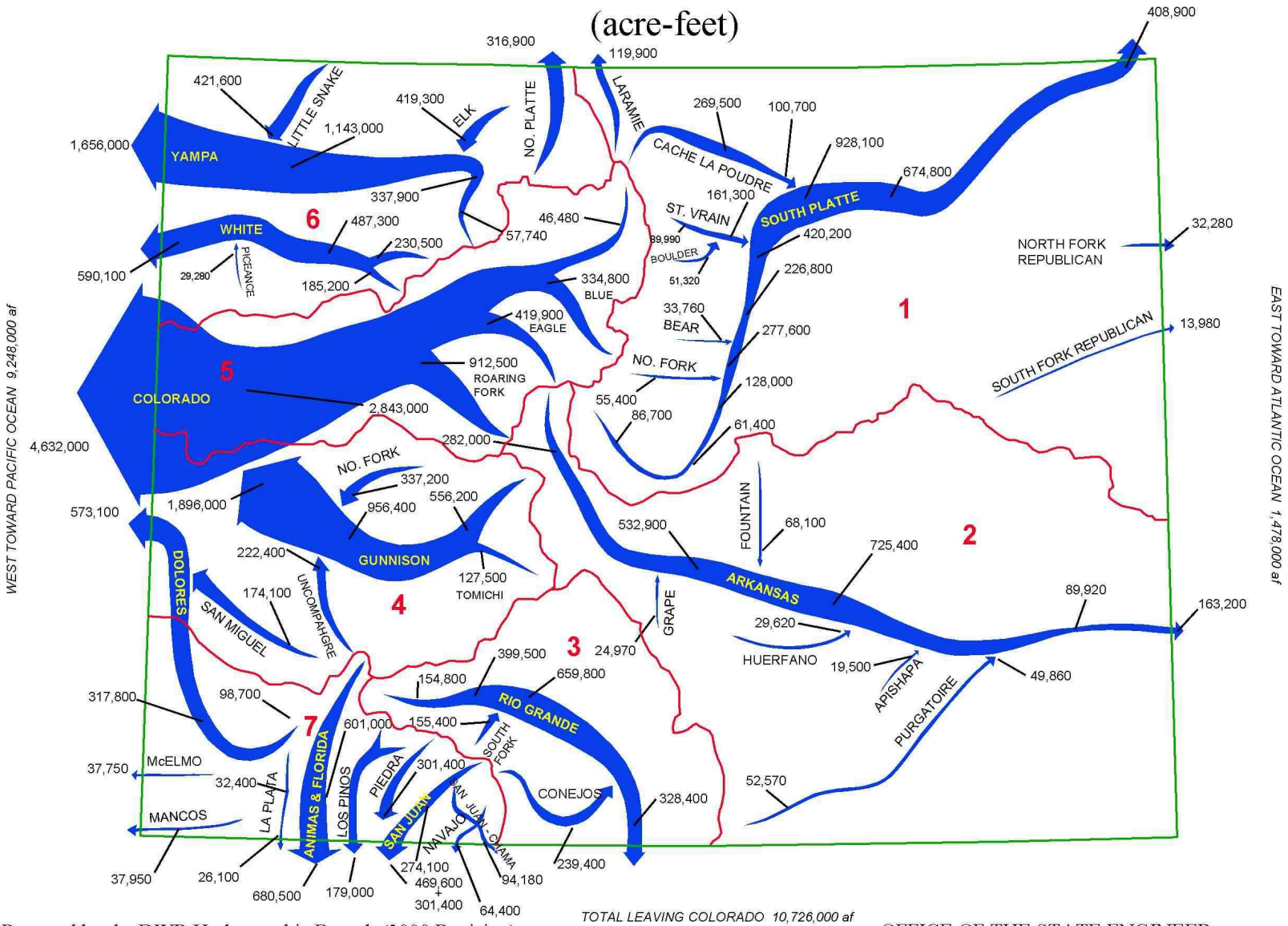
Geology, Mining, and Water Quality

by Matthew A. Sares

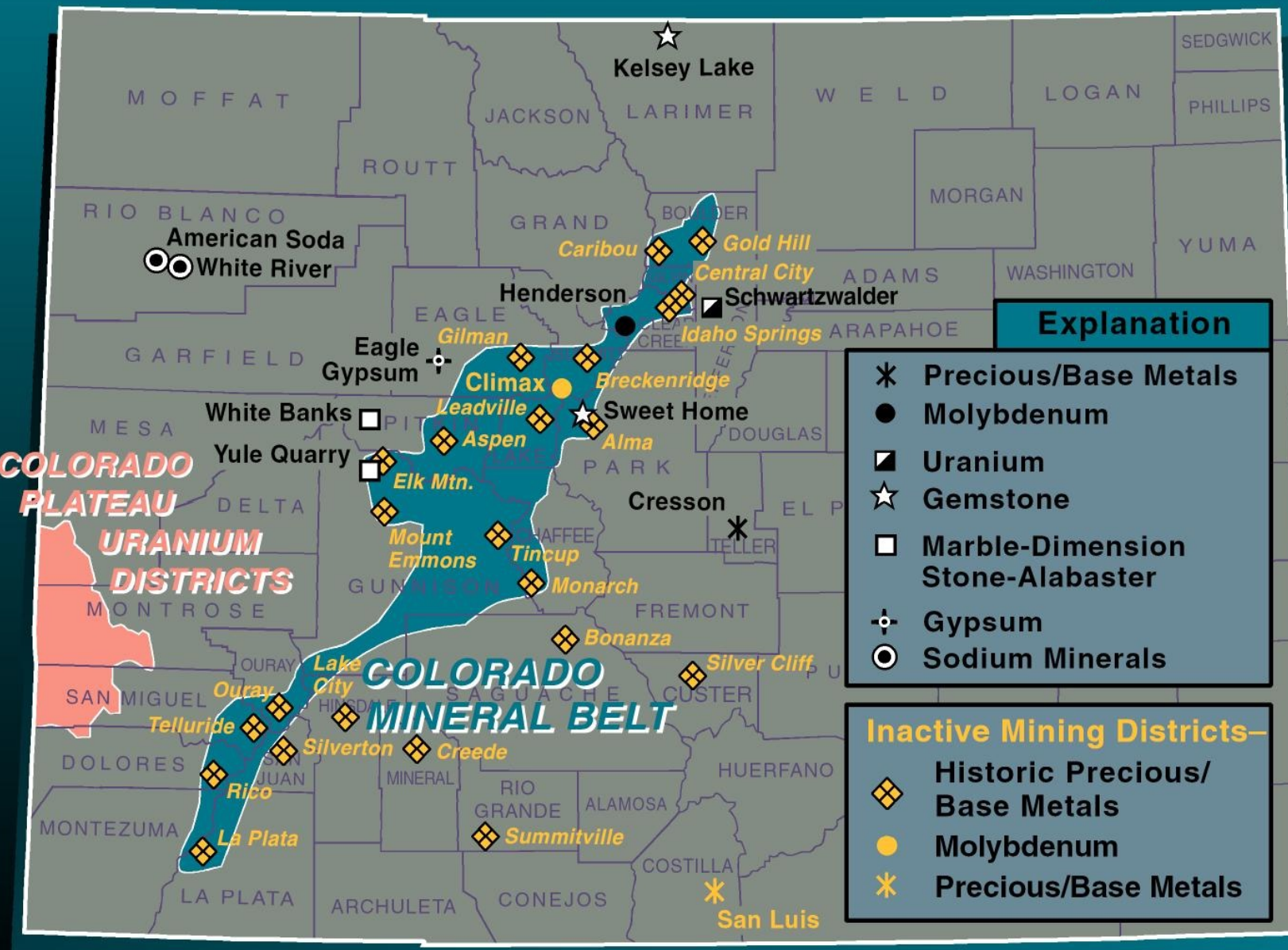
COLORADO
HISTORIC AVERAGE ANNUAL STREAM FLOWS
(acre-feet)



Prepared by the DWR Hydrographic Branch (2000 Revision)
Historic averages obtained from 1999 USGS and DWR Water Data Reports

OFFICE OF THE STATE ENGINEER
COLORADO DIVISION OF WATER RESOURCES

Major Mineral Producers and Prospects



Acid Mine Drainage

Water - from rain and snowmelt

+

Oxygen - from the air

+

Pyrite - from the mine

Reaction =

Sulfuric Acid

Sources of Acid Mine Drainage (AMD)

- **Mine Effluent**

Burbank Mine, San Juan Co.

