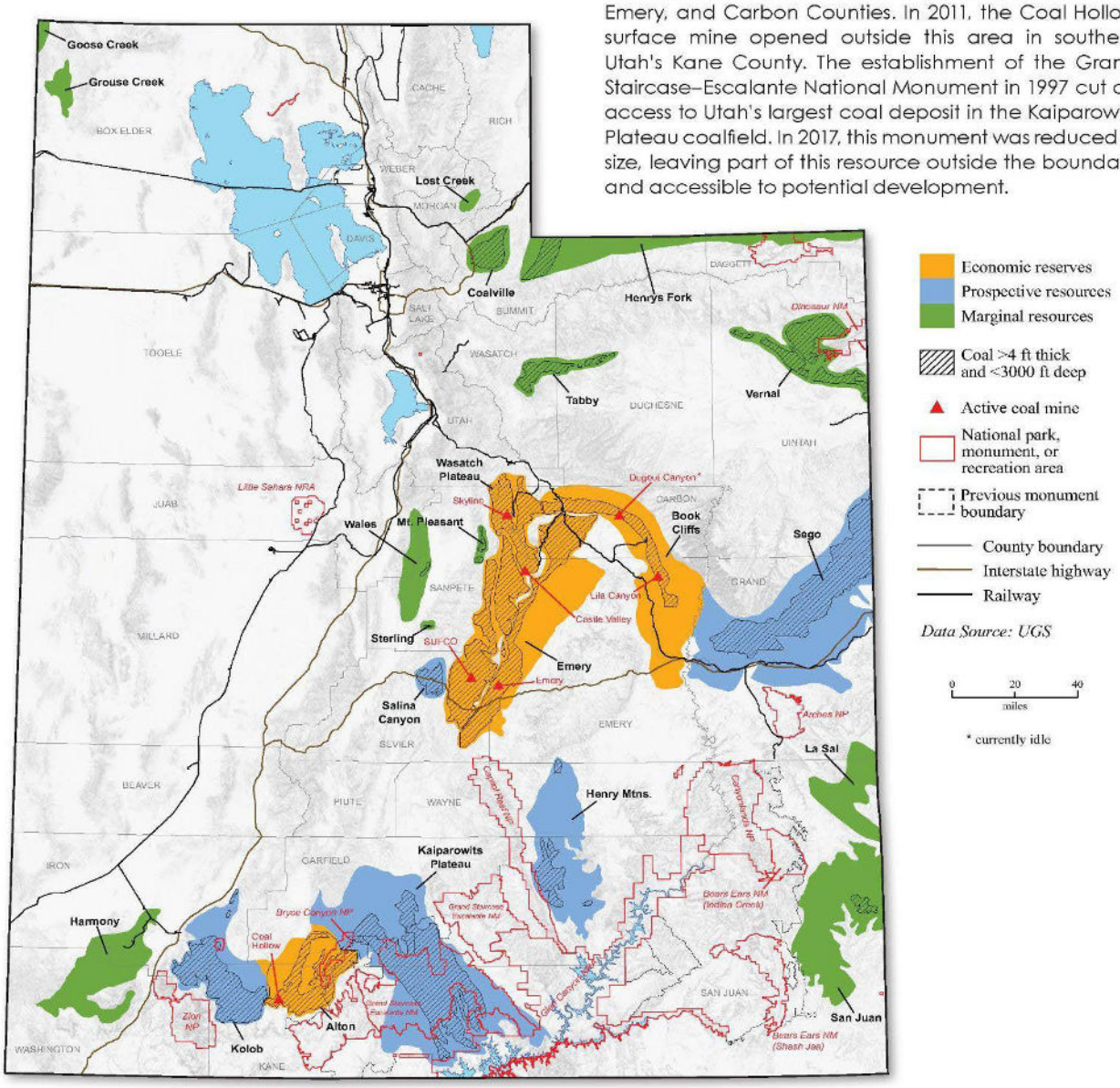
The geothermal energy resource potential of Utah has been evaluated on the basis of information extracted from various types of thermal data throughout the state. Heat-flow data, thermal spring and well temperatures, and fluid chemistries are typically used as a first step in the screening for geothermal resources. Recent studies indicate deep (>10,000 ft) sedimentary basins within the Basin and Range physiographic province of western Utah may have significant geothermal potential. The Uinta Basin also has a potential geothermal resource due primarily to the existence of well infrastructure from the oil and gas industry combined with favorable data on co-produced fluid temperatures and production rates. Utah is home to a variety of geothermal resource utilization projects for both direct applications (greenhouses, spas, space heating, aquaculture) as well as electric power generation. Potential geothermal resources of the Basin and Range would likely include both types of geothermal applications, whereas those of the Uinta Basin would mostly be direct use. The newly established Frontier Observatory for Research in Geothermal Energy (FORGE) is a dedicated underground field laboratory sponsored by the U.S. Department of Energy for developing, testing, and accelerating breakthroughs in Enhanced Geothermal System technologies to advance the uptake of geothermal resources around the world.



Vanden Berg, M. D. (2020). *Utah's Energy Landscape - 5th Edition*. Utah Geological Survey. C-127. Retrieved from https://ugspub.nr.utah.gov/publications/circular/c-127/c-127.pdf

coal

Utah's most economic coal reserves are located in three coalfields forming an inverted "U" primarily across Sevier, Emery, and Carbon Counties. In 2011, the Coal Hollow surface mine opened outside this area in southern Utah's Kane County. The establishment of the Grand Staircase–Escalante National Monument in 1997 cut off access to Utah's largest coal deposit in the Kaiparowits Plateau coalfield. In 2017, this monument was reduced in size, leaving part of this resource outside the boundary and accessible to potential development.



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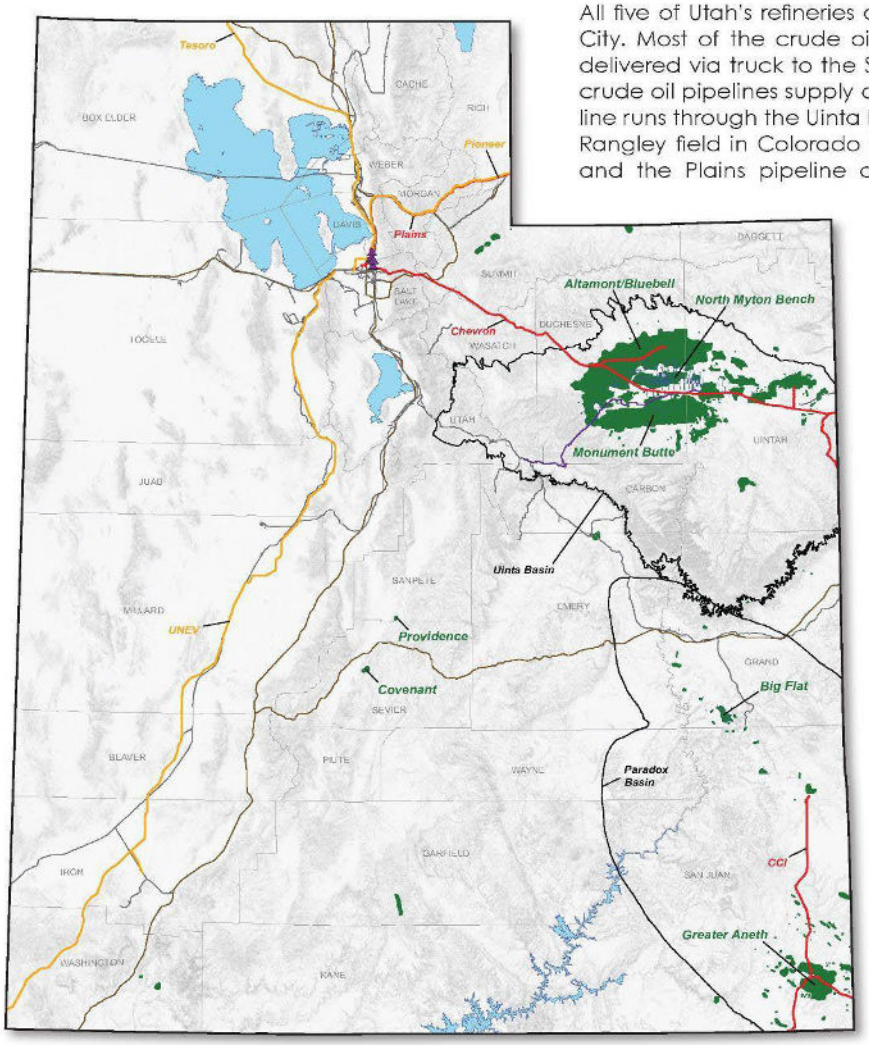
crude oil & petroleum products

