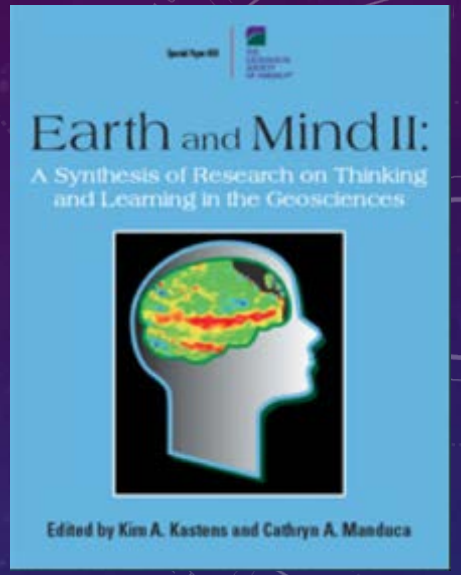
GEOHERITAGE AND UNDERGRADUATE/GRADUATE EDUCATION

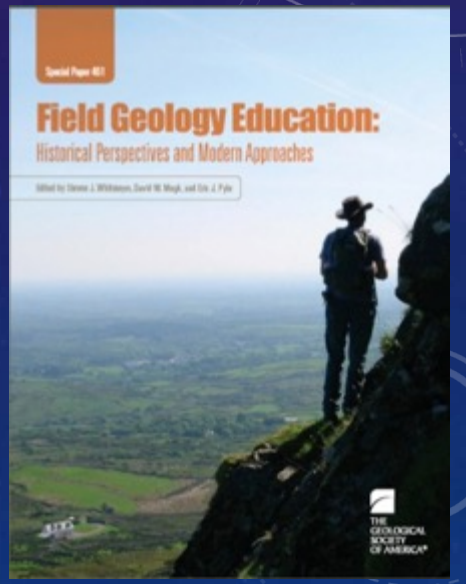
David W. Mogk
Dept. of Earth Sciences
Montana State University
Chair, USNC-GS

America's Geoheritage Workshop II: Identifying, Developing, and Preserving America's Natural Legacy
November 17, 2020

FIELD WORK IS GOOD…. (FOR GEO MAJORS, PRE-SERVICE TEACHERS, AND ALL STUDENTS AND LEARNERS)

- Central to the geoscience curriculum (Whitmeyer, Mogk and Pyle, 2009)
- Cognitive benefits (Mogk and Goodwin, 2012)
  - Temporal, spatial, systems thinking
  - Critical-thinking; higher order thinking skills
- Affective gains
  - Motivation, curiosity, self-confidence
  - Engaging community of practice, recruiting mentoring, networking
- The case is easily made that Geoheritage sites are important for undergraduate and graduate Geoscience education.





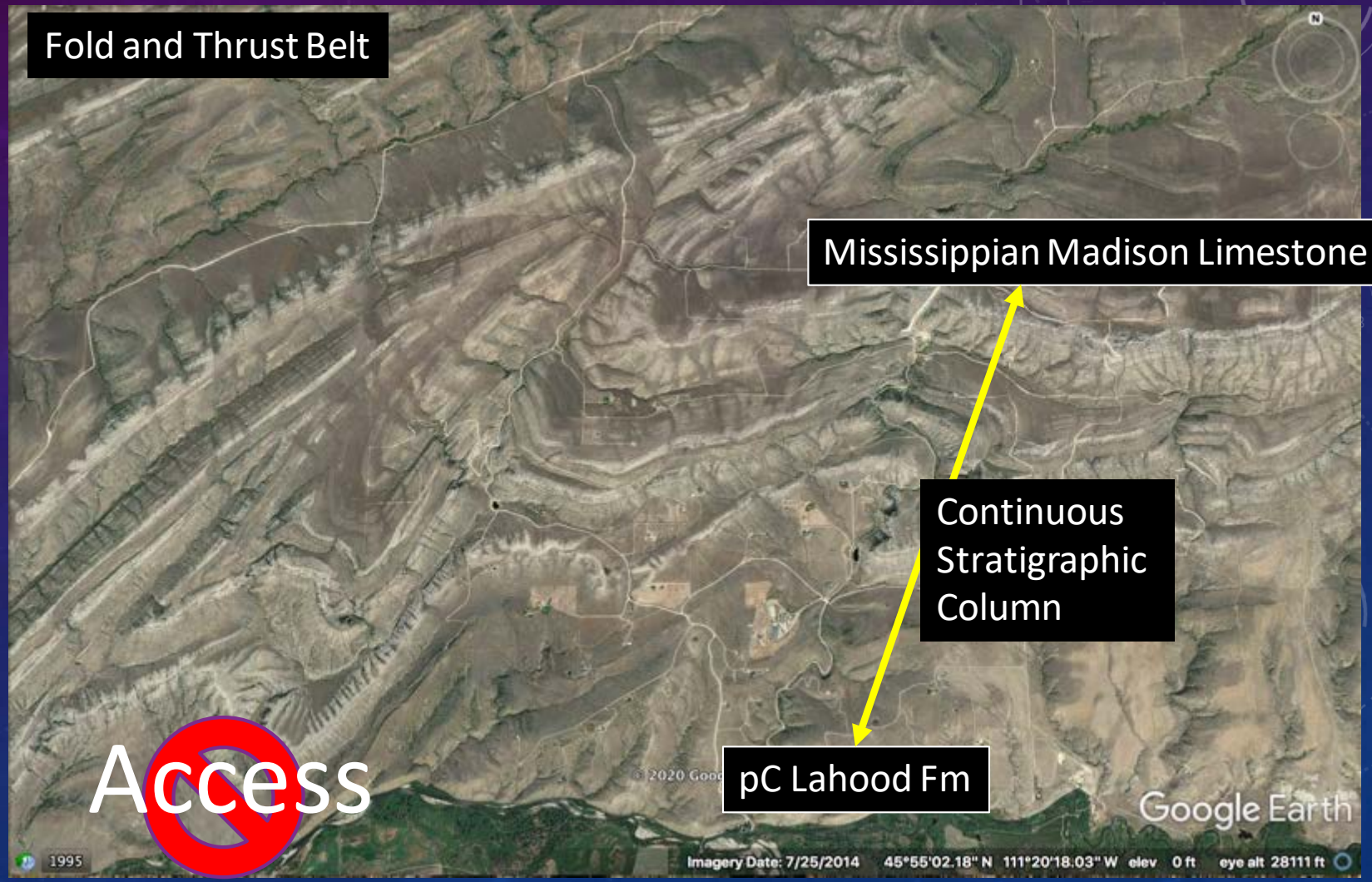
Learning in the field: Synthesis of research on thinking and learning in the geosciences

David W. Mogk and Charles Goodwin

Geological Society of America Special Papers 2012;486;131-163
doi: 10.1130/2012.2486(24)

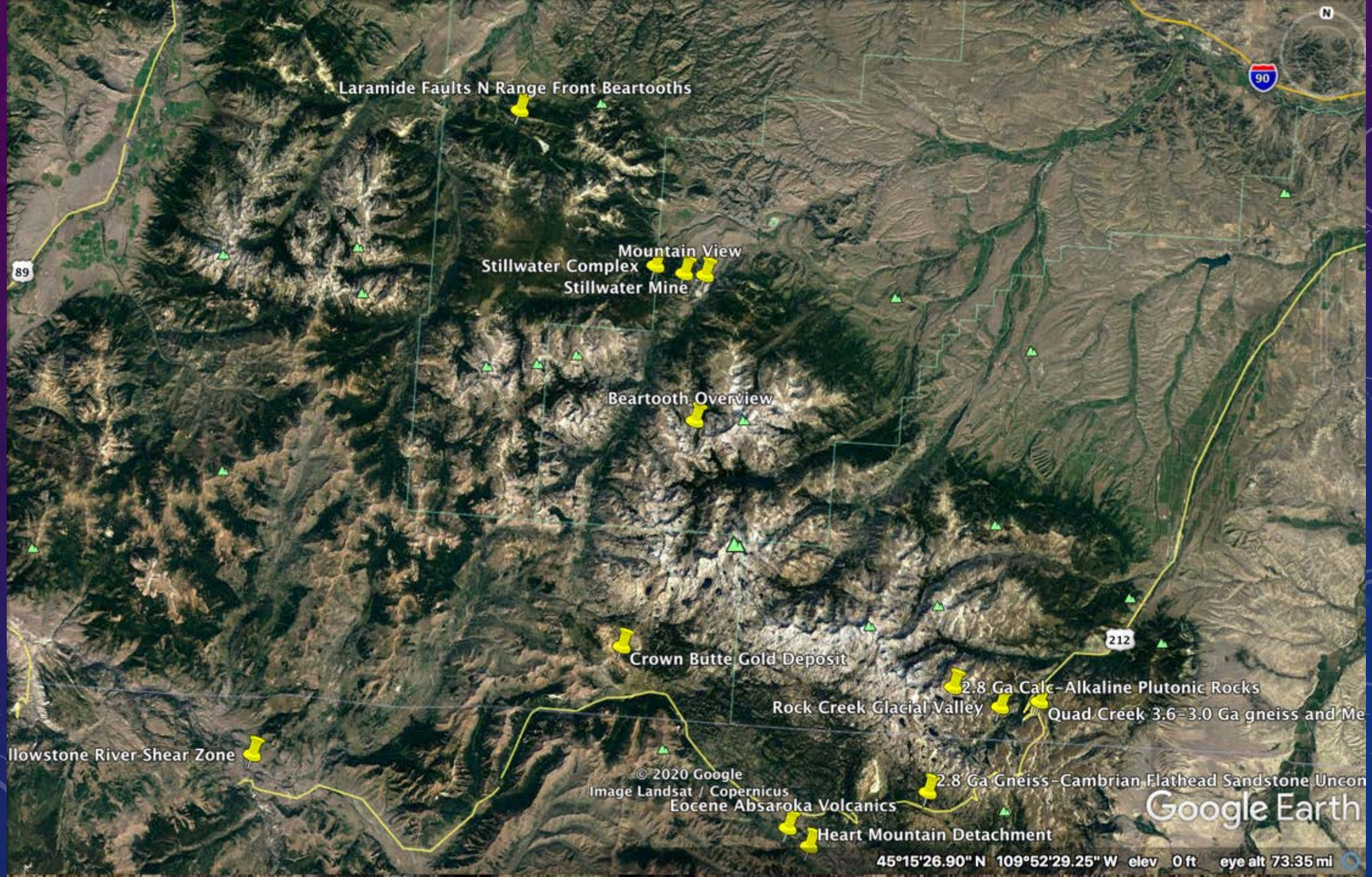
MY INTRODUCTION TO THE NEED FOR GEOHERITAGE: LAND ACCESS ISSUES FOR FIELD CAMP/ COURSE FIELD TRIPS

