The Wasabizawa - Akinomiya Geothermal Field: Reservoir Characterization, Sustainable Development Plan, Monitoring and Stakeholder Engagement

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Outline

1. The Wasabizawa - Akinomiya Geothermal System
2. Numerical Reservoir Simulation
3. Monitoring (Hot spring etc.)
4. Stakeholder Engagement (Local community, Hot spring owners)
Background of the Wasabizawa Geothermal Project

- **NEDO** supported geothermal development promotion surveys for the Wasabizawa area and the Akinomiya area in 1993-1997 and 1998-2002, respectively.
- After the NEDO’s survey, these areas were transferred to **J-Power** and **MMC** (Mitsubishi Material Co.).
- We started exploration cooperatively since 2008. Two exploratory wells were drilled. GW-1:1998m / GW-2:1488m
- **Hot spring monitoring program** initiated in 2009 before the exploratory wells spud in.
- **A numerical reservoir simulation study** was performed.
- **Yuzawa Geothermal Power Corporation (YGP)** was established in 2010 by J-Power, MMC and **MGC** (Mitsubishi Gas and Chemical Co.).
- Environmental Impact Assessment was performed in 2011 - 2014.

>> This project progressed to construction phase in 2015.
Temperature Profile of Wells
The pressure gradient corresponds to saturated water of 262 degree C.
Inferred temperature distribution at -500 m ASL
Conceptual Model (SW-NE cross section)

Akinomiya Hot Spring Area (NaCl type)

Kawarage Fumarole Area (Volcanic gas & Acidic Cl-SO$_4$ type hot spring)

Doroyu Hot Sp. Area (Acidic SO$_4$ type hot spring)

Basement rock

Legend:
- Unconsolidated Sediment
- Granite
- Impermeable Zone
- Hot Spring Aquifer
- Isotherm (°C)
- Injection Zone
- Production Zone
- Steam and Gas Flow
- Heat Flow
- Fluid Flow with production and injection
- Geothermal Fluid Flow
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Location of the computational grid

- In $x$-direction (8.0 km): 24 blocks
- In $y$-direction (7.0 km): 22 blocks
- In $z$-direction ($z \geq -2.5$ km RSL): $\leq 23$ blocks

Total grid blocks: $(24 - 22 - 23 =) 12,144$

Case 86:
- “void” grid blocks (above surface): 2,946
- Active grid blocks: 9,198
For Case 86, the total number of “void” grid blocks was 2,946, leaving 9,198 blocks that were actually involved in the simulation.

**Yellow:** drilling data availability

- This means that only the uppermost 36% of the computational grid volume has been adequately explored by drilling.
- *The deepest 45% of the grid volume has never been reached at all.*
Rock Properties (1)

- Rock properties other than permeability (grain density, porosity, heat capacity and thermal conductivity) were fixed in the simulation calculation, and based on measured data for each rock type.

- The spatial distributions of absolute permeability were treated as unconstrained parameters in the modeling study, and were varied freely from case to case to try to improve the quality of the data match.

Absolute permeabilities:

- $k_h (\text{md}) = 0.01 \quad 0.10 \quad 0.10 \quad 2.00 \quad 0.20 \quad 10.00 \quad 1.00$
- $k_v (\text{md}) = 0.02 \quad 0.02 \quad 0.20 \quad 1.00 \quad 5.00 \quad 5.00 \quad 20.00$
Available data from drilling in the field clearly indicates that, where formations are permeable, the permeability arises from the presence of fractures that penetrate the otherwise impermeable country rock and provide discrete conduits for fluid flow.

Representative “conductive MINC” assembly used to represent non-equilibrium heat transfer between impermeable country rock matrix and permeable fracture zone for all computational grid blocks.

Matrix region (yellow) subdivided into 31 concentric spherical “shells”, each of equal volume, and with zero porosity and zero permeability. Fracture zone (red) represented by single permeable outer shell with 50% porosity. Volume fraction of “fracture zone” varies between 4% and 28% of the volume of the entire spherical assembly (depending on the overall porosity of the rock formation).

Diameter of spherical assembly (50 meters) is the “average fracture separation” ($\lambda$).
Calculated heat content changes in computational volume over 200,000-year history

Change in total thermal energy ($\times 10^{18}$ joules)

Time derivative of upper curve (MW)
Comparison between measured and computed pressure

Comparison between measured feedpoint pressure (yellow) and computed natural state pressure at feedpoint locations (blue)
Comparison of measured temperatures with computed results (1)

Comparison of stabilized downhole temperatures measured in well AY-3, AY-4 and AY-7 (yellow) with computed natural-state temperatures along well path (red)
Comparison of measured temperatures with computed results (2)

Comparison of stabilized downhole temperatures measured in well WZ-7, WZ-9 and KN-2 (yellow) with computed natural-state temperatures along well path (red)
Pressure Interference Calculation

- Although the relatively coarse spatial discretization (minimum block size is 0.3 km \( \times \) 0.3 km \( \times \) 0.1 km) may not be ideal for simulating the field pressure interference experiments, the model was employed in several pressure interference tests calculations to confirm the model responses to the actual long term flow tests.