Utah's crude oil production is mostly concentrated within Duchesne and Uintah Counties (Uinta Basin) to the north and San Juan County (Paradox Basin) to the south. The 2004 discovery of the Covenant field, and later the Providence field, in central Utah opened this previously undeveloped area to new production. Horizontal drilling in the Uinta Basin's Green River Formation has proven very successful, especially in the North Myton Bench field and surrounding area. Production from these new wells, most of which have been drilled since the early to mid-2010s and are up to 10,000 feet in lateral length, are on par with some of the most successful unconventional wells in the country. The Cane Creek shale in the Paradox Basin, centered around the Big Flat field, has also been successfully drilled with horizontal wells.



All five of Utah's refineries are located just north of Salt Lake City. Most of the crude oil production in the Uinta Basin is delivered via truck to the Salt Lake City refineries, while two crude oil pipelines supply additional feedstock; the Chevron line runs through the Uinta Basin delivering crude oil from the Rangley field in Colorado (with minor inputs of Utah crude) and the Plains pipeline delivers crude oil from Wyoming and Canada. With the recent large increase in Uinta Basin production, some crude oil is also being loaded onto trains near Price for shipment to refineries out of state. In addition, most crude oil produced in southeastern Utah is shipped via pipeline to New Mexico. The Pioneer petroleum product pipeline carries refined fuel to Salt Lake City from the Sinclair refinery in Wyoming, while two product pipelines carry refined petroleum product out of Utah: the Tesoro line supplies markets in the northwest and the UNEV line delivers product to Cedar City and Las Vegas.

- Crude oil field
- Horizontal well
- Petroleum refinery
- Crude oil pipeline
- Petroleum products pipeline
- County boundary
- Interstate highway
- Railway
- Proposed railway

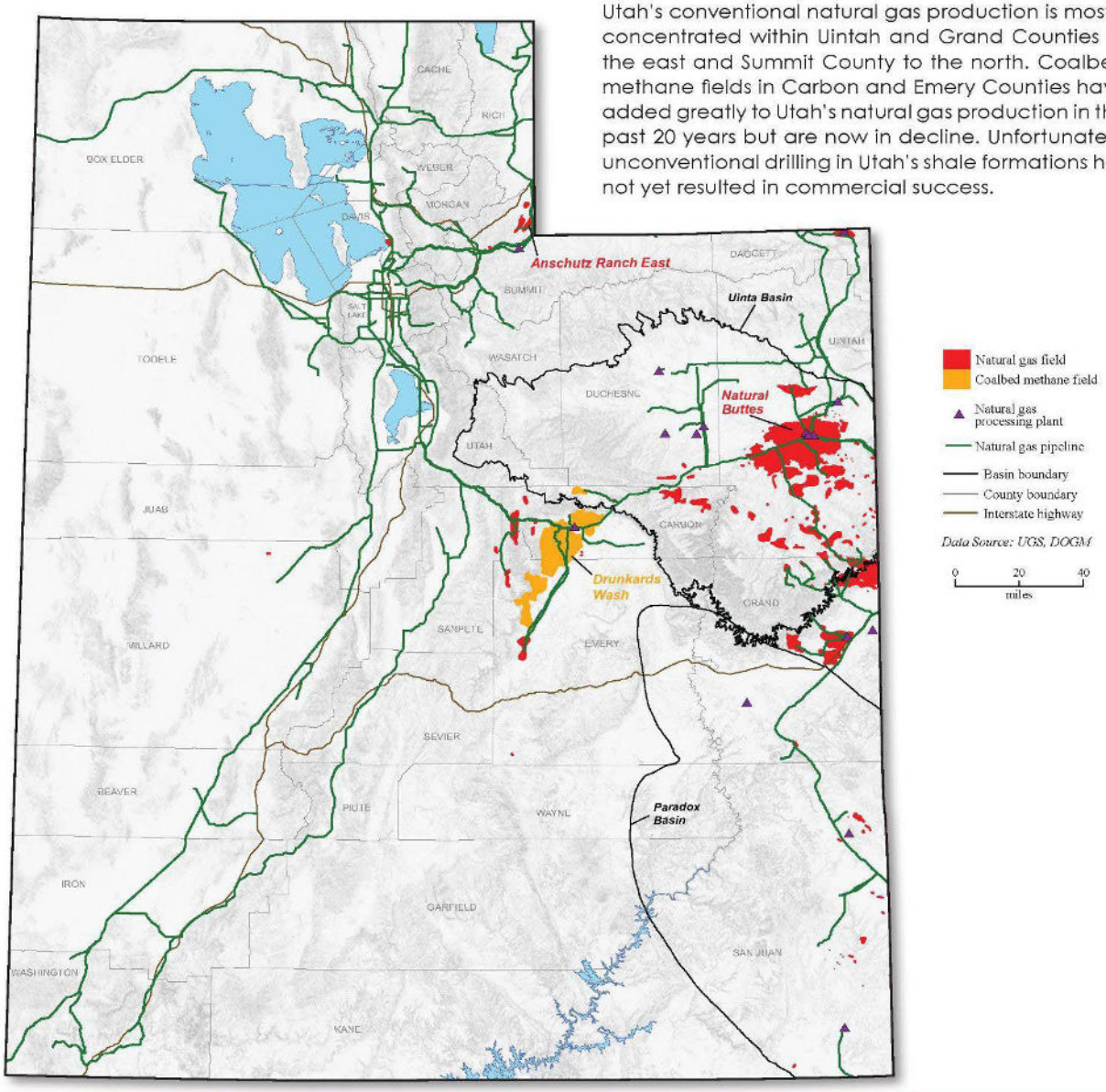
Data Source: UGS, DOGM

0 20 40 miles

Vanden Berg, M. D. (2020). *Utah's Energy Landscape - 5th Edition*. Utah Geological Survey. C-127. Retrieved from https://ugspub.nr.utah.gov/publications/circular/c-127/c-127.pdf

natural gas

Utah's conventional natural gas production is mostly concentrated within Uintah and Grand Counties to the east and Summit County to the north. Coalbed methane fields in Carbon and Emery Counties have added greatly to Utah's natural gas production in the past 20 years but are now in decline. Unfortunately, unconventional drilling in Utah's shale formations has not yet resulted in commercial success.



