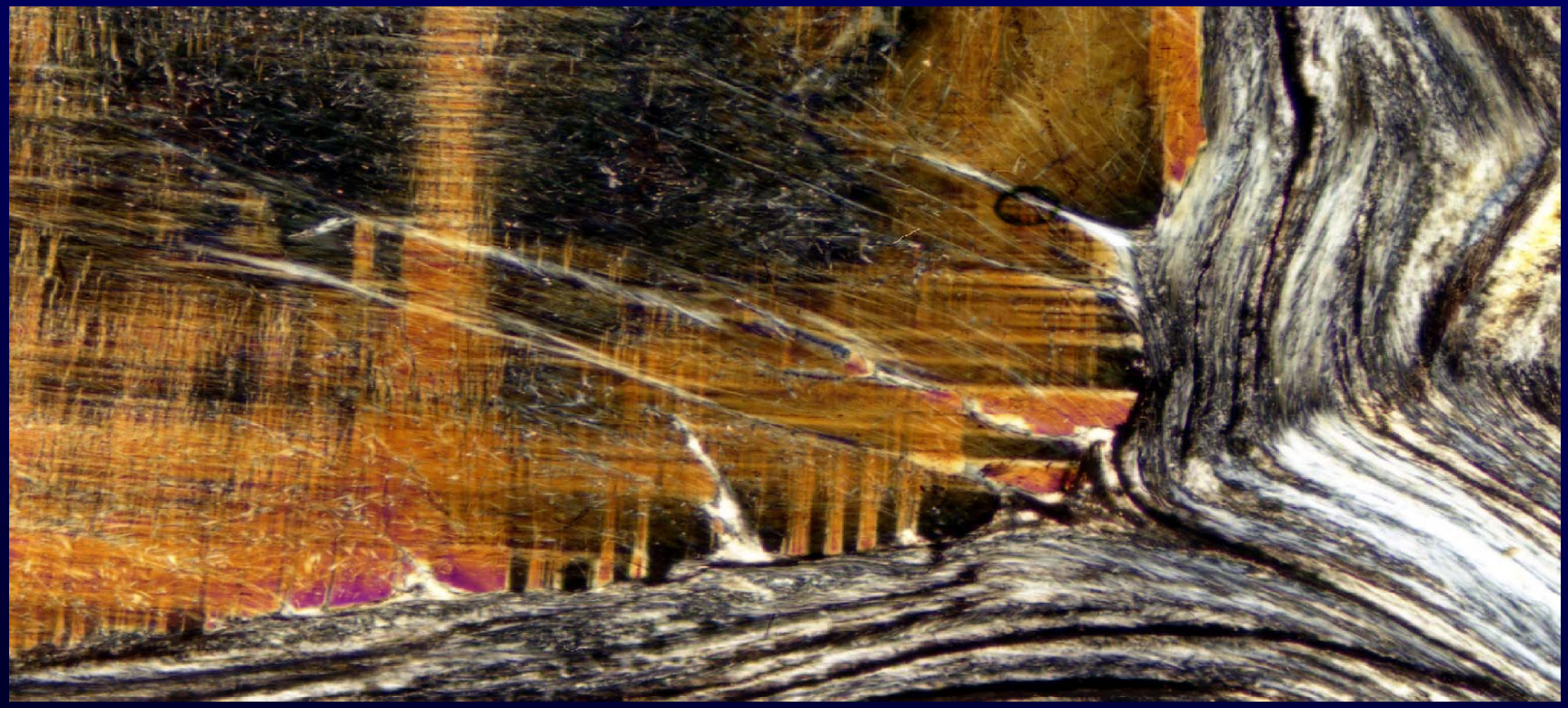
Deriving Meaning from Complex Geosystems

Simplifying Complexity



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Visual Interpretation of Complex Systems

Elbaite-Albite-Fluorite, Pakistan, 10”
Photo © and courtesy of Jeff Scovil .

Developing meaning

- Micro- to macroscopic
- Space and time scales
- Coupling with feedback
- Real to analog world
- Physical models, time lines