Lewis Mine and Mill, San Miguel Co.

THE CHEMISTRY of ACID MINE DRAINAGE

Reaction 1: $FeS_{2(s)} + H_2O + 7/2O_2 \longrightarrow Fe^{2+} + 2SO_4 + 2H^+$

pyrite water sulfate acid

Reaction 2:* $Fe^{2+} + 1/4O_2 + H^+ \longrightarrow Fe^{3+} + 1/2H_2O$

Reaction 3: $FeS_{2(s)} + 8H_2O + 14Fe^{3+} \rightarrow 15Fe^{2+} + 2SO_4 + 16H^+$

Reaction 4: $Fe^{3+} + 3H_2O \longrightarrow Fe(OH)_{3(s)} + 3H^+$

* catalyzed by bacteria

Lewis Mine and Mill, San Miguel Co.

THE CHEMISTRY of ACID ~~MINE~~ ROCK DRAINAGE

Reaction 1: $FeS_{2(s)} + H_2O + 7/2O_2 \longrightarrow Fe^{2+} + 2SO_4 + 2H^+$

pyrite water sulfate acid

Reaction 2:* $Fe^{2+} + 1/4O_2 + H^+ \longrightarrow Fe^{3+} + 1/2H_2O$

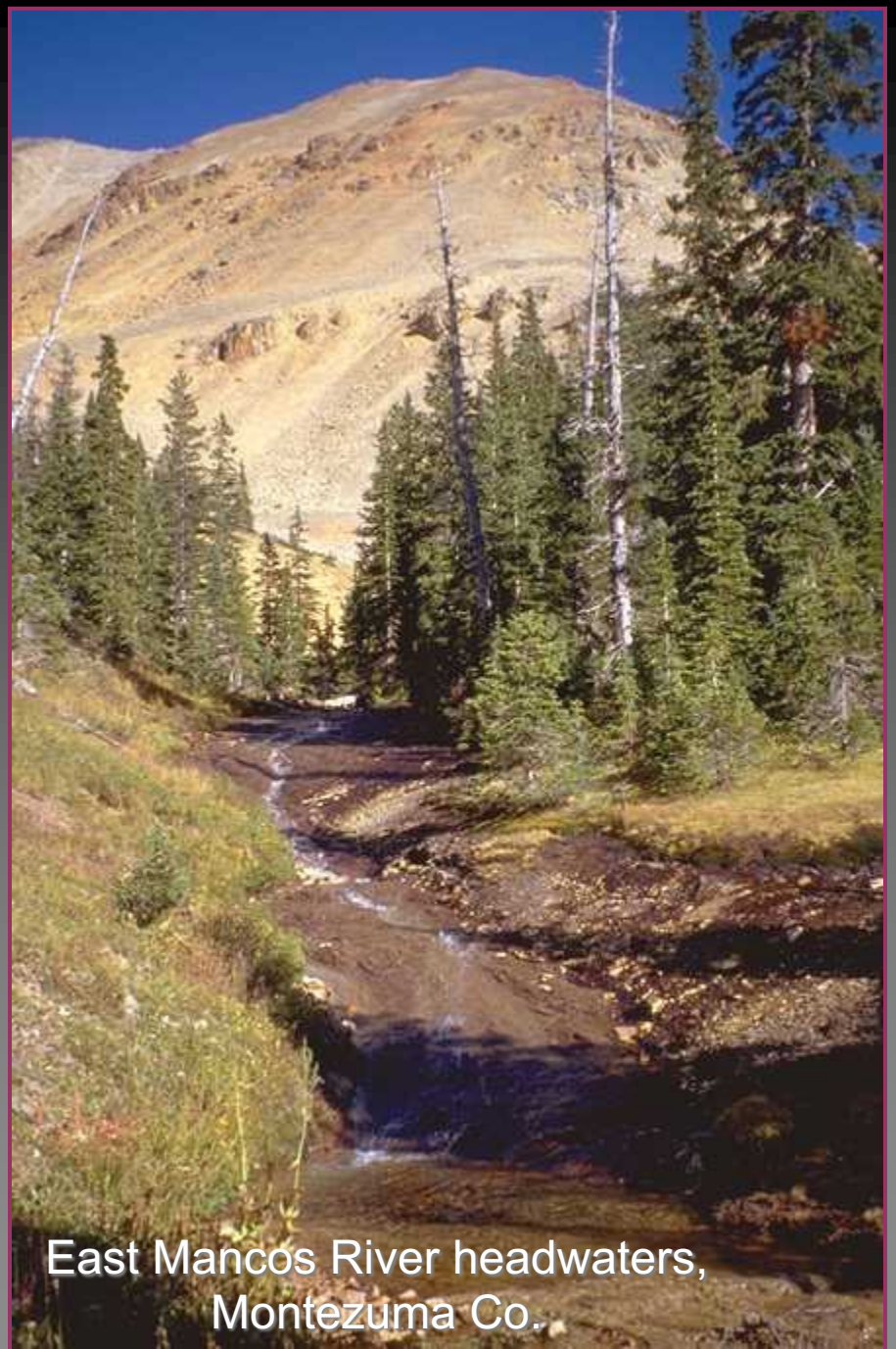
Reaction 3: $FeS_{2(s)} + 8H_2O + 14Fe^{3+} \rightarrow 15Fe^{2+} + 2SO_4 + 16H^+$