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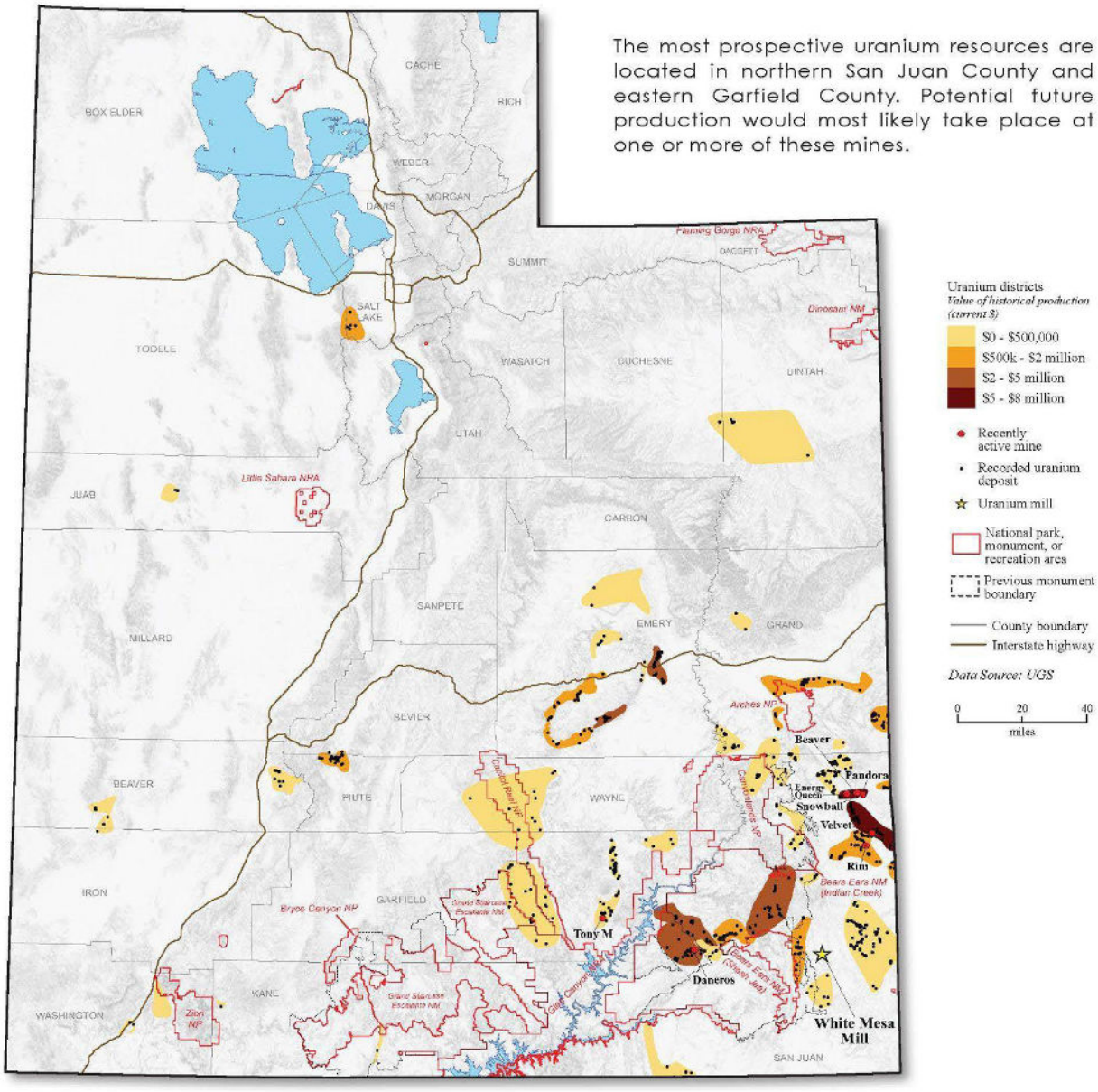
uranium



Vanden Berg, D. (2020). *Utah's Landscape - 5th* . Utah Geological Survey. CM. *Energy Edition*127. Retrieved from https://ugspub.nr.utah.gov/publications/circular/c-127/c-127.pdf

Station 1: Energy Resources

Group leader _____

Discussion leader _____

Other member _____

Background Information:

- At this station, you will be exploring 5 maps that show the location of geothermal, hydrocarbon, and uranium resources in Utah. Each map includes information about the distribution of these resources.
- Utah is divided into 3 different geological provinces, Basin and Range, Rocky Mountains, and Colorado Plateau, these regions are shown on the blank map.

Discuss this:

- How do you read each map?
- Where do you find areas with many resources? Are there areas with few resources?
- Are the resources all located in the same place? Or are different resources located in different places?
- What patterns do you see?

(you can write notes here)

Reader _____

Scribe _____

Other member _____

Do this:

- Read the information on each map.
- Spend 5 minutes viewing the maps without talking. Look for patterns. Is there anything about the maps you don't understand? Is there anything about the maps you think is important or interesting?

Write this:

1. Where do you find the most geothermal resources? Which province is this in?

2. Where do you find the most coal resources? Which province is this in?

3. Where do you find the most petroleum resources? Which province is this in?

4. Where do you find the most natural gas resources?

Which province is this in?

5. Where do you find the most uranium resources?

Which province is this in?

6. Are there places on the map with more than one type of resource? Where are these located?

7. Are there places on the map with few or no energy resources? Where are these located?

8. What patterns do you see?

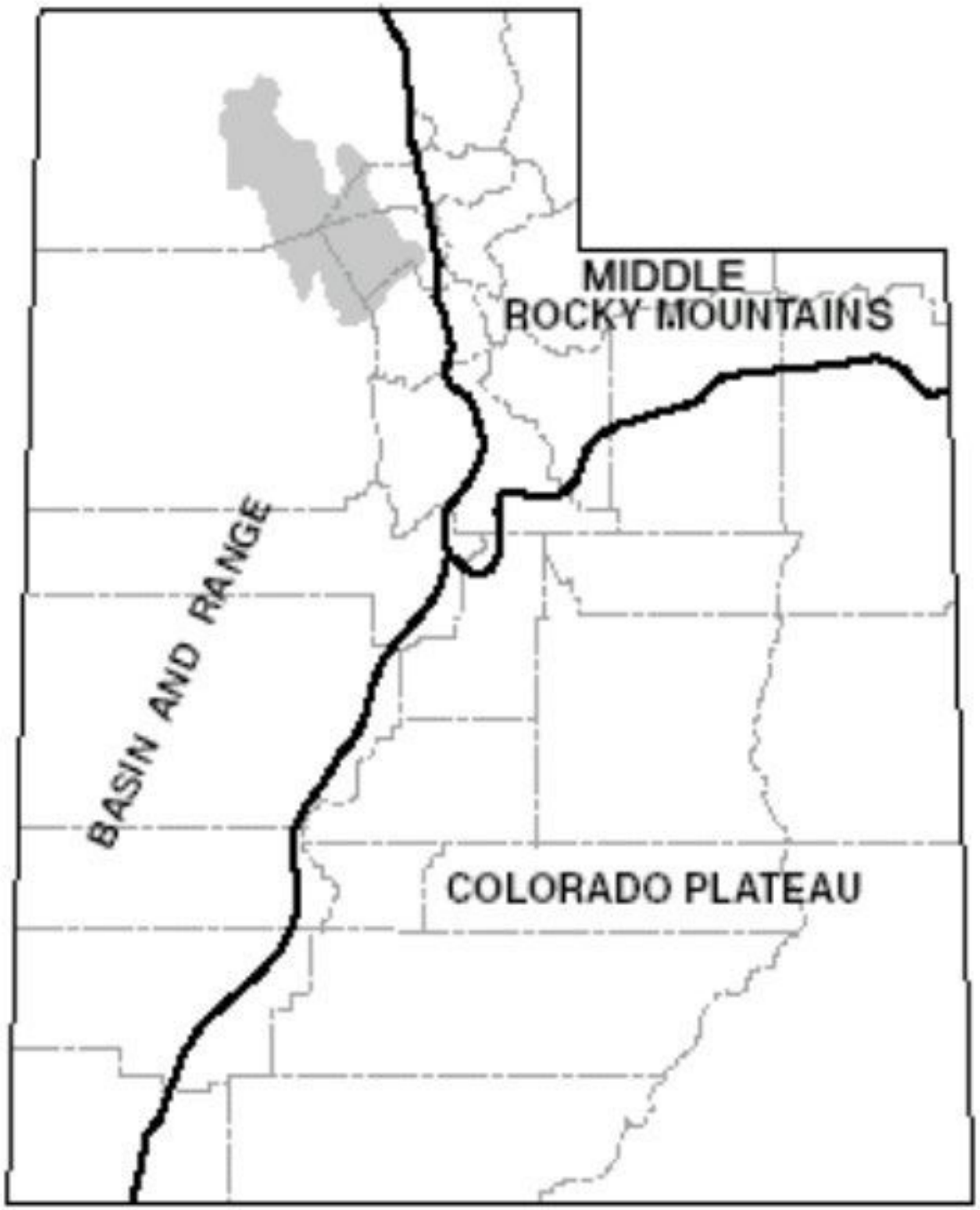
Think about this:

Why do you think that the resources aren't evenly distributed?

Which locations on the GeoSights map would be good cache locations for each type of energy resource?