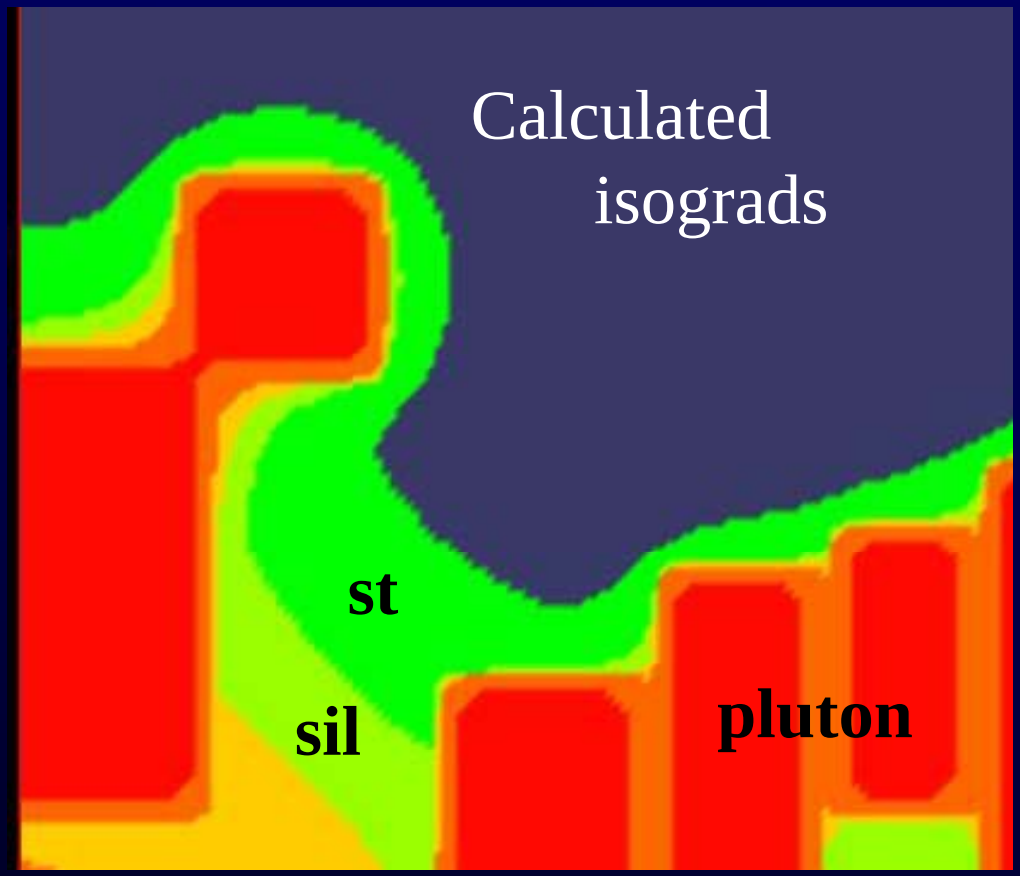
Principles

- Prior Knowledge
- Coherence - match nature
- Apprehension - familiar is easier

Methods for meaning

- Rock slabs
- Computational experiments

Visual Communication – Why?



2D x-y slice at z from a 3D computational model of a 25km x 25 km domain, showing maximum temperature attained over a 3 million year period. (1 GB of data)
Image source: B. Dutrow

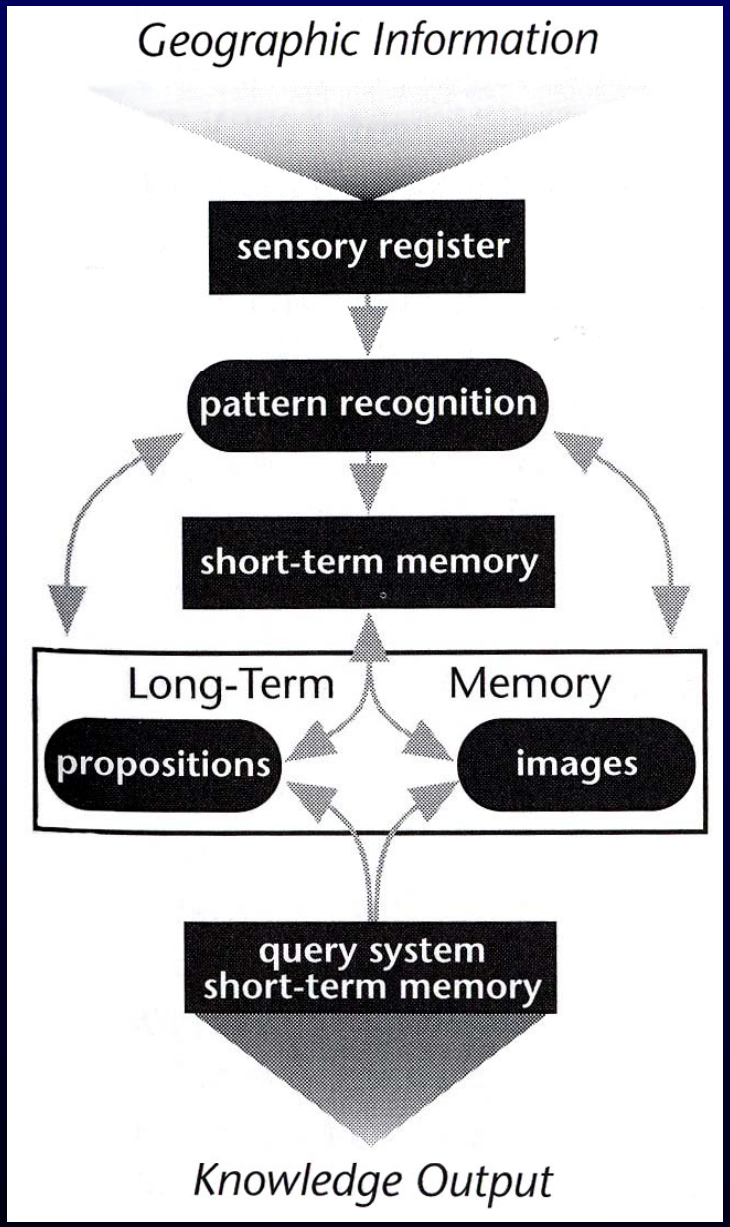
- **To depict data efficiently**
- **To allow observation of processes over inaccessible scales: temporal, spatial**
  - **Computer visualization**
- **To facilitate comprehension and learning**
- **To test hypothesis**
  - **Determine cause, effect**
- **To add interest**

Visual Communication and Literacy

Field Trip in Maine with visuals depicting the world around us. *Image: B. Dutrow*

- **Nearly 65% of students prefer visual learning**
  - data from 2400 students surveyed (Tversky et al)
- **What does one "see" and interpret in visuals?**
  - Is reading a visual as easy as reading a book?
  - Need to develop the skill sets for interpretation
  - See what we are taught - the social norm

