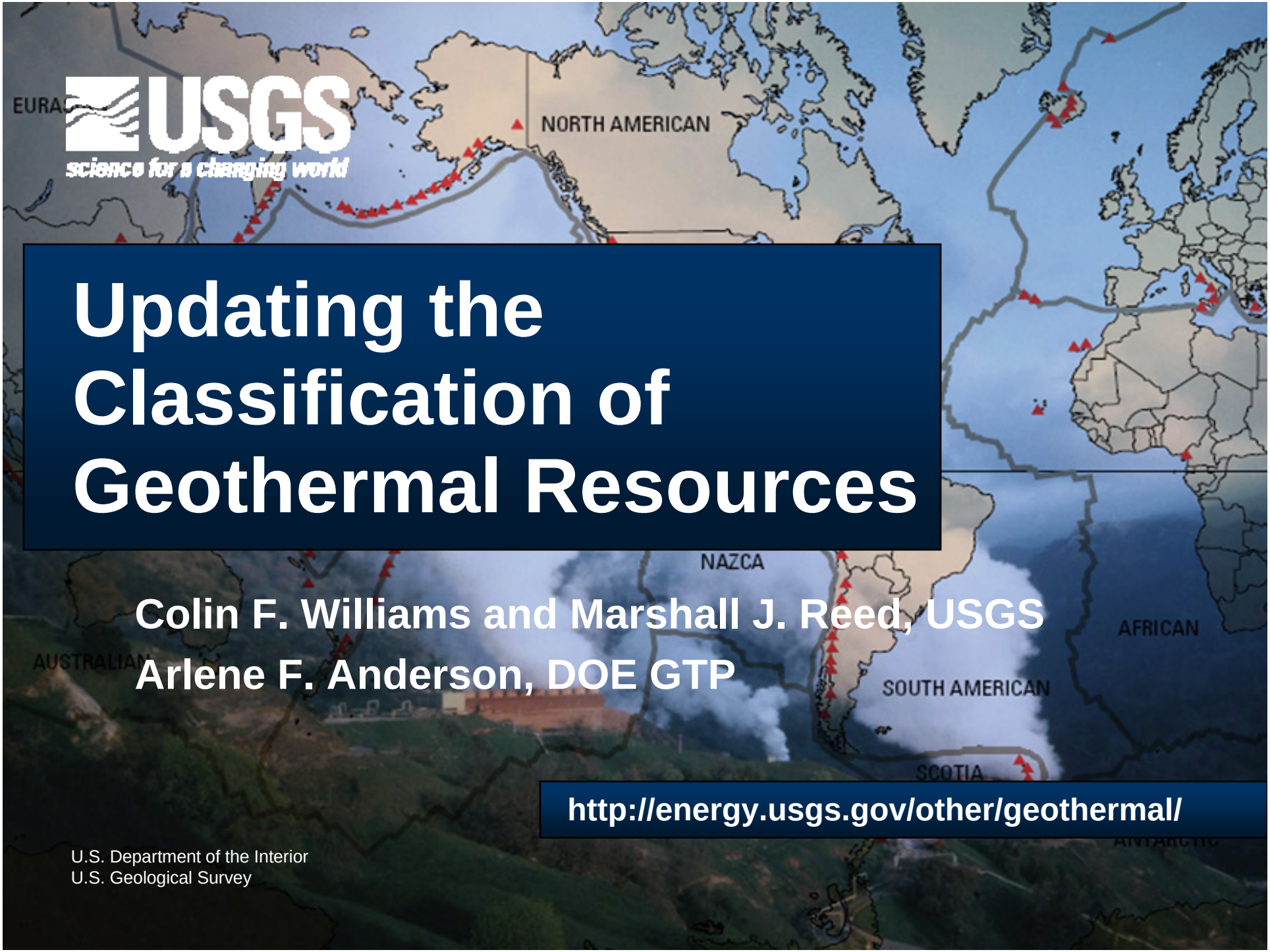

Updating the Classification of Geothermal Resources

Colin F. Williams and Marshall J. Reed, USGS
Arlene F. Anderson, DOE GTP

http://energy.usgs.gov/other/geothermal/

U.S. Department of the Interior
U.S. Geological Survey

Outline

- Background/Motivation
- Classification Project - Objectives and Dates
- Desired Characteristics
- Examples of Classifications
  - Assessment Confidence and Definitions
  - Temperature and other thermodynamic properties
  - Geologic Setting and Fluid Type
  - Convective/Advective vs. Conductive
- Community Input and the Next Steps

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Geothermal Manifestations

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Background and Motivation

- Resource classification is a key element in the characterization, assessment and development of geothermal energy.
- Stakeholders at all levels of government, within the geothermal industry, and among the general public need to be able to use and understand consistent terminology regarding issues such as location, quality, feasibility of development, and potential impacts.
- This terminology must encompass both the geological nature of geothermal resources and the practical technological and economic aspects of resource exploitation while remaining understandable to the broad community of non-specialists.

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Background and Motivation

- Developments over the past 30 years, especially advances in geothermal technology, have expanded the scope of exploitable geothermal resources beyond the earlier classifications.
- The USGS is working with DOE to engage the geothermal industry and academic partners on an update of geothermal resource classification in order to better reflect developments in geothermal technology and to serve as a effective means of characterizing, quantifying, assessing and communicating geothermal energy potential.
- There will always be diversity in the characterization of geothermal resources, and we are not attempting to impose a single approach. Consequently, a key component of this effort will be the development of tools to translate between different approaches.

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Outline

- Background/Motivation
- Classification Project - Objectives and Dates
  - Communicate Project Goals to Community
    - National Resources Council Webinar - January
    - Stanford workshop paper and presentation
  - Report on draft classification system and translation tools (June/July)
  - Public meeting and presentation at GRC (October)
  - Formally engage the international community
- Desired Characteristics
- Examples of Classifications
- Community Input and the Next Steps

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Desired Characteristics

- Desired Characteristics
  - Is simple and logical for effective communication and understanding
  - Is valid from scientific and technical perspectives
  - Meets clearly identified need
  - Is easily translated to other systems
  - Is stable over a relatively long period of time
  - Avoids misconceptions that adversely affect commercial activities
  - Eliminates gaps or overlap between categories
  - Avoids unnecessary predictions