- Land ownership changes—Old time ranchers were very welcoming; now the property is subdivided—not so much
- Even on federal lands ran into issues requiring permitting, outfitters license; we now have a MOU between MSU and USFS/BLM



A QUICK GOOGLE EARTH FIELD TRIP AROUND THE BEARTOOTH MOUNTAINS: FOR COURSE FIELD TRIPS AND FIELD CAMPS

- An example using an integrated Earth System Approach
- Opportunities for students to revisit areas to explore different geologic phenomena
- Every community / institution has a special place to develop as a Geoheritage site


Laramide Faults N Range Front Beartooths
Mountain View
Stillwater Complex
Stillwater Mine
Beartooth Overview
Crown Butte Gold Deposit
2.8 Ga Calc-Alkaline Plutonic Rocks
Rock Creek Glacial Valley
Quad Creek 3.6-3.0 Ga gneiss and Me
llowstone River Shear Zone
© 2020 Google
Image Landsat / Copernicus
2.8 Ga Gneiss-Cambrian Flathead Sandstone Uncon
Eocene Absaroka Volcanics
Heart Mountain Detachment
Google Earth
45°15'26.90" N 109°52'29.25" W elev 0 ft eye alt 73.35 mi
89
90
212
N


Flying Mule Rd
Silver Creek Rd
Stillwater Mine
NF-846
© 2020 Google
Google Earth
1998
419
Imagery Date: 9/11/2015 45°23'17.18" N 109°52'28.64" W elev 0 ft eye alt 10346 ft

“G” Chromite Layer

Mountain View

Mountain View Lake

Google Earth

Imagery Date: 9/11/2015 45°23'18.49" N 109°54'03.99" W elev 0 ft eye alt 1855 ft

PGE-Cr Deposits

Stillwater Complex

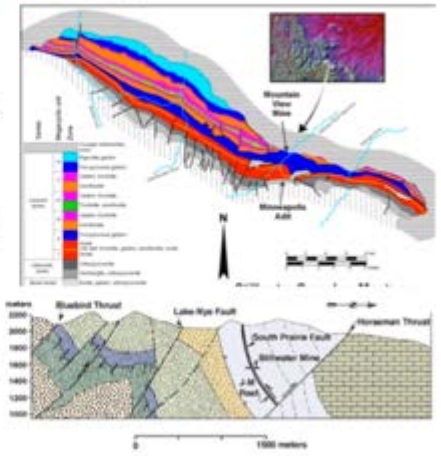
Located in Montana

25 km long x 2-6 km wide.

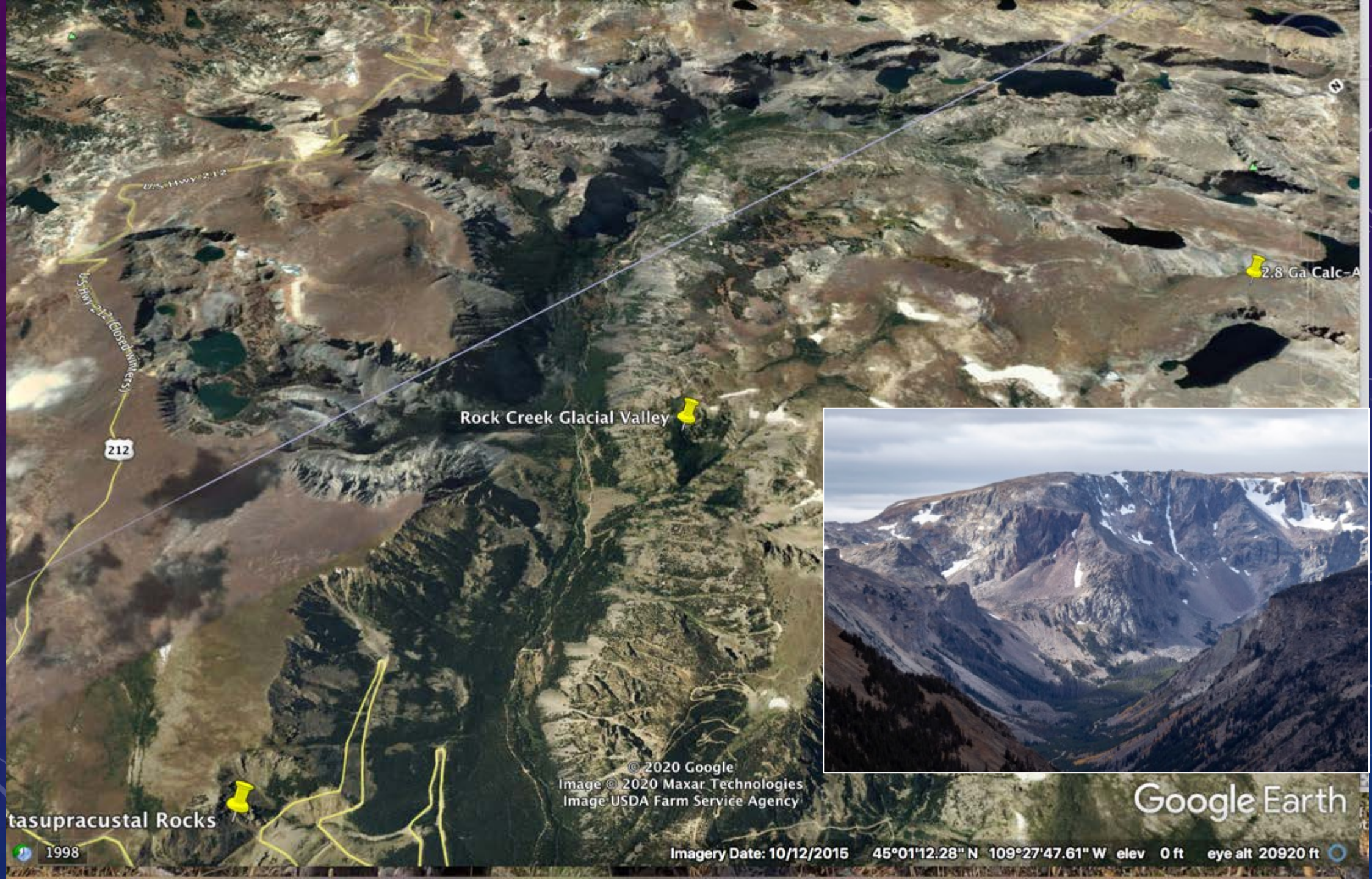
Interbedded pyroxenites, dunites and gabbros. Hosts bedded chromite deposits and a 2.4m thick, 10g/t PGE horizon, low in the sequence.

Cr/Cu/Ni produced in WW2. PGE production began 1985

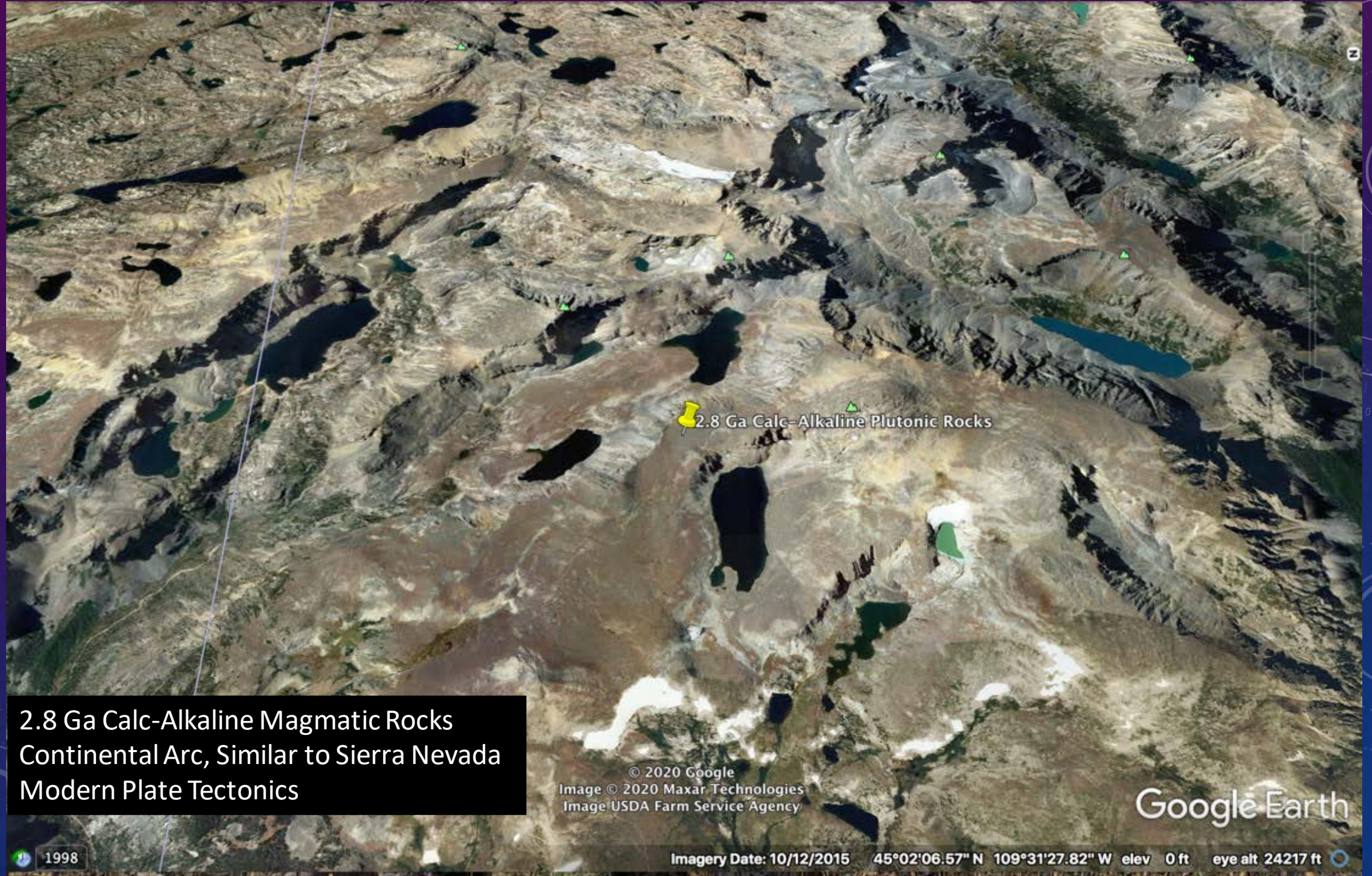
2005 production: 560,000 oz PGEs (13% of world production)




East Boulder Mine
Laramide Faults N Range Front Beartooths
Google Earth
1998
Imagery Date: 9/9/2013 45°31'26.17" N 110°07'33.55" W elev 0 ft eye alt 22539 ft

