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K-area Conceptual Model Development

Sandia/INER/EEL Workshop

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Objectives

- Discuss goals of conceptual model development for (1) site characterization and (2) performance assessment
- Discuss framework and preliminary conclusions for conceptual model of hydrology for site characterization of K-area
- Discuss framework and preliminary conclusions for conceptual model of hydrology for performance assessment

Conceptual Model for Site Characterization

- A conceptual model for site characterization is considerably more general than for performance assessment
  - Covers a larger, regional-scale area
  - Focuses on present and past conditions in the natural system
  - Covers a broader range of geological, hydrologic, geochemical, and tectonic topics to demonstrate an integrated understanding of the natural system
  - Addresses the natural boundary conditions of the hydrologic system
  - Must retain emphasis on usefulness and relevance to performance assessment

Conceptual Model for Performance Assessment

- A conceptual model for performance assessment is considerably more focused than for site characterization
  - Covers a smaller, site-scale area
  - Focuses on present and future conditions at the site
  - Covers a narrower range of geological, hydrologic, geochemical, and tectonic topics that are directly related to FEPs that are important to performance assessment
  - Usually relies on local (often not natural) boundary conditions of the hydrologic system
  - Must retain consistency with major aspects of the site-characterization conceptual model

Major Topics in the Conceptual Model for Site Characterization

- Geological and structural framework
  - Rock types and mineralogy
  - Age relationships
  - Faults and lineaments
- Tectonic history and stability
  - Uplift (or subsidence) rates
  - Seismicity
  - In situ stress and rock mechanics
  - Volcanism (not an issue at K-area?)

Major Topics in the Conceptual Model for Site Characterization

- Geochemistry
  - Constraints on geologic history, tectonics, hydrology, etc.
  - Constraints on groundwater age, flow paths, chemical evolution, and recharge
  - Eh, pH, and major ion chemistry related to waste package degradation, radionuclide solubility, and radionuclide transport

Major Topics in the Conceptual Model for Site Characterization

- Groundwater hydrology
  - Groundwater flow boundary conditions: recharge, discharge, pumping, no-flow
  - Horizontal and vertical hydraulic gradients
  - Fracture network characteristics and flow channelization – relationship to mechanical stress
  - Permeability structure and anisotropy
  - Groundwater ages and flow history related to climate change and sea-level change
  - Steady-state versus transient groundwater flow

Major Topics in the Conceptual Model for Performance Assessment

- Geological and structural framework
  - Rock types and mineralogy at the site scale
  - Faults and lineaments near potential repository
- Tectonic history and stability
  - Uplift (or subsidence) rates
  - Seismicity
  - In situ stress and rock mechanics
  - Volcanism (not an issue at K-area?)