Draw this:

On the map below, mark the major locations of each resource: geothermal, coal, petroleum, natural gas, and uranium.



Station 2: Metal Resources

Directions:

1. Selecting roles: (<1 min)
   a. The group leader will help choose volunteers to fill the roles of reader and scribe.
   b. Record the group members' names next to their assigned/self-selected roles.
2. Background reading: (~5 min)
   a. The reader will read the background information to the group.
   b. Group members will listen and/or read along, pay particular attention to information about how to read the map and the locations of resources on the map.
3. Map Exploration: (5 min)
   a. Each group member will take 3-5 minutes, without talking, to look at the printed map. What is the map showing? How do you read the maps? Is there anything about the maps you do not understand? What patterns do you see? What information do you think is important or interesting? Write down some of your ideas about the maps to prepare for the group discussion.
4. Further Exploration: (5-10 min)
   a. Using the interactive map located at https://geology.utah.gov/apps/blm_mineral/ the group members can further explore the mining districts in Utah.
5. Discussion: (5-10 min)
   a. The discussion leader will lead a discussion on the information from this new map.
   b. Each group member will contribute both new ideas and active listening responses.
   c. Use the talk moves to facilitate and contribute to the discussion.
   d. The scribe will take notes on important ideas.
   e. Here are some questions to help facilitate the discussion:
      i. How do you read this map?
      ii. Where do you find areas with many resources? Are there areas with few resources?
      iii. Are the resources all located in the same place? Or are different resources located in different places?
      iv. What patterns do you see? Using the information: (5-10 min)
   f. Either as a group, or individually, answer the questions about the distribution of metal resources in Utah.
6. Rotate to the next station.

Utah Mining Districts

By Ken Krahulec

INTRODUCTION

The metal mining industry has been an integral part of Utah since the 1860s, long before becoming a state in 1896. The arrival of the railroad in 1869 and its rapid expansion across western Utah facilitated the transportation of needed mining materials and supplies to the mines and the haulage of ore from them. The railroad resulted in the rapid growth of the mining industry and the Salt Lake City area became the main ore concentrating and smelting center for the eastern Great Basin from the 1890s to the 1970s (Whitley, 2006).

Early in Utah's mining history, individual mining districts were organized by the miners and prospectors from the local camp. They elected a recorder, determined regulations for claims, named the district, and defined district boundaries. The U.S. General Mining Act of 1872 formalized a uniform set of claim regulations and the federal government eventually took over the recorder functions. After 1872, the organization of individual mining districts and the definition of their boundaries became somewhat superfluous due to the uniform federal regulations. However, by 1920, 115 mining districts were recognized in Utah along with numerous unorganized camps outside of these district boundaries (Butler and others, 1920). By 1983, Doelling and Tooker (1983) showed 159 districts in Utah. More recently the Utah U-V mining districts were defined by Gloyn and others (2005).

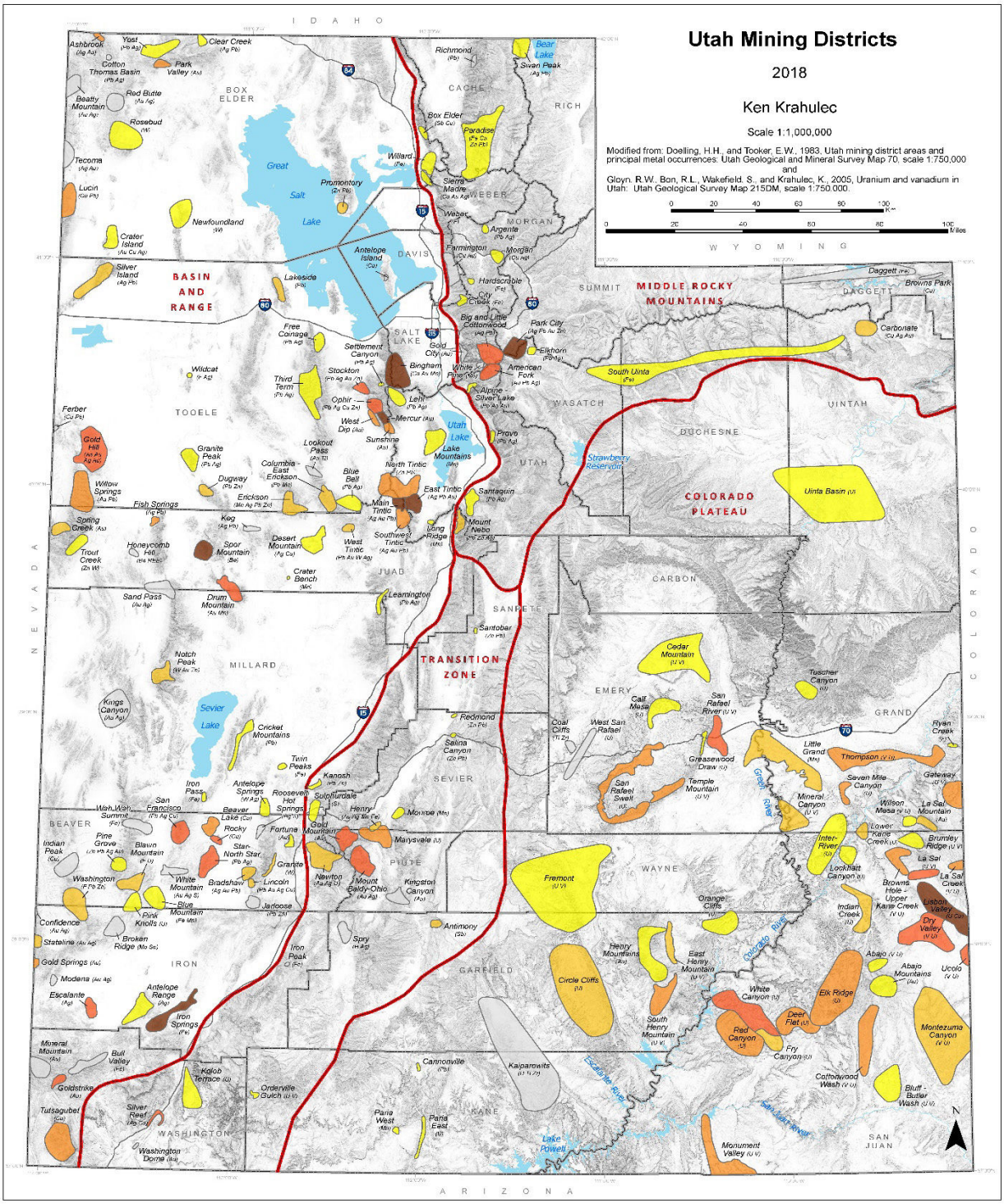
This report discusses 185 Utah mining districts but does not include several poorly documented mineralized areas in the state that have little or no production and several scattered placer gold prospects having limited production along the Colorado and Green Rivers. In an effort to make the district boundaries align better with the underpinning geological framework, a few of the previously defined districts were combined in this report (for example, Big Cottonwood and Little Cottonwood were combined into the Big and Little Cottonwood district), and some districts were subdivided (for example, the Tintic district was subdivided into the Main Tintic, East Tintic, Southwest Tintic, and North Tintic subdistricts). However, the vast majority of the previously recognized district boundaries have only undergone minor changes from Doelling and Tooker (1983) and Gloyn and others (2005).

Utah is situated at the intersection of three important geological provinces, the Middle Rocky Mountains in the northeast, the Colorado Plateau in the southeast, and the Basin and Range Province in the west. In addition, a transition zone lies along the boundary between the Basin and Range Province and the Colorado Plateau. These provinces have significantly different geologic histories resulting in the formation of different ore deposit types and the production of unique metal assemblages. For example, the Basin and Range Province has mainly produced Cu, Pb, Zn, Au, and Ag from intrusive-centered mining districts, but the Colorado Plateau is primarily recognized for sandstone-hosted U, V, and Cu deposits.

