ASSESSING FRACTURE NETWORK CONNECTIVITY OF PREFEASIBILITY-LEVEL HIGH TEMPERATURE GEOTHERMAL PROJECTS USING DISCRETE FRACTURE NETWORK MODELLING

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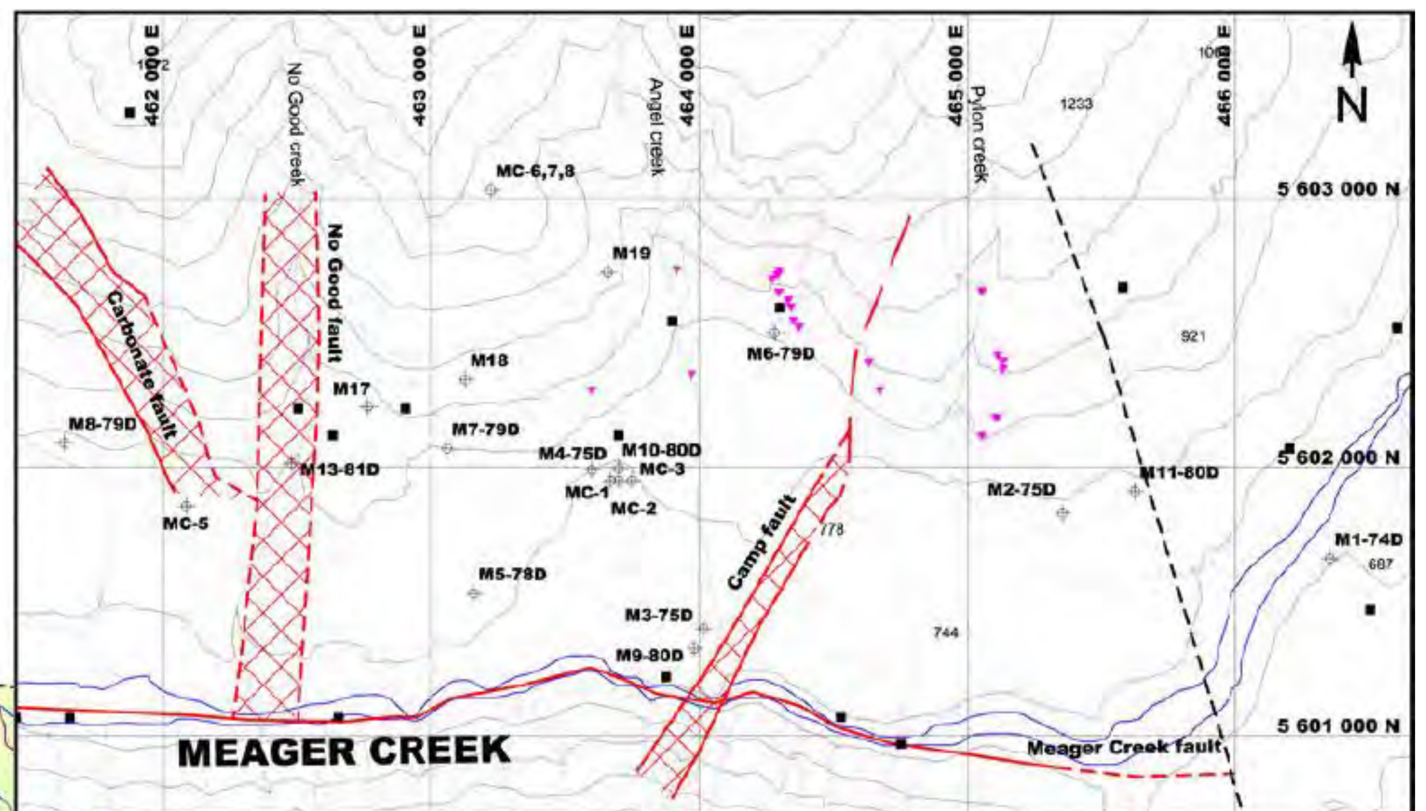
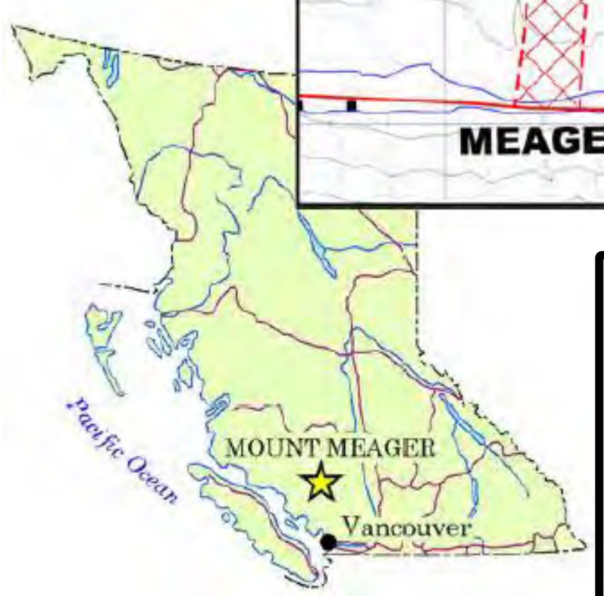
RESEARCH OBJECTIVES