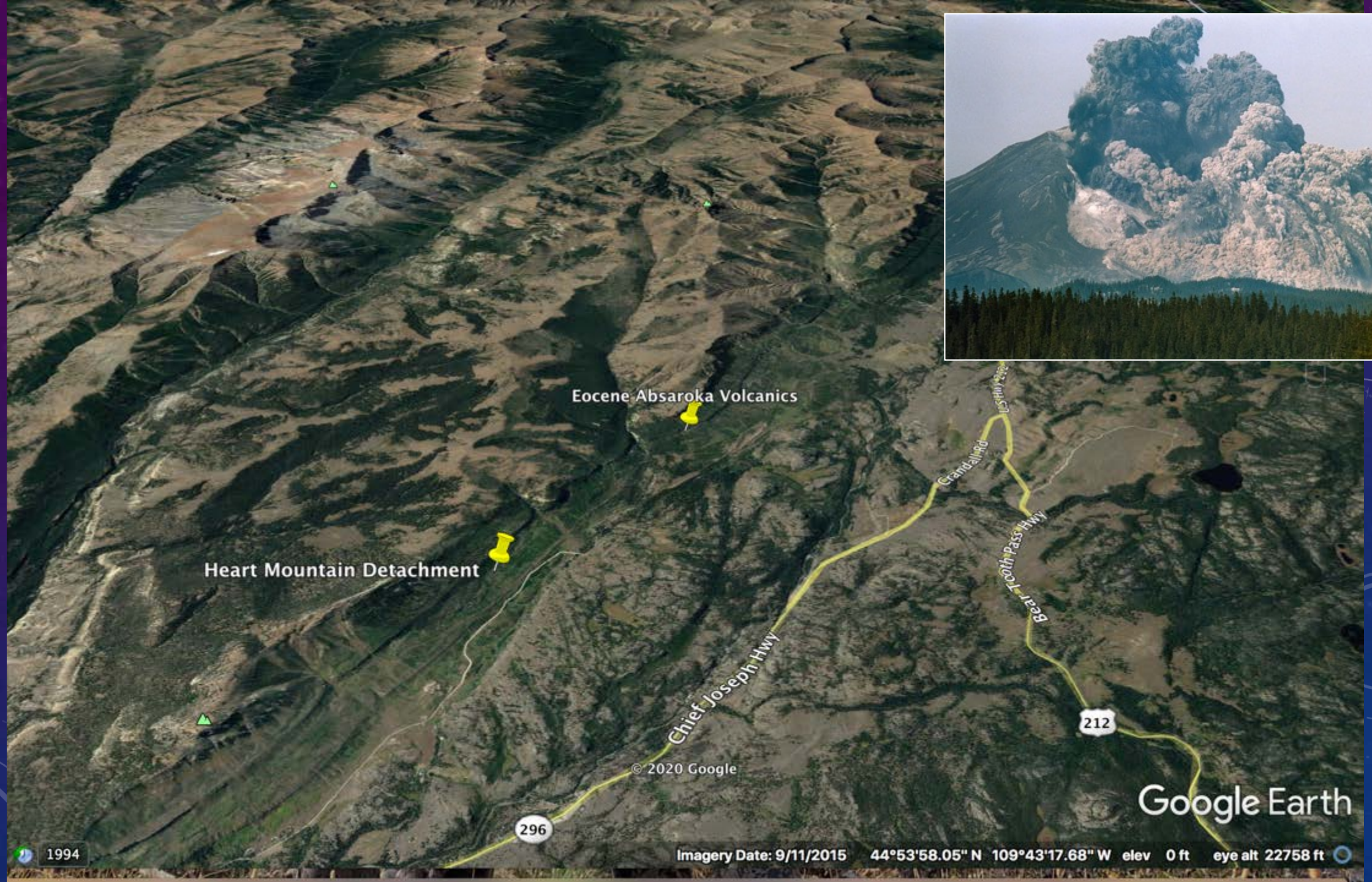

US Hwy 212
US Hwy 212 (Closed in Winters)
212
2.8 Ga Calc-A
Rock Creek Glacial Valley
tasupracustal Rocks
© 2020 Google
Image © 2020 Maxar Technologies
Image USDA Farm Service Agency
Google Earth
1998
Imagery Date: 10/12/2015 45°01'12.28" N 109°27'47.61" W elev 0 ft eye alt 20920 ft

3.6-3.0 Ga TTG Gneisses
4.0 Ga detrital zircons
History of Geology
--1968, Granitization; “chemical resistors”
--1978, Pendants in Magmatic Rocks

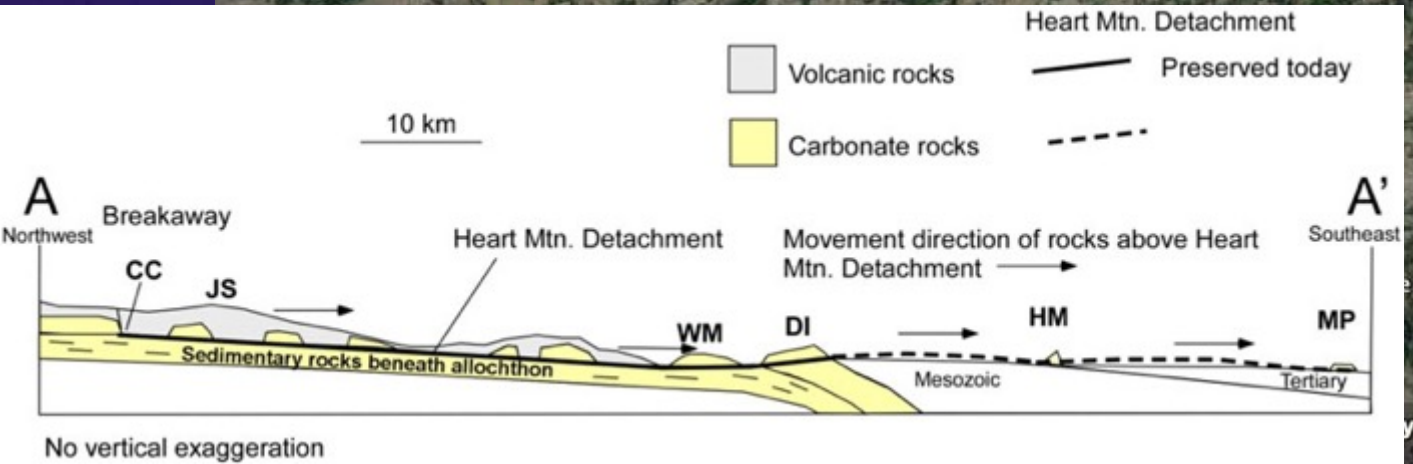


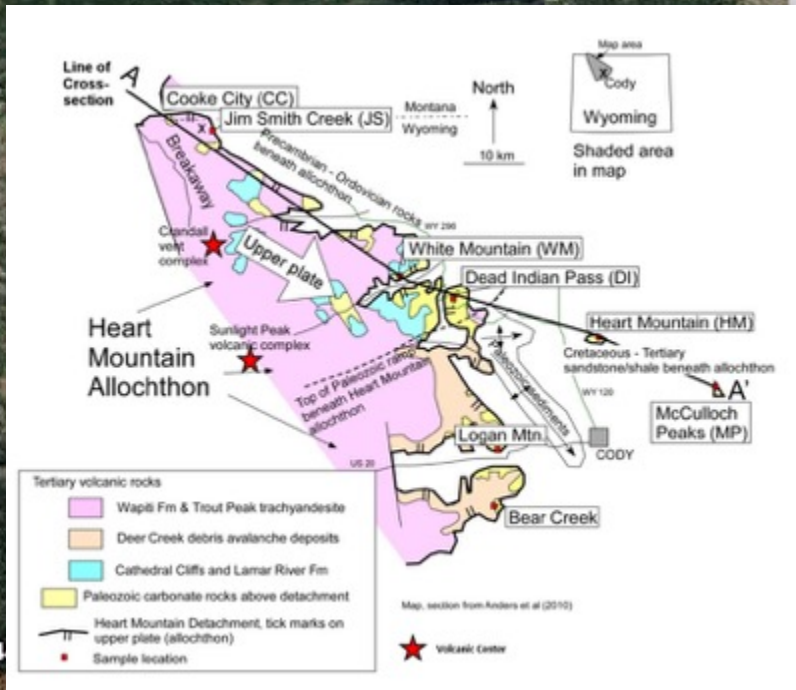
2.8 Ga Calc-Alkaline Magmatic Rocks
Continental Arc, Similar to Sierra Nevada
Modern Plate Tectonics


A “Profound Unconfrmity”—2.3 Ga Earth History Missing
Cambrian Flathead Sandstone
2.8 Ga Gneisses
2.8 Ga Gneiss–Cambrian Flathead Sandstone Unconformity
© 2020 Google
Google Earth
1994
Imagery Date: 9/11/2015 44°56'23.01" N 109°32'51.25" W elev 0 ft eye alt 274 ft