Krahulec, K. (2018). *Utah Mining Districts*. Utah Geological Survey. OFR-695. Retrieved from https://ugspub.nr.utah.gov/publications/open_file_reports/ofr-695.pdf

Chemical symbols and names of metals/minerals mined in Utah:

Ag – Silver
Au – Gold
Be – Berylium
Cu – Copper
F – Fluorine
Fe – Iron
Mn – Manganese
Mo – Molybdenum
Pb – Lead
Sb – Tin
Ti – Titanium
U – Uranium
V – Vanadium
W – Tungsten
Zn – Zinc
Zr – Zirconium
(REE) – Rare Earth Elements



District Total Production Value*

Geologic Province Boundary

No Production

< $1,000,000

$1,000,000 – $10,000,000

$10,000,000 – $100,000,000

$100,000,000 – $1,000,000,000

>$1,000,000,000

*Mining districts are color coded by their estimated total historical production value. District production values are calculated by multiplying the total quantities of metals produced by their estimated recent average price. Prices used: Cu $2.50/lb, Pb $1/lb, Zn $1/lb, Au $1100/oz, Ag $15/oz, Be $175/lb, As $0.90/lb, Bi $3.35/lb, Ga $250/lb, Ge $180/lb, Sb $1.30/lb, Mn $0.75/lb, MoS_2 $10/lb, U_3O_8 $30/lb, V_2O_5 $6/lb, WO_3 $7/lb, Hg $400/76 lb flask, iron ore $65/long ton, S $30/short ton, and fluorite $250/short ton.

Station 2: Metal Resources

Group leader _____

Discussion leader _____

Other member _____

Reader _____

Scribe _____

Other member _____

Background Information:

- At this station, you will be exploring a printed map and an interactive map that show the location of metal, mineral, and energy resources in Utah. You will be focusing on the metal resources. Energy and some mineral resources are explored at other stations. Each map includes information about the distribution of these resources.
- Utah is divided into 3 different geological provinces, Basin and Range, Rocky Mountains, and Colorado Plateau, these regions are shown on the blank map.

Do this:

- Read the background information.
- Spend 5 minutes viewing the map without talking. Look for patterns. Is there anything about the maps you don't understand? Is there anything about the maps you think is important or interesting?
- Use the interactive map at https://geology.utah.gov/apps/blm_mineral/ to find out more.

Discuss this:

- How do you read the map?
- Where do you find areas with many resources? Are there areas with few resources?
- Are the resources all located in the same place? Or are different resources located in different places?
- What patterns do you see?

(you can write notes here)

Write this:

1. Where do you find iron, Fe?
   Which province is this in?
2. Where do you find copper, Cu?

Which province is this in?

3. Where do you find lead, Pb?

Which province is this in?

4. Where do you find gold, Au?

Which province is this in?

5. Where do you find silver, Ag?

Which province is this in?

6. Are there places on the map with more than one type of metal resource?

Where are these located?

7. Are there places on the map with few or no metal resources?

Where are these located?

8. What patterns do you see?

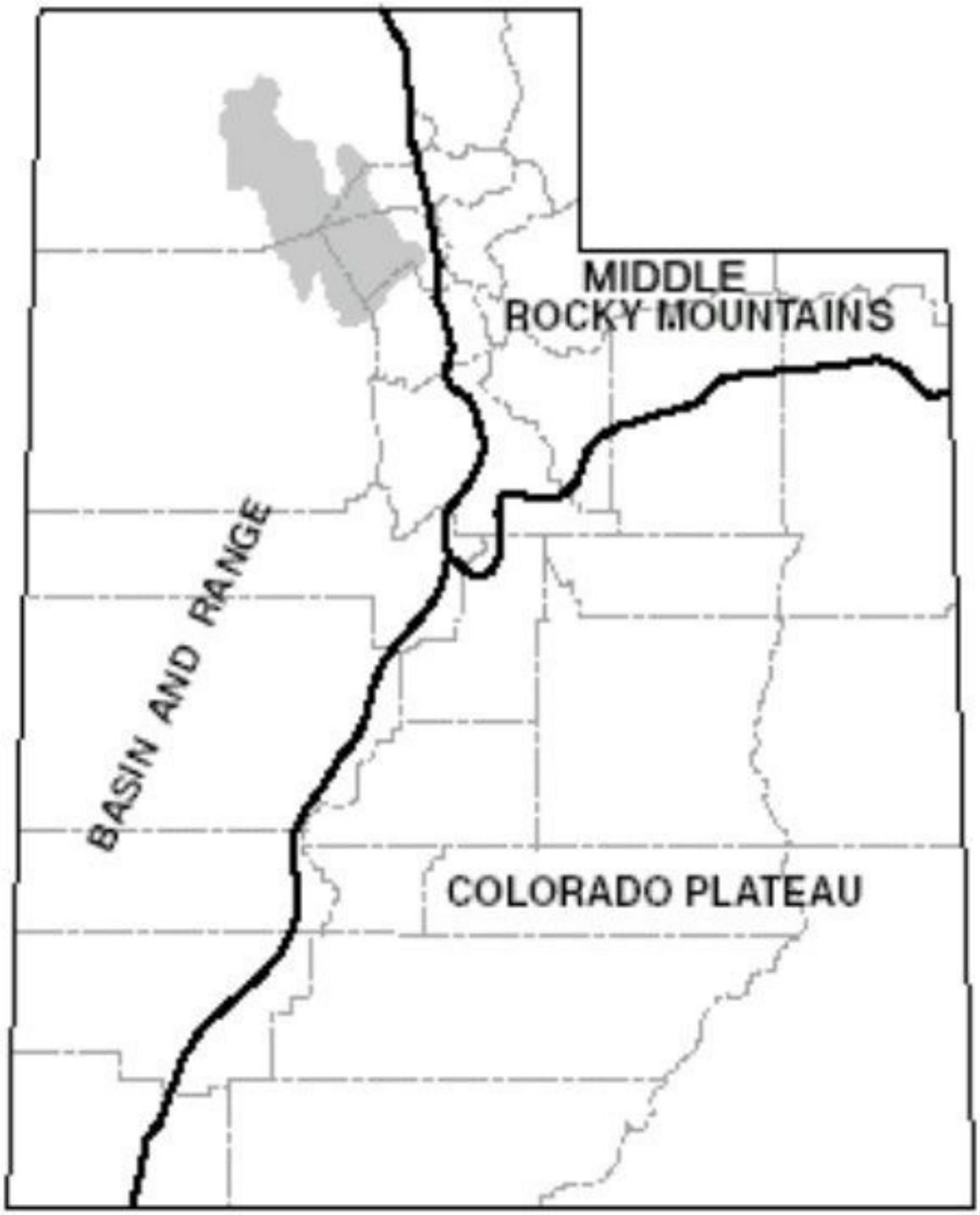
Think about this:

Why do you think that the resources aren't evenly distributed?

Which locations on the GeoSights map would be good cache locations for each metal resource?

Draw this:

On the map below, mark the major locations of the iron (Fe), copper (Cu), lead (Pb), gold (Au), and silver (Ag) resources. Add major locations of any other metal resources you think are interesting.



Station 3: Gem and Unusual Rock Resources

Directions:

1. Selecting roles: (<1 min)
   a. The group leader will help choose volunteers to fill the roles of reader and scribe.
   b. Record the group members' names next to their assigned/self-selected roles.
2. Background reading: (~5 min)
   a. The reader will read the background information to the group.
   b. Group members will listen and/or read along, pay particular attention to information about how to read the map and the locations of resources on the map.
3. Map Exploration: (5 min)
   a. Each group member needs to take 5 minutes, without talking, to look at the map. What is the map showing? How do you read the map? Is there anything about the map you do not understand? What patterns do you see? What information do you think is important or interesting? Which rocks or minerals would you include on your final map? Write down some of your ideas about the map to prepare for the group discussion.
4. Discussion: (5-10 min)
   a. The discussion leader will lead a discussion on the information from the map.
   b. Each group member will contribute both new ideas and active listening responses.
   c. Use the talk moves to facilitate and contribute to the discussion.
   d. The scribe will take notes on important ideas.
   e. Here are some questions to help facilitate the discussion:
      i. How do you read the map?
      ii. Where do you find areas with many resources? Are there areas with few resources?
      iii. Are the resources all located in the same place? Or are different resources located in different places?
      iv. What patterns do you see?
      v. What rocks and gems should you include on the final map? Using the information: (5-10 min)
   f. Either as a group, or individually, answer the questions about the distribution of gem and other resources in Utah.
5. Rotate to the next station.