Reaction 4: $Fe^{3+} + 3H_2O \longrightarrow Fe(OH)_{3(s)} + 3H^+$

* catalyzed by bacteria

Acid Rock Drainage (ARD) sources:

- *Abandoned mines*
- *Natural springs and drainages in hydrothermally altered areas*

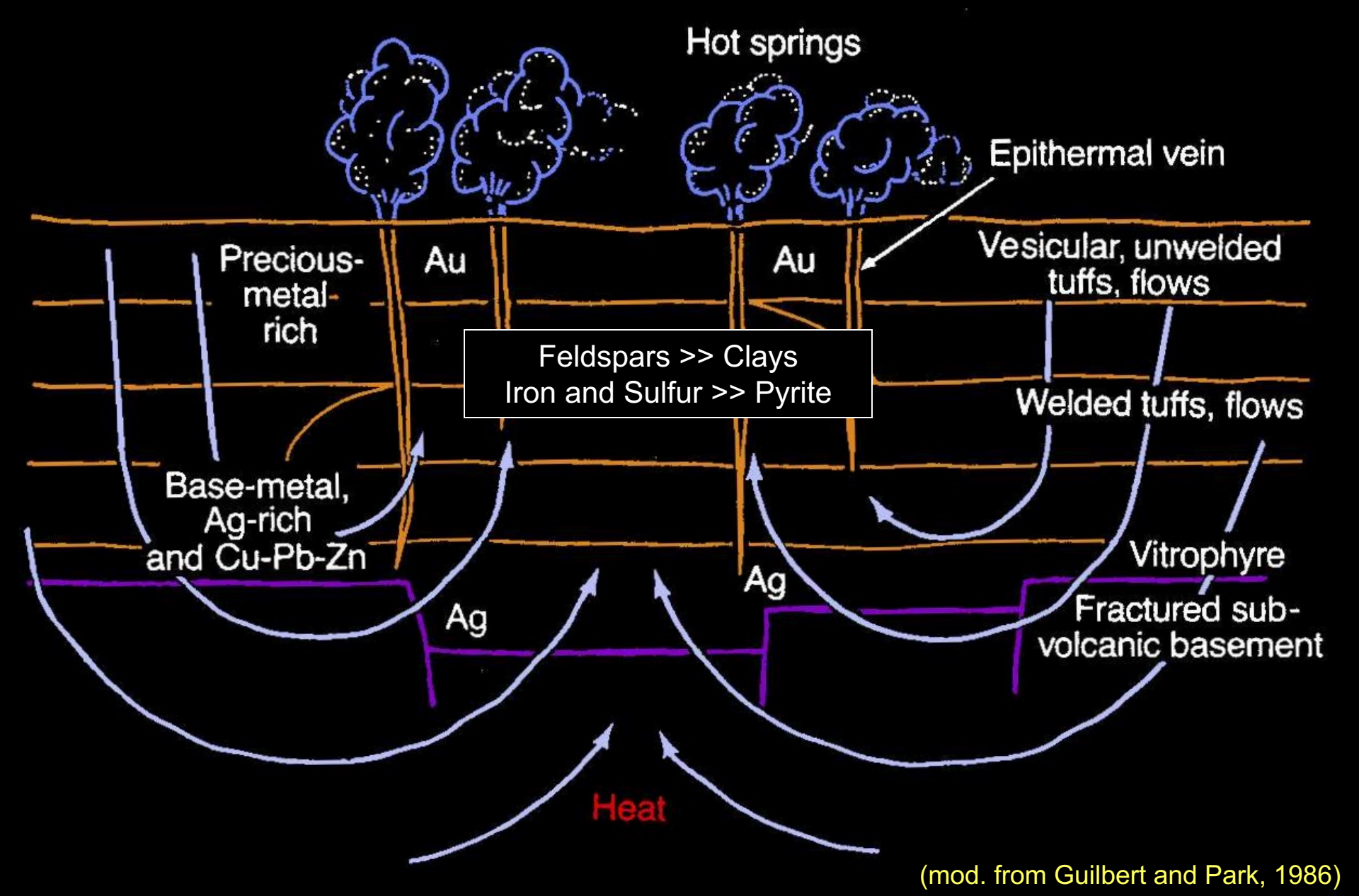


East Mancos River headwaters, Montezuma Co.

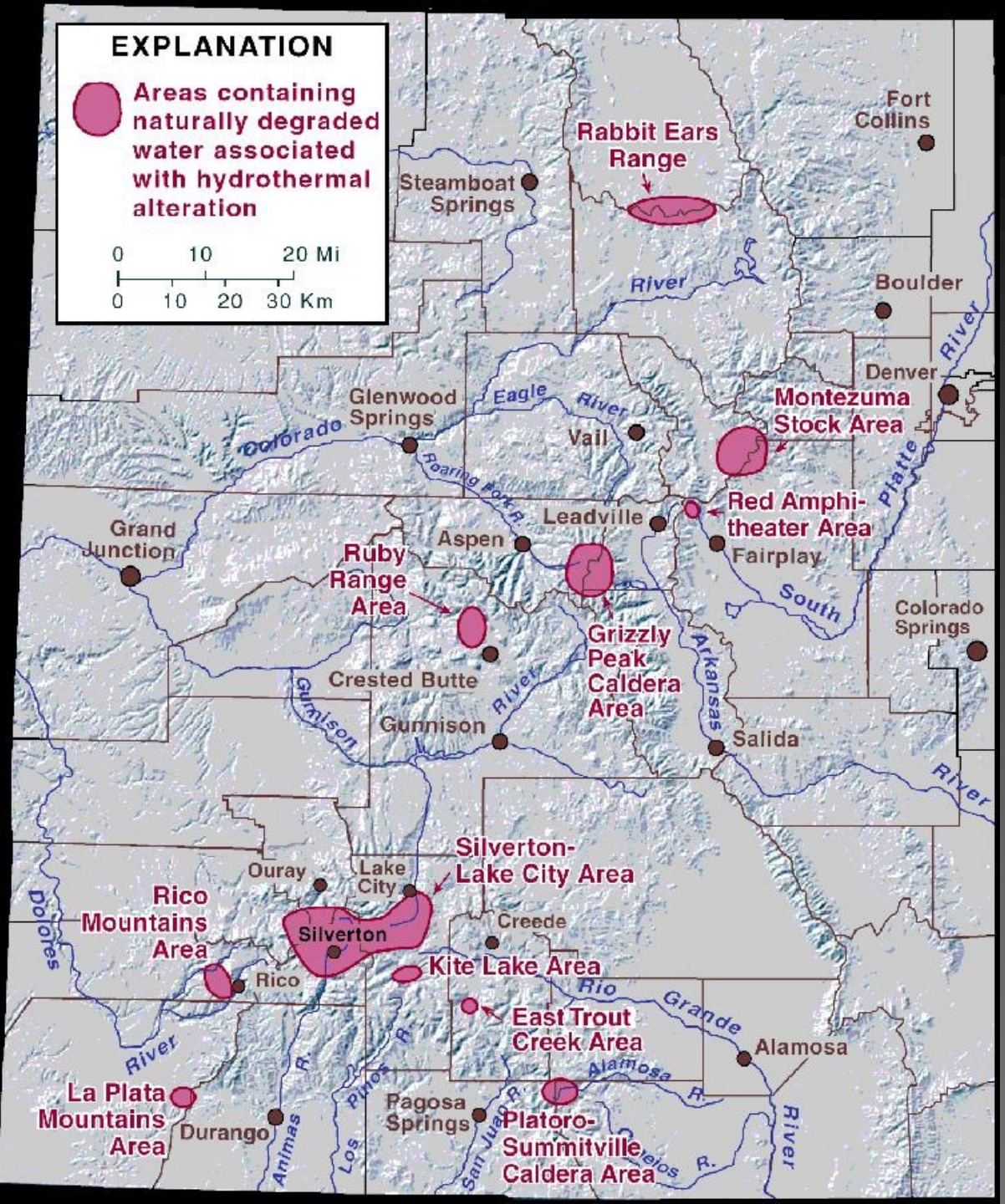
Hydrothermal alteration is a process whereby hot water circulating within the earth changes the composition of rocks.