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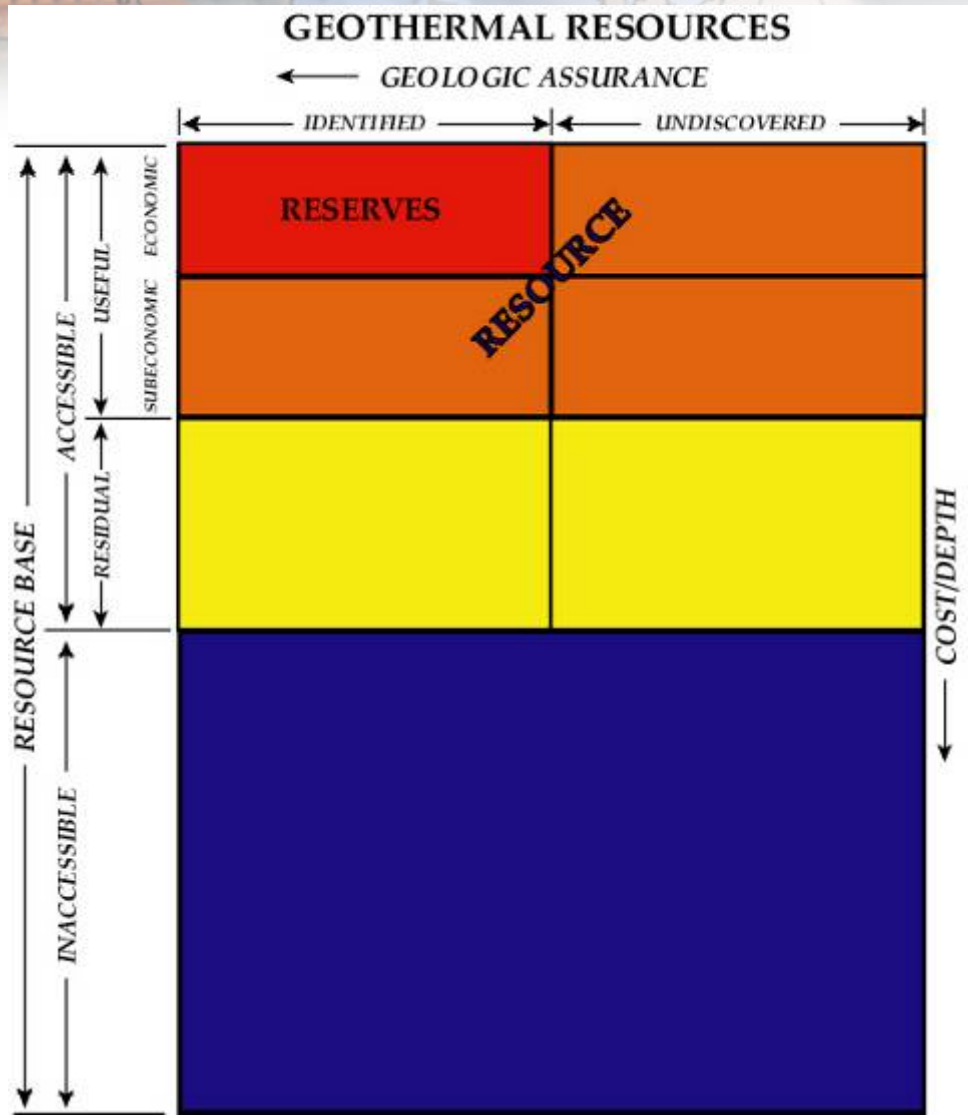
USGS Resource Assessment Concepts

Reserve – Geothermal energy that can be extracted legally and economically.

Resource – Geothermal energy that is technically recoverable and can be added to Reserves at some future time.

Resource Base – Thermal energy in the crust in specific area.



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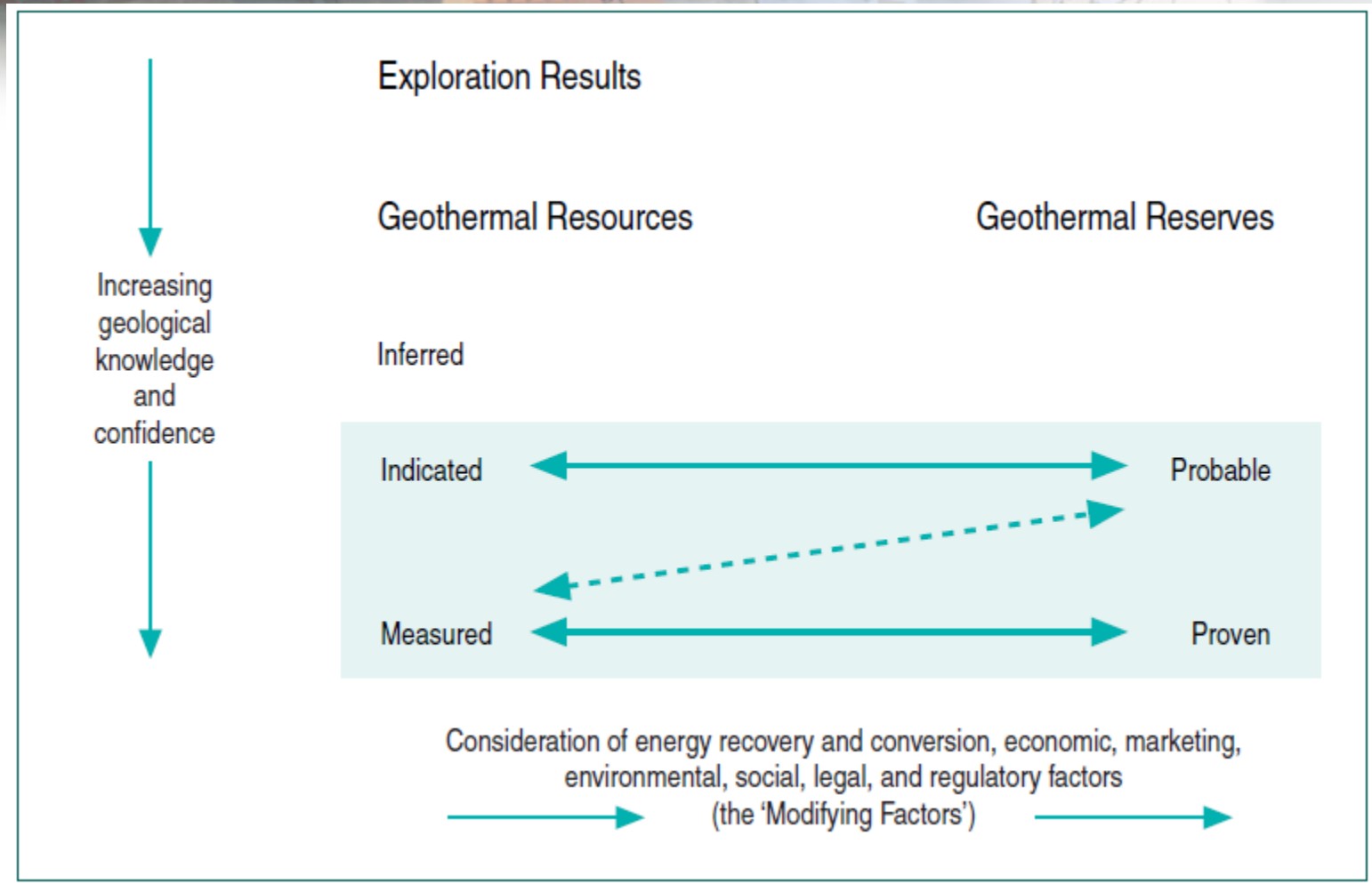
Australian and Canadian Protocol Terms