Station 3: Gem and Unusual Rock Resources

Group leader _____

Discussion leader _____

Other member _____

Scribe _____

Other member _____

Background Information:

- At this station, you will be exploring an interactive map that shows you places in Utah where you can collect unusual rocks and gemstones.
- Utah is divided into 3 different geological provinces, Basin and Range, Rocky Mountains, and Colorado Plateau, these regions are shown on the blank map.

Discuss this:

- How do you read this map?
- Where do you find areas with many resources? Are there areas with few resources?
- Are the resources all located in the same place? Or are different resources located in different places?
- What patterns do you see?
- What rocks and gems do you want to include on the final map?

(you can write notes here)

Do this:

- Spend 5-10 minutes viewing the map without talking. Look for patterns. Is there anything about the maps you don't understand? Is there anything about the maps you think is important or interesting?
- Read the background information about each of the rocks and mineral sites you view.
- Select your top 5 rocks and gems to include on your final map.

Write this:

1. Where do you find the unusual volcanic rock (wonderstone, obsidian)? Which province is this in?
2. Where do you find the unusual sedimentary rock (chert, geodes, pyrite)? Which province is this in?

3. Where do you find the unusual metamorphic rock (marble)? Which province is this in?

4. Where do you find the fossils (fossils, petrified wood, pelecypods, ammonites)? Which province is this in?

5. Where do you find the semi-precious gemstones (topaz, sunstones, smokey quartz, quartz, agate, jasper, amethyst)? Which province is this in?

6. Are there places on the map with more than one type of unusual rock or mineral? Where are these located?

7. Are there places on the map with few or no unusual rocks and minerals? Where are these located?

8. What patterns do you see?

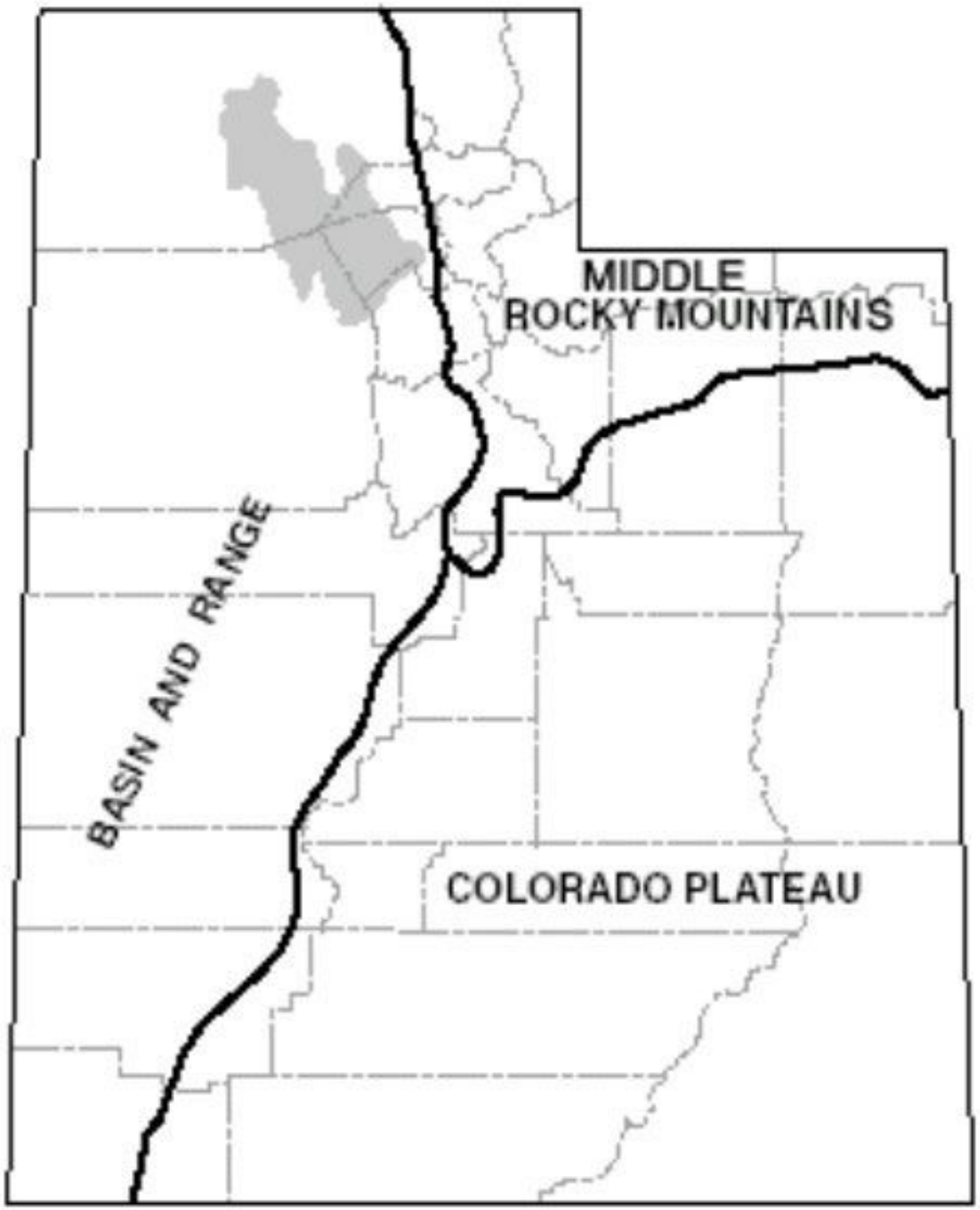
Think about this:

Why do you think that the resources aren't evenly distributed?

Which locations on the GeoSights map would be good cache locations for the unusual rocks and gemstone resources?

Draw this:

On the map below, mark the locations of the unusual rocks and minerals that you decided to include. Mark at least 5 different locations.



Geological Provinces Jigsaw

In order to figure out why the resources in Utah are not evenly distributed, you need to find out more about the geological provinces in the state. To do this, you will be using a jigsaw format, in which each member of a group will investigate part of the problem, then report their findings to the rest of the group. After each member reports their findings, the group will answer the discussion questions together. Use the same rotating leadership roles from the previous part of the lesson.

Directions:

1. Individual research (15-20 min)
    a. Each student will be assigned a province to research.
    b. Begin by reading recommended online readings and watching the suggested videos. Your teacher may instruct you to search for other information online, as needed.
    c. Look for answers to these questions.
        i. What is the topology of this province?
        ii. How did this province form?
        iii. What geological/geothermal resources are found here?
    d. Think about how the geology of the province would allow these resources to be found in these locations.
2. Group discussion (15-20 min)
    a. Selecting roles: (<1 min)
        i. The group leader will help choose volunteers to fill the role of reader and scribe. (The group may wish to rotate the role of reader.)
        ii. Record the group members' names next to their assigned/self-selected roles.
    b. Discussion: (5-10 min)
        i. Each group member will present the information they found about their geological province.
        ii. The discussion leader will facilitate the presentations, making sure that each member has a chance to present.
        iii. The discussion leader will then facilitate a discussion about the differences in the regions and the resources found there.
        iv. Use the talk moves to facilitate and contribute to the discussion.
        v. The scribe will take notes on important ideas.
    c. Using the information: (5-10 min)
        i. Either as a group, or individually, answer the questions about the relationship between the geology of a region and the resources located there.
        ii. Explain, with evidence, what causes this uneven distribution of resources. Be prepared to share your explanation with the class.