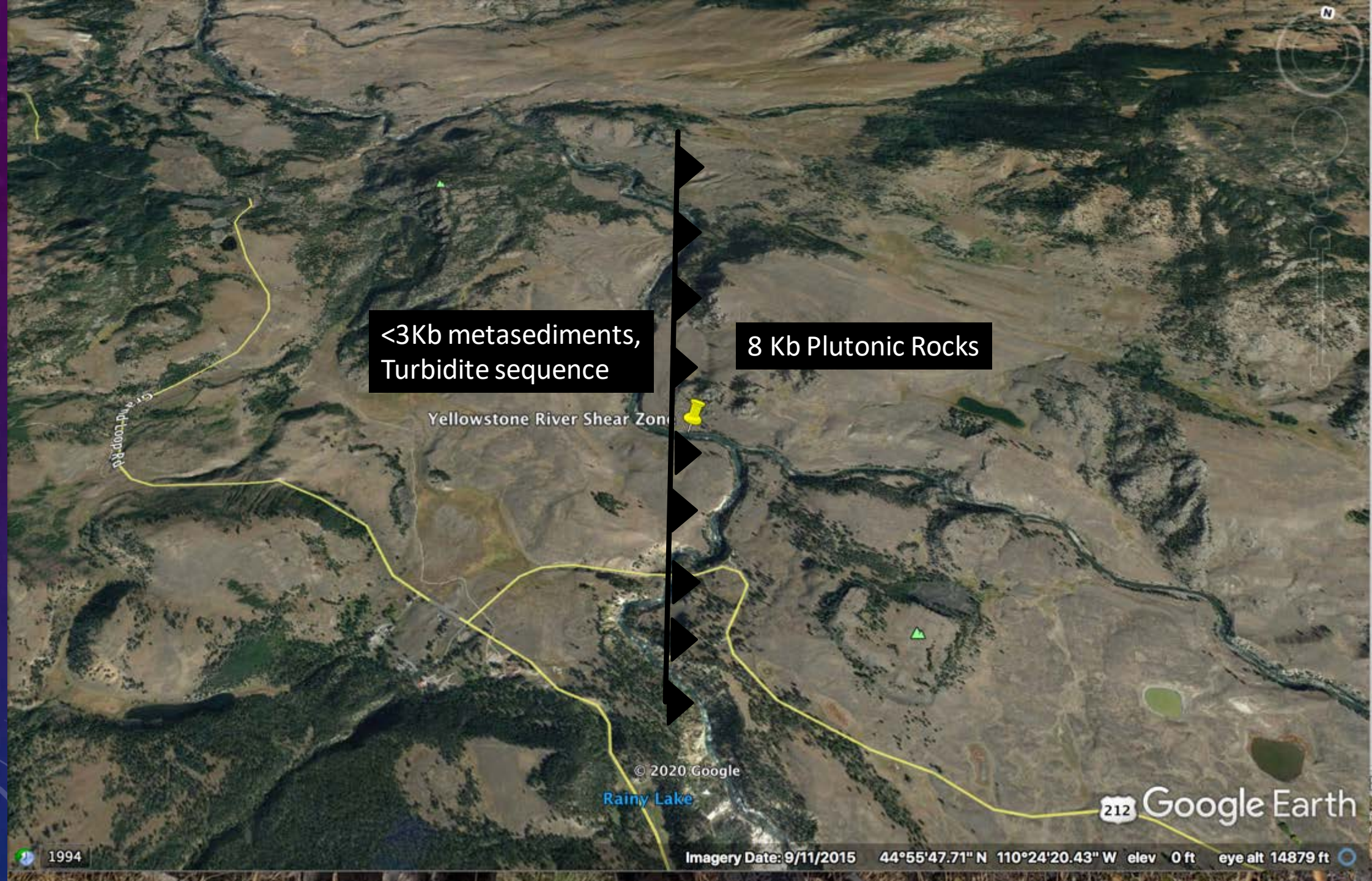

Eocene Absaroka Volcanics
Heart Mountain Detachment
Chief Joseph Hwy
Grandeur Rd
Bear Tooth Pass Hwy
212
296
© 2020 Google
Google Earth
1994
Imagery Date: 9/11/2015 44°53'58.05" N 109°43'17.68" W elev 0 ft eye alt 22758 ft


Heart Mountain Detachment


Heart Mtn. Detachment
Volcanic rocks
Preserved today
Carbonate rocks
10 km
A
Northwest
Breakaway
CC
JS
Heart Mtn. Detachment
Movement direction of rocks above Heart Mtn. Detachment
WM
DI
HM
MP
A'
Southeast
Sedimentary rocks beneath allochthon
Mesozoic
Tertiary
No vertical exaggeration


Line of Cross-section
A
Cooke City (CC)
Jim Smith Creek (JS)
Montana
Wyoming
North
10 km
Map area
Cody
Wyoming
Shaded area in map
Precambrian - Ordovician rocks beneath allochthon
Breakaway
Upper plate
Crandall vent complex
White Mountain (WM)
Dead Indian Pass (DI)
Heart Mountain (HM)
Heart Mountain Allochthon
Sunlight Peak volcanic complex
Cretaceous - Tertiary sandstone/shale beneath allochthon
A'
McCulloch Peaks (MP)
Top of Paleozoic range beneath Heart Mountain allochthon
Logan Mtn.
CODY
Bear Creek
Tertiary volcanic rocks
Wapiti Fm & Trout Peak trachyandesite
Deer Creek debris avalanche deposits
Cathedral Cliffs and Lamar River Fm
Paleozoic carbonate rocks above detachment
Heart Mountain Detachment, tick marks on upper plate (allochthon)
Sample location
Volcanic Center

2 million oz proven gold reserve, BUT
Heavy metal contamination into Yellowstone


<3Kb metasediments,
Turbidite sequence
8 Kb Plutonic Rocks
Yellowstone River Shear Zon
Grayback Rd
© 2020 Google
Rainy Lake
212
Google Earth
1994
Imagery Date: 9/11/2015 44°55'47.71" N 110°24'20.43" W elev 0 ft eye alt 14879 ft

GEOHERITAGE SITES TO SUPPORT REU, INDEPENDENT STUDY, THESES… TRUE RESEARCH EXPERIENCES…

- Applying “core” concepts and content from the geoscience curriculum
- Meaningful and relevant to students, career aspirations
- Preparation for the Geoscience community of practice
- Excitement about making truly new discoveries

ACTIVITY DESIGN

Photo credit: David Mogk

- "Cradle to grave" research experience
- Field work—sampling and mapping
  - Formulation of research questions
  - Planning and execution of research plan
  - Sampling, mapping as required
  - Daily data compilations; sample control
  - Sample preparation (cutting billets, crushing rocks)
- Analytical studies during following semester
  - Microprobe, XRF, LA-ICPMS, Ar-Ar,…..
- Communicating results
  - Poster at Rocky Mountain GSA
  - Writing retreat—each project will be a section of a larger research manuscript
  - Senior Thesis
- Information fed back into Geoheritage Site development

GET OFF THE INTERSTATE, PUT BOOTS ON THE GROUND….FOR STUDENTS, BY STUDENTS

1. A service-learning project by students in the Dept. of Earth Sciences, Montana State Univ. Web-based Resources
2. Compilation of road logs in Montana; “gray literature” to help discover geologic sites.
3. Trail Guides: step by step guides with interpretive information to explain what you are walking over
4. Geoheritage sites: Augusta-Choteau area

The Montana-Yellowstone Geologic Field Guide Database

A Digital Resource for Integrating Field-Based Research, Teaching, and Learning

Developed by Kent Ratajeski

Integrating Research and Education

- Cretaceous
- Crystallography
- EarthChem
- Environmental Health Risk Assessment
- Geochemical Instrumentation and Analysis
- Hurricane Katrina
- Impacts on American Indian Lands
- Montana Geoscience Data Project
- Teaching Phase

Montana-Yellowstone Geologic Field Guide Database

Facilitating Field-Based Teaching and Learning in Montana and the Yellowstone Region

Introduction

Field experiences are a central component of the modern geoscience curriculum, and published field guides and road logs are invaluable resources to facilitate the development of teaching and learning in the field. These references are also a primary means by which field-based geologic information is transferred from experienced

Related Links

NAGT: Safety in the Field

Trail Guides

Integrating Research and Education

- Cretaceous
- Crystallography
- EarthChem
- Environmental Health Risk Assessment
- Geochemical Instrumentation and Analysis
- Hurricane Katrina
- Impacts on American Indian Lands
- Montana Geoscience Data Project

Trail Guide to Sacagawea Peak, Northern Bridger Range, MT

By Travis Corthouts and Donald Bent, geology majors, Department of Earth Sciences, Montana State University

Jump down to: Introduction | Directions | Trailhead | Fossils | Cirque Basin Area | Structural Geology |Active Geomorphology | More Fossils | Cirque to Summit | Stratigraphy and Geologic History

Fossils to look for on this stretch of the trail

Back to Top

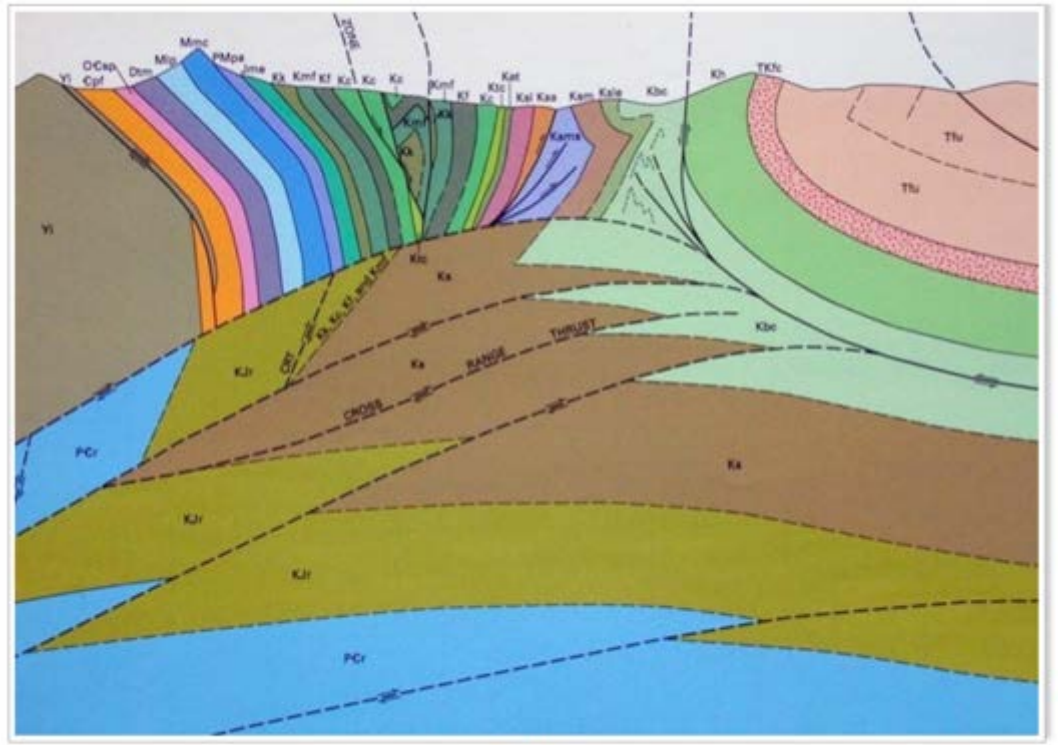
The rocks seen along the majority of the trail are limestone from the Mississippian Madison Formation, which include the lower thinly-layered Lodgepole Limestone, and the upper section which is the more massive Mission Canyon Limestone. These limestones were originally deposited in warm, shallow seas that covered this part of North America ~340 million years ago. This environment was similar to modern day sub-tropical carbonate platforms--thus, this geologic occurrence has been referred to as "**Bahama Montana**" (a term coined by Dr. David Lageson). Imagine this countryside once covered by coral reefs and all the organisms that typically live there....