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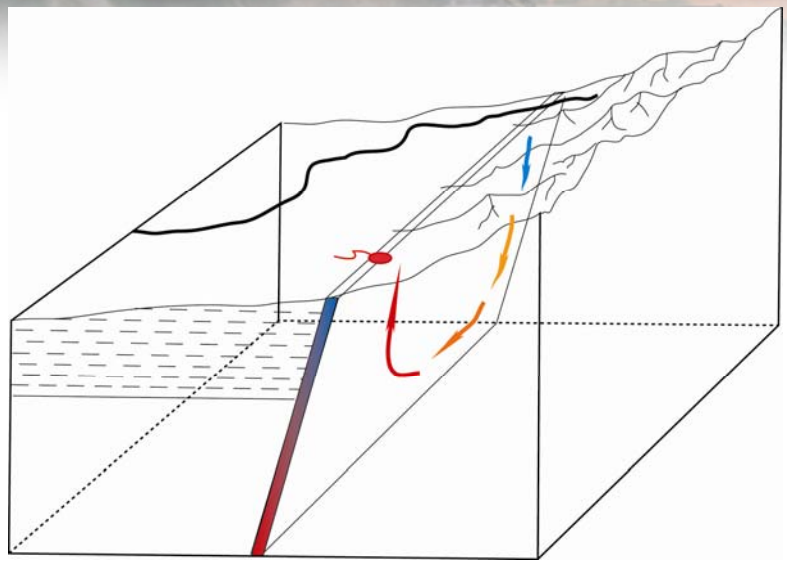
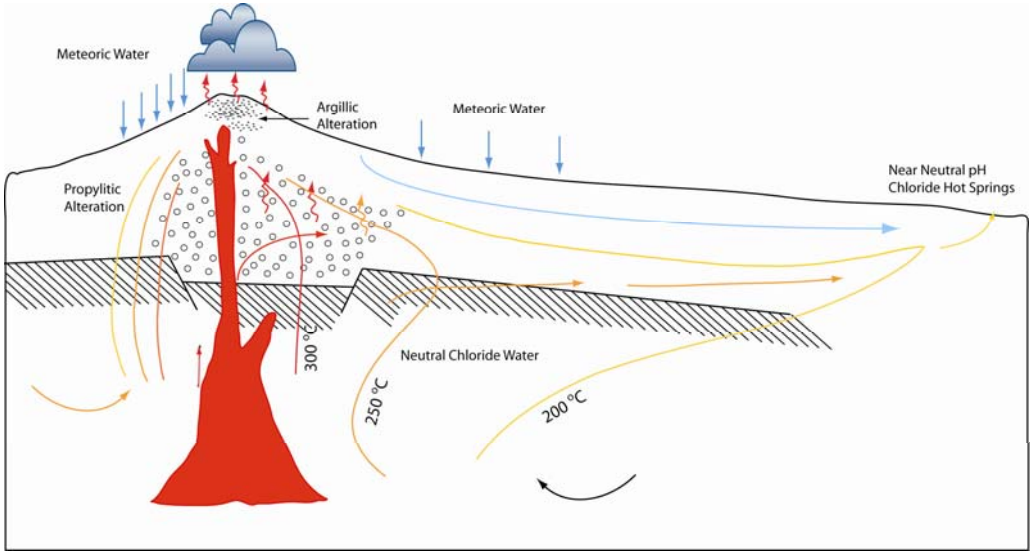
AGEA (2008)