Major Topics in the Conceptual Model for Performance Assessment

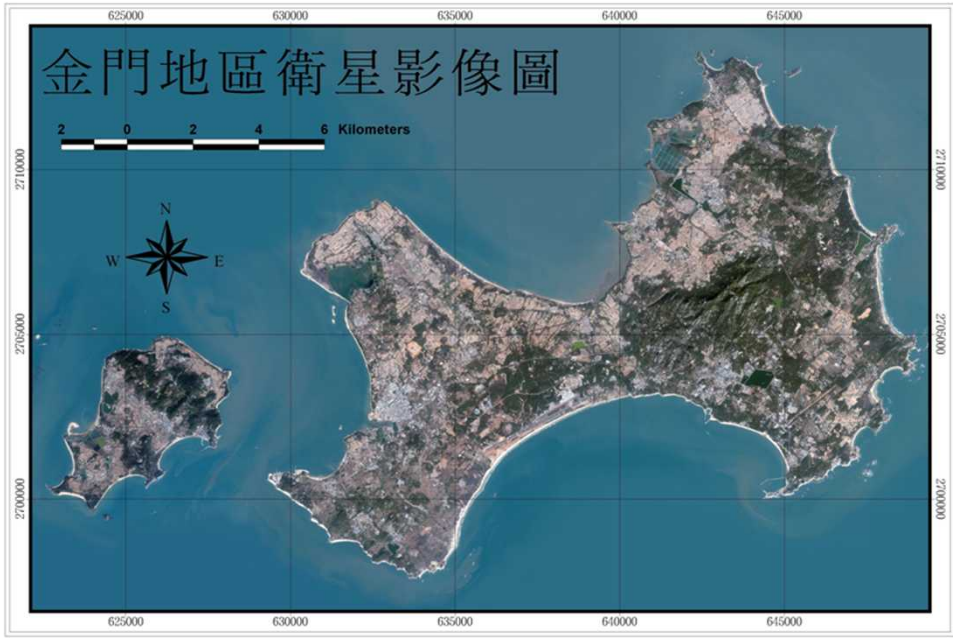
- Geochemistry
  - Eh, pH, and major ion chemistry related to waste package degradation, radionuclide solubility, and radionuclide transport
  - Evolution of geochemistry due to the presence of repository materials and changes in the natural system (e.g., climate change)
  - Relationships between geochemistry and corrosion, radionuclide solubility, and sorption
  - Potential colloid-facilitated transport of radionuclides

Major Topics in the Conceptual Model for Performance Assessment

- Groundwater hydrology
  - Local groundwater flow boundary conditions near the repository out to the biosphere
  - Horizontal and vertical hydraulic gradients at the site scale
  - Fracture network characteristics and flow channelization – relationship to mechanical stress
  - Permeability structure and anisotropy
  - Steady-state versus transient groundwater flow
  - Radionuclide transport processes of dispersion, diffusion, sorption, and facilitation by colloids
  - Future changes to groundwater flow and/or chemistry

Conceptual Model for Site Characterization: Flow Boundary Conditions

- **Lateral boundary conditions: constant head probably defined by sea level for shallow flow system**
- **For deeper flow system the natural boundaries may extend beyond the shoreline**
  - **Seafloor discharge?**
  - **Underflow from mainland?**
- **Lower boundary condition: no-flow conditions must be deeper than 500 m depth, given deep flow connectivity in KMBH01, 02, and 04, and deep flow observed in KMBH03 – fresh/seawater interface at depth?**



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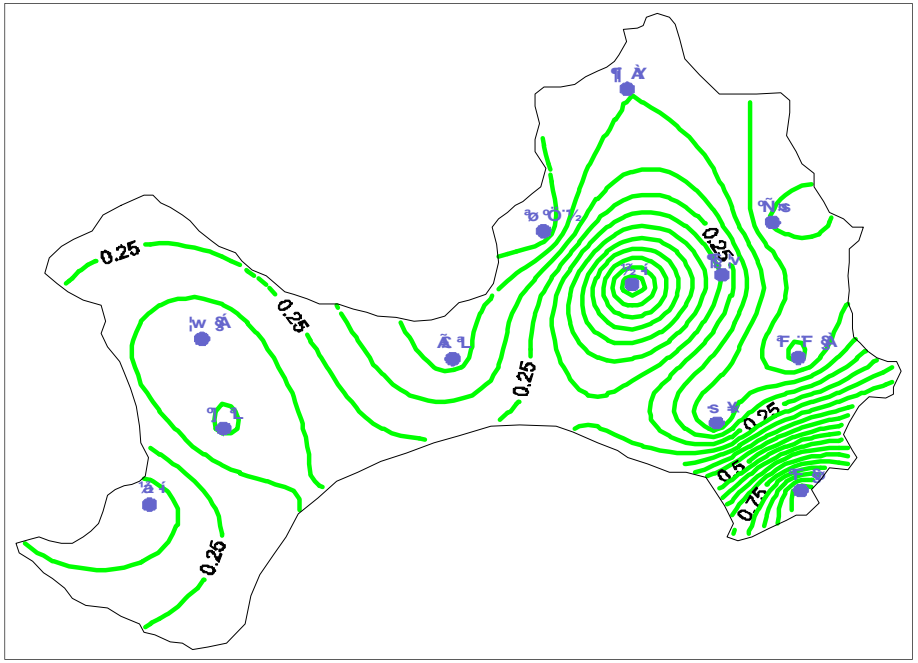
Conceptual Model for Site Characterization: Flow Boundary Conditions