The goal of this research is to use historical geomechanical and hydrogeological data collected from the Meager Mountain area to assess the natural fracture connectivity of the reservoir rocks that host the geothermal resource at the Meager Creek site using discrete fracture network (DFN) modelling. This will lead to a greater understanding of why past attempts to develop the site were unsuccessful, and if measures can be taken to increase the likelihood of successfully developing high temperature geothermal resources in the future.





SITE DESCRIPTION

The Meager Creek geothermal site is located at the base of Meager Mountain, located approximately 65 km northwest of Pemberton, B.C. and 150 km north of Vancouver, B.C., Canada. The Meager Creek site is located within the Coast Plutonic Complex, near the intersection of the late Tertiary and Quaternary northwesterly-trending Pemberton Belt and the north-south-trending Quaternary volcanoes that are part of the Garibaldi belt[1].

DISCRETE FRACTURE NETWORK MODELLING

Discrete fracture network (DFN) modelling is a method that can be used to model fluid flow and transport processes in fractured rock masses. Unlike equivalent continuum rock mass models, DFN models can represent the geometric characteristics of connected fracture networks in rock masses through the stochastic simulation of discrete fractures over a model area/volume. Through the development of multiple DFN models of the Meager Creek site, the connectivity of the existing fracture network was estimated and the likelihood that sufficient fracture network connectivity exists at the site to support a high temperature geothermal project was assessed.

ABSTRACT

The Meager Creek geothermal anomaly has been identified as one of Canada's most promising high temperature geothermal sites. Results from exploratory drilling and the presence of natural hot springs indicate that a convective hydrothermal system exists within the crystalline basement rocks at the site. These positive results prompted several companies to engage in production drilling campaigns as early as 1981. To date, all attempts to establish sustainable levels of geothermal fluid production have been unsuccessful. Low permeability and poor hydraulic connectivity of the basement granodiorites are often cited as the key geological factors limiting the development of the Meager Creek site. These conclusions are inferred from qualitative assessments of core samples and the low production yields of completed test wells, and are not based on a detailed analysis of the geometric properties of the underlying fracture network.

Through the interpretation and analysis of geomechanical and hydrogeological data collected during historical field investigations at the site, stochastic discrete fracture network (DFN) models were constructed. An iterative process of simulation and analysis of individual DFN models led to a rigorous assessment of the existing connectivity of the natural fracture network. The connectivity of the existing fracture network at the Meager Creek site appears to be favourable in the area surrounding the Meager Creek Fault, which was not intersected by any of the test wells drilled.

It was found that the use of DFN models was useful in estimating fracture network connectivity and can serve as a tool for optimizing the location and orientation of production wells. A high degree of uncertainty is associated with fracture network connectivity estimates due to the absence of downhole linear fracture intensity measurements and a rigorous surface mapping methodology. Fracture network connectivity estimates can be greatly improved by adjusting the design of prefeasibility-level field investigations. The additional cost and time required to incorporate these adjustments into standard prefeasibility-level geothermal field investigations is minimal.

REFERENCES

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MODELLING METHODOLOGY

DFN models were constructed based on two different geologic models in order to analyze the effects of large-scale faults on fracture network connectivity estimates. The first geologic model assumes that regional-scale faults have no effect on fracture network connectivity. The second geologic model incorporates an extensive east-west striking fault that dips towards the north at approximately 50° with and associated 100 m-wide fault damage zone. The fault damage zone is assigned a greater fracture intensity value relative to the rocks that constitute the hanging and footwall of the fault. The fault geometry used in the model is reflective of the Meager Creek fault geometry, which was mapped in exposed outcrops along the banks of Meager Creek.

Numerous studies have reported that fluid flow in fractured media is typically limited to a small percentage of the total number of observed fractures[2]. This was accounted for in DFN simulations by assigning transmissivity values to individual fractures and utilizing transmissivity thresholds to exclude a certain percentage of fractures from contributing to the development of connected fracture networks.