Geothermal Systems Definitions



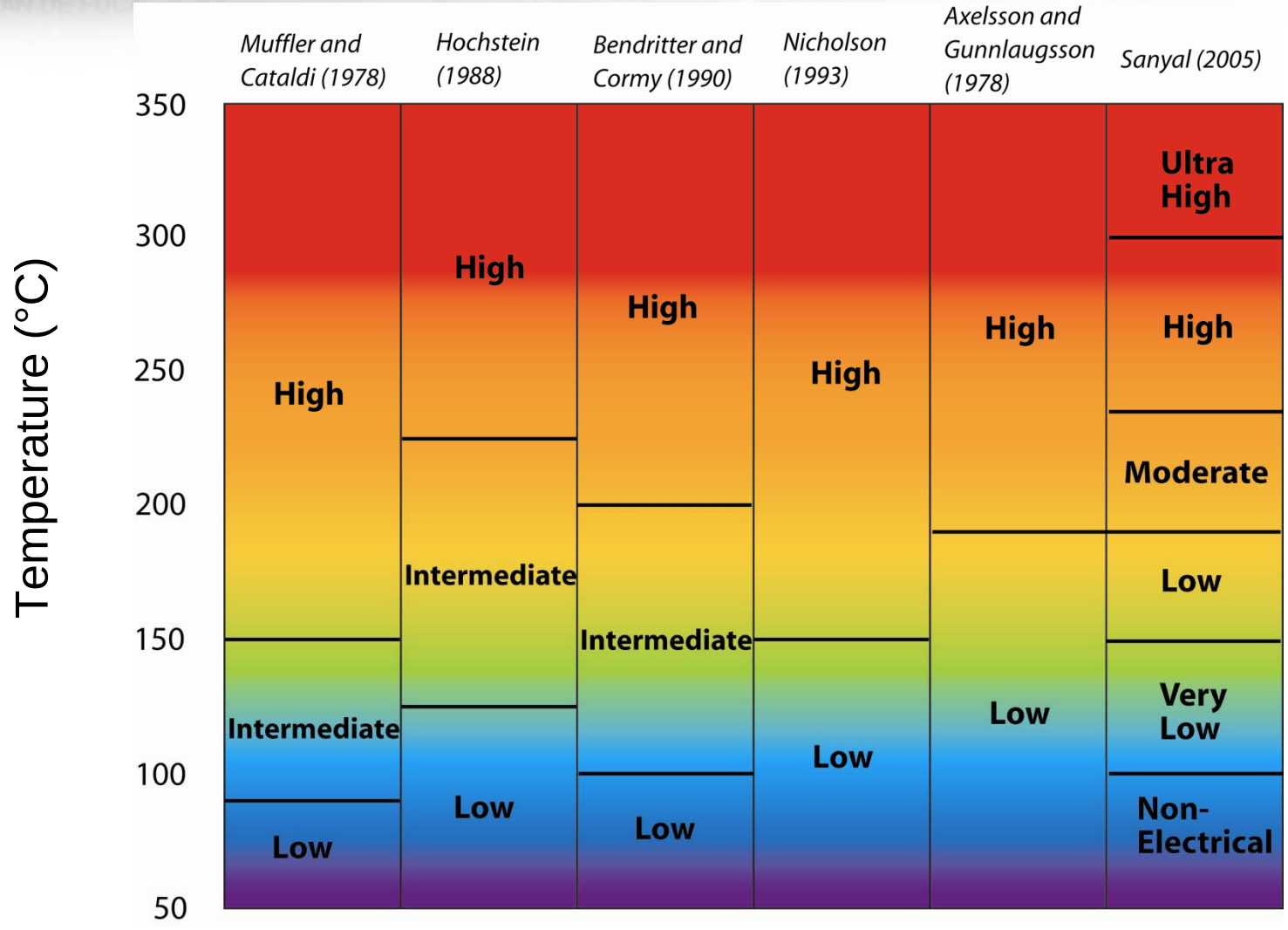


AGI Glossary of Geology (earlier USGS) definition - "any regionally localized geological setting where naturally occurring portions of the Earth's thermal energy are transported close enough to the Earth's surface by circulating steam or hot water to be readily harnessed for use."

Provisional National Geothermal Data System definition – "A body of material in the Earth from which energy may be extracted as heat in a fluid circulated through the body and transported to an external point of use."

Draft definition for this study – "A geothermal system is any localized geologic setting where portions of the Earth's thermal energy may be extracted from a circulating fluid and transported to a point of use. A geothermal system includes fundamental elements and processes, such as fluid and heat sources, fluid flow pathways, and a caprock or seal, which are necessary for the formation of a geothermal resource."

Examples of Temperature/Enthalpy Classes



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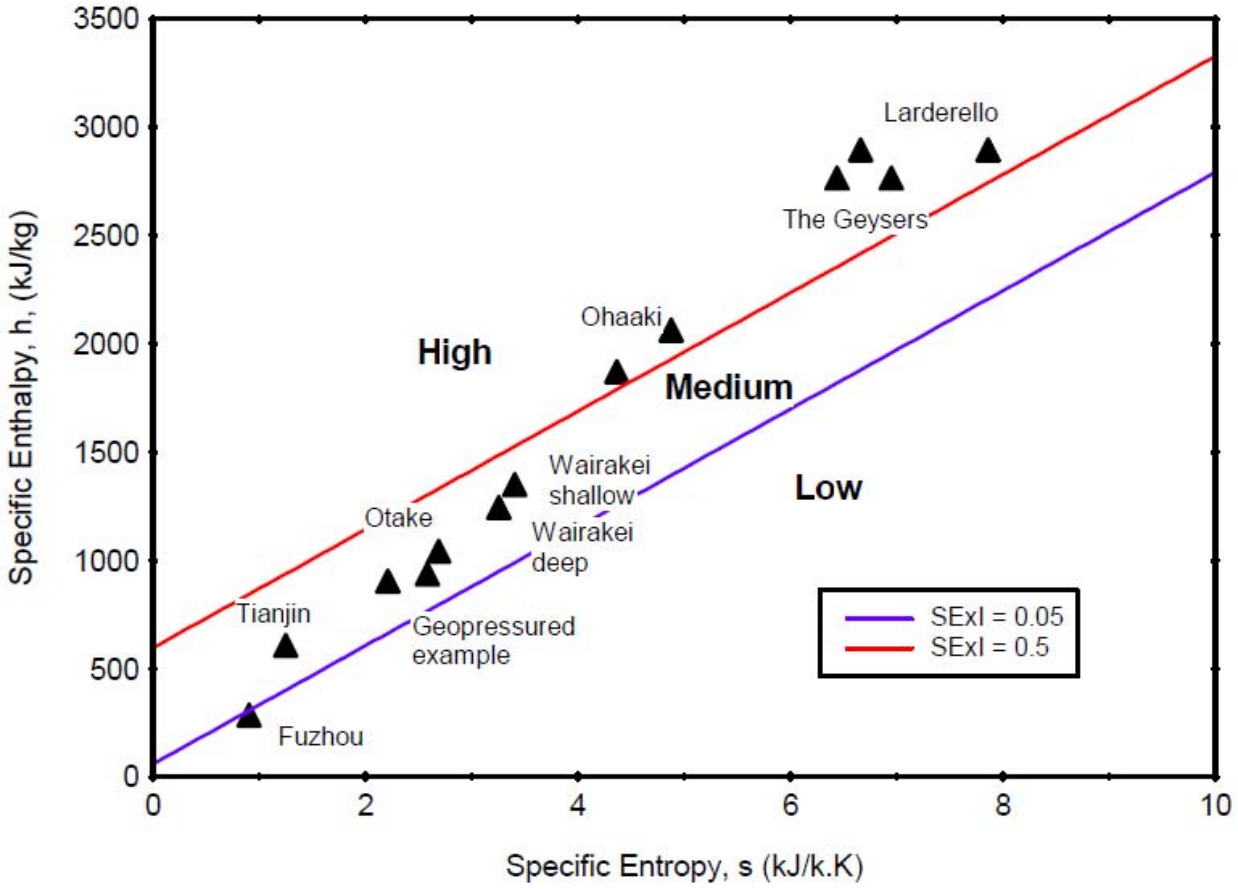
Relation of Exergy to Enthalpy and Temperature

