Baker Hughes

Case study: Habanero Geothermal Field, Australia

Geomechanical technologies proved ESG heat extraction, electricity generation feasible and profitable

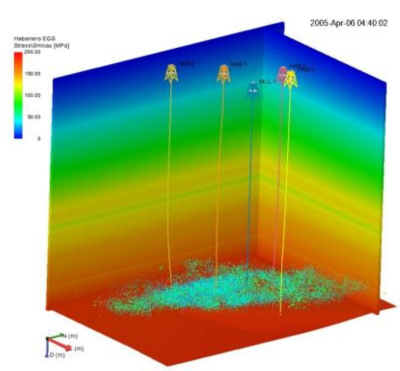
The Habanero Field, Australia, is an extremely deep fracture/fault hosted granitic enhanced geothermal systems (EGS) reservoir approximately 16,404 ft (5000 m) below a thick sedimentary cover greater than 9,842 ft (3000 m) with interbedded weak shale and coal intervals. With temperatures above 464°F (240°C), the reservoir is overpressured at 1.7 SG. As an EGS reservoir, there is no natural fluid source, compelling the operator to use expensive stimulation fluids, so stimulation must be optimally targeted.

With reservoir characteristics such as these, an operator faced daunting challenges. The operator didn't possess good knowledge of the heterogeneity in fracture intensity throughout the field not the fracture flow properties and the expected response of the fracture network to stimulation. Drilling through the weak shales and coal intervals in the overburden would prove problematic as well as the time dependent wellbore instability in the reservoir and overburden.

The operator needed a plan to deliver a subsurface characterization of the fracture/fault network and the *in situ* state of stress. A better understanding of the hydro-mechanics between reservoir fractures and faults and away from well controls was also necessary. Finally, the operator required a full-field well planning strategy to mitigate wellbore instabilities during drilling and optimize production.

Drawing on its field-proven expertise, Baker Hughes recommended 1D and 3D geomechanical modeling including a calibrated discrete fracture network (DFN) model, all part of the **JewelSuite™ integrated reservoir modeling software**. This application is an innovative, powerful tool to quickly create precise geological models—regardless of the reservoir's structural complexity—in half the time as traditional solutions. This modeling tool can seamlessly transfer into any industry standard simulator. Reservoir models can be updated and modified easily with new well information or alternative geological scenarios to optimize field development plans and drive greater production.

The analysts utilized a comprehensive data set from a basement granite reservoir in the Cooper Basin to determine the present day *in situ* stress field and characterize the natural fracture population. A fracture



The 3D geomechanical model of the Habanero Field and microseismicity induced by low are long terms stimulation.

Challenges

- Mitigate wellbore instabilities during drilling
- Determine subsurface characterization of fracture/fault network and the *in situ* state of stress
- Understand hydro-mechanics between reservoir fractures and faults and away from well controls
- Optimize production with a full-field well planning strategy

Results

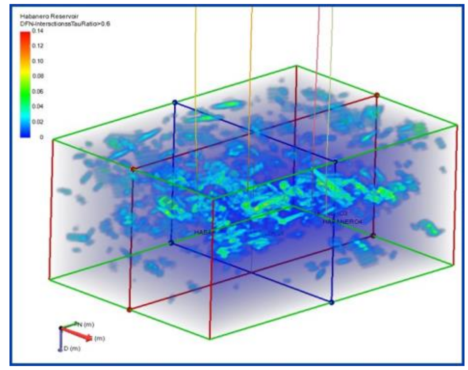
- Provided specific drilling and completion designs to manage overpressure and mitigate time dependent wellbore instabilities
- Provided a 3D reservoir model of target sweet spots for natural fracture stimulation and optimal enhanced production of the closed-loop EGS system for 6 potential wells to generate approximately 7.5 megawatts (MW) electrical power production
- Reduced nonproductive time (NPT) and risk of expensive deep sidetracks for drilling through geomechanically unstable overburden formations
- Delivered a solution to drill 3 wells for $10 million (where typical costs range from $11 to $25 million)
- Experienced no health, safety and environmental (HSE) issues

conceptual model was derived based on wellbore image analysis, well tests, and tracer tests. In addition, Baker Hughes interpreted the available microseismic event data to more precisely define fracture geometry away from the wellbores. The microseismic data was also used to calibrate the model for the dynamic behavior of the fracture system during stimulation. By carefully animating the development of the microseismic cloud, engineers can infer fractures in the order in which they were stimulated. In this way, a realistic model of the dynamic stimulation of pressure build-up and consequent fracture stimulation along connected pathways was obtained.

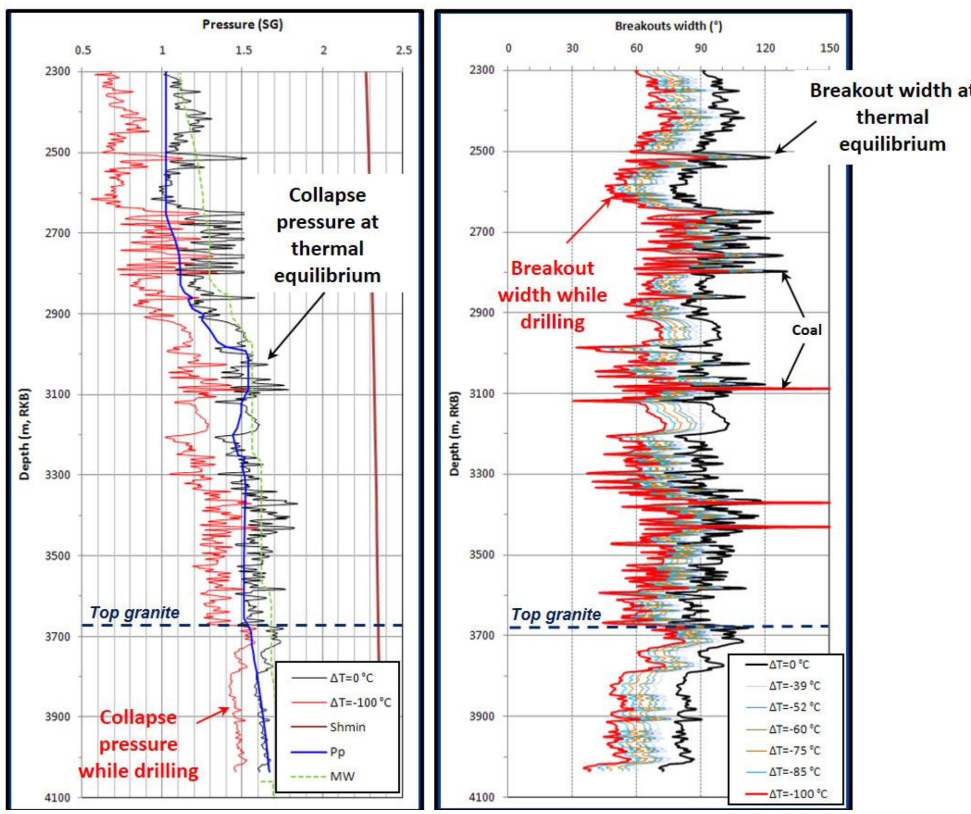
Low flow rate injection tests were used to characterize the hydraulic properties of the fractures, their width, stiffness and strength—properties that are often difficult to quantify *in situ*. These fracture flow properties, stresses, and the measured fracture data were used to explicitly model flow and transport through individual fractures, which form the connected DFN. Fracture stress sensitivity was internally coupled to the flow simulation and calibrated with microseismic data (positions and times of events) and injection data (rates and pressures). The simulation provided the post-stimulation stimulated reservoir volume (SRV) of the field, including extent, geometry, and volume of hydro-shearing resulting from the stimulation. A post-stimulation tracer test for dipole injection between two wells was then used to confirm the resulting model.

Using the final model generated for Habanero, Baker Hughes engineers calculated the fracture connectivity, both the connectivity of the intersecting fractures (intersection length) and their connectivity to the wellbore. By mapping the fracture intersections to the structural grid, the team evaluated the "fracture sweet spots," reservoir zones with a probabilistically high density of stress sensitive fractures.

With the field-wide wellbore, microseismic and stimulation data, Baker Hughes established the geothermal potential reserves of the Habanero field and, thus, the feasibility of EGS geothermal power generation. The JewelSuite software provided the operator options to reduce the exposure time between drilling and casing the well, mitigating expensive wellbore instabilities and sidetracks. Additionally, the Baker Hughes team delivered a characterization of the hydro-mechanics of the reservoir fracture network, enabling the operator to design optimal hydro-shearing operations.



DFN fracture intersections mapped to the Habanero structural grid indicating "fracture sweet spots," reservoir zones with a probabilistically high fracture density



The effects of temperature changes in wellbore stability

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