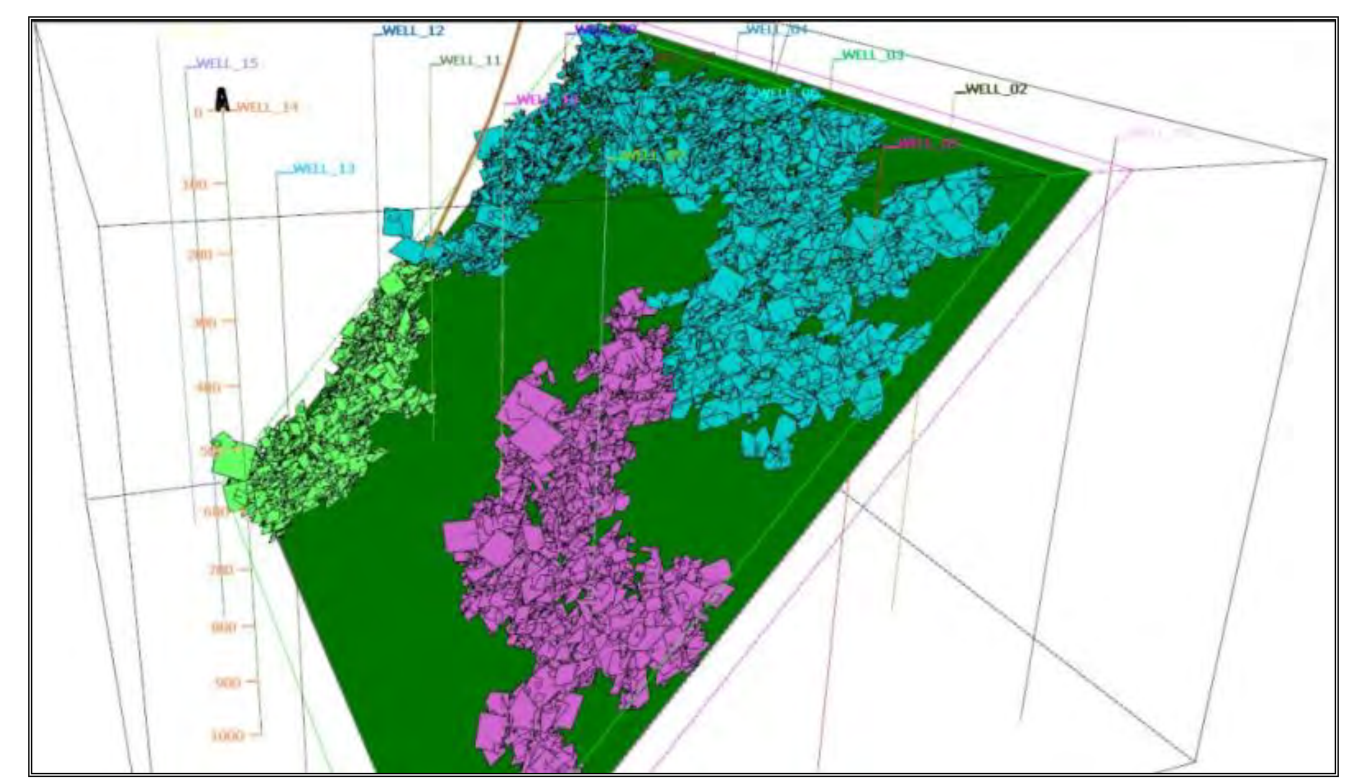

Figure 1: A single DFN model simulation of the Meager Creek site. The large dark green plane represents the Meager Creek fault, and the smaller light green, blue, and magenta planes represent connected fracture clusters. A relatively high degree of fracture network connectivity must exist in order to support a high temperature geothermal project.

DISCUSSION OF RESULTS

Fracture network connectivity analysis results indicate that although the geothermal resource at the Meager Creek site is hosted in low-permeability reservoir rocks, the presence of the Meager Creek fault may provide sufficient connectivity for the upwelling and circulation of heated geothermal fluids that may permit the future development of a commercial geothermal project at the site. The higher fracture intensity value assigned to the fault damage zone allows clusters of connected fractures to develop along the fault plane, even when the percentage of transmissive fractures that exist in the model is low.

Significant uncertainty is associated with the fracture connectivity assessments of the Meager Creek site due to the absence of certain geological information that was not collected during the initial field investigations. This data included measurements of fracture orientation and the depth of all fractures encountered during drilling. The data collected from structural mapping could not be corrected for sampling biases, which increases the potential error in the delineation of fracture set orientations and trace length distribution.