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

Field and Technology Skills

• 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

Non-technical Skills

• 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