- Pressure interference data at well AY-2 (Left) and AY-8 (Right) due to production of well AY-3 and injection to wells AY-1 & 6. Black: measured pressure. Red: calculated pressure.

![Graphs showing pressure interference data at AY-2 and AY-8 wells](image)
Base case geometry for future forecast calculation
Study on generation capacity and plant design concepts

- Base Case: 30 MWe Single-flash plant, flash-tank, wet cooling tower
- Single-flash plant design variants. (pressurized injection, hybrid cooling etc.)
- Plant capacity: 22.5 MWe, 30 MWe (base case), 35 MWe and 45 MWe

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<td>Double flush plant</td>
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- Finally planned: 42 MW double-flash plant
Forecasts of production well drilling requirements, production well discharge enthalpy histories and pressure changes.

Drilling requirements to maintain steam supply for plants

Mass-averaged discharge enthalpy from operating production wells

Time-history of pressure at -1 km ASL in hypothetical Wasabizawa monitor well.
Evolution of temperature distribution at -0.5 km ASL elevation for the final double-flash 42 MWe case forecast

- It appears that cold reinjected water from the Akinomiya wellfield will not influence the production enthalpies even after many years operation.

A numerical model has been constructed for the Wasabizawa-Akinomiya geothermal field which is conservative in character and in good agreement with available measurements from the field.

- Calculation based upon the model indicate that the field can sustain more than 42 MW of electrical output using a double-flash steam plant for more than fifty years.
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Hot springs monitoring

- 13 hot springs and 1 water spring
- Objective: To confirm changes in discharge conditions (discharge rate, temperature etc.).
- Monitoring program initiated in June 2009, and continued now
- 10 years background information will be available before commencement of operation of the plant.
- We share the data with hot spring owners and local government; Yuzawa city.

GW-1 Drilling (2009)

Photos: from YGP
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Stakeholder engagement

- The Environment Impact Assessment report meeting to local community.

- Detailed and timely explanation to hot spring owners about exploration results and the relationship between hot springs and the geothermal reservoir to be exploited.

- Report monitoring data to hot spring owner individually, and to local government; Yuzawa city.

- Local community meetings for each district. (Exploration results and next year’s plan, P/S plan and construction schedule, etc.)

- Site visiting tours for local community.

These activities made possible to build trust in a relationship with local residents.
Local community meetings

Meeting to explain to local residents about project progress and future plan

We started to hold such meetings since the exploration phase. The meetings were held timely and twice a day (daytime and night) for their convenience.
Site visiting tour for local residents

YGP’s “Yuzawa Geothermal Power Station” constructing site

We expect that local people feel close to the power station by such a tour.

Photos: from YGP
The Yuzawa Japanese Geopark activity led by Yuzawa city involves “geothermal manifestations and geothermal energy utilization”, and it makes more people familiar with “geothermal development”.

All-party parliamentary group to promote geothermal development was established in the Yuzawa municipal council, and supported our project in the back.

Yuzawa city set up an advisory panel of local community including hot spring owners to provide us an opportunity to keep a channel of communication open.
Concluding Remarks: What have we learned?

- Correct understanding of subsurface geothermal system (correct characterization of reservoir) is required for both of sustainable development and stakeholder engagement.

- Extensive and continuous stakeholder engagement is required for building trust in a relationship with local community, and for successful implementation of project.

- Monitoring is essential:
  - Continued hot spring monitoring
  - Various monitoring for reservoir performance are also planned in order to observe changes in reservoir conditions:
    - Reservoir pressure monitoring at the observation wells.
    - Micro seismic monitoring
    - Surface micro-gravity monitoring
    - Geochemical monitoring of production fluid etc.

- Local government’s role is important in establishing a symbiotic relationship between a developer and local residents including hot spring owners.
YGP’s new “Wasabizawa Geothermal Power Station” (42MWe) (under construction)

Production test of new well WB-1 (May 19, 2017)

Production test of well WC-1 after workover (Oct. 24, 2017)

Photos: from YGP
Thank you for your kind attention!!

Commercial operation of the plant will begin in May 2019.

Drilling of new well WC-2 and land preparation of the plant (May 19, 2017)