Development of Visual Literacy

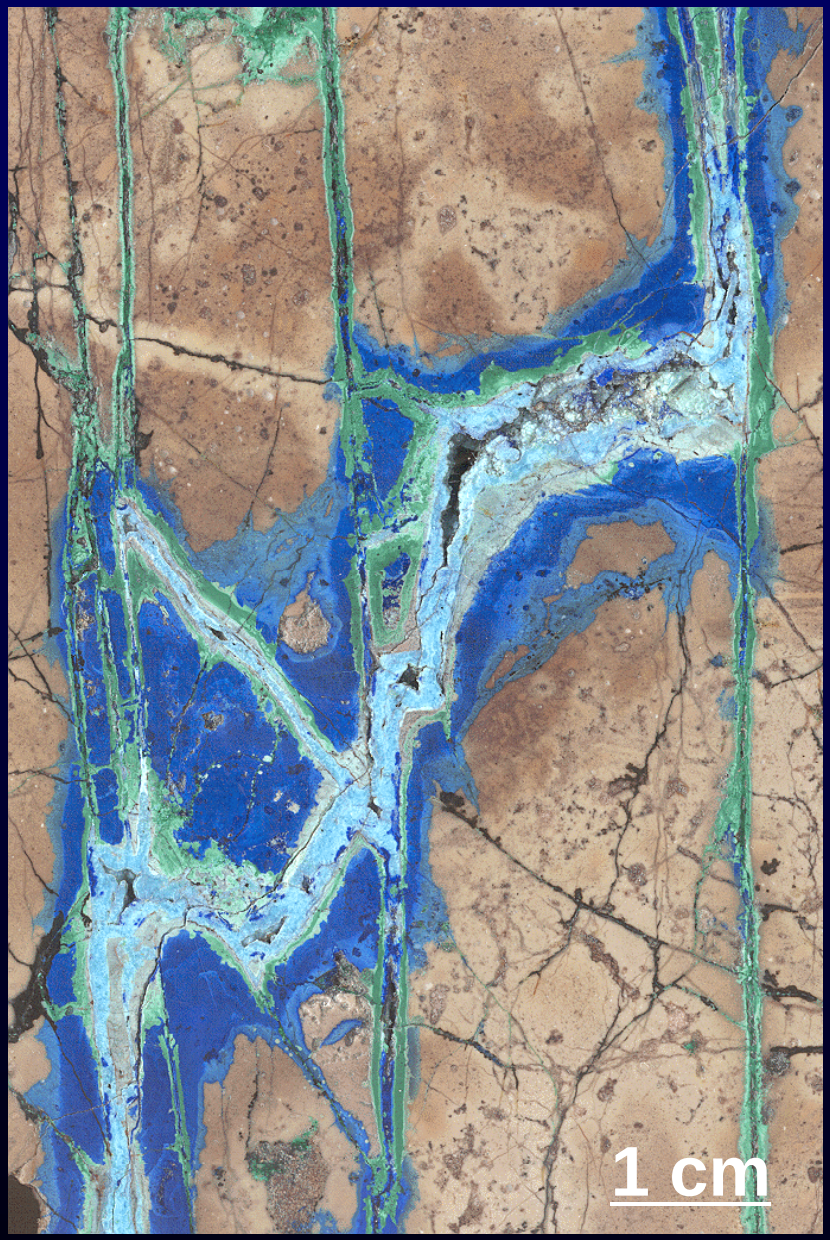


Human information system model.
From MacEachren,1995; after Peterson, 1987

Visual memory derives from:

- reading visual signals,
- translating into understandable information, forming a mental image
  - Discriminates, organizes, prioritizes, distorts
- in short term memory,
  - Encodes, reorganizing loop
- committing to long term memory,
- creating knowledge

“Unpacking the Meaning”