$$E = m_{WH}[h_{WH} - h_0 - T_0(s_{WH} - s_0)]$$

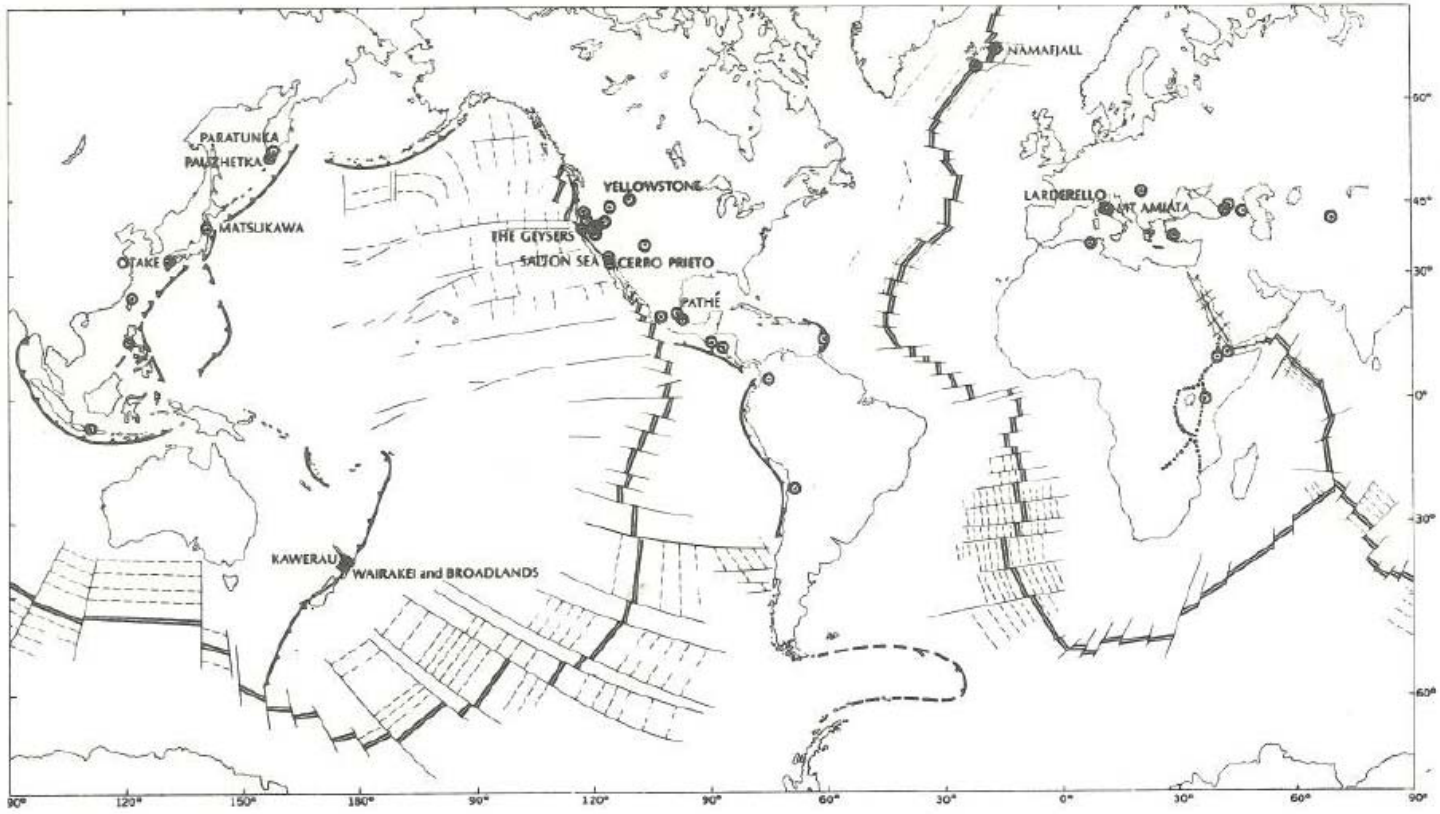
Exergy (or available work) is a also useful for classifying resources (Lee, 2001) and can be calculated easily using public domair software.



Modified from Lee (2001)

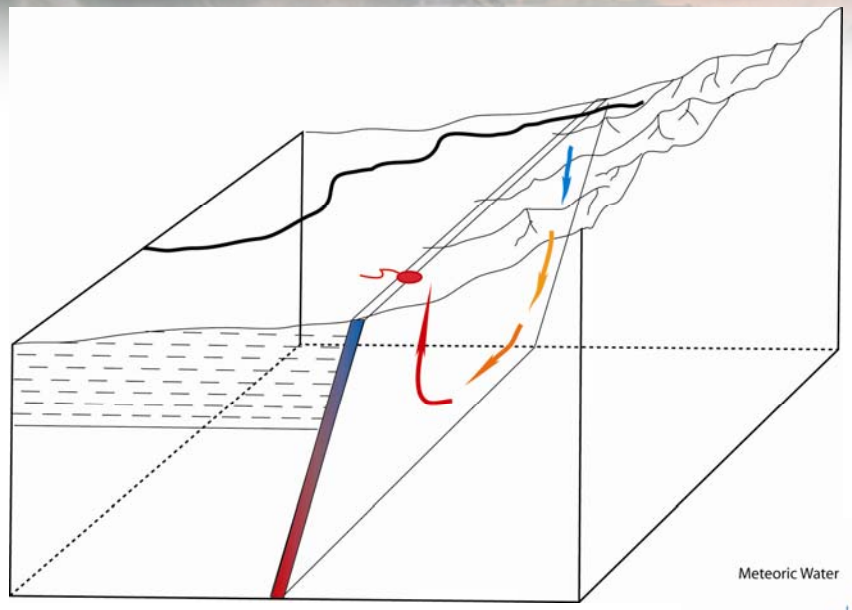
Geothermal Systems and Plate Tectonics

"Different classifications can be based on total salinity, dominant chemical characteristics, temperature range, structural and stratigraphic environments, presence or absence of permeable reservoirs, and insulating cap-rocks."



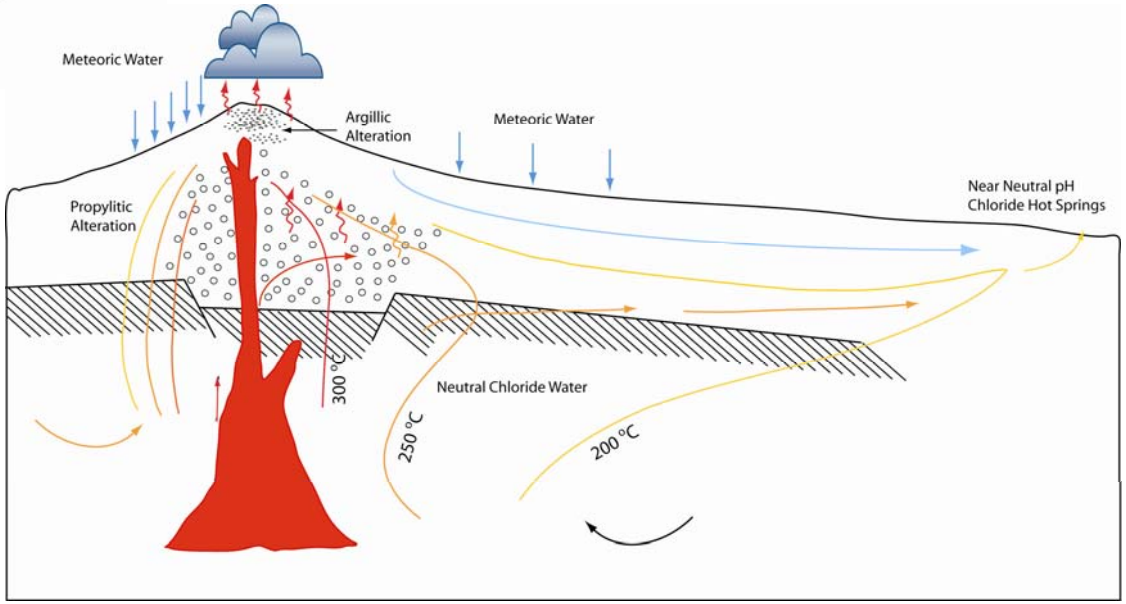
From White, D.E., 1973, Characteristics of geothermal resources, in Kruger, P. and Otte, C., Geothermal Energy: Resources, Production, Stimulation, Stanford Univ. Press.

