Overview of Geoscience Employers Workshop Outcomes

General thoughts on concepts: From Geoscience Employers Workshop

Systems Thinking

How systems work and interact

- Atmosphere: Climate, Weather, Ocean-atmospheric circulation
- Hydrosphere: Ocean, Ice, Surface water, Groundwater
- Lithosphere: rock cycle, deformation, structure, tectonics
- Pedosphere/surface: Geomorphic, Erosion, and Surface Processes, Landscape evolution
- Biosphere: Paleontology, Ecosystems
- Solar/Earth Interactions: Tidal, Climate; planetary geology
- Human/Societal Coupled to Earth: Natural Resources, Energy, Anthropomorphic Climate Change, Natural Hazards
    - Influence of geology on society
    - Influences of society on earth processes

Processes

- Geochemical Cycles: C, H2O, N, P
- Thermodynamics: energy, kinetics, diffusion, heat, mass transfer, fluid flow
- Geomechanics/Stress State/Rheology
- Geological Time/Earth Evolution
- Plate Tectonics/Geodynamics
- Tectonic Processes
- Depositional Processes
- Crystallization Processes

Tools

- Statistics/Uncertainty/Probability
- Mathematics (differential equations, linear algebra)
- Field Methods
- Geography and spatial thinking
- Seismology/Geophysical sensing
- Potential Fields
- Remote Sensing
- Analytical/Numerical Modeling
- Age Dating
- Instrumentation
- Cartography

Geoscience concepts: Identified by 1st Summit, validated by survey; granularity added at Geoscience Employers Workshop

Earth as a Complex System

- Nonlinear complex systems

    - Size of systems – complexity of scale and interactions
    - Feedback loops, interactions, forcings
    - Implications and predictions
- Energy, mass, fluid transport (movement and flow), residency, and cycles
- Work/changes that affect the Earth's systems
    - Human drivers and impacts of change, Anthropocene
    - Environmental transitions
    - Scales of change
    - Using the present processes to infer past processes: Advantages/risks
- Solar system interaction

Deep Time

- Conventional concepts of geologic time
    - Paleontology, superposition
    - Relative vs absolute age
    - Tools to determine absolute age (radioisotopes, stable isotopes, etc.), precision of data, limitations
    - Extrapolate from lab to field
- Impact on processes
    - Time scales over which processes are relevant
    - Specific periods in geologic time that are critical for different processes
    - Impact of time on "Earth" events (i.e. weathering, geodynamics, resources, etc.)
- Events and rates
    - Duration, frequency, magnitude and residence time
    - Timing, scale, sequencing and rates of change
- Temporal reasoning

Climate Change

- What is climate change? Geologic scale vs. present change
    - Significant climate change in geologic past
    - Relevant space and time scales
    - Continental vs local scale change
    - Proxy records
    - Rate of climate change; rapid change
- Driving forces and causal mechanisms
    - External forcing vs. internal forcing
    - Dependence upon spatial and temporal scale and feedbacks
    - Impact of plate tectonics, atmosphere-earth interactions, etc.
    - Human-induced climate change
- Carbon cycle
- Difference between weather and climate
- Impacts of climate change
    - Water resources, hydrologic cycle, other climate change effects
    - Biosphere implications, ocean acidification, sea level rise
    - Implications on soil, agriculture
    - Economics and social aspects of climate change
    - Climate element to environmental consulting and hydrogeology as well as petroleum exploration

Natural Resources

- Understanding of what is included in "natural resources"
    - Economic geology (commodities and finite resources)
    - Energy, water, minerals, geologic materials
- Solid vs. liquid resources, geographic distribution, uses
- Ecosystem services, analysis of renewable and non-renewable (finite) resources
- Resource dependency and limits
    - Finite resource or commodity
    - Understanding your environment (where do our materials, energy, and medicines come from)
    - Ore and fossil fuel supply and demand and getting it to market
    - Time and space scale of formation and depletion, sustainability
    - Economics and viability of resources
    - How things are made
        - Process from ore to refined product
        - Process from fossil fuel to energy or material objects