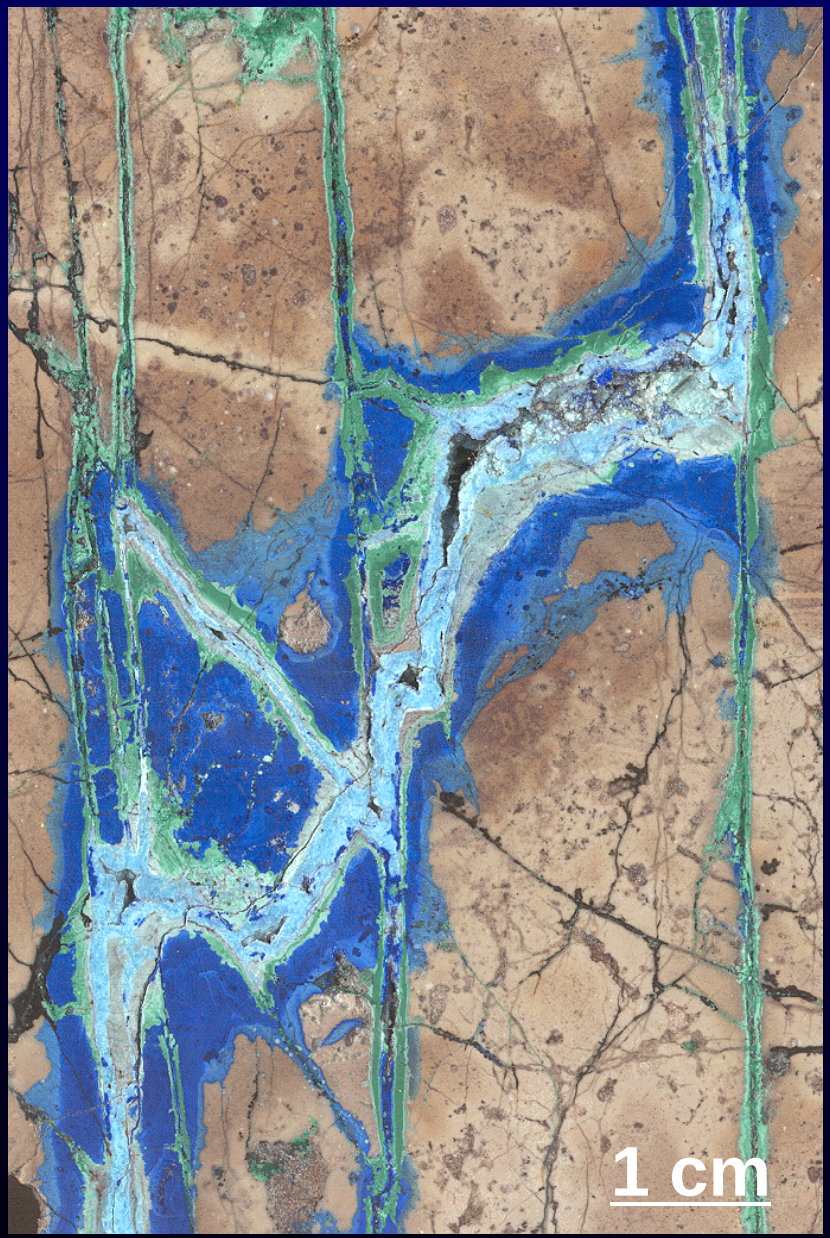


Interpret this image

Visually contained in this rock slab is a complex system that embodies:

- **Non-linear coupled processes: Physical, chemical, and mechanical acting on the rock,**
  - **chemical reactions,**
  - **mechanical work,**
- **Coupled interactions**
- **Reflect the prior state**

Visual Interpretation: Prior Knowledge



Interpret this image © B. Dutrow