Intensely altered rocks have yellow, orange, and red colors from the oxidation of iron in pyrite.

Hydrothermal Alteration



(mod. from Guilbert and Park, 1986)

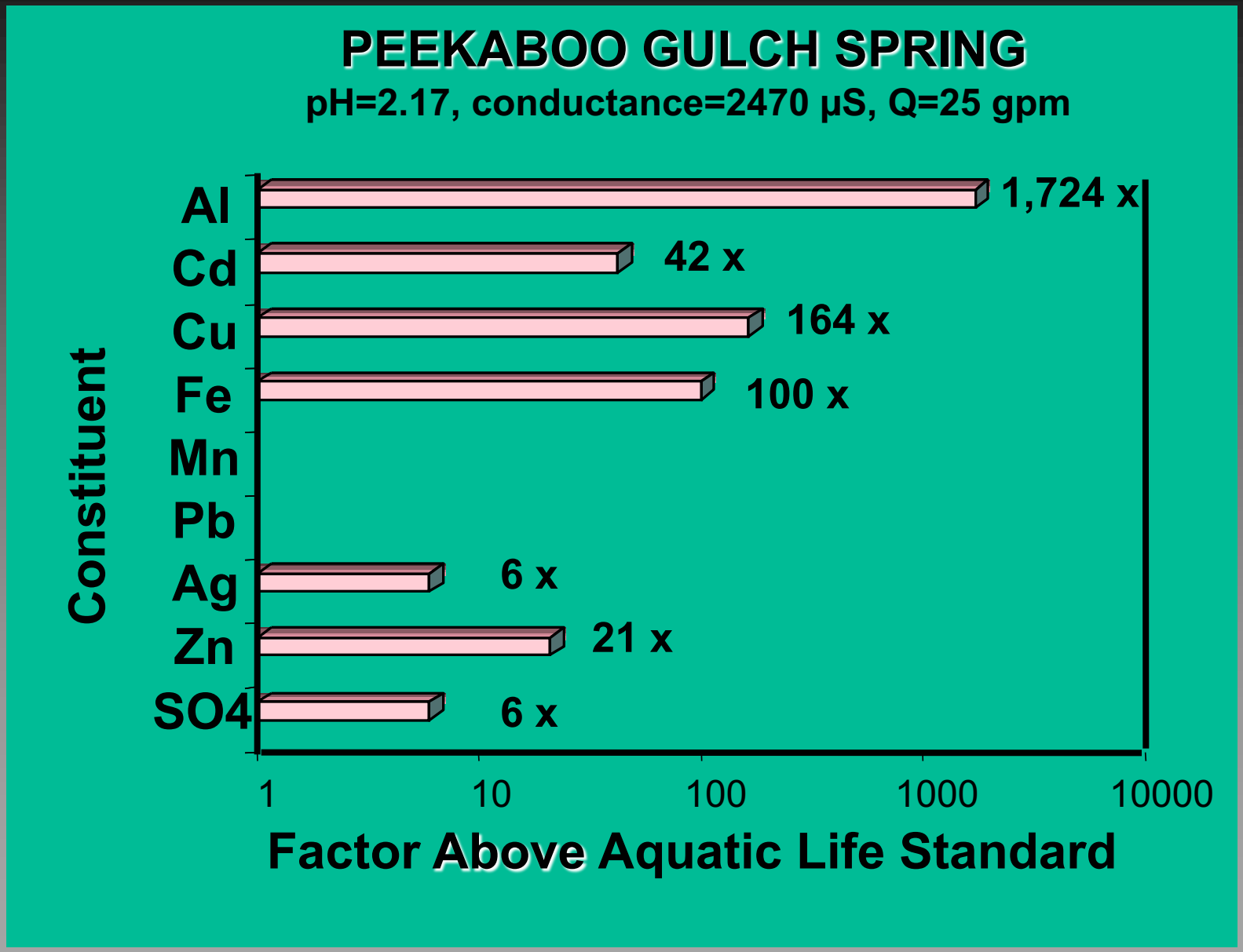


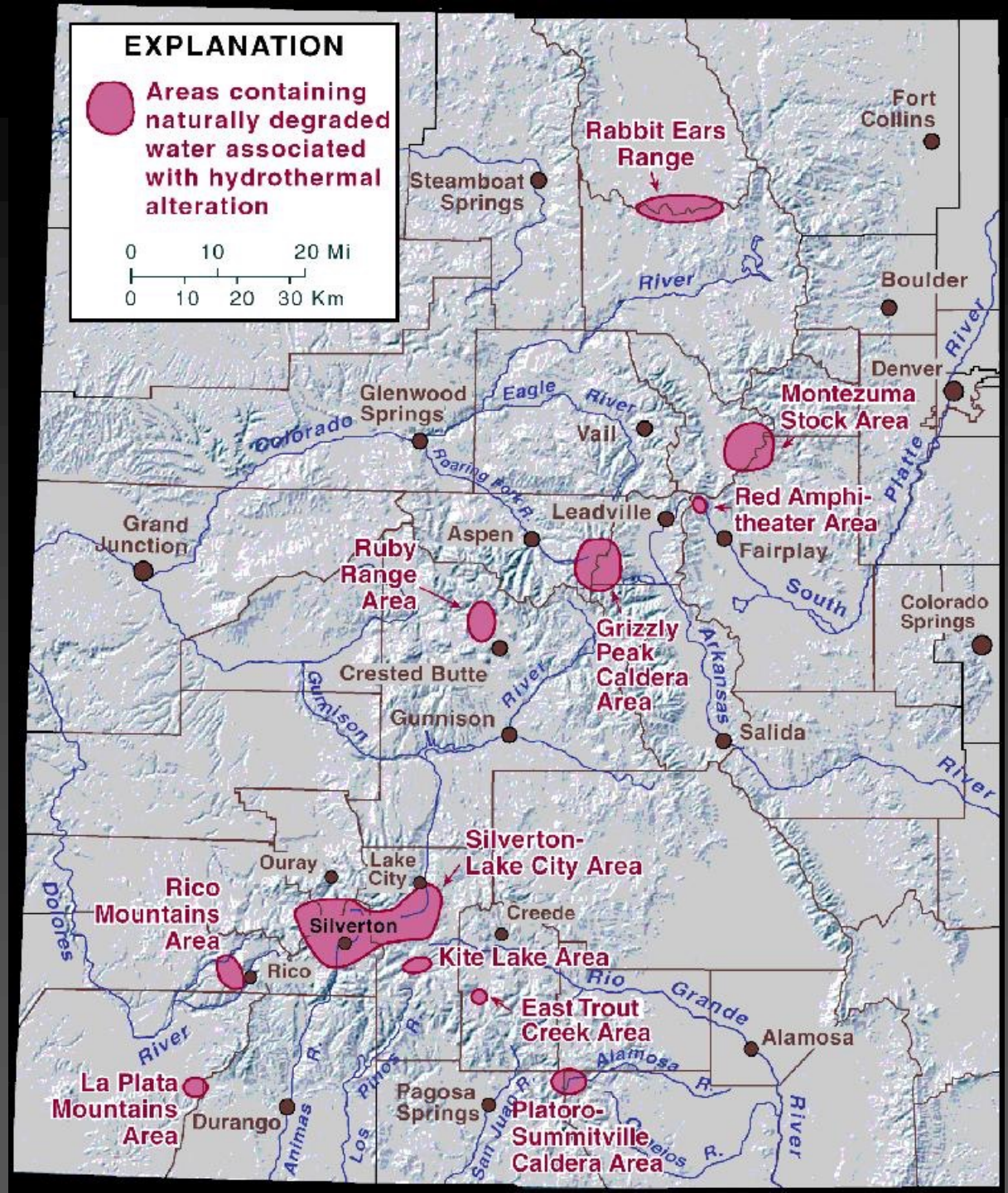
A number of streams in eleven different headwater areas of Colorado have *naturally* high concentrations of metals and/or acidity, *upstream of any significant human impacts.* Rocks in these areas have been affected by intense **"hydrothermal alteration"** in the geologic past.