Surface Processes

- Sediment deposition & erosion
    - Stream/River flow, morphology, deposition, erosion, effect of floods
    - Transport relationships (all surface processes)
    - Magnitude and frequency relationships of surficial deposits
    - Subsurface analogs
- Terrestrial and marine surface interactions
    - Biological, chemical, and physical interactions
    - Rates of chemical and physical changes
- Landscape alteration (geomorphology)
    - Surface mechanical and chemical processes
    - Karst formation
    - Glacial till and overburden thickness
- Habitability, sustaining life
    - Ties to natural hazards

Earth Materials

- What is a rock, mineral? Rock cycle
- Rocks: physical and chemical properties
    - How measure, scale of measurement
    - Mechanical characteristics
    - Scales of heterogeneity
    - How change over time
- Processes that form rocks and minerals
    - Processes and conditions of formation
    - Localizing mechanisms for deposits
    - Fluid dynamics, flow and fluid chemistry
    - Role of microbiology and organisms
- Resource applications, organic-inorganic materials

Earth Structure

- Structure of Earth

    - Mechanical and compositional layers
    - Tools for defining earth structure (seismic waves, analysis of earthquakes, etc.)
- Deformation
    - Stress and strain
    - Rock mechanics & deformation processes
    - Fractures, faults, folds, other structural features, etc.
- Plate Tectonics, including
    - Basin formation
    - Episodic nature, planning perspectives, uncertainty
- Structural controls on resource accumulations

Hydrogeology

- Water cycle
- Groundwater/aquifers, confined vs unconfined aquifers
    - Phase behaviors
    - Saturated vs unsaturated conditions
    - Scales of heterogeneity in space and time
    - Contaminant transfer
- Biogeochemistry and aqueous geochemistry
    - Microbe interactions
    - Nutrient cycling
- Subsurface-surface water interactions
- Economics and public policy
    - Groundwater quality
    - Regulatory standards

Technical and nontechnical skills: Identified primarily by 1st Summit, validated by survey, and granularity and additions by Geoscience Employers Workshop

Geoscience Thinking

- Earth Science habits of mind/geoscientific thinking
    - Temporal and spatial thinking
    - Systems thinking
    - Geologic reasoning and synthesis
- Problem solving in the context of an open and dynamic system
    - Understand context of problem
    - Asking appropriate questions
- Problem solving in 3- and 4-D
    - Ability to work on problems with no clear answers
    - Managing uncertainty in problem solving
    - Have a passion for solving problems
- Working by analogy, inference and the limits of certainty
- Intellectually flexible - applying skills in new scenarios

Technical Skills

- Problem Solving with data
    - Data collection and interpretation, use and application of data
    - Begin with understanding of how data will answer question, purpose of collecting data

    - Evaluation of data, data quality
    - Understanding data and uncertainties
    - Make predictions with limited data
    - Use of appropriate methods, reading and interpreting graphs
- Quantitative/Math skills – integrate into geo courses throughout
    - Differential equations/linear algebra
    - Probability and statistics (so understand risk)
    - Understanding of scale
    - Computer programming skills (think about how to solve a problem computationally)
- Experience with authentic research, collection of new information
- Critically evaluate literature, encourage critical thinking

<u>Field and Technology Skills</u>

- Field Camp and Field Experiences
    - Improves spatial cognition, creative problem solving, teamwork, geoscience synthesis
    - Data supports field skills are unique and essential, difficult to replicate or substitute
- GIS – Most essential for building large data sets
- Data Analysis Skills
    - Ability to handle and analyze Big Data
    - Use of visual models, modeling tools (Stella, Modflow, Matlab, etc.)
    - Integration of technical and quantitative skills, programming, application development
- Technological diversity (need skills and training beyond point, click, and type) – i.e. not just black box
- Preparation for life-long learning
    - How to learn and use new technology and software

<u>Non-technical Skills</u>

- Oral and written communication competency
    - Science writing and verbal communication; knowing your audience
    - Public speaking
    - Listening skills
- Project management
    - Ability to work in teams
        - Be a leader and follower
        - Don't divide work; iterative process between students with different backgrounds/disciplines
    - Goal setting
    - Solution-oriented approaches
    - Conflict resolution (open minded – answer may lie in the conflict space)
    - Managing problems on the front end
    - Time management
- Professionalism, interpersonal skills
    - Ethics, ethical awareness, codes of conduct, awareness of implicit biases
    - Business acumen and risk management
    - Cultural interactions, cultural literacy, emotional literacy, learning styles
    - Leadership
    - Career awareness/resume/interview preparation
- Global perspective
- Understand societal relevance