▶ Show Caption

▶ Show Caption

Structural Geology

Back to Top



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Cross Section: David Lageson

The Montana Geoheritage Project

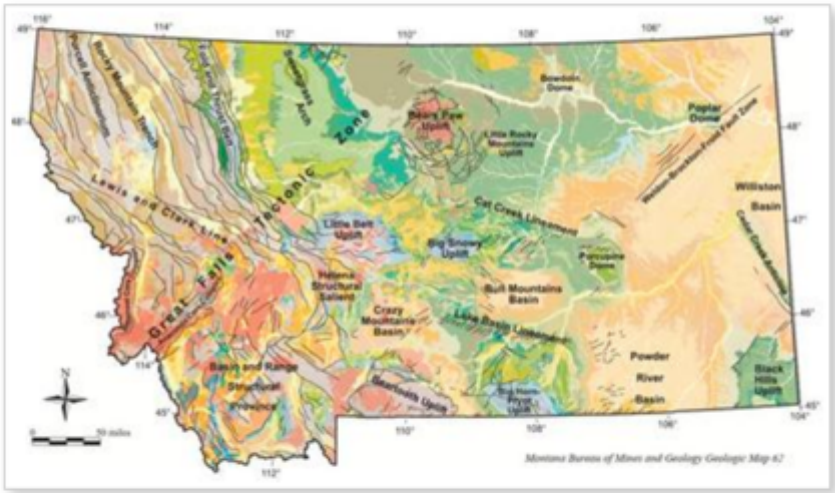
Integrating Research and Education

- Cretaceous
- Crystallography
- EarthChem
- Environmental Health Risk Assessment
- Geochemical Instrumentation and Analysis
- Hurricane Katrina
- Impacts on American Indian Lands
- Montana Geoscience Data Project

Montana Geoheritage Sites

About This Project

Following the Global Geoparks Network model, the purpose of this project is to introduce the natural and cultural heritage of selected sites in Montana for the enjoyment and education of learners of all ages. We take an Earth System Science approach, emphasizing the connections between the numerous components of the Earth system: bedrock geology, surficial processes, landscapes, geologic time, weather/climate, ecosystems and biota, human interactions with Earth, and impacts on society and culture. We selected the Augusta–Chateau area as our inaugural Montana Geoheritage site because of the diversity of geologic features present in this landscape, the rich cultural heritage of the people who live here, and the stunning beauty of the Rocky Mountain Front.

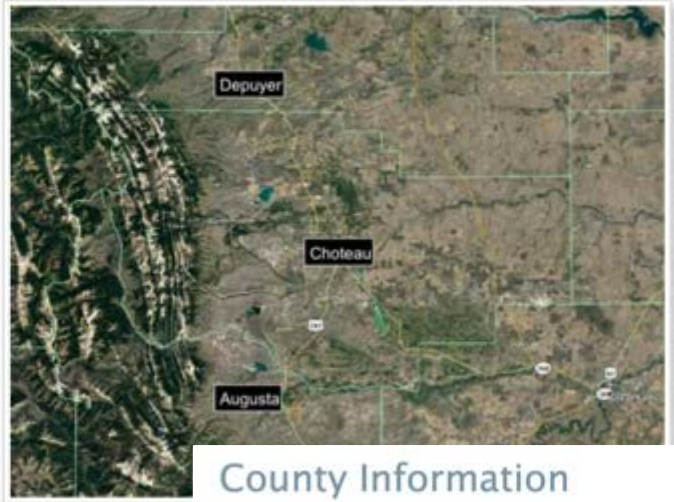


Geologic Map of Montana, Montana Bureau of Mines and Geology Map 62

This project is being done as a service learning project by students Mariah Cannon, Sarah Devaney, and Willie Freimuth, in the Department of Earth Sciences, Montana State University. This is a pilot project that demonstrates how web resources can be used to encourage exploration and discovery of the geoheritage of the Augusta–Choteau area. In coming school years we plan to extend our coverage to other geoheritage sites across Montana. We also hope that this project will serve as a model to develop geoheritage sites in other areas across the United States.

Augusta-Choteau Geographic Setting

Get off the interstate, head down US Highway 287 from Wolf Creek or US Highway 89 from Vaughn/Great Falls, slow down, get out of the car and put boots on the ground, and experience the majesty of the Rocky Mountain Front in northern Montana. The Augusta-Choteau area is the portal to the Bob Marshall Wilderness Complex that includes the Bob Marshall Wilderness, Great Bear, and Scapegoat Wilderness areas. Experience first hand this remarkable landscape where the Rocky Mountains rise abruptly from the Great Plains. To the east, lies the world famous Egg Mountain paleontologic site. This is also an area of rich cultural heritage, home of the Blackfoot Indian tribe and location of the lyrical writings of Ivan Doig. It is also the site of contemporary issues that include the question of whether oil and gas development should be allowed along the Rocky Mountain Front, should the Badger-Two Medicine Roadless Area (south of Glacier National Park and nestled between the Blackfoot Indian Reservation and the Bob



Google Earth Map of Au

County Information

- Pondera County Website
- Teton County Website
- Lewis and Clark County Website

China Wall Bob Marshall Wilderness Area

Geographic, Socio-Economic Indicators from Headwaters Economics

See the report on Montana's Rock Mountain Front by Chris Mehl (2012), Headwaters Economics, that contains extensive historical, demographic and economic (agricultural, land use, hunting and outdoor recreation, and much more) information about this area.

Headwaters Economics has developed an Economic Profile System that produces "socioeconomic reports of communities, counties, & states, including aggregations and comparisons. The Economic Profile System uses federal data sources, including the Bureaus of Economic Analysis, Census, & others." Explore the geographies of the of the Ro Mountain Front by exploring these topical reports for each county.

Teton County

- Profile of Socioeconomic Measures Teton County, MT (Acrobat (PDF) 803kB Apr10 18)
- Profile of Land Use, Teton County, MT (Acrobat (PDF) 374kB Apr10 18)
- Profile of Public Land Amenities, Teton County, MT (Acrobat (PDF) 477kB Apr10 18)
- Profile of Agriculture, Teton County, MT (Acrobat (PDF) 504kB Apr10 18)
- Profile of Mining Including Oil and Gas, Teton County, MT (Acrobat (PDF) 410kB Apr10 18)

Structural Geology of the Rocky Mountain Front

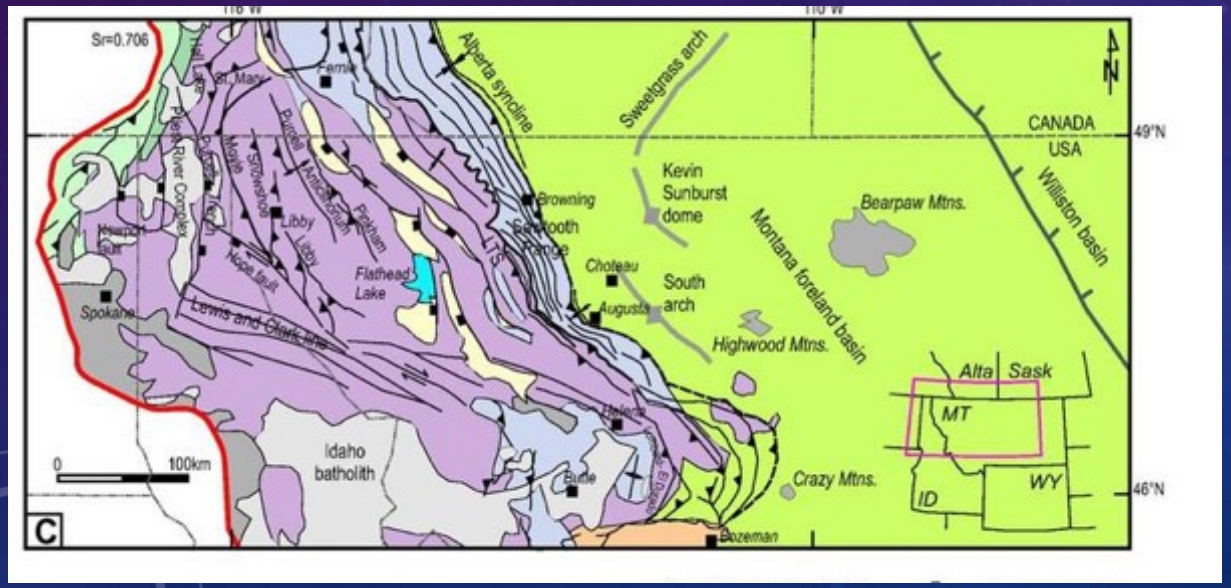
Author: Sarah Anne Devaney, Department of Earth Sciences, Montana State University

Overview

The area of the Rocky Mountain Front is famous for its

rugged mountain ranges. The Sawtooth Range rises dramatically from the plains west of Choteau and Bynum, and trending NW-SE across Pondera, Teton and Lewis and Clark Counties. The Sawtooth Range formed at the frontal part of the Cordilleran thrust system on the massive Lewis thrust system (see: DeCelles, P.G., 2004, Late Jurassic to Eocene evolution of the Cordilleran thrust belt and foreland basin system, western USA: American Journal of Science, v. 304, p. 105-168, doi:10.2475/ajs.304.2.105). To the north of the Sawtooth Range, the Lewis Thrust is very visible at the surface of the Earth in Glacier National Park.

This thrust then crosses the Continental Divide close to Marias Pass and then again south of the Sun River forming t
the Sawtooth Range. An early study of the Structural Geology of the Sun River Canyon and Adjacent Areas, Northwes
published by Mudge (1972), U.S. Geological Survey Professional Paper 663-B (Acrobat (PDF) 23.5MB May16 18), and Mudge ar



Paleontology – Egg Mountain

Author: Willie Freimuth, Dept. of Earth Sciences, Montana State University

"There's an incomparable rush that comes from finding dinosaur bones. You know you're the first person to lay hands on a critter that lived 80 or 90 million years ago" -- Jack Horner in *People* magazine, 1984

Training for students AND citizen science programs

Topical Issues That Impact the Rocky Mountain Front

Authors: Willie Freimuth, Sarah Anne Devaney, David MogkDept. of Earth Sciences, Montana State University

Preservation vs. Conservation

At first glance, the terms **conservation** and **preservation** may hold similar meanings. However, there are key differences between the two practices, and their implementation on the Rocky Mountain Front has far-reaching implications for the wildlife and the people of the area. Generally, conservation seeks the proper use of nature, while the goal of preservation is to protect nature from use. Overall, efforts on the Rocky Mountain Front seem to strike a balance between conservation and preservation--many efforts prioritize involvement of landowners and locals along with protecting wildlife habitat and natural landscapes. For more on general information regarding conservation, visit the National Park Service website.

The Endangered Species Act, Land Rights, and Grizzly Bears: How Much Conservation is "Enough?"

Despite great success in preserving species and the pristine landscape, there are issues that accompany conservation efforts in the Rocky Mountain Front area. Recently, grizzly bears have made a return to the Front and have been seen wandering onto the plains as far east as Great Falls. Attacks on livestock and people have been reported recently, with bears wandering onto the plains which is part of their natural habitat. How should human-grizzly bear conflicts be managed and hopefully prevented?

Additionally, overlap of conservation area and private land entails issues. Though some conservation easements provide private landowners with ample rights and tax benefits, there are some federal entities (Bureau of Land Management, US Forest Service) charge landowners grazing fees per animal on federal land.

