The DEEP Geothermal Power Project: Wildcat Drilling for the Earth’s Heat

Williston Basin (Canada)

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**ABSTRACT**

The DEEP Earth Energy Production Corp. ("DEEP") geothermal power project is located in Southeastern Saskatchewan, Canada, a few kilometres north of the United States border. In December 2018, DEEP successfully drilled the first geothermal test well. The vertical well reached its target total depth of 3,530 metres (m), the deepest well ever drilled in Saskatchewan’s history. Preliminary data, acquired to assess the geothermal reservoir, indicate bottom-hole temperatures exceeding 125°C, in addition to positive reservoir pressure and permeability exceeding the minimum threshold for project feasibility. This was a major step forward for the first renewable power project of its kind in Canada. Final testing results from the drilling program will refine the assumptions made on the reservoir and effectively optimize the design parameters. This has the potential to be a transformative energy innovation for Saskatchewan.

The DEEP well, named Border-01, targeted the early Paleozoic age basal clastic reservoirs of the Winnipeg and Deadwood formations and fractured Precambrian granite. Injection wells for water disposal in Saskatchewan and gas wells in North Dakota demonstrate a basin-scale resource with reservoir characteristics suitable for large fluid production and injection rates, however temperatures greater than 100°C are only found in the south-easterly most part of Saskatchewan and western North Dakota. Analysis of image logs, drill stem tests and the flow and build-up test from the DEEP well indicate that fractured Precambrian basement is an important contributor to fluid flow. The well is unique in that it targets deep hot water in a highly productive oil region. The well has hundreds of horizontal oil wells as neighbours and is located in a Saskatchewan oil field and just north of North Dakota’s renowned Bakken trend. The decades of petroleum exploration data were critical to the development of DEEP’s project. DEEP’s project will have benefit of local petroleum industry expertise and services.

A Preliminary Study was completed in 2014 through grant funding from Natural Resources Canada and SaskPower Corporation. The study concluded that the project is viable from an economic, legal, environmental, and technical perspective. The Full Bankable Feasibility Study is scheduled to be completed early in 2020.

The next steps for the project include the analysis of an injectivity and fall off test completed on the Border-01 well in October 2019 and drilling a new production well (Border-02) in Q4 of 2019. During production testing operations, brine from the new source well will be injected into Border-01 enabling the first production/injection doublet. Further geothermal parameters will be acquired during this process, which includes a long term (30-60 day) production/injection flow and build-up test. Final feasibility engineering reporting are expected by Q2 2020, with full scale construction commencing later in 2020 and final commissioning scheduled for completion by the beginning of 2022.

DEEP’s long-term strategy is to build geothermal power facilities with the capability of generating hundreds of Megawatts (MW) of power. This strategy complies with a vision of a cleaner energy future for Saskatchewan and simultaneously supports SaskPower’s goal to reduce 2005 emission levels by 40 per cent by 2030. Produced electricity from the first facility will be sold under an existing Power Purchase Agreement with SaskPower and will generate roughly the power required by 5,000 homes and offset about 27,000 tonnes of carbon dioxide per year, equal to removing 7,400 cars off the roads annually. In addition to revenue from direct power sales to SaskPower, DEEP is exploring additional revenue streams including a commercial greenhouse development, which would be a new opportunity for the Saskatchewan agricultural sector.

1. **INTRODUCTION**

Wildcat drilling exploration in the petroleum industry is the high-risk activity of drilling for reserves in areas that have no history of production. Wildcatting is perhaps the most compelling and exciting aspect of hydrocarbon exploration. In the petroleum industry, successful Wildcatters are not thought of as lucky but rather viewed as extremely clever for recognizing an opportunity where others didn’t. Wildcat wells require the greatest integration of all data to give the well every possibility of success. Developing geothermal projects in sedimentary basins, particularly if the boreholes are deep and the resource is not well understood, share many of the attributes of wildcatting in the fossil fuel industry. In this paper we share the exploration process and results of the DEEP’s geothermal test well.

DEEP’s geothermal project is located approximately 34 kilometres (km) southwest of Estevan Saskatchewan Canada and 2.4 km north of the North Dakota United States border in the Williston Sedimentary Basin. The vertical well is the deepest well drilled in Saskatchewan with a total depth of 3,530 m. The test well targeted the early Paleozoic age basal clastic Deadwood and Winnipeg formations, and fractured Precambrian basement on a deep high temperature trend in the Williston Basin. Recognizing that fracture enhancement of the target lithology was critical for success, the well bore was positioned near the intersection of two major structural elements of the Williston Basin; the Brockton Froid fault zone and the Nesson anticline.
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The process of drilling an exploration well and developing a project starts with a vision and then requires the financial resources to execute that vision. At its essence, the concept is straightforward; drill a deep borehole in a mature oil basin to determine if a sufficient volume of hot brine could be produced to generate electricity utilizing Organic Rankine Cycle technology. However, the challenges were significant; attracting investment capital, utilizing and understanding the available data (particularly if the data was acquired for different objectives or distal from the project area), choosing a well site, and executing optimal drilling and production operations.

2. GEOLOGICAL SETTING

The Williston Basin is an inter-cratic basin centrally located on the North American continent straddling the Canadian American border. It is an ellipsoidal bowl-shaped depression that forms the south-west extremity of the Western Canadian Sedimentary Basin (WCSB) (Gerhard 1982; Kent and Christopher 1994). Oil was first discovered in the Williston Basin in southeastern Montana in the 1920s and in North Dakota in 1951 (Gerhard et al. 1990; American Oil and Gas Historical Society) and subsequently, more than 115,000 wells have been drilled. The sedimentary section of the Williston Basin reaches a thickness of over 4,800 m in northern North Dakota and the stratigraphic section demonstrates that the predominant depositional environment was a shallow sea from the Cambrian until the late Cretaceous (Gerhard et al. 1990).

The Precambrian basement below the Williston Basin is comprised of three main tectonic zones defined primarily through aeromagnetic geophysical analysis. There are two cratons (Superior and Wyoming) separated by the Trans Hudson Orogenic zone. The Trans Hudson Orogenic belt consists of numerous north-south trending terrains, the result of the convergence of the cratons and the associated compression of the subduction zone and volcanic arc that separated the cratons (Li and Morozov 2006; Bader 2019). These terrains may be associated with deep faults and sutures and are important to the Phanerozoic evolution of the basin (and potential trends of deep heat flow, fracturing and fluid movement). Reactivation of Trans-Hudson basement structures resulting from sediment loading is postulated as a mechanism for basin subsidence and development (Gerhard 1982). Williston Basin Precambrian terrane rock types and their associated thermogenic values vary based on their genesis and location in the fragmentation of the craton and associated opening and closing of the Proterozoic ocean basin and include schists, granites, diorites, granodiorite, gabbros and quartzite (Bader 2019). The Trans-Hudson orogenic belt rocks are predominately volcanic arc related and separate the Superior and Wyoming Archean cratons consisting of greenstone-granite and gneissic terranes (Ricker 2015).

The Basal Clastics in the Williston Basin were deposited after a long period of Precambrian erosion. The lower Cambrian Deadwood formation represents the first transgressive event as Cambrian seas transgressed the low relief and irregular Precambrian surface. This initial deposition was predominately sandstones interbedded with siltstones and shales. In the DEEP project area, the Deadwood is unconformably overlain by transgressive sandstones, siltstones and shales of the middle Ordovician Winnipeg formation (Anderson 1988; Kreis 2004). The deposition of the Winnipeg formation is contemporaneous with the initiation of the structural depression that forms the basin. The sediments of the Williston Basin are representative of all periods of the Phanerozoic. Following the deposition of the Deadwood and Winnipeg formations the later Paleozoic is composed predominately of carbonates and evaporites. The Mesozoic sediments are almost entirely clastic. Clastic Tertiary rocks and Quaternary Glacial drift complete the deposition in the basin (Gerhard 1982).

The Nessan Anticline is a north-south trending structural feature near the center of the Williston Basin along 103 degrees longitude W that is associated with a geothermal anomaly. The Nessan Anticline has experienced episodic structural movement since Precambrian time (Osadetz 1989; Lindsay et al. 1998). This structure has a surface expression (Gerhard 1982) and is associated with oil and gas production from Cambrian to Cretaceous formations.

The Brockton Froid fault zone is interpreted to be a basement related left-lateral shear zone (Gerhard et al. 1990; Wright et al 1994) with surface expression (Penner 2006). The Brockton-Froid fault zone may be a conduit for the migration of North Dakota Bakken oil into Saskatchewan (Silver 2013). It has been interpreted as a flower structure (Penner 2006).

3. PREVIOUS WORK

As the desire for alternative energy sources intensifies, increased effort is being made to understand the geothermal potential of basins worldwide and the Williston Basin and the Western Canadian Sedimentary Basin (WCSB) are no exception. Researchers on both sides of the border have researched temperature data and geothermal opportunities, but there is very little cross border integration. Deadwood formation temperatures greater than 120°C have been measured in a small area of southeast Saskatchewan and up to 160°C in North Dakota.

The geothermal potential of the Williston Basin has been recognized since the 1970s. Williston Basin heat flow and temperature distributions have been studied in considerable detail (Porro 2012, Anderson 2013, Gosnold 2015, 2019). The basal clastic Deadwood and Winnipeg formations have received special focus due to their depth and reservoir parameters (Vigrass 2007; Ferguson and Grasby 2014; Ufondo 2017). In 1978 a 2,226 m vertical geothermal well was completed in the Winnipeg and Deadwood formations to supply direct heat to buildings at the University of Regina. The well had 111 m of effective net reservoir with average porosity of 13.2%, an average permeably of 350 Millidarcies (mD) and a bottom hole temperature of 61°C (Vigrass 2007). Based on the formation temperatures and the disposal rates of greater than 30 litres per second (l/s) in numerous disposal wells in the basin, the basal clastic zones have potential for direct use geothermal applications in broad regions across the basin (Ferguson and Grasby 2014). However, the Williston Basin is only hot enough for electric power generation in southeast Saskatchewan and northeast North Dakota due to a southward deepening in the basin from Regina.
Sedimentary basins have some advantages relative to other geothermal regimes although they may not have the higher temperatures found in volcanic hosted geothermal resources. The reservoir properties and extents are often better characterized by hydrocarbon drilling and seismic surveys. The oil and gas industry has inadvertently taken up much of early stage exploration risk that is a hurdle.
for geothermal development in the exploration for fossil fuels. Sedimentary reservoirs often have suitable permeability thickness and storage for high fluid production rates and volumes. In the Williston Basin the basal clastics exhibit these qualities (Ferguson and Grasby 2014; Ufondo 2017). Potash fluid disposal wells in the northern Williston Basin have permeabilities of hundreds of millidarcies, greater than 15% porosity and are capable of disposal rates up to 150 l/s. In general, sandstone porosity decreases as a function of depth, age and basin temperature gradient. Deeper in the basin, diagenetic processes resulting from hydrothermal alteration from the interaction of hot aqueous fluids and the rock through which they circulate can lead to the occlusion of porosity and permeability as the hot fluids dissolve and precipitate minerals. As a result, the injection wells may not provide good analogues for deeper wells near the hot basin center.

The measurements of downhole temperatures from drill stem tests (DSTs) and logging from oil and gas drilling are suspect due to the cooling of the formation by drilling fluids and require lengthy periods for reservoir temperature equalization. Reliable corrections for bottom hole temperatures have been calculated using temperature gradients, thermal conductivity and heat flow data (Gosnold et al. 2012).

The Deadwood Formation was investigated and modelled in North Dakota for Enhanced Geothermal Systems (EGS). Initial models indicate that the Deadwood Formation could be developed as a significant EGS resource (Gosnold et al. 2013).

4. VISION, FUNDING AND EARLY WORK BY DEEP

Figure 3: Canadian Prime Minister, Justin Trudeau, announces Federal Funding

DEEP Earth Energy Production Corp. is a privately held company with a mission to develop Saskatchewan’s geothermal resources for power generation. DEEP’s vision is to be a producer of secure, stable and sustainable energy.

In 2014, a C$2M Prefeasibility Study was completed through grant funding. Natural Resources Canada’s ecoENERGY Innovation Initiative and SaskPower each contributed C$1M. The study concluded that the project is viable from an economic, legal, environmental, and technical perspective.

Since the Company’s inception, DEEP has advanced the project through private equity investments from shareholders primarily in Saskatchewan and Alberta. In the fall of 2018, significant investments totaling approximately C$5M were achieved to fund the first test well.

In January 2019, Canada’s Prime Minister, Justin Trudeau, announced $25.6M of funding to provide approximately 50% total project funding for the first 5 MW power facility. Funding for this project is being provided through Natural Resources Canada’s Emerging Renewable Power Program. Natural Resource Canada’s Clean Energy Innovation Program and Innovation Saskatchewan have also contributed $350,000 and $175,000, respectively.

DEEP and SaskPower have signed a Power Purchase Agreement for the first 5 MW electrical facility. This agreement sets forth the detailed terms governing the power purchase price, construction, ownership and operation by DEEP of the geothermal power facility. DEEP is also in receipt of a previously signed Letter of Intent from SaskPower for an additional 20 MW of power sales, under similar terms, which addresses the next phase of growth. Each MW of power production will provide power to roughly 1,000 homes.

DEEP’s long-term strategy is to build multiple geothermal power facilities. This growth would only be limited by the extent of the heat resource in the basin and SaskPower’s appetite for baseload renewable power and DEEP’s access to capital. SaskPower’s
demand for power is forecasted to continue to grow and Saskatchewan has seen a considerable increase in demand over the past five years. SaskPower has also committed to a 40% reduction in greenhouse gas emissions from 2005 levels by 2030. Matching projected growth with lowering total greenhouse gas emissions means that a significant portion of new power generation must come from renewable sources like geothermal. Once DEEP’s first power plant nears completion, subsequent projects can be constructed with debt that utilizes the equity in the preceding facilities as leverage with its AAA rated government power sale contract.

One of the most significant accomplishments for this project will be to prove the benefit of Canada’s first fully operational geothermal power facility, connected to SaskPower’s electrical grid, as a viable and reliable power source. This will open the door to many additional facilities in the years to come which would increase Saskatchewan’s competitiveness in the clean tech industry. It will also increase awareness and understanding of geothermal power generation, waste heat usage opportunities and associated processes affiliated with reducing greenhouse gas emissions.

This first geothermal facility will be a transformative energy innovation for the province and will unveil for the first time, an entirely new renewable power resource for Saskatchewan and Canada. The success of this first facility will break barriers to entry for other geothermal projects nation-wide.

5. PRE-DRILL (INCLUDING SITE SELECTION)

An in-depth review of the available Williston Basin literature was followed by mapping the Deadwood and Winnipeg formations throughout the Williston Basin. An extensive well data base exists in Saskatchewan and North Dakota, the result of over 60 years of oil and gas drilling. However, the control is relatively sparse for the Deadwood and Winnipeg formations and less data exists for the Precambrian basement. Several areas were chosen for further study. Cross-sections were constructed and available core information integrated. These areas were mapped for structure, temperature, thickness and general porosity – permeability distributions. A roughly 1,000 km² area west of Estevan along the United States border was prioritized based primarily on bottom hole temperature (BHT) data and formation thickness trends.

Key data points were a pair of CO₂ storage project wells (Aquistore CO₂ Capture and Storage Demonstration Project) near a coal-fired generation facility located 9 km southwest of the town of Estevan as well as from an abandoned well drilled by Home Oil in 1985 located 36 km southwest of Estevan which was ultimately 2 km southwest of DEEP’s first geothermal well, Border-01.

The Aquistore project captures CO₂ from the Boundary Dam coal-fired generation station and injects the CO₂ into the Winnipeg and Deadwood zones in a purpose drilled 3,400 m deep well. An observation well is located 150 m away for the initial reservoir testing and to monitor CO₂ migration and operational reservoir performance. The Aquistore wells were drilled in 2012 by the Saskatchewan Petroleum Technology Research Center as part of SaskPower’s Boundary Dam Integrated Carbon Capture and Storage (CCS) project.

The Aquistore project had an extensive technical program integrating geology, geophysics, hydrogeologic and geochemical data (Rostron 2014). The program, which included Vertical Seismic Profiles (VSPs), bore-hole tomography, and downhole and surface monitoring, was a source of valuable information to DEEP’s feasibility analysis of the basal clastic units. Relative to disposal wells in the shallower northern regions of the basin, the Aquistore wells had poor reservoir characteristics. The open hole logs of the Deadwood formation show a gross thickness of 172.9 m. A 6% porosity cut-off resulted in a 42 m net porous sand thickness. However, using a cut-off of 9% and 12% reduced the net sand thickness to 17 m and 5 m respectively. Core porosity was a close match to log porosity and the average core permeability was 4.9 mD.

The Home Oil well drilled in 1985 evaluated the uppermost Deadwood and is mapped with one of the hottest bottom hole temperatures in Saskatchewan. Over a three-day period between logging runs the well bore began to equilibrate with formation temperature and the measured BHT increased 31 degrees from 95°C to 126°C.

The target area was the hottest mapped in the Canadian portion of the Williston Basin. Achieving the required wellhead temperatures was not a concern but there was uncertainty on the reservoir quality required for sustainable high flow rates. Well productivity modeled solely on the primary transmissivity and porosity of the proximal deep basal clastics was in question. Therefore, secondary fracture permeability was required to achieve economic well performance. Fractured basement rocks could yield additional mass flow and higher overall temperatures. A decision was made to focus on the area near the intersection of the Nesson Anticline and the Brockton Froid fault zone. The Nesson Anticline in known to be associated with fracture development and a thermal anomaly. The strike-slip kinematics of the Brockton Froid fault zone indicated the potential for higher fracture densities in the basement and basal sedimentary section. The well test site was chosen 2.6 km northeast of the high temperature 1985 Home Oil abandoned well.
6. THE WILDCAT

Drilling of DEEP’s first test well commenced on November 14th, 2018, located in Section 10, Township 1, Range 11, west of the 2nd Meridian (Western Canada’s Dominion Land Survey System). The vertical well, named Border-01, reached its target total depth of 3,530 m on December 16th, 2018. This is the deepest well ever drilled in Saskatchewan’s history and the Williston Basin’s first geothermal wildcat.

A total of 216 m of core was recovered across the targeted reservoir, including the Winnipeg and Deadwood Formations terminating in the Precambrian bedrock. The well drilled 27 m of Precambrian basement and acquired 4.3 m of Precambrian core before jamming off. The core likely jammed due to the fractured and friable nature of the weathered Precambrian at the unconformity. The drilling was uneventful except for two significant losses of oil-based drilling fluids into fractures in the Cambrian Yeoman Formation.

Temperatures up to 128°C were measured during the logging operations. A standard logging suite of open hole logs were run; Gamma, Spontaneous Potential, Neutron-Density and Dual lateral logs. Additionally, Dipole Sonic, Sonic Image and Formation Micro-image logs were acquired. A drill stem test (DST) over the Deadwood formation and Precambrian interval had an excellent pressure response and indicated high permeability and transmissivity. The well was completed having met threshold transmissivity parameters. A planned DST over the Winnipeg Formation failed due to the high temperatures which compromised the DST packer equipment. The well was completed with 7 inch (177.88 mm) casing and 4.5 inch (114.3 mm) slotted liner over the target Winnipeg, Deadwood and Precambrian section. The well was then shut in awaiting further data analysis and further pressure transient and flow testing.

The average porosity and permeability from routine core analysis of the Winnipeg zone was 8.3% and 9.27 mD respectively over a 21.4 m interval. An 8 m zone with 11% porosity and 28.5 mD of permeability was included in the reservoir flow calculations. The average porosity and permeability of the Deadwood Formation from routine core analysis are 8% and 9.87 mD respectively. The permeability value is skewed by a handful of sample points with permeability in excess of 50 mD (Deadwood mean permeability is 9.87 mD vs median permeability 0.93 mD). Two Deadwood zones have adequate reservoir parameters to be included in the flow calculations. The Upper Deadwood is a 7 m zone with core porosity of 12% and core permeability of 1.59 mD. The Deadwood main reservoir zone has a thickness of 26 m with a core porosity of 10.6% and 17.8 mD.

Darcie flow analysis on the logs and core data over the Winnipeg and Deadwood zones demonstrated reservoir parameters that would not solely be sufficient for an economic geothermal power project. The fractured Precambrian is postulated to be the source of the almost instantaneous pressure response measured on the DST.

The 3.77 m of core acquired over the Precambrian basement rock was of a highly altered and fractured granite. The potassium-feldspars have been altered and replaced. The alteration is accompanied by the precipitation of oxide minerals, primarily hematite. Samples near the unconformity appear to be a former weathering surface as it appears to be brecciated with rounded “pebbles” of previously altered granite. Routine core analysis of the Precambrian had porosity measurements up to 9%; however, the rock proved too friable for permeability analysis. The petrophysical analysis and image logs clearly show that the Precambrian can be divided into two distinct units: the 8-meter altered interval where the Precambrian is less dense with low sonic velocity and a deeper zone with characteristics typical of igneous or metamorphic basement rocks.

The well logs and core were integrated in a petrophysical study. The multimineral analysