Additional Potential of Microseismic Monitoring in Geothermal Development

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Overview

1. MicroSeismic (MS) Monitoring in Japan

2. JOGMEC Enhanced Geothermal Systems (EGS) Project

3. Contribution of Microseismic Data in Geothermal Development

4. Conclusions
In Japan, “MS Monitoring” has been conducted mainly for an environmental monitoring in geothermal development.

MS monitoring can:

1. notify the operator to stop pumping if:
   • the fractures are approaching environmentally sensitive areas.
   • relatively large magnitude events occur.

2. prove that large magnitude events did not occur during geothermal development.
1. MS Monitoring in Japan - Examples

Various organizations are monitoring the microseismicity all over Japan.
OKUAIZU geothermal Co. Ltd. has been monitoring around YNGP since 1987, and reporting the results to the interested party every year.
Some geothermal power plants are facing difficulty sustaining production of steam and hot water.

Since 2013, JOGMEC has been performing R&D of EGS around YNGP. In 2015, a recharge injection test was conducted.
2. JOGMEC EGS Project
   - Overview of Recharge Injection Test

YNGP Location Map

- Estimated faults
- Power plant
- TD: 2,100.26mMD (8-1/2” Hole)
- KOP: 1,560mMD
- Recharge: approx. 2,040 mMD

Recharge Well (14JN-R1)

- EGS Target: Southeastern part of Chinoikesawa footwall

1km

Estimated faults
【Term】
1st: Jun. 4, 2015 ~ Aug. 31, 2015 (88 days)
2nd: Nov. 27, 2015 ~ Dec. 26, 2015 (29 days)

【Recharge Rate】

【Amount of Recharged Water】
1st: approx. 120,000 ton, 2nd: approx. 50,000 ton
We were monitoring the microseismicity for operating EGS test safely. We used MS data to solve a problem in the geothermal development for YNGP.
2. JOGMEC EGS Project - MS Observation Systems

**Ground Observation**

- Solar Battery + Battery
- Logger
- Seismograph (YAE1-5)
- GPS

**Wellbore Observation**

- Power Supply
- Logger
- Seismograph (YAE6-9)
- GPS
- 3G Wireless router

**Okuaizu Observation**

- Seismograph (OMS1-5)

**Network Diagram**

- Internet (VPN)
- Generate SAC data
- Yanaizu Server
- YAE Data
- FREA Analysis
- Daily Report
- Interested party
- OMS Server
- OMS data
- Serial Communication
3. Contribution of MS Data in Geothermal Development
- Problem in Geothermal Development for YNGP

An initial geothermal model was built based on the existing data (well log, MT).
A temperature simulation was conducted using the initial geothermal model. However, the results didn’t match the actual temperature profile well.

Calculated by TOUGH2 Supercritical Module
3. Contribution of MS Data in Geothermal Development
- MS Data Used for Updating the Model

Baseline (1 mo.): 207 events
Monitoring term (13 mo.): 3,633 events

Note: Nearly half the data was used to determine the positions of MS events.
3. Contribution of MS Data in Geothermal Development
- Integration of the MS Events

MS events were plotted on the resistivity map.

The events were occurred at the specific area.
3. Contribution of MS Data in Geothermal Development
- Grouping using the MS data

The model was grouped by MS data, well-log and resistivity.

✓ Zone ①: Low resistivity, Observed the Microseismicity
✓ Zone ②: Very low resistivity, Observed the Microseismicity
✓ Zone ④&⑤: High resistivity, Not observed the Microseismicity
Microseismicity is tiny ($M_L \leq 2.5$) seismic events caused by shear slip of existing fractures. (in most of the geothermal cases).

Recharge well

Stable state

Shear slip

Fracture network model

Receivers

P: Pore-pressure

Trigger

Fractures with shear slip

Criterion for shear slip

Effective normal stress

Effective normal stress
3. Contribution of MS Data in Geothermal Development
- Characteristics of Microseismicity

**Triggers**

- **Increase of pore pressure**
  - Expansion or Evaporation of recharged water

- **Reduction in coefficient of friction**
  - Moving of steam and hot water

- **Change in stress state**
  - Moving of cold water (recharged water)

Microseismicity is not common in the following area.

- **Very** high permeability area
- **Very** low permeability area
  - (Clay rock, Argillic alteration zones)
- Areas without existing cracks of fractures
Initial geothermal model was updated considering MS events. We re-interpreted:

- Cap rock shape (② is not a cap rock)
- Movement range and boundary of recharged water (④ & ⑤ are very low permeability zone)
4. Geothermal Structure Modelling Utilizing Microseismic Data - Comparison of the Temperature Simulation Results

The accuracy of the temperature simulation was improved.
4. Conclusions

• MS monitoring are usually used for an environmental monitoring in Japan.

• JOGMEC conducted the recharged injection test around YNGP for R&D of EGS while monitoring the microseismicity for safe operation.

• We re-interpreted the shape of the cap rock and the movement range and boundary of recharged water using MS data.

• Accuracy of temperature simulation was improved by using the model which was built by MS data.

Additional potential of MS monitoring in geothermal development has been indicated.
Thank you for your attention