Selected readings from “The Teacher-Friendly Guide to the Earth Science of the Southwestern US”

Edited by Andrielle N. Swaby, Mark D. Lucas, & Robert M. Ross

Geothermal Energy

Geothermal energy comes from heat within the Earth, which is created on an ongoing basis by radioactivity. This energy powers mantle convection and plate tectonics. The highest-temperature conditions exist in tectonically active areas, including the Basin and Range, Iceland (a mid-Atlantic ridge), Japan (an area of subduction), and Hawaii and Yellowstone (areas with hot spots). Warm springs associated with tectonic activity in the Basin and Range have been enjoyed by the region's inhabitants for hundreds of years, beginning with Native Americans. This tectonic thermal energy is associated with a thinning of the crust, high heat flow relatively close to the surface, and groundwater that has been heated by cooling intrusive volcanic rocks. The heat of the Basin and Range has become the basis for both geothermal power plants and "direct use" operations (that is, use of geothermal energy at the site where it is generated). Typical examples of direct use include geothermally heated greenhouses, swimming pools, and buildings. Western Utah has several geothermal plants and many direct use facilities, and is the third leading producer of geothermal energy in the US (behind California and Nevada, where geothermal energy is also associated with the Basin and Range). New Mexico is also beginning to develop its geothermal resources (p. 253).

Oil and Gas

The Colorado Plateau contains numerous sedimentary basins, each of which contains many organic-rich layers. It is possible to make sense of why we find petroleum and natural gas in these areas by understanding the region's geologic history. Mud with relatively high organic matter content tends to accumulate in shallow continental seas and in coastal marine environments. The history of the Southwest's sedimentary basins extends back to the Cambrian period, when a broad shallow sea covered much of the area. Thick sequences of carbonate rocks accumulated in these basins. During the Carboniferous and Permian, as sea levels dropped and tectonic changes affected the landscape, parts of these basins became more restricted. As land emerged and weathered into silt and sand, layers of sandstones and organic-rich shales were laid down and organic material was preserved on the seabed. When seawater in the basins evaporated, evaporites were also deposited. With time, pressure, and heat, organic material in the shale was changed into petroleum and gas, and the organic-rich shales became source beds for hydrocarbons. Later deposition of non-marine sandstones in the Mesozoic created additional reservoirs for the oil. The Cretaceous saw the development of the Western Interior Seaway, which accumulated additional organic-rich shales, along with coastal coals, sandstones, and deeper marine limestones. Finally, terrestrial sedimentation in large lake basins during the early Cenozoic trapped yet more organic-rich sediments in lacustrine shales. The thick set of sediments that built up over millions of years created heat and pressure in deeper layers, compacting and "cooking" much of the organic matter into forms that are now used as fuels (p. 240).

Coal

Billion-ton coal deposits formed in the Colorado Plateau during the late Cretaceous, as the Western Interior Seaway grew and shrank with sea level and local tectonic changes. North American Cretaceous coals are nearly as extensive as those of Carboniferous age, largely due to the widespread extent and long history of the Western Interior Seaway. The thickest coals accumulated as peat in coastal swamps while the basins in the area subsided, and others accumulated farther inland on alluvial plains. Some later Paleocene coals were also deposited in intermontane basins. These Cretaceous and Paleocene deposits are typically high-volatile (low-grade) bituminous coals. Most of the region's coals are deeply buried toward the centers of the major basins, and crop out around the exposed edges of the Piceance Basin in Colorado, the Kaiparowits and Uinta basins in Utah, the Black Mesa Basin in Arizona, and the Raton and San Juan basins in Colorado and New Mexico. Coal mining has continued for over 115 years in some of these basins (p. 247).

Metallic Resources of the Colorado Plateau

Although the US has perennially imported over 90% of its uranium ore from foreign sources, the Paradox Basin in the Colorado Plateau is seen as an important source for US uranium supplies (Figure 5.2), which are mined for use in nuclear energy. These uranium deposits occur largely as “roll-front” deposits, in which groundwater leaches uranium from the source rock (usually igneous or metamorphic basement rock or volcanic ash deposits), and carries it through a porous and permeable rock, typically sandstone or conglomerate. Uranium oxide minerals are precipitated when the uranium-bearing groundwater is reduced by contact with organic materials within the rock. The uranium minerals carnotite and coffinite account for the majority of the ores in these deposits. Vanadium minerals such as corvurite and doloresite are also found with these ores. Most commonly, the region's uranium- and vanadium-bearing minerals are hosted in fluvial and lacustrine sandstones and limestones of the Triassic Chinle, Jurassic Morrison and Todilto, and Cretaceous Dakota formations. Lithium, a major component of hightech batteries, is recovered from the Paradox Basin.

Of the US states, New Mexico currently ranks second in uranium resources after Wyoming. Most of the state's deposits are located in the Grants Mineral Belt to the northwest, although no mining has taken place there since 2002. Other major uranium deposits are found near Moab, Utah in the Paradox Basin; on the San Rafael Swell in central Utah; and near Uravan, Colorado, where the last uranium mine was closed in 2009 due to a drop in uranium prices. New mines are being planned for the Colorado Plateau should demand increase for nuclear power (pp. 208-210).

Metallic Resources of the Basin and Range

The Basin and Range is a hotbed of metallic ore deposits, especially along orogenic belts—the sites of mountain formation. The Sevier Orogenic Belt, a major geologic feature of the Basin and Range (and of the much larger Cordilleran Fold and Thrust Belt), marks the transition from the Colorado Plateau to the Basin and Range. Formed in the late Cretaceous and Paleogene, its structures provided fluid paths and hosts for mineral deposits all along this transition line. Economic deposits of gold, silver, copper, tungsten, and oil and gas are found within the margins of the Sevier Belt. Thanks to the prolific amounts of copper ore found in Utah and Arizona, both states have taken copper as their state mineral. The Uinta, Tintic, and Pioche belts in Utah produce copper, gold, silver, lead, molybdenum, tungsten, uranium, and beryllium. The Tintic Mining District, although largely defunct today, was an important source of silver, gold, copper, and bismuth during the late 19th and early 20th centuries. The Pioche Belt also contains the world's largest deposit of alunite, a sulfate mineral that is a source of both potassium and aluminum. The Bingham Canyon deposit, located within the Uinta Belt, contains significant quantities of copper as well as considerable amount of gold and other minerals. Kennecott Copper's Bingham Canyon Mine, near Salt Lake City, Utah, is one of the largest open pit mines in the world and produces 25% of the US domestic copper supply. So large that it is visible from space, the mine is about a kilometer (over half a mile) deep and produces 408,000 metric tons (450,000 tons) of material per day. Since extraction began in 1863, the mine has produced over 15.4 billion kilograms (17 million tons) of copper, 715,000 kilograms (23 million troy ounces) of gold, 5.9 million kilograms (190 million troy ounces) of silver, and 317 million kilograms (850 million pounds) of molybdenum. This quantity exceeds all of the metals ever produced from the famous Comstock Lode, the Klondike, and the California Gold Rush combined (p. 215)

Non-Metallic Resources of the Basin and Range

The Southwestern US, particularly the Basin and Range, is especially wellknown for its gemstones and precious stones. This region, with its combination of faulted sedimentary rocks and intrusive and extrusive igneous rocks, provides a rich set of geochemical environments for a diversity of minerals to grow along fracture surfaces, in cavities, and within the igneous bodies themselves. Thus, while the individual minerals form under specific conditions (e.g., chemistry, heat, pressure, and space for growth), the region has a sufficiently broad mix of conditions to allow many different precious gems to form. Gems and precious stones found in the Basin and Range include turquoise, peridot, amethyst, garnet, jade, opal, beryl, topaz, and many others. The Basin and Range is especially famous for turquoise; it is the state gemstone of both Arizona and New Mexico. This copper-bearing precious

mineral is found in areas with substantial copper deposits, and is sometimes removed during copper mining. In the Basin and Range, turquoise is found where copper sulfide deposits weather around certain intrusive igneous rocks. It was one of the first gems to be mined, generally for use in jewelry or sculpture, with extraction dating back over one thousand years. Arizona and parts of New Mexico are among the largest turquoise producing areas of the US, and Arizona still produces the most valuable turquoise in the country, though many mines there have now been depleted. The precious stones azurite and malachite, spectacular blue and green by-products of copper ore weathering, are also common in this area and highly prized by collectors.