Geothermal Systems and Geologic Setting



From Reed (1983)

Characterizing the geologic setting of a geothermal system can be an important interpretive tool in evaluating geothermal resources, but it is important to remember the diversity of characteristics.



From Henley And Ellis (1983)

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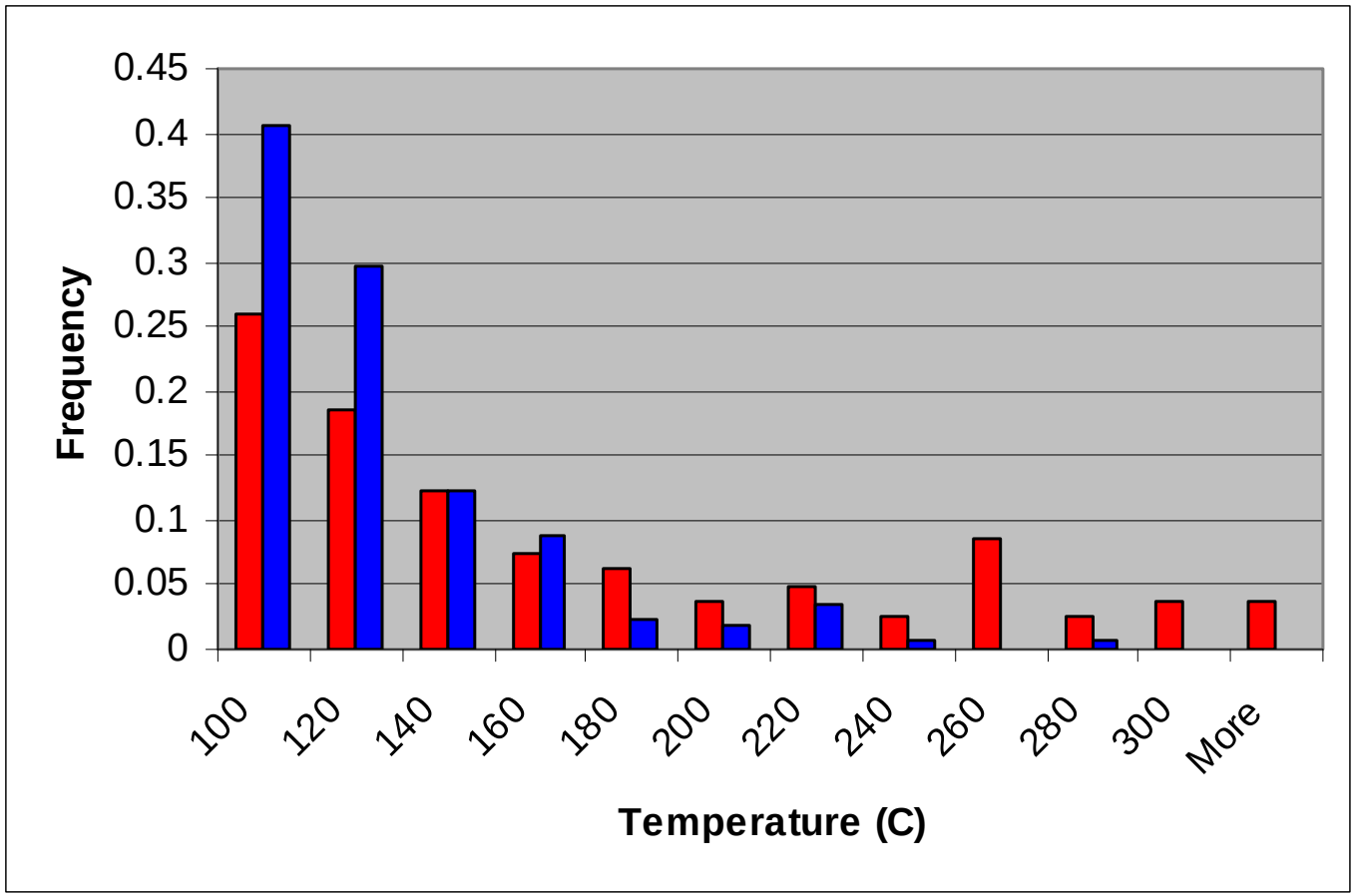
Magmatic and “Amagmatic” Systems - 1

On average, U.S. geothermal systems associated with magmatic activity (red) are hotter than those in other settings (blue).