- **What one sees, derives from prior knowledge**
  - **Memory is searched for similar depictions**
  - **Geologists,**
  - **Engineers,**
  - **Social Scientists**
  - **Artists ‘see’ differently**
- **Experts and non-experts do not “see” equivalent images**

“Unpacking Meaning” – Let’s test this

Interpret this image

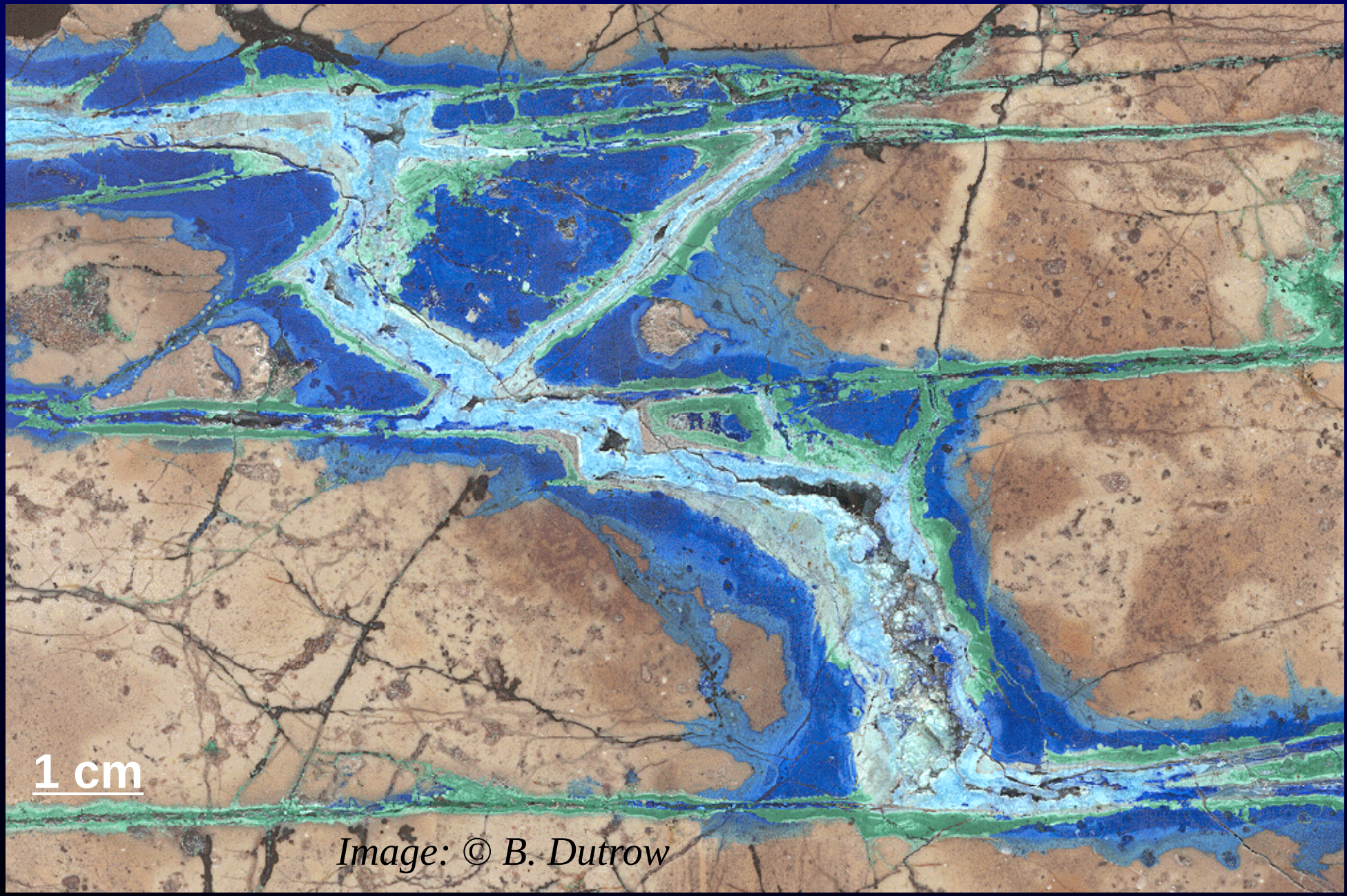
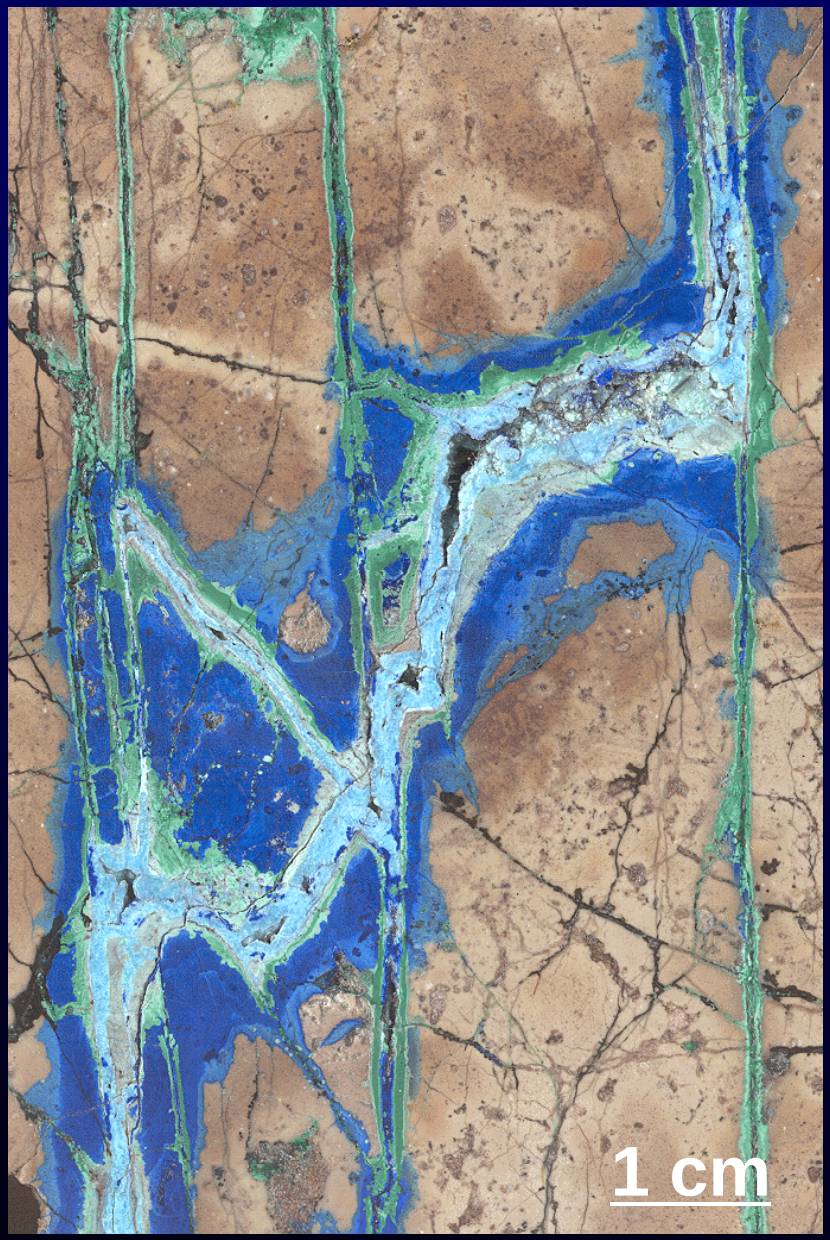