Red Cone, Park Co.

Red Mountain, Chaffee and Pitkin Co.

Natural acid rock drainage dissolves metals present in the rock, affecting downstream water quality.




EXPLANATION
Areas containing naturally degraded water associated with hydrothermal alteration
0 10 20 Mi
0 10 20 30 Km
Rabbit Ears Range
Fort Collins
Steamboat Springs
Boulder
Denver
Glenwood Springs
Eagle River
Vail
Montezuma Stock Area
Colorado River
Roaring Fork R.
Leadville
Red Amphi-theater Area
Platte River
Grand Junction
Aspen
Fairplay
Ruby Range Area
South Arkansas River
Colorado Springs
Grizzly Peak Caldera Area
Crested Butte
Gunnison River
Gunnison
Salida
Arkansas River
Silverton-Lake City Area
Ouray
Lake City
Rico Mountains Area
Creede
Silverton
Kite Lake Area
Dolores River
Rico
Rio Grande
East Trout Creek Area
Alamosa
Alamosa R.
La Plata Mountains Area
Durango
Animas R.
Pinos R.
Los
Pagosa Springs
San Juan R.
Platoro-Summitville Caldera Area
Conejos R.
Rio Grande River

Lookout Mountain, Conejos Co.

Ferricrete mounds are characteristic of springs in hydrothermally altered areas.

Iron Creek Lower Spring, Conejos Co.

Some hydrothermally altered areas have high rates of erosion, and are prone to debris flows and landslides because bedrock has been weakened.

Headwall

Slide

Red Mountain #2, Ouray Co.

Slumgullion landslide is in an area of hydrothermally altered rock. Movement and erosion continually expose acid-producing minerals. Drainage from the slide area is very acidic (pH ≅ 3.4).

Slumgullion Landslide near Lake City, Mineral Co.

Conclusions

- Acid rock drainage is generated at mines and naturally where sulfide minerals are present and the buffering capacity of the water is exceeded.

- AMD degradation can be acute because:

  1) Mines act as collectors of groundwater

  2) Water is in contact with high grade ore minerals

  3) Mine dumps and tailings provide dramatically increased surface areas for the interaction of water, oxygen, and sulfide minerals.

Conclusions

- Natural ARD is important in areas of intense hydrothermal alteration because:
  1) Rocks contain disseminated sulfide minerals.
  2) Rocks are depleted of buffering minerals.
  3) Large volumes of rock are affected.

- Both ARD sources must be characterized to determine realistic remediation goals.