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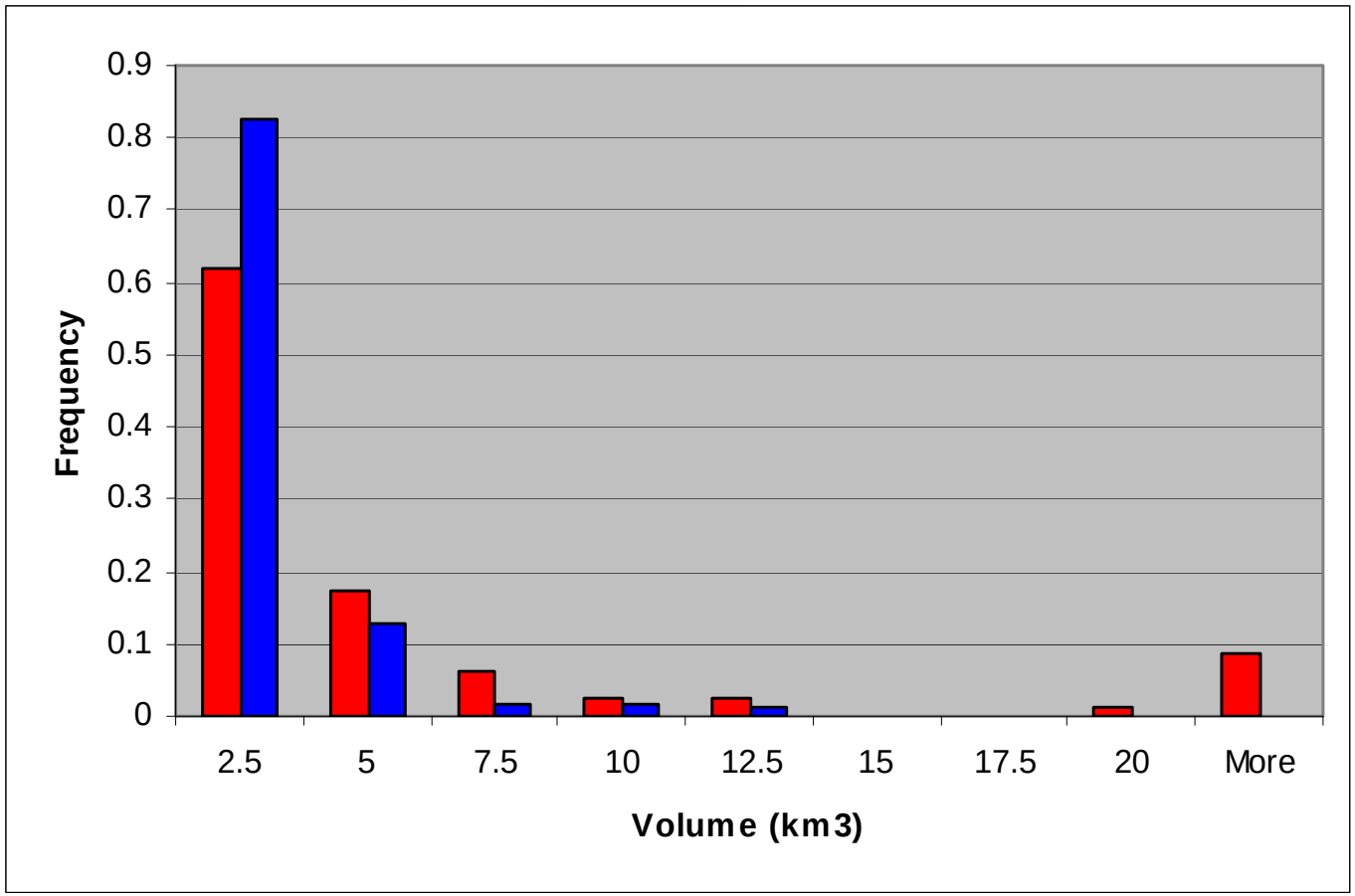
Magmatic and "Amagmatic" Systems - 2

Similarly, geothermal reservoirs associated with magmatic activity (red) are often larger than those in other settings (blue).



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Geothermal Resources by Geologic Setting from Paul Brophy, EGS Inc.

Defining resources by geologic setting is critically important for both exploration and assessment.

Exploration Setting	Topography	Climate	Depth to Resource (m)	Surface Manifestations	Permeability	Environmental or Political
Type A: Magma-heated, Dry stream Resources *Ex: The Geysers*	Rugged? Mountainous?	Variable?	Usually deep (2500 - 4000)	Restricted	Low to moderate fracture permeability	None
Type B: Andesitic Volcanic Resources *Ex: Philippines, Indonesia, Central & South America*	Usually mountainous	Variable-usually high precipitation	Deep to moderate	Restricted-depending on depth and shallow ground water	Low to moderate fracture permeability – often high	Some countries with political issues
Type C: Caldera Resources *Ex: Medicine Lake, Valles Caldera, Los Humeros, Yellowstone*	Ring fractures often rugged, with gentle floor topography	Variable?	Moderate to shallow (- 2500)	Common	Low fracture permeability-often think tuff units	Often very scenic-sensitive
Type D: Sedimentary-hosted, Volcanic-related Resources *Ex: Imperial Valley*	Usually low topographic	Arid, low precipitation	Intermediate (2000 – 3500)	Very restricted	Variable?	Usually limited?
Type E: Extensional Tectonic, Fault-Controlled Resources *Ex: Great Basin*	Rugged on upthrow, low on valley floor	Usually dry with low precipitation	Usually deep (2500 – 3500)	Usually restricted to fault traces	Dominantly fault controlled	None
Type F: Oceanic-ridge, Basaltic Resources *Ex: Hawaii & Iceland*	Rugged to flat?	Islands – high precipitation	Shallow (1000 – 2000)	Common	High horizontal permeability, variable vertical permeability	Environmentally sensitive

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Conductive, sediment-hosted resources