Image: © B. Dutrow

Visual Interpretation: Prior Knowledge



Interpret this image © B. Dutrow

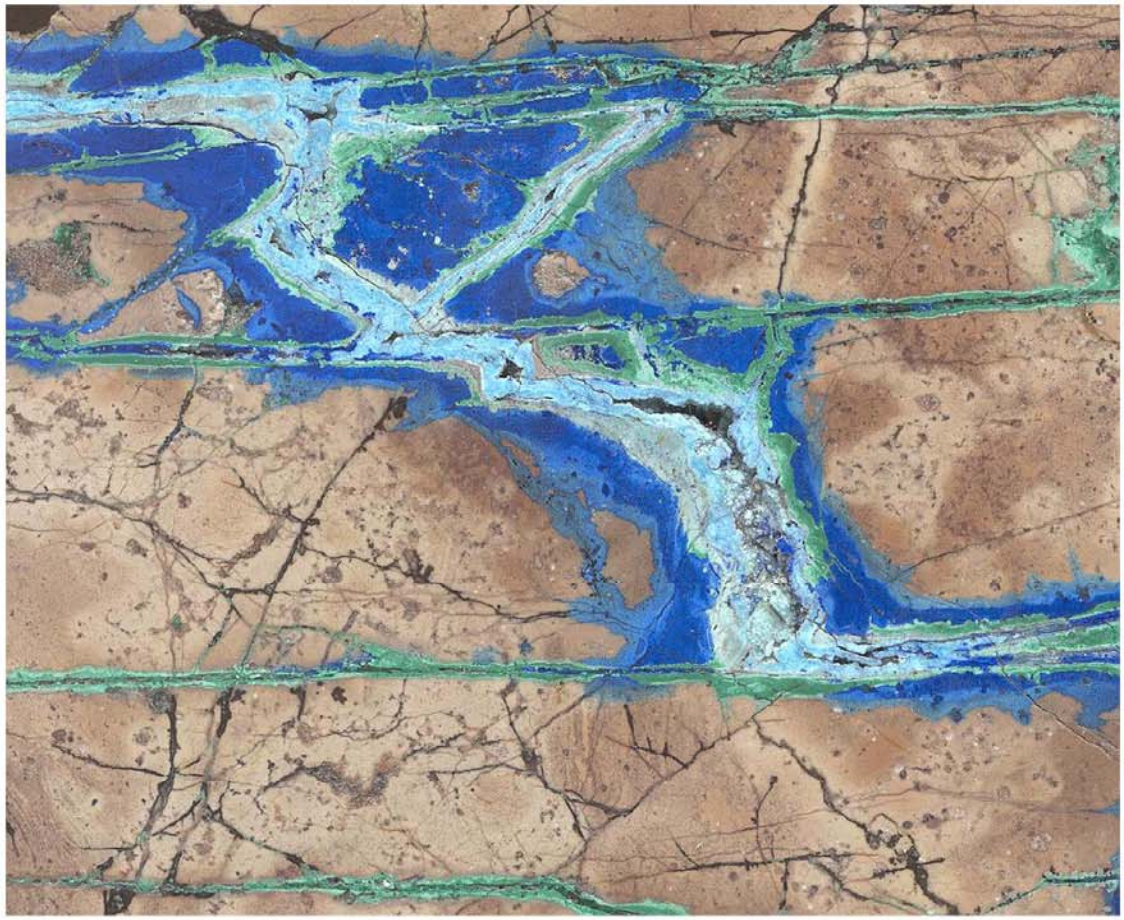
As we interpret – try to bring similar meaning together