- **Point estimates of infiltration and recharge suggest positive correlation between infiltration and elevation**
- **Recharge boundary conditions may also be related to land use – higher recharge in forested areas and lower recharge for agricultural and developed areas**



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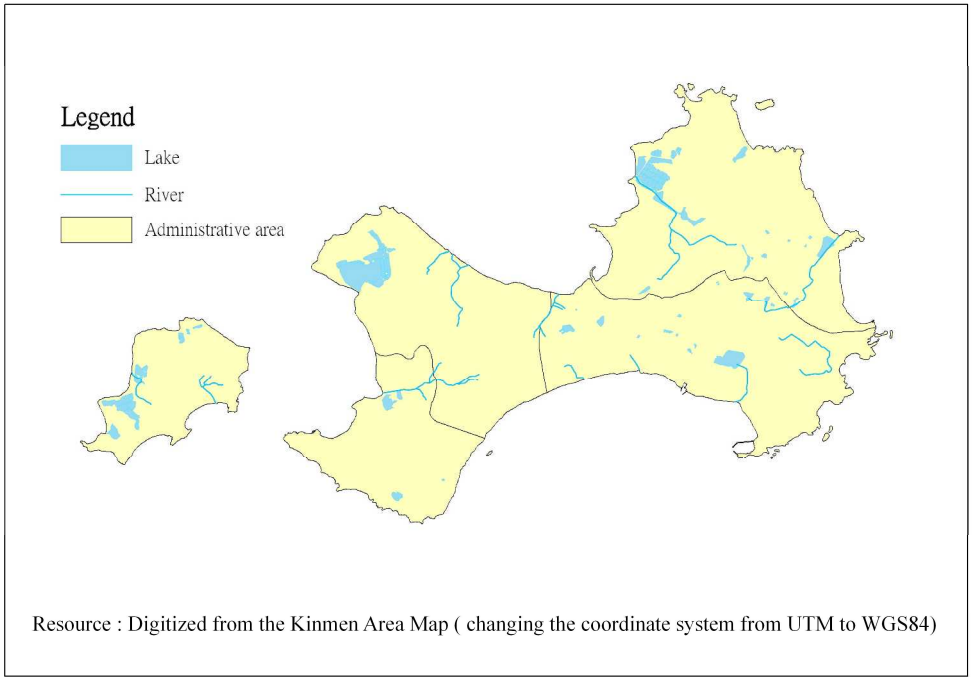
Conceptual Model for Site Characterization: Flow Boundary Conditions

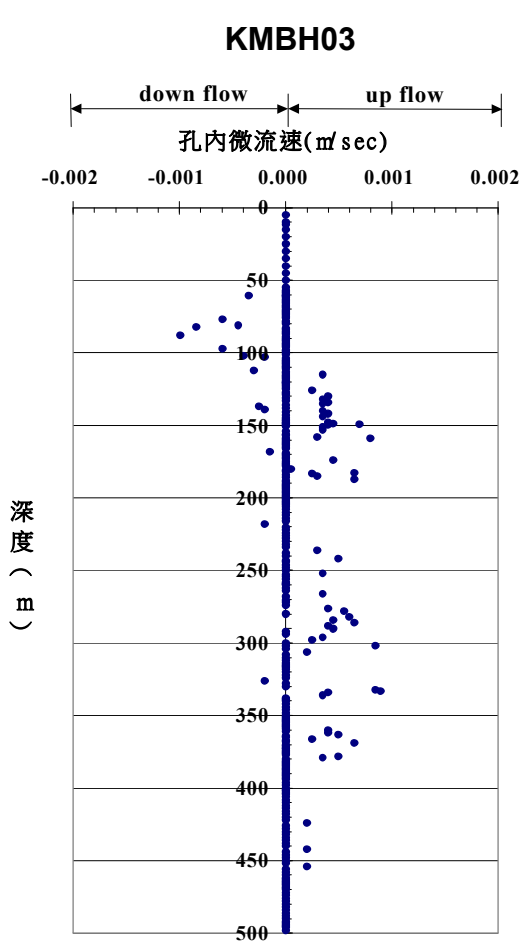
- **Majority of natural groundwater discharge probably occurs to the sea at or near the shoreline**
- **Significant groundwater discharge could occur to springs, lakes, and rivers – streamflow data available?**
- **Significant discharge could be occurring by pumping, given population on Kinmen – pumping data available?**