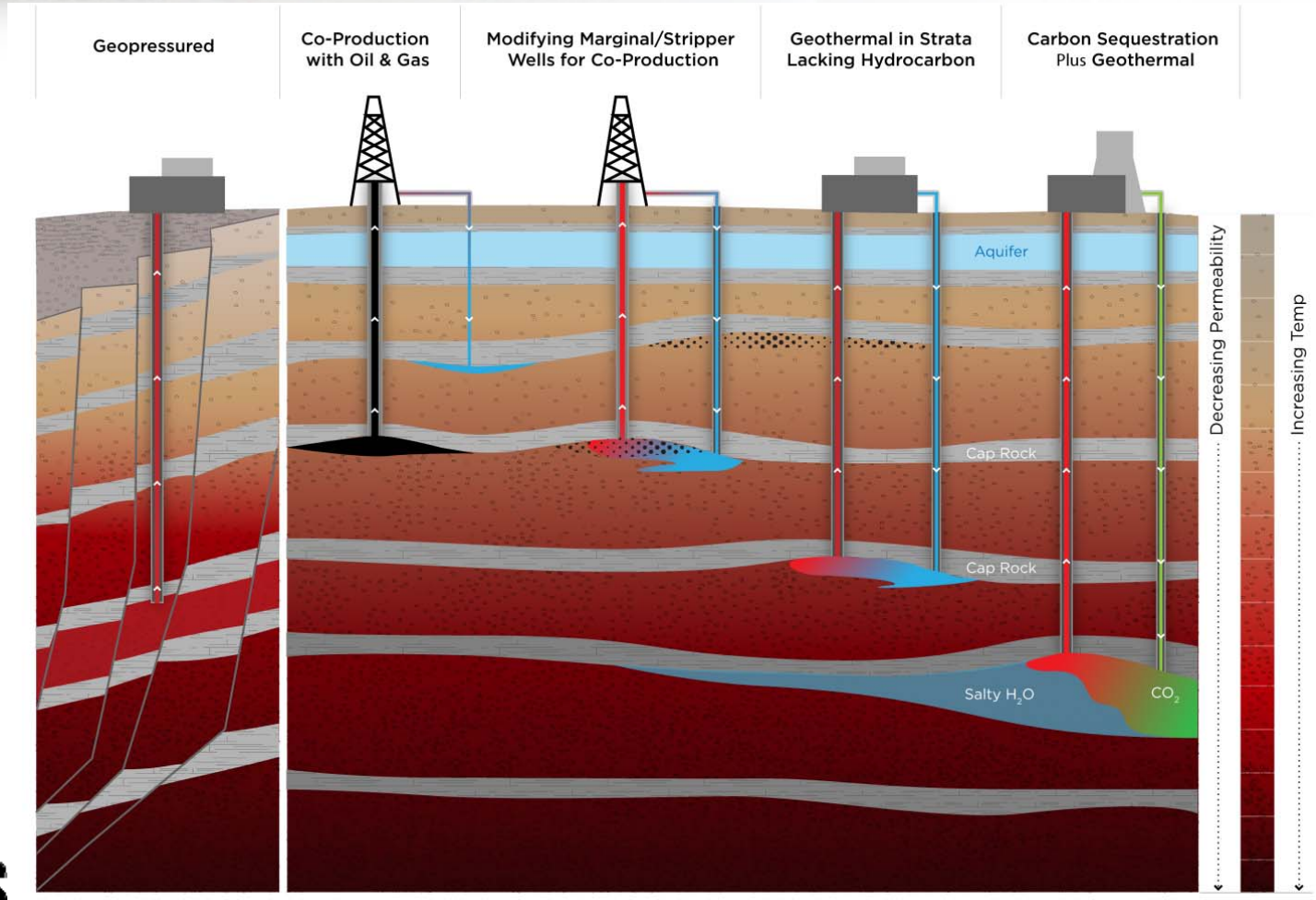

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Image courtesy of Alison LaBonte (DOE)

Enhanced Geothermal Systems (EGS)

Draft definition for comment – "Enhanced Geothermal Systems comprise the portion of a geothermal resource for which a measureable increase in production over its natural state is or can be attained through mechanical, thermal, and/or chemical stimulation of the reservoir rock. In this definition there are no restrictions on temperature, rock type, or pre-existing geothermal exploitation."

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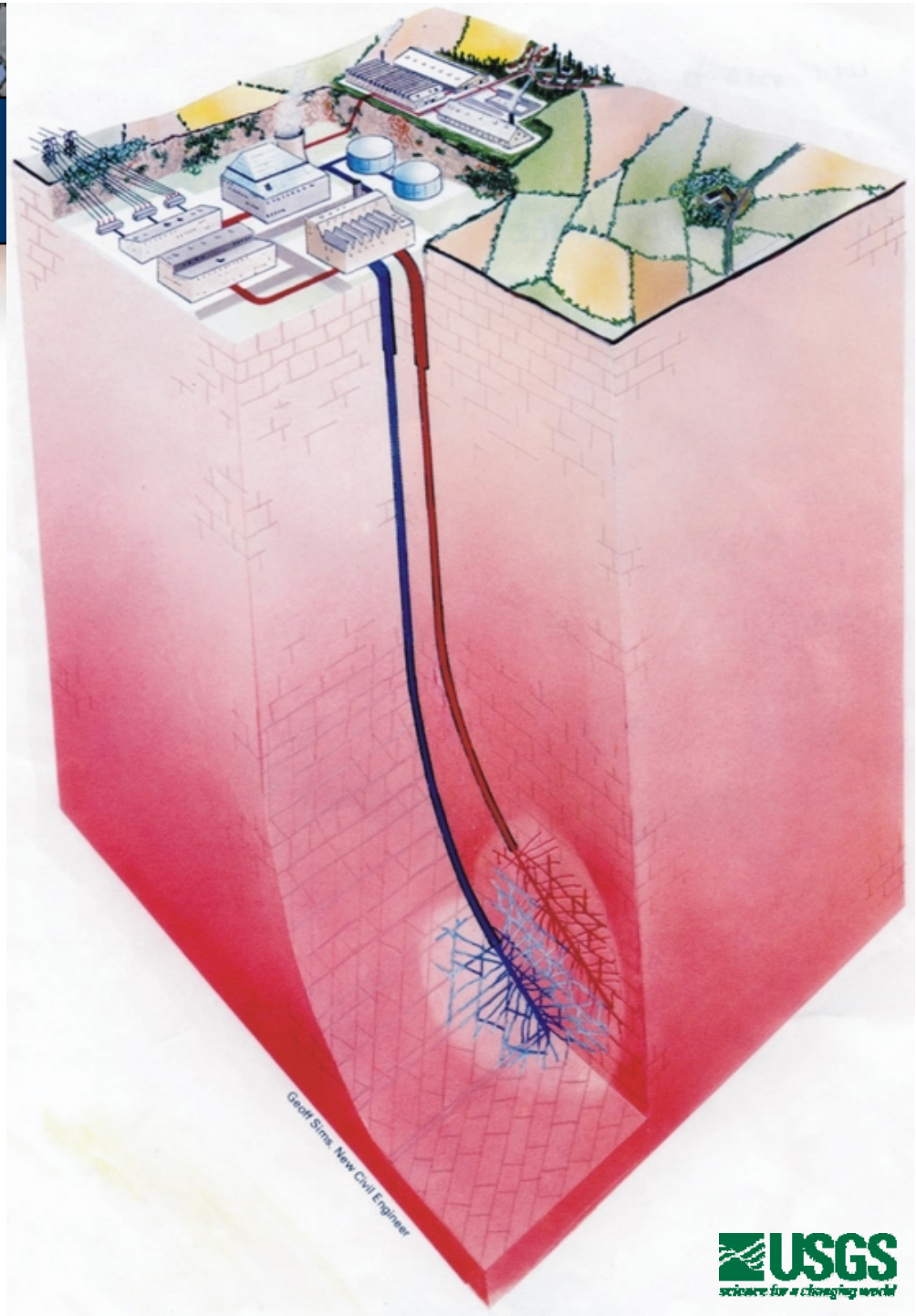

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science for a changing world

Outline

- Background/Motivation
- Classification Project - Objectives and Dates
- Desired Characteristics
- Examples of Classifications
- Community Input and the Next Steps
  - Share your opinions, priorities and needs
  - Opportunities to evaluate classification concepts and translation tools in the summer
  - Meeting at GRC
  - Contact **colin@usgs.gov and/or Arlene.Anderson@ee.doe.gov**

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Input from Dave Ponce (USGS), Peter Galanis (USGS), Steve Richard (AZGS) and many attendees at the January NRC Webinar greatly appreciated.

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Thank You

colin@usgs.gov