- **Geologists "see" minerals,**
- **Engineers "see" fluid flow paths,**
- **Artists 'see' ??**

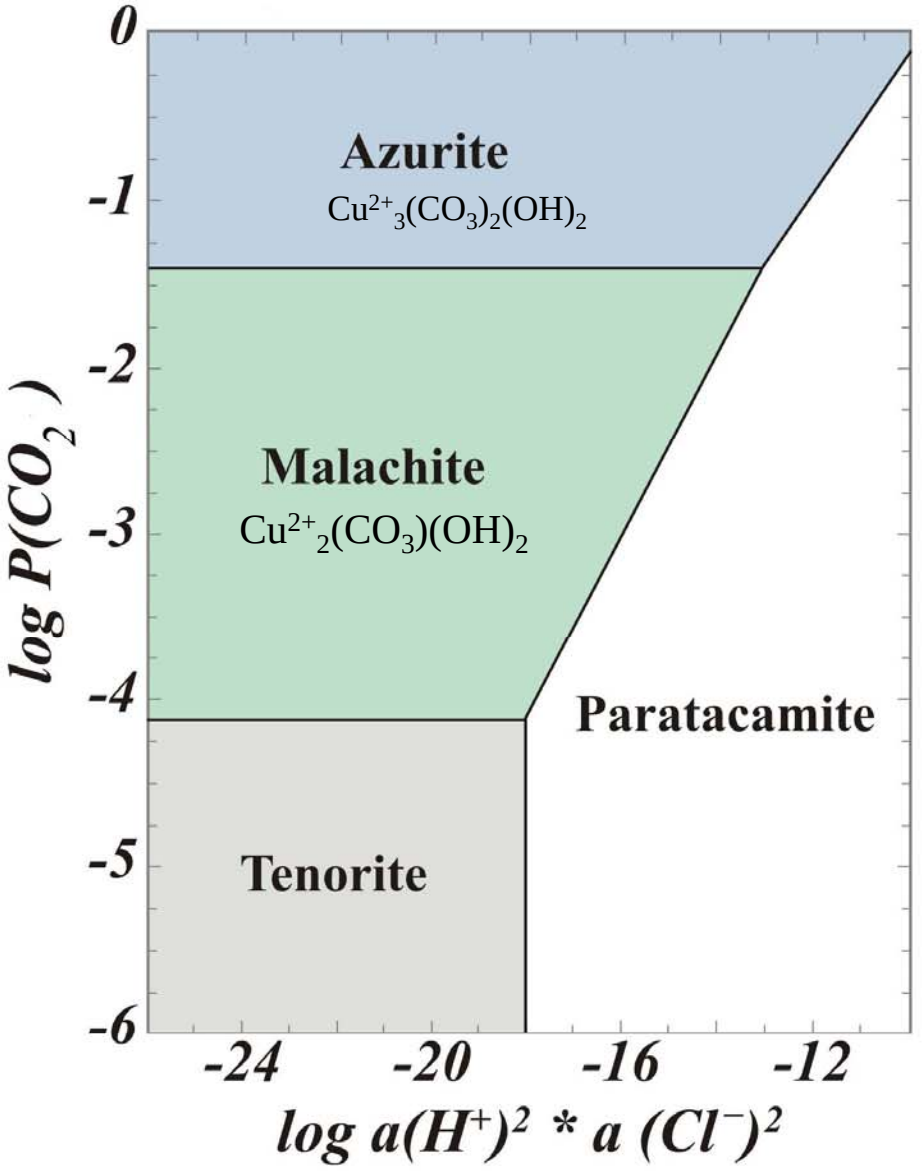
- **Continue the interpretation**

Rock to the Fluid Composition

Congruency - be consistent with physical reality



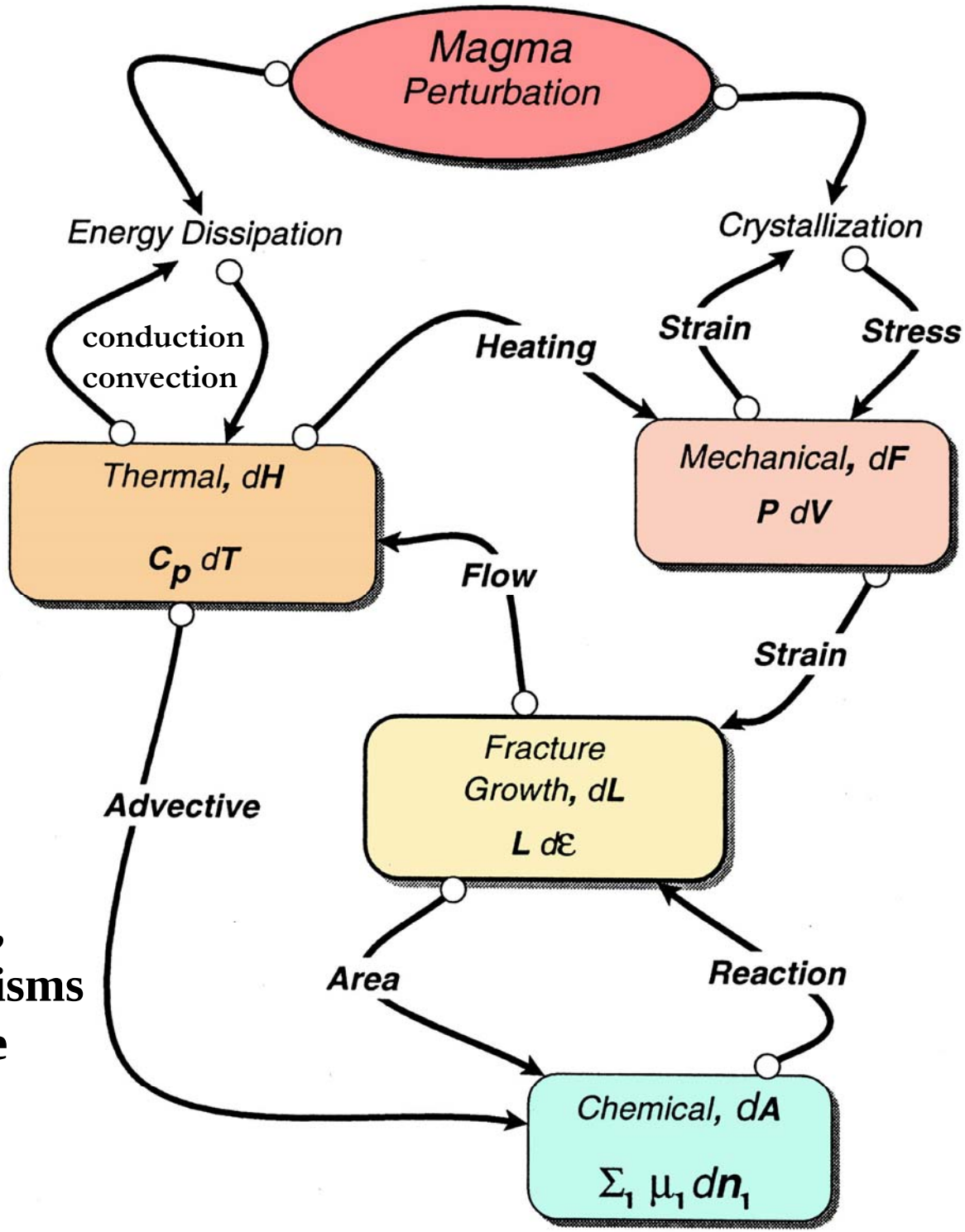
Azurite → malachite → chryscolla precipitation separated by episodes of fracturing



Schematic of non-linear coupled processes related to dissipation of thermal energy: magma - fluid interactions