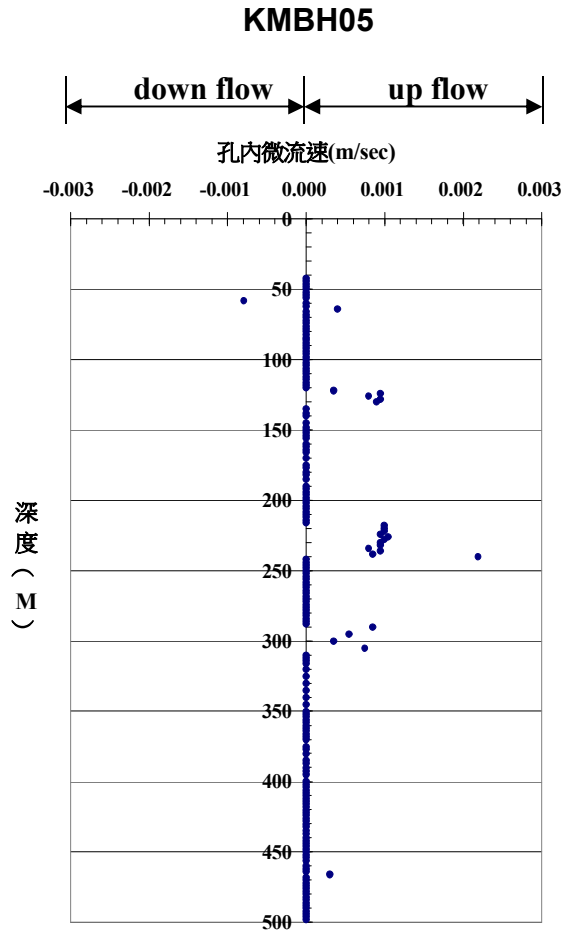


Resource : Digitized from the Kinmen Area Map (changing the coordinate system from UTM to WGS84)

Conceptual Model for Site Characterization: Vertical Gradients

- Vertical upward flow below 100 m depth in wells KMBH03 and 05 measured with flowmeter indicates upward hydraulic gradients in the deeper flow system at these locations
- Electrical conductivity log shows higher TDS water below 100 m depth
- Upward gradient at these locations may be related to position near higher elevation terrain





