The 10th IGD-TP Exchange Forum

SRA Topic 7. Methodologies for Site Characterisation No.27

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Development of a Hydrogeological Site Descriptive Model for Crystalline Rock: A Hypothetical Reference Case in Taiwan

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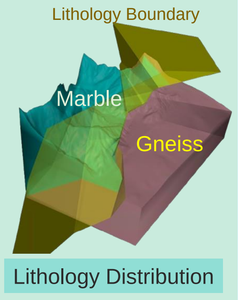
I. INTRODUCTION

A hypothetical case study was conducted in Taiwan's metamorphic region, including **gneissic crystalline rocks** and **marble**, using in-situ geophysical and hydrogeological methods.



Lithology Distribution

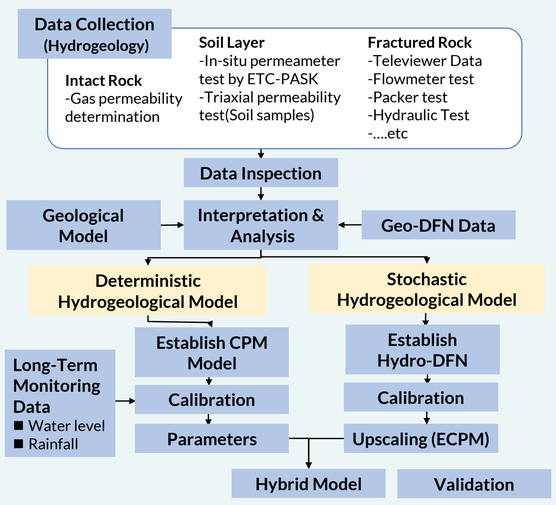
In Taiwan, **crystalline rock** formations have been identified as potential host environments, following the **KBS-3V** deep geological disposal concept.

This study establishes a Hydrogeological Site Descriptive Model (SDM) for Taiwan's crystalline rock regions based on data acquired from field investigations.

KBS-3V disposal concept

II. PROCESSES OF MODEL DEVELOPMENT

1. Flowchart of Hydrogeological SDM



2. Laboratory test & Field investigation

Intact Rock Samples – Gas Permeability Test

Fractured Rock - Hydraulic Test (Drawdown Curve Fitting)

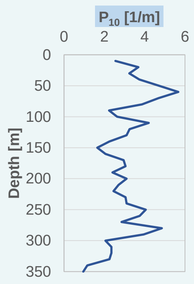
Soil Layer – In Situ Permeability (ETC-PASK Permeameter)

3. Conceptual Structure & Boundary Conditions

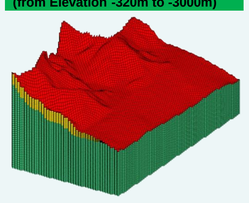
■Model Stratification

Model stratification was determined based on distinct shifts in fracture characteristics observed across depth.

Fracture Intensity (P_{10}) Derived from Borehole Image Logging

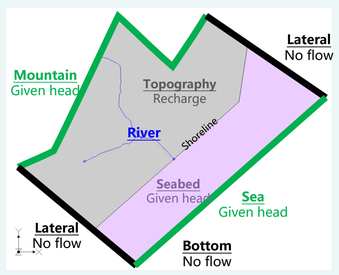


HSD - Regolith layer
(from surface to 20m depth)
HRD I - Shallow Bedrock
(from +20m to Elevation -320m)
HRD II – Deep Bedrock
(from Elevation -320m to -3000m)



■Flow boundary condition

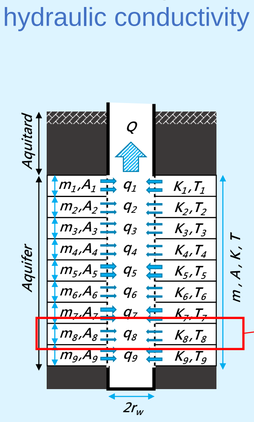
No flow: Lateral
Given head: Mountain Side, Sea Side
Recharge: Top
River: River Object



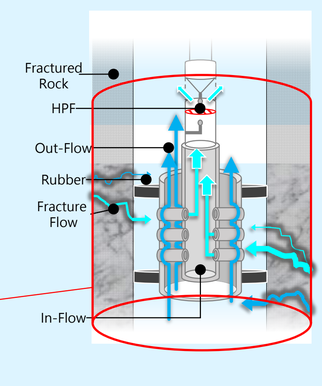
III. CHARACTERISTICS OF HYDRAULIC PROPERTIES OF FRACTURES

1. High-Precision Heat-Pulse Flowmeter - Sinotech Flow Cell (SFC)

The **SFC** is a patented Sinotech-developed tool for in-situ measurement of hydraulic conductivity in small subsurface formation intervals.

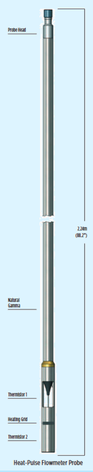


Groundwater Flow Velocity Measurement in Small Subsurface Intervals



SFC Measurement Mechanism

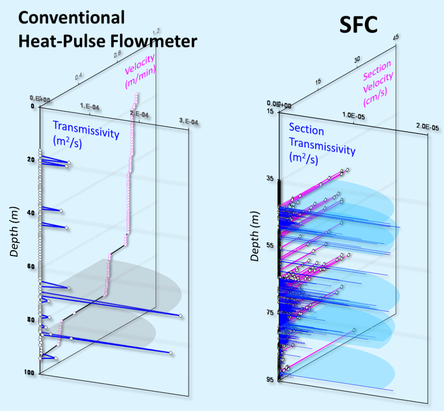
Sinotech Flow Cell (SFC)



Downhole Flow Measurement Tool - Heat-Pulse Flowmeter

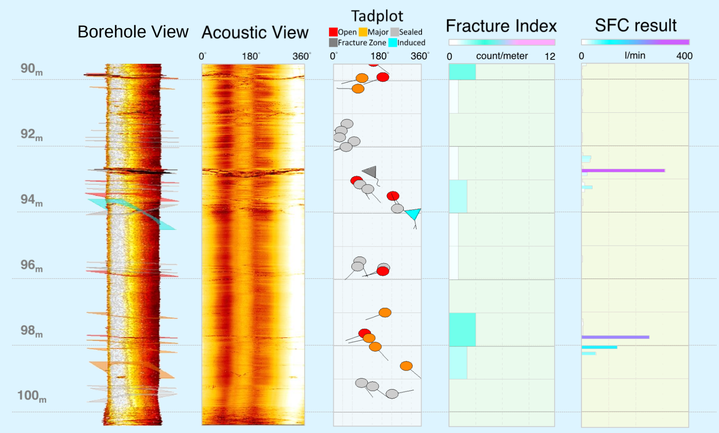
Heat-pulse Flowmeter upgraded with **SFC** system.
Measurement interval set to **10 cm**, enabling **single-fracture flow** characterization.

2. SFC vs. Heat-Pulse Flowmeter



Comparing to conventional flowmeters, the **SFC** provides the ability to identify fracture-specific hydraulic conductivities

3. ACTV Imaging & Fracture Analysis



Fracture characteristics—including **orientation, intensity**, and related attributes—were derived from **borehole imaging** logs and compiled into fracture parameter sets for DFN generation.

IV. ANALYSIS RESULTS

1. Fracture Parameter Sets (Hydro-DFN Recipe)

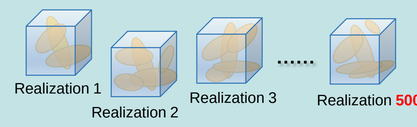
Gneiss Hydro-DFN recipe

Fracture Orientation	Gneiss, Set 1	Gneiss, Set 2	Gneiss, Set 3	Gneiss, Set 4	Gneiss, Set 5
Fisher distribution parameter, κ	8.2	12.6	10.0	11.2	9.8
Pole trend [°]	312	60	134	175	107
Pole plunge [°]	35	54	29	42	37
Fracture Intensity	**Gneiss, Set 1**	**Gneiss, Set 2**	**Gneiss, Set 3**	**Gneiss, Set 4**	**Gneiss, Set 5**
$P_{10}\ [m^{-1}]$	0.762	0.789	0.353	0.320	0.100
$P_{32}\ [m^{-1}]$	1.413	1.120	0.713	0.447	0.173
Fracture Size	**Gneiss, Set 1**	**Gneiss, Set 2**	**Gneiss, Set 3**	**Gneiss, Set 4**	**Gneiss, Set 5**
Distribution	Power-Law				
$k_r\ [-]$	2.97	2.75	2.83	2.83	2.83
$r_0\ [m]$	0.282				
Fracture Spatial distribution					
Enhanced Baecher model					
Fracture Transmissivity	**Gneiss, Set 1**	**Gneiss, Set 2**	**Gneiss, Set 3**	**Gneiss, Set 4**	**Gneiss, Set 5**
Transmissivity [m^2/s]	T=3.3E-7*r^0.72			T=3.3E-10*r^0.72	

Marble Hydro-DFN recipe

Fracture Orientation	Marble, Set 1	Marble, Set 2	Marble, Set 3	Marble, Set 4
Fisher distribution parameter, κ	9.8	9.4	9.8	9.4
Pole trend [°]	123	296	123	296
Pole plunge [°]	30	57	30	57
Fracture Intensity	**Marble, Set 1**	**Marble, Set 2**	**Marble, Set 3**	**Marble, Set 4**
$P_{10}\ [m^{-1}]$	1.030	0.570	0.227	0.126
$P_{32}\ [m^{-1}]$	2.820	1.050	0.539	0.201
Fracture Size	**Marble, Set 1**	**Marble, Set 2**	**Marble, Set 3**	**Marble, Set 4**
Distribution	Power-Law			
$k_r\ [-]$	2.97			
$r_0\ [m]$	0.282			
Fracture Spatial distribution				
Enhanced Baecher model				
Fracture Transmissivity	**Marble, Set 1**	**Marble, Set 2**	**Marble, Set 3**	**Marble, Set 4**
Transmissivity [m^2/s]	T=3.3E-7*r^0.72		T=3.3E-10*r^0.72	

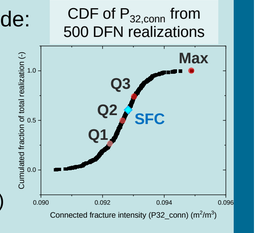
2. Multiple DFN Realizations



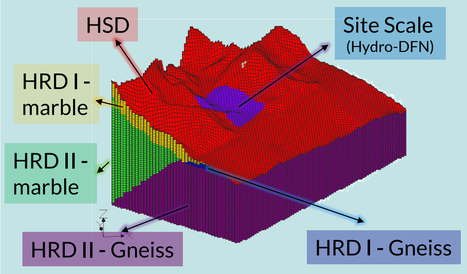
Representative DFN realizations were selected from multiple DFN generations based on the distribution of **Connected Fracture Intensity ($P_{32,conn}$)**.

The selected realizations include:

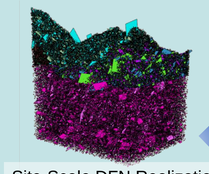
CDF of $P_{32,conn}$ from 500 DFN realizations

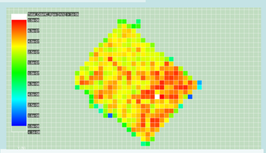


1. **Q1** (lower connectivity)
2. **Q2** (median connectivity)
3. **Q3** (higher connectivity)
4. **Max** (Maximum connectivity)
5. **Best-match realization** based on field **SFC** observations

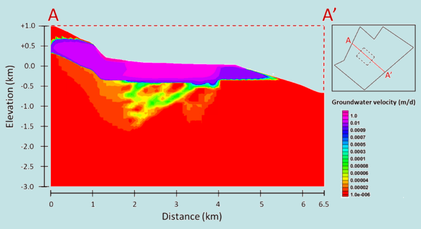


	Gneiss	Marble
Shallow Bedrock	HRD I, Gneiss	HRD I, Marble
Deep Bedrock	HRD II, Gneiss	HRD II, Marble





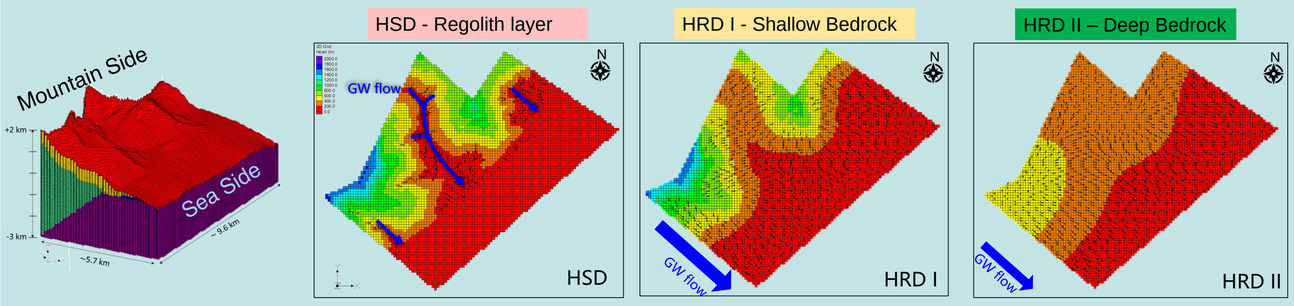
Equivalent Continuous Porous Media (ECPM) model



Distribution of Groundwater Flow Velocity

3. Regional Groundwater Flow of the Model Domains

Regional groundwater flow strongly influenced by topography, causing the flow direction from northwest (Mountain Side) to southeast (Sea Side).



V. CONCLUSIONS

- **The SDM integrates field investigations, SFC-based fracture hydraulic characterization, DFN modeling, and ECPM upscaling.**
- **Results indicate that steep regional topography governs groundwater flow from mountain recharge to coastal discharge.**
- **The developed SDM enhances regional hydrogeological understanding and supports subsequent safety assessments.**

Acknowledgments | This research was supported by the **Taiwan Power Company**