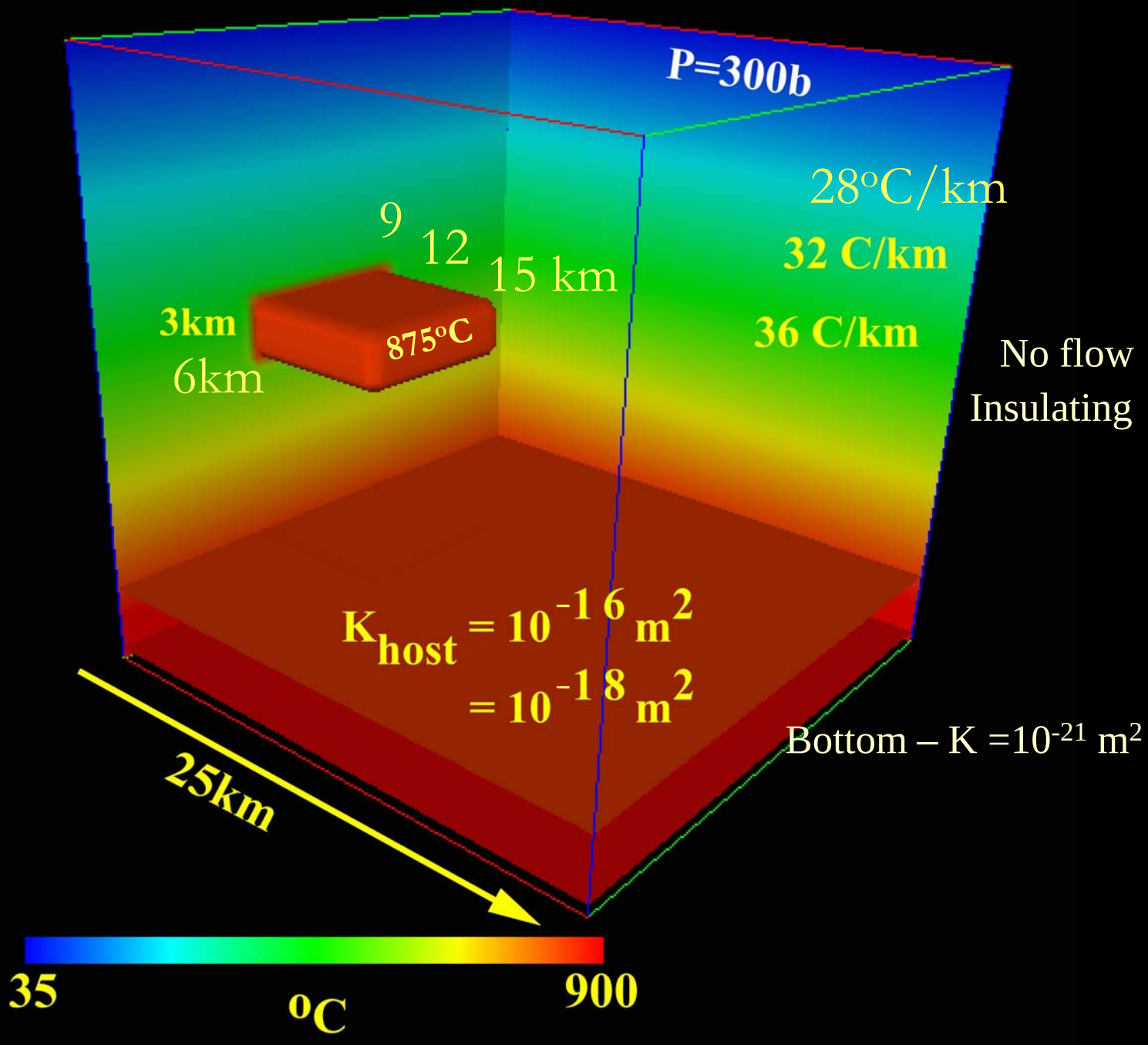
Levels

Energies, Rate mechanisms of change



From Norton & Dutrow, 2001, Geochimica CA

Computational Example of Coupled System



Temperature Evolution – Drives coupling

0 – 3 Ma

500^{o}C isotherm

K = 10^{-16}m^{2} (convective)

3 km thick, 12km, 32^{o}C/km

Pluton

500^{o}

C

Heating Rate across 500°C isotherm

0 – 3 Ma

$K = 10^{-16} m^2$

12km, 32°C/km
3km thick

°C/yr

Summary

- Our background framework dictates what we see and interpret (Prior Knowledge)
  - Each of our perspectives/expertise reflects our background/bias
    - Also the need for doing collaborative work, using alternate approaches to bring different biases
    - Scientific breakthroughs come from people unfettered by same bias, from different background (T. Kuhn)
  - Rich megacognitive skills are required for interpretation of rock and movie (Mogk)
  - Observer must reconcile new forms and function with what is in mental map to “make sense”
  - Need to facilitate the teaching from expert to novice

Summary

We need to promote self-efficacy among our learners (Mogk)

- **they have to have the cognitive skills and confidence to look at a complex natural phenomena (vein) or model (4D movies) and be able to extract order and meaning out of chaos/complexity**

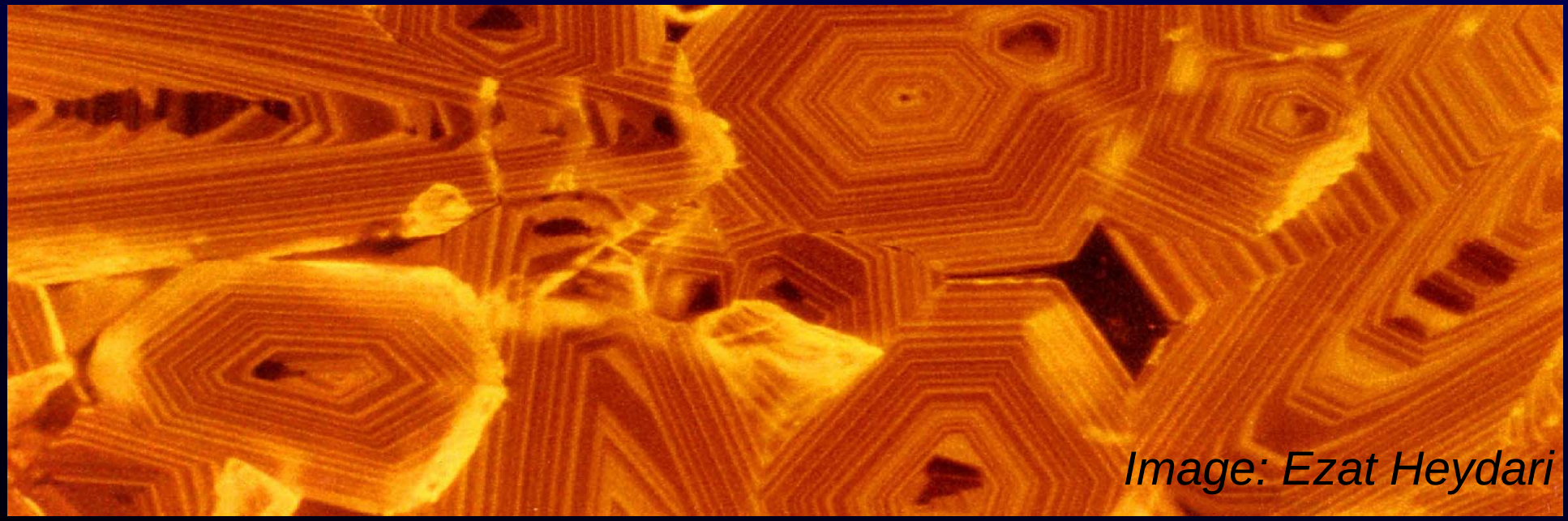


Image: Ezat Heydari

Summary

- Using “real” rock systems, develop layers of meaning sequentially
  - Visual interpretation and pattern recognition
  - Attention to detail permits interpretation of processes (prior knowledge)
  - Place this in a conceptual framework
- Move to theoretical, then computational framework for understanding non-linear coupled progress and how a real rock develops
  - Provides practice moving from real to conceptual and back