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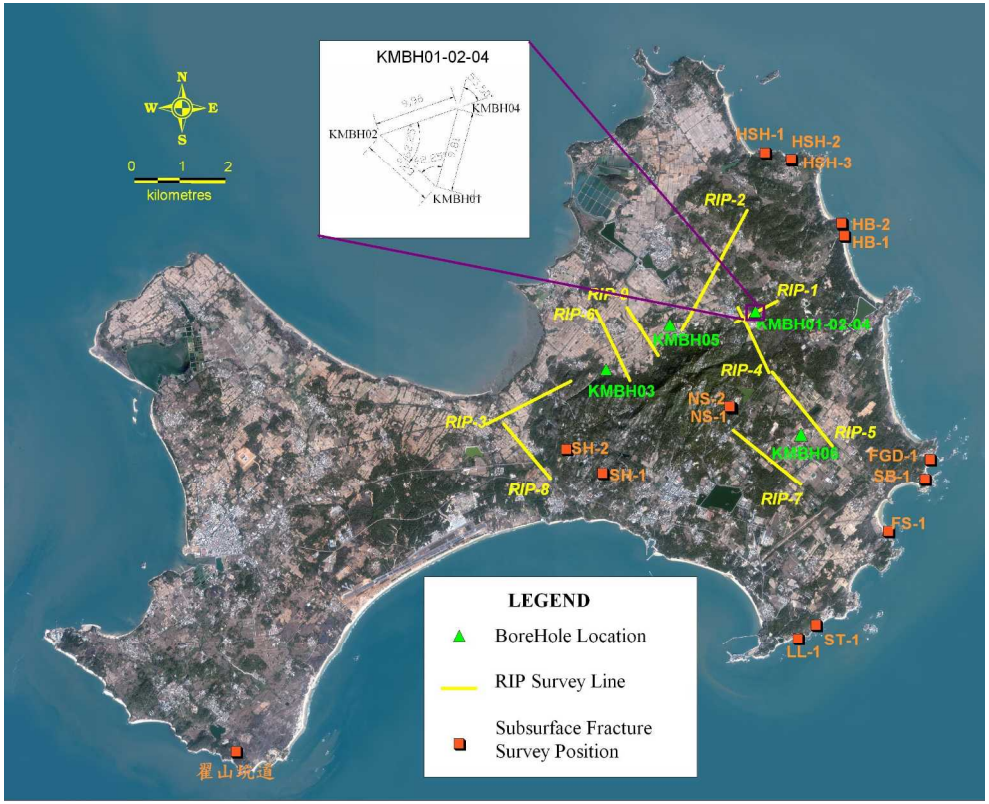
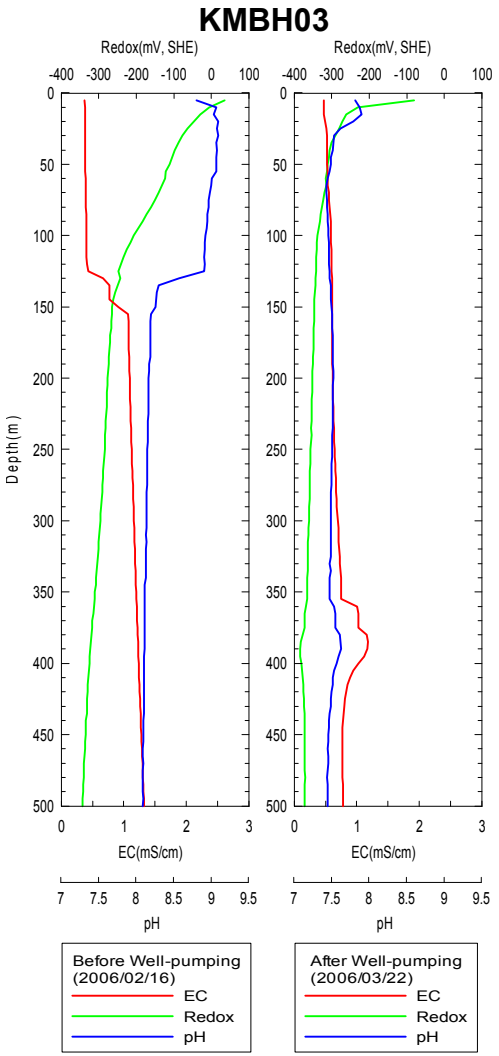
Conceptual Model for Site Characterization: Vertical Gradients