Oil and Gas Exploration

During the 1980's, the Reagan administration allowed several oil and gas exploration leases in the Bob Marshall Wilderness Area and the Badger Two Medicine area without consulting Blackfeet tribal government or performing any environmental analysis (actually, because of these explorations, Egg Mountain was discovered). While the leases were deemed invalid in the Bob Marshall Wilderness, it was not until 2016 that leases were retired on sacred Blackfeet land of the Badger Two Medicine area. However, backlash from the Lousiana-based energy company Solenex ensued, and a lawsuit and trial is currently underway. The Solonex party argues the leases were terminated illegally and the ramifications extend beyond oil and gas into contract law and property rights. Proponents of the lease termination--

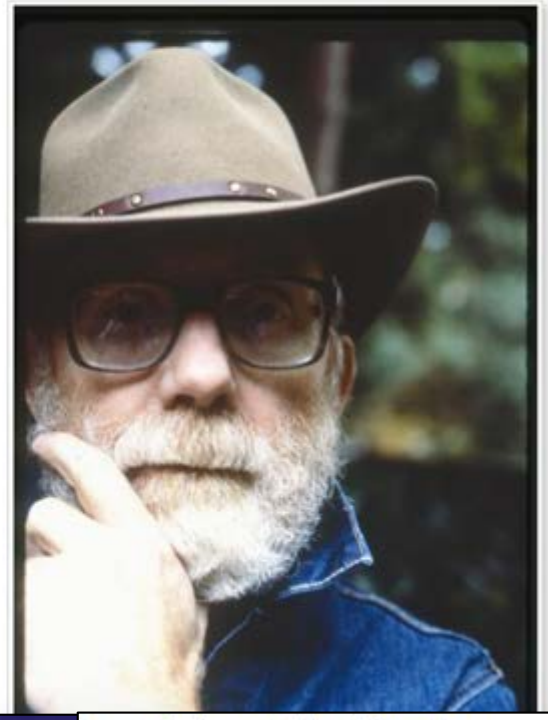
This is Ivan Doig Country

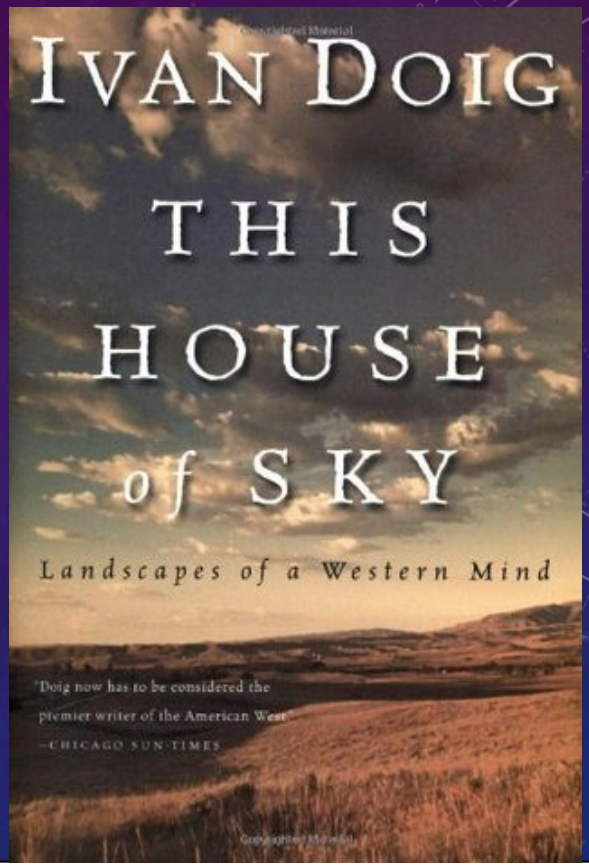
Authors: Jan Zauha, Jodi Rasker, Montana State University Library; Sarah Devaney, Willi Freimuth, Mariah Cannon, David Mogk, Dept. of Earth Sciences, Montana State University

Montana native son and award-winning author Ivan Doig (1939-2015) is one of the most-beloved authors who chronicled life in the northern Rocky Mountain region in the latter half of the 20th Century. "Ivan Clark Doig, a third-generation Montanan of Scottish descent, was born June 27, 1939 in White Sulphur Springs, Montana, the only child of Charlie Doig and Berneta Ringer Doig. He grew up in Montana along the east slope of the Rocky Mountains, where much of his writing takes place. A former ranch hand, newspaperman and magazine editor, Doig graduated from Northwestern University where he received bachelor's and master's degrees in journalism. He earned a Ph.D. in history from the University of Washington in 1969, and during his career was the recipient of three honorary doctorates, including one from Montana State University in 1984.

His 16 works of fiction and non-fiction won him numerous awards that propelled him to national prominence as one of the West's most distinguished authors. At century's end, the San-Francisco Chronicle polls named Ivan Doig the only living author in the top 12 of both the Best Fiction of the American West and Best Non-Fiction of the American West. He lived in Seattle, Washington, with his wife Carol Muller Doig. Ivan Doig died April 9, 2015, from multiple myeloma" (Jodi Rasker, Montana State University Library).

Learn more about Ivan Doig's Biography and Bibliographic Record at the Ivan Doig Archive in the Montana State University Library.





"Along those mountainsides the thunder can roll and roll, and constant claps were arriving to us now like beer barrels tumbling down stairs." --Jick, English Creek

Ivan Doig and the Weather

Montana is known for seeing the extreme sides of weather. From intense cold to sweltering heat, harsh blizzards to booming thunderstorms, Montana sees every variation. Ivan Doig uses his way with words to paint fantastic pictures of the weather in Montana.

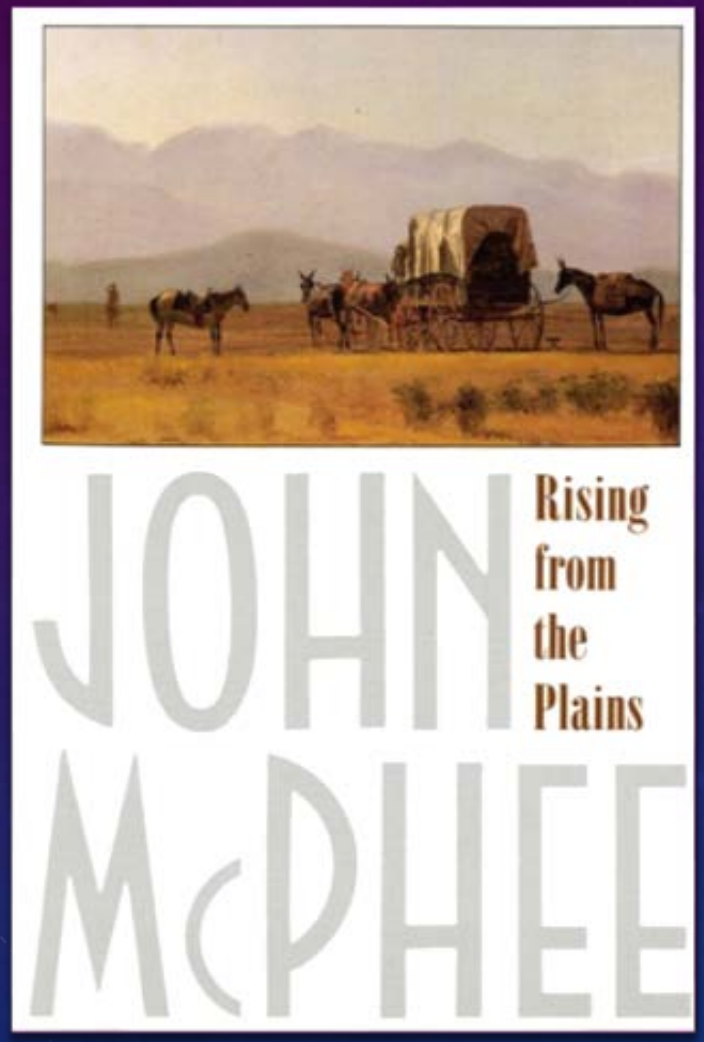
"When a Montanan doesn't have anything else to do, he can always worry about the weather." Ivan Doig, Ride With Me, Mariah Montana –
draft and notes for insert ideas

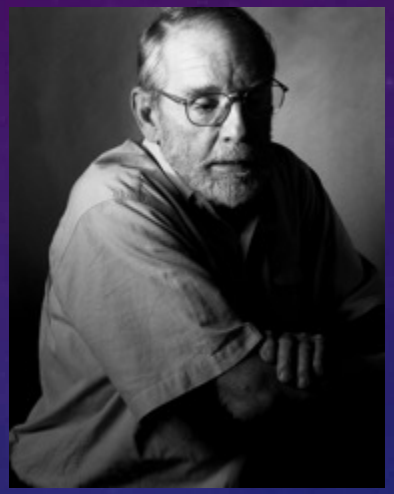
A northwest landscape view of Moiese National Bison Range in Montana. The view is looking down over a valley at the base of the Mission Mountain Range while the overcast sky is creating a sunbeam effect across the landscape. There are trees lining a river in the valley, and the Mission Mountain Range in the background is silhouetted by the sunbeams in the foreground.

Visit the Ivan Doig Archive at Montana State University-Bozeman

The MSU Library has developed the Ivan Doig Archive which contains extensive collections of Doig's writings (manuscripts, diaries, files, correspondences, interviews and other memorabilia accessible in digital format), biographic and bibliographic information, photographs, and related projects and exhibitions.

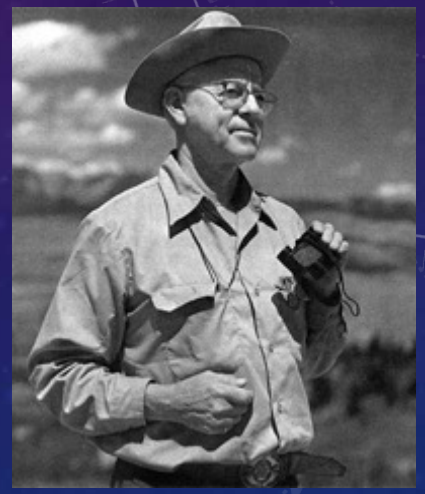
Increasing public interest in geosciences through geoheritage:
A geologic companion to John McPhee's *Rising from the Plains (1986)*