Topaz and beryl form in the fractures and cavities of silica-rich igneous rocks such as granite and rhyolite. Topaz is hard (Mohs scale 8) and resistant to erosion, often weathering out of its matrix to be found as pebbles in streams. In Utah, where it is the state gem, topaz can be collected from the rhyolites of the Thomas Range, specifically at Topaz Mountain. The mineral is fairly rare, as it contains fluorine, which does not occur frequently in quantities sufficient for mineral formation. Other gemstones can be found at Topaz Mountain, including red beryl. This rare mineral contains the element beryllium, and is colored red due to trace amounts of manganese (pp. 219-222).

Metallic Resources of the Rocky Mountains

The Rocky Mountains saw its greatest development with the advent of the Great Pikes Peak Gold Rush of 1859, when gold and silver were discovered in the mountains just west of Denver, Colorado. With the Gold Rush came the discovery and development of rich mineral resources all along the Colorado Mineral Belt, which trends northeastward from the southwest corner of the state in the La Plata Mountains to the Front Range near Denver before disappearing at a depth of around 4200 meters (13,000 feet) beneath the sedimentary cover of the Denver Basin. The Colorado Mineral Belt generally follows a pre-existing and deep-seated crustal structure or a zone of crustal weakness that is Precambrian in age (about 1.4 billion years old). It lies within an ancient terrane formed by the crustal accretion of central Colorado 1.8 to 1.7 billion years ago. During magmatic events in the Cretaceous and Paleogene, minerals (e.g., gold, silver, and uranium) were carried from deeper Precambrian rocks and deposited as veins and other ore bodies. Abundant quantities of gold, silver, molybdenum, lead, zinc, and other minerals have been found in the Colorado Mineral Belt (p. 223).

The Colorado Mineral Belt is not the only area of the Rocky Mountains to have hosted large ore mines. Park City, Utah was a site of a major silver rush in the 1860s thanks to the finding of silver, gold, and lead; the town flourished for nearly one hundred years before silver prices dropped in the late 1950s. Park City Mountain and the neighboring Deer Valley are major ski resorts today, but beneath those slopes lie more than 1600 kilometers (1000 miles) of old silver mine workings and tunnels (p. 227).

Swaby, A. N., Lucas, M. D., & Ross, R. M. (Eds.). (2016). *The teacher-friendly guide to the earth*
science of the Southeastern US. Paleontological Research Institution.

Geological Provinces Jigsaw – Basin and Range

Name _____

Background Information:

- At this station, you will be learning more about the topology and the formation of the Basin and Range province in order to figure out why certain resources are found in this province.

Do this:

- Using your web browser, navigate to each of the pages listed here, and read the information on these pages:
  - https://geology.utah.gov/popular/general-geology/utah-landforms/physiographic-provinces/
  - https://geology.utah.gov/map-pub/survey-notes/glad-you-asked/how-was-utahs-topography-formed/
  - https://www.nps.gov/articles/basinrange.htm
  - http://geology.teacherfriendlyguide.org/index.php/topography-w/topography-region1-w
- Using your web browser, navigate to each of the pages listed here, and read and watch the videos on these pages:
  - https://www.iris.edu/hq/inclass/animation/basin__range_structural_evolution
  - https://www.iris.edu/hq/inclass/animation/basin__range_deformation_erosion__sedimentation
  - https://www.iris.edu/hq/inclass/animation/basin__range_volcanoes
- Look over the maps you created previously. Find the resources that are located primarily in the Basin and Range province

Write this:

1. According to the reading and the videos, what are the primary characteristics of the Basin and Range province?

2. According to the reading and the videos, how was the Basin and Range formed?

3. From the maps you created previously, what are the resources that are located in the Basin and Range province?

4. Why do you think these resources are located in the Basin and Range?

5. Which geologic processes make it more likely that these resources would be found in the Basin and Range?

Geological Provinces Jigsaw – Colorado Plateau

Name _____

Background Information:

- At this station, you will be learning more about the topology and the formation of the Colorado Plateau province in order to figure out why certain resources are found in this province.

Do this:

- Using your web browser, navigate to each of the pages listed here, and read the information on these pages:
  - https://geology.utah.gov/popular/general-geology/utah-landforms/physiographic-provinces/
  - https://geology.utah.gov/map-pub/survey-notes/glad-you-asked/how-was-utahs-topography-formed/
  - https://www.nps.gov/articles/coloradoplateaus.htm
  - http://geology.teacherfriendlyguide.org/index.php/77-southwestern/topography-sw/600-topgraphy-region1-sw
- Using your web browser, navigate to each of the pages listed here, and watch the videos on these pages:
  - https://www.youtube.com/watch?v=RVMKzxtJAto (watch the first 2 minutes)
  - https://www.youtube.com/watch?v=6oTUZDBpbio
- Look over the maps you created previously. Find the resources that are located primarily in the Colorado Plateau province

Write this:

1. According to the reading and videos, what are the primary characteristics of the Colorado Plateau province?

2. According to the reading and the videos, how was the Colorado Plateau formed?

3. From the maps you created previously, what are the resources that are located in the Colorado Plateau province?

4. Why do you think these resources are located in the Colorado Plateau?

5. Which geologic processes make it more likely that these resources would be found in the Colorado Plateau?

Geological Provinces Jigsaw – Middle Rocky Mountains

Name _____

Background Information:

- At this station, you will be learning more about the topology and the formation of the Middle Rocky Mountain province in order to figure out why certain resources are found in this province.

Do this:

- Using your web browser, navigate to each of the pages listed here, and read the information on these pages:
  - https://geology.utah.gov/popular/general-geology/utah-landforms/physiographic-provinces/
  - https://geology.utah.gov/map-pub/survey-notes/glad-you-asked/how-was-utahs-topography-formed/
  - https://www.nps.gov/articles/rockies.htm
  - http://geology.teacherfriendlyguide.org/index.php/topography-nc/topography-region3-nc (read the section on the Middle Rocky Mountains)
- Using your web browser, navigate to the page listed here, and watch the videos on this page:
  - https://www.youtube.com/watch?v=tJk9cFz152s
- Look over the maps you created previously. Find the resources that are located primarily in the Middle Rocky Mountain province

Write this:

6. According to the reading and videos, what are the primary characteristics of the Middle Rocky Mountain province?

7. According to the reading and the videos, how were the Middle Rocky Mountains formed?

8. From the maps you created previously, what are the resources that are located in the Middle Rocky Mountain province?

9. Why do you think these resources are located in the Middle Rocky Mountains?

10. Which geologic processes make it more likely that these resources would be found in the Middle Rocky Mountain?

Geological Provinces Jigsaw – Putting the Pieces Together

Group leader _____ Reader _____

Discussion leader _____ Scribe _____

Other member _____ Other member _____

Background Information:

- Here your group will put the pieces together to figure out why the geologic/geothermal resources are unevenly distributed. You may need to refer to prior readings.

Do this:

- Each group member will share with the group their findings about their assigned geological province.
- Read the additional information about the locations of energy and mineral resources.

Discuss this:

- What evidence do you have that connects the geological process that shaped each of the provinces to the geological/geothermal resources you found there?

(you can write notes here)

Write this:

1. Most of the geothermal resources are found in the Basin and Range province. What unique characteristics does the Basin and Range have that would make this a good location for geothermal energy?

2. Most of the hydrocarbon resources are found in the Colorado Plateau province. What unique characteristics does the Colorado Plateau have that would make this a good location for hydrocarbon energy resources?

3. Most of the uranium resources are found in the Colorado Plateau province. What unique characteristics does the Colorado Plateau have that would make this a good location for hydrocarbon energy resources?

4. Most of the iron resources are found in the Rocky Mountain province. What unique characteristics do the Rocky Mountains have that would make this a good location for iron?

5. Copper is found in both the Basin and Range and the Rocky Mountain provinces. What unique characteristics do these provinces have that makes these good locations for copper?

6. Most of the precious metal (gold and silver) and lead resources are found in the Basin and Range province. What unique characteristics does the Basin and Range have that would make this a good location for these metals?

7. Most of the gemstones are found in the Basin and Range province. What unique characteristics does the Basin and Range have that would make this a good location for gemstones?

8. Explain with evidence how the geological processes that formed the Basin and Range, Colorado Plateau, and the Rocky Mountain provinces caused the uneven distribution of energy, metal, and gemstone resources in Utah. (Be prepared to share this answer with the class.)