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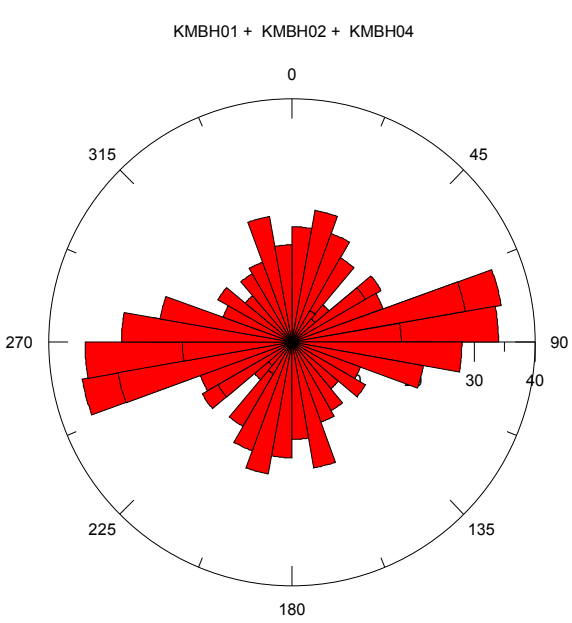
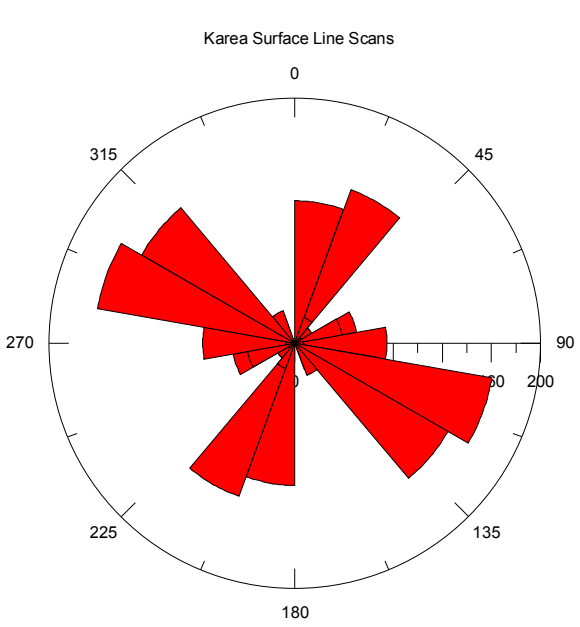
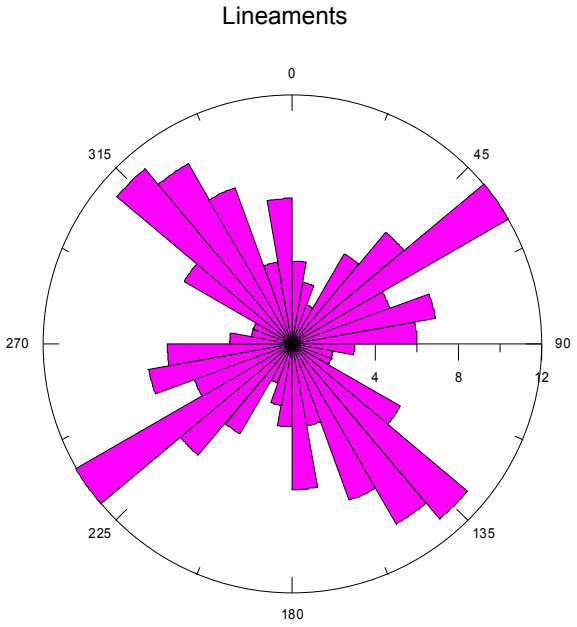
Conceptual Model for Site Characterization: Fracture Network







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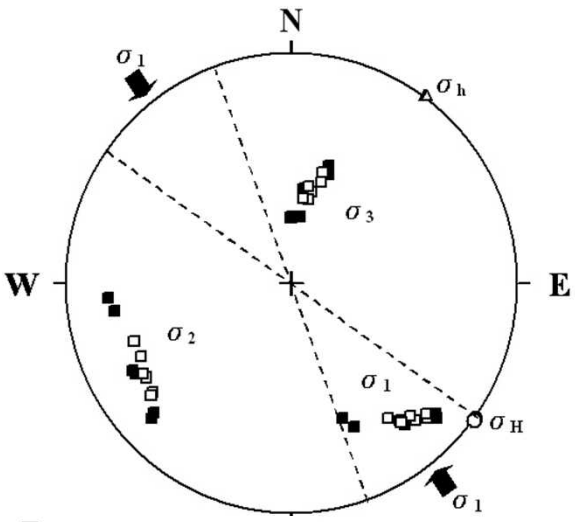
Conceptual Model for Site Characterization: Fracture Network

- Hydraulic testing indicates approximately log-normal distribution of hydraulic conductivity with geometric mean of about 10^{-6} to 10^{-5} m/s (10^{-13} m^2 to 10^{-12} m^2 permeability)
- Results suggest generally well interconnected background fracture network without major hydraulic compartmentalization
- Potential relationship between fracture orientation and in situ stress – anisotropy in permeability (not yet tested)

Conceptual Model for Site Characterization: Stress and Anisotropy

KMBH01



HF AND HTPF combine analysis of principal stress σ1,σ2,σ3

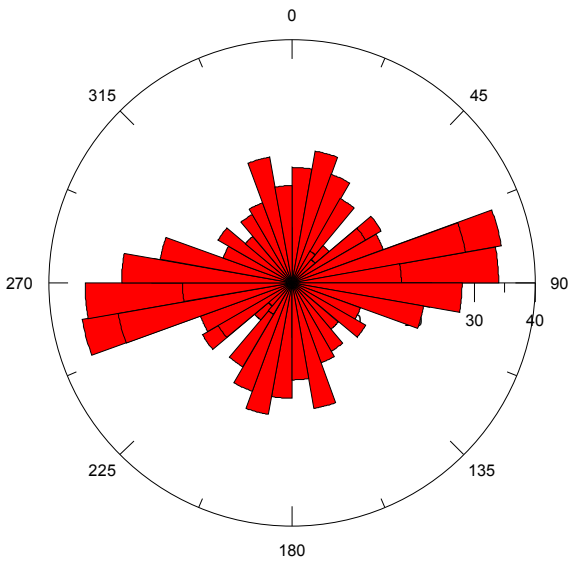
HF maximum horizontal principal stress

HF minimum horizontal principal stress

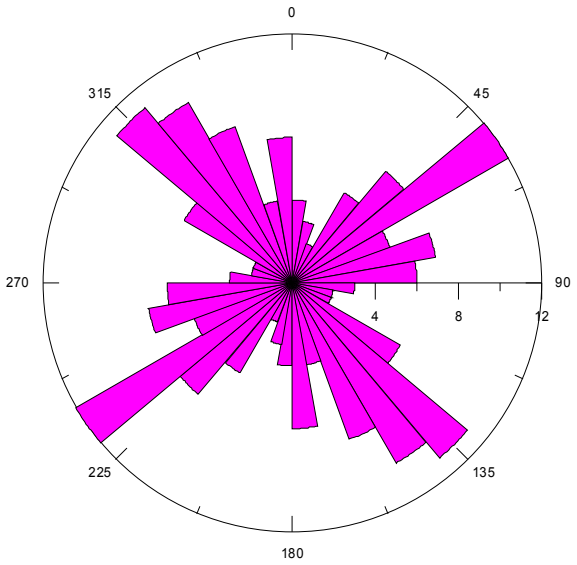
Solid circles : 292m analytical result

Open circles : 306m analytical result

KMBH01 + KMBH02 + KMBH04



Lineaments



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Conceptual Model for Site Characterization: Flow History and Change

- ^{14}C dating of deeper water in KMBH03 indicates Holocene age (7500 – 8900 years), even for brackish, more highly evolved groundwater at depth
- Oxygen and hydrogen isotopic composition for groundwater from KMBH03 falls on meteoric water line
- Data suggest the groundwater flow system may be stratified, but stable with infiltration unmodified by evaporation