John McPhee
Peter Cook photo
textpublishing.com.au

Ethel Waxham Love
Barbara Love photo
Jackson Hole News and Guide



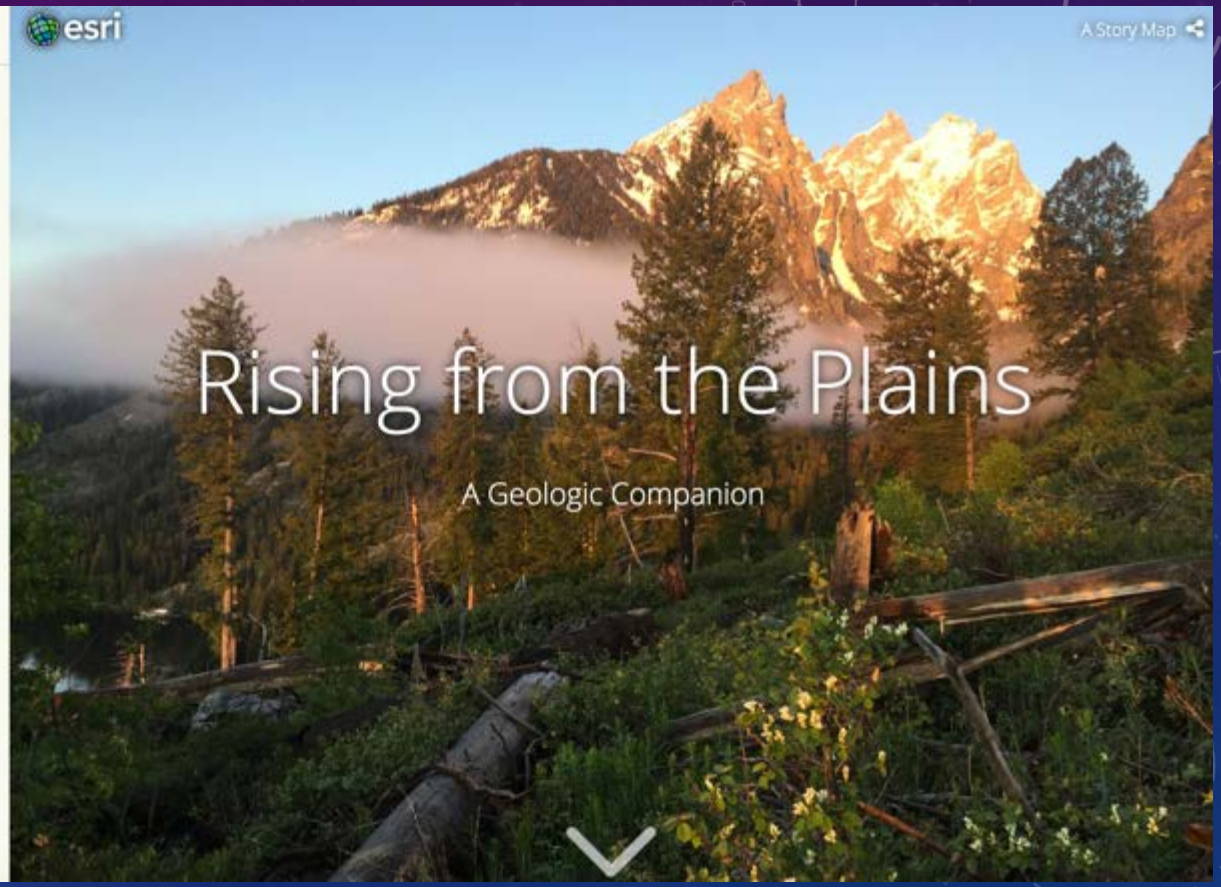
J. David Love
1980 WGA guidebook
WyoHIstory.org

A group project in Carol Frost's *Communicating Earth Science* class at the University of Wyoming

Courtesy: Carol Frost, Univ. Wyoming

ESRI STORY MAP

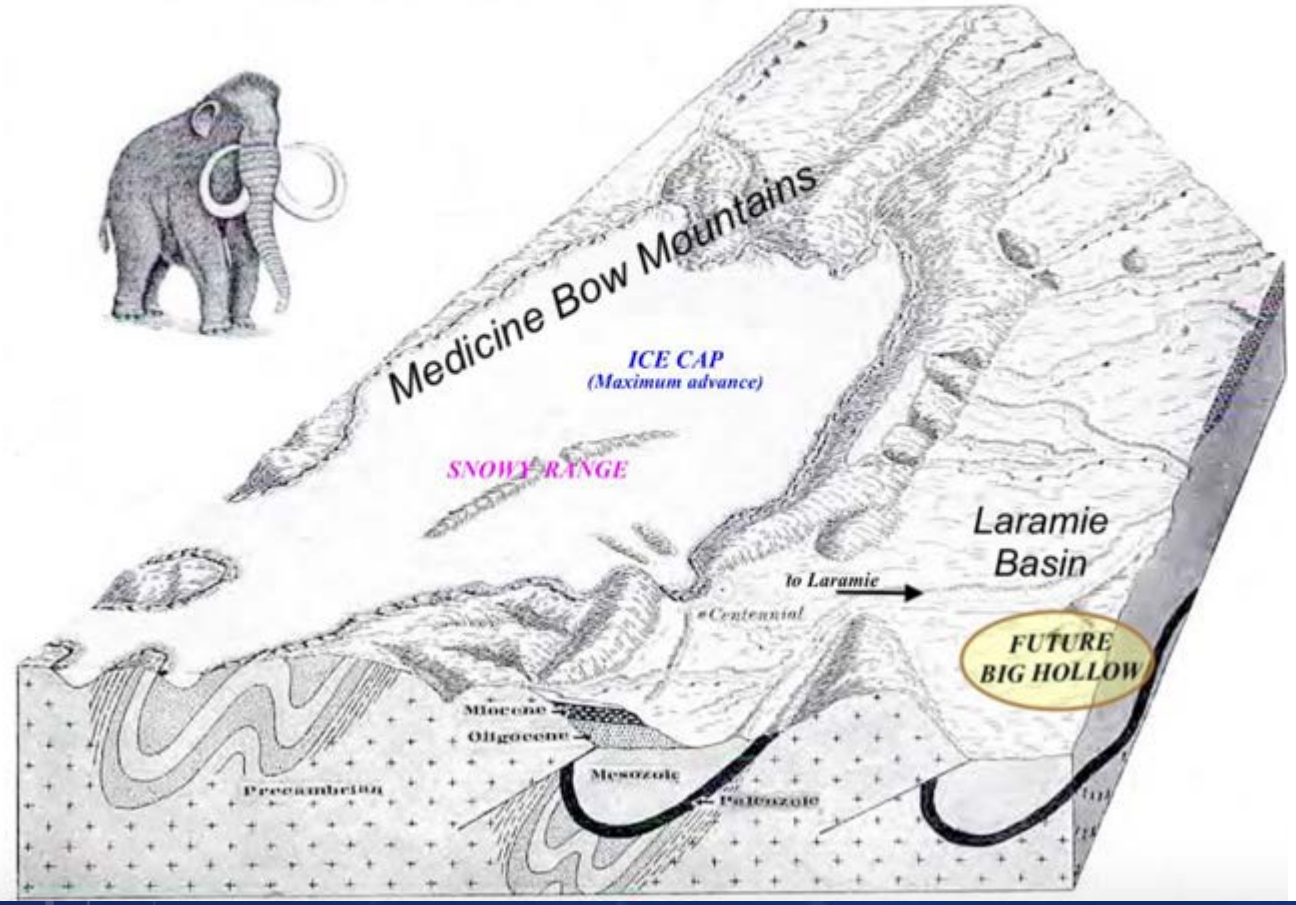
- Each student contributes one feature
- Two parts:
  - Geologists and Geology of Wyoming
  - Sites from Love and McPhee on the Road

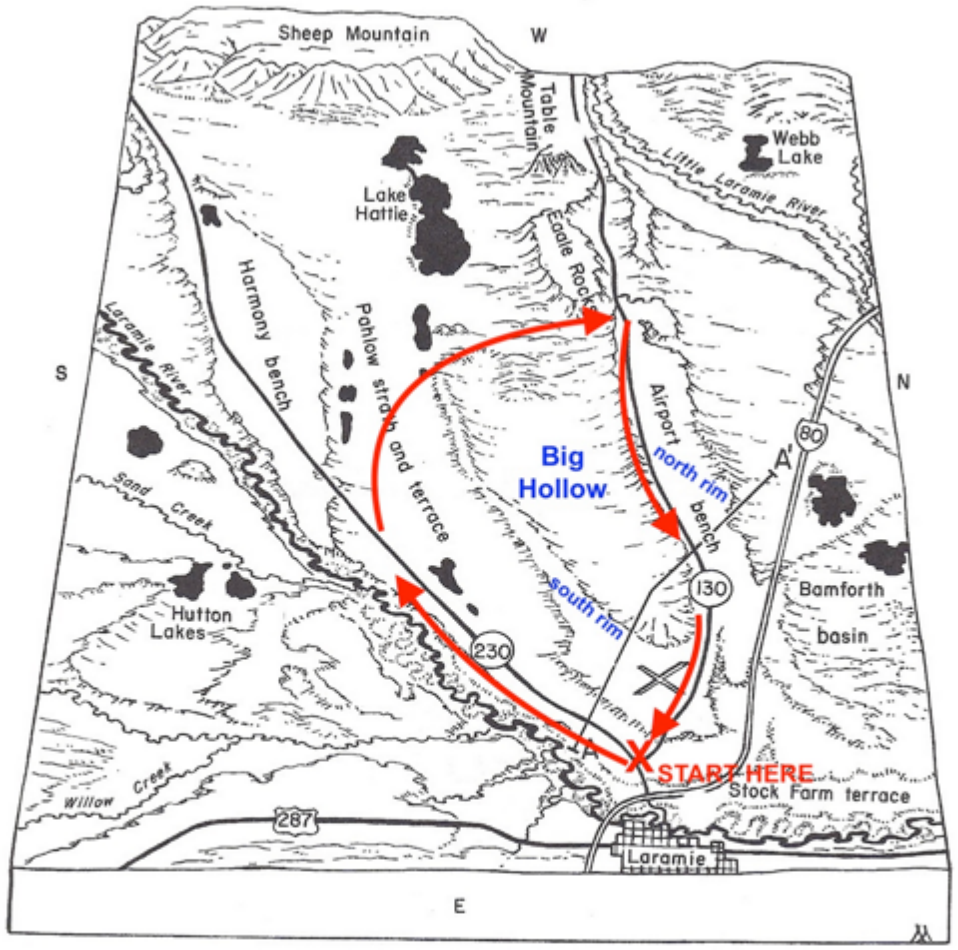


Visit http://www.uwyo.edu/geolgeophys/news/news-archive/2019/rising_from_the_plains_a_geological-companion.html

- Diagrams and field guide

Even better, let's visit the north rim when Big Hollow was under construction. Bring an extra-warm coat and a snug-fitting hat!

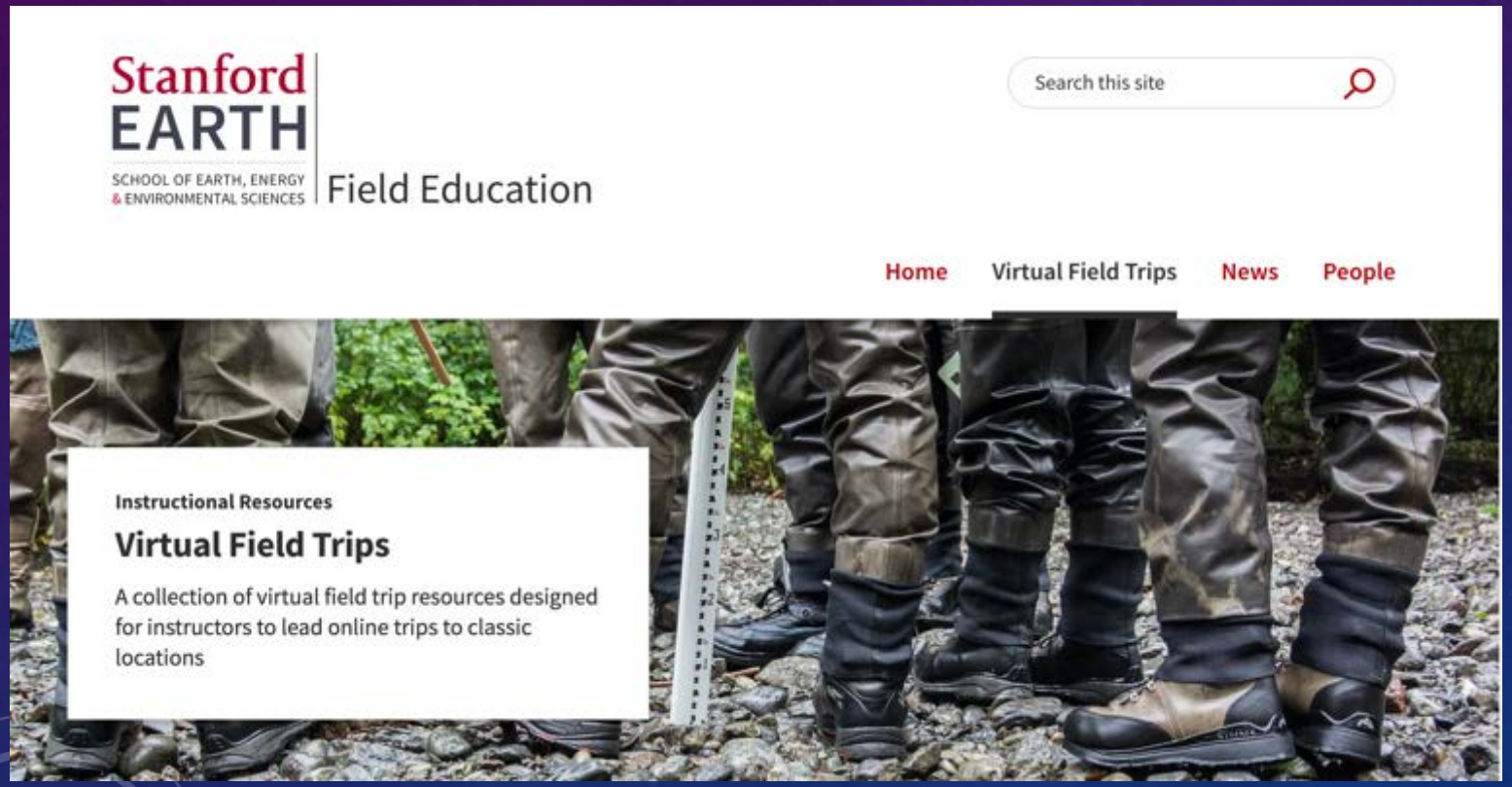




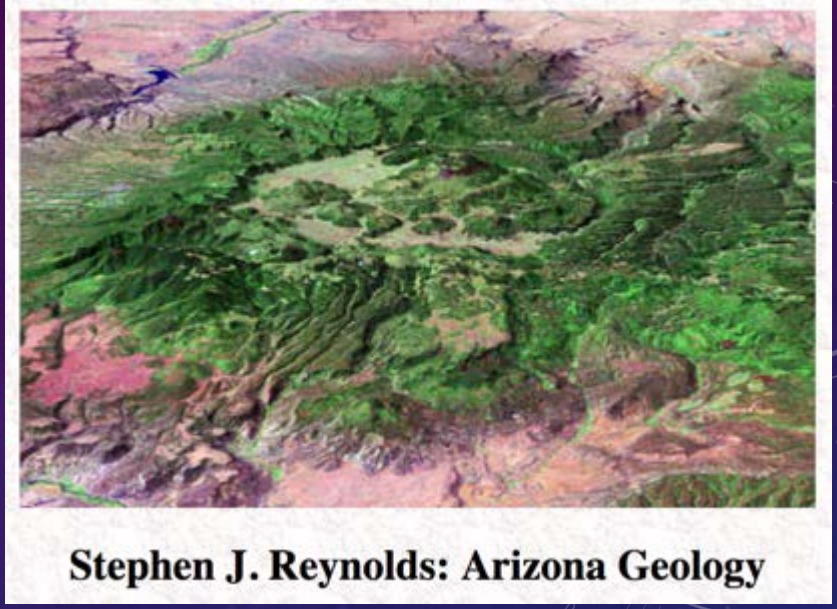
View west across Big Hollow. The old stream channels that form today's rims joined near the airport (black X). Red arrows show approximate tour route.

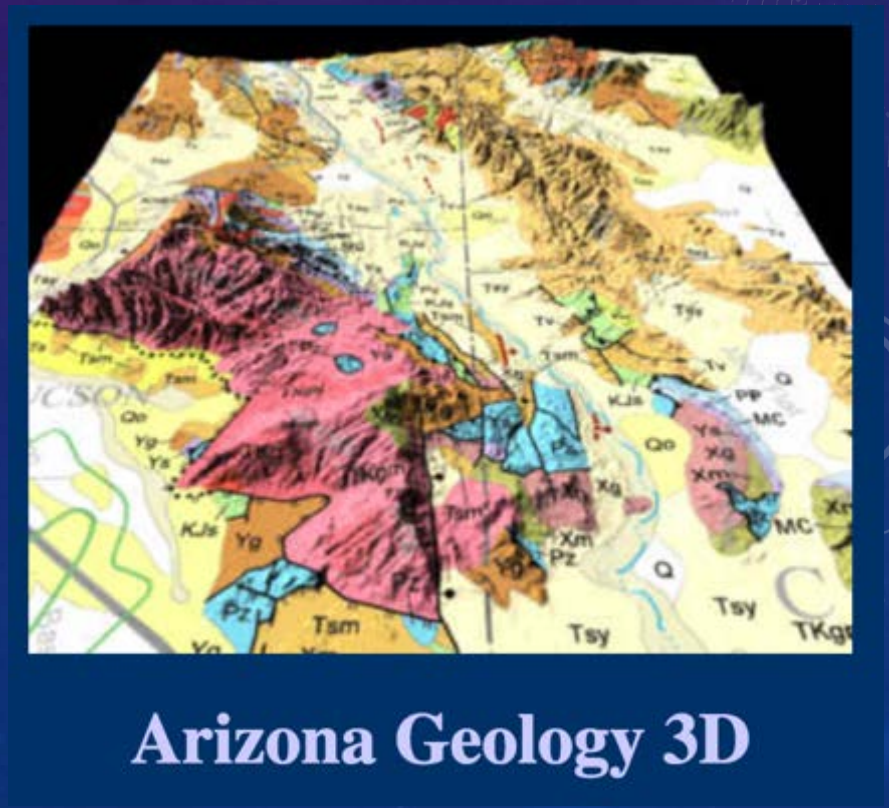
WEB RESOURCES AND VIRTUAL FIELD TRIPS

- Not as a substitute for field experiences—
- Provide a portal, as a complement, as a supplement



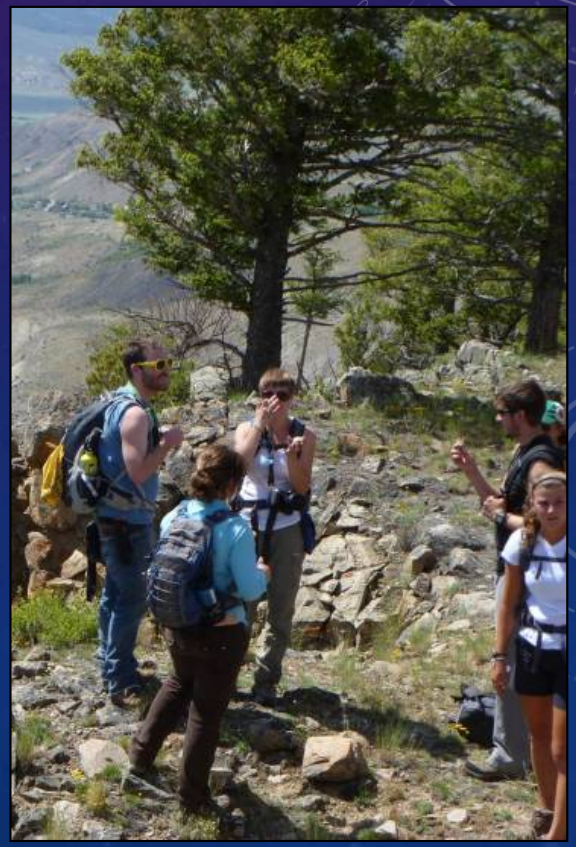
Courtesy: Ryan Petterson





A VISION

- Mobilize GSA and NAGT Section members to identify and develop Geoheritage sites in all communities across America;
- Develop scaffolded teaching activities to engage learners of all ages; support exploration, discovery, inquiry;
- Sites that are shared by multiple schools; and where learners can have diverse experiences
- Information systems (web-based) that are organic and continue to grow
  - Basic scientific information--maps, photos, strat columns, data/representations
  - Teaching activities, and teaching tips
  - Student projects
  - All users encouraged to add to collections



GET OUT INTO NATURE EARLY AND OFTEN…

The Earth never tires,

The Earth is rude, silent incomprehensible at first,

Nature is rude and incomprehensible at first,

Be not discourag'd, keep on, there are divine things well envelop'd,

I swear to you there are divine things more beautiful

than words can tell.

Walt Whitman

Leaves of Grass

Song of the Open Road

EXTRA SLIDES, HAD TO NOT SHOW DUE TO TIME LIMITS.

GEOHERITAGE, GEOETHICS, AND GEOLOGIC SAMPLING

Do I really need this sample?

- For teaching?
- For research?
- Are there alternatives?
- Will a picture suffice?
- Do I need to sample outcrop, or is talus OK?
- Will this do irreversible damage?
- Are permits needed?
- Is this a “vanity” sample that will reside on my bookshelf?
- When does sampling become “geovandalism”?

GEOHERITAGE SITES AND UNIVERSAL ACCESS

Great resources from the International Association for Geoscience Diversity https://theiagd.org/

- Gilley, B., Atchison, C., Feig, A. and Stokes, A., 2015. Impact of inclusive field trips. *Nature Geoscience*, *8*(8), pp.579-580.
- Feig, A.D., Atchison, C., Stokes, A. and Gilley, B., 2019. Achieving inclusive field-based education: Results and recommendations from an accessible geoscience field trip. *Journal of the Scholarship of Teaching and Learning*, *19*(2).
- Stokes, A., Feig, A.D., Atchison, C.L. and Gilley, B., 2019. Making geoscience fieldwork inclusive and accessible for students with disabilities. *Geosphere*, *15*(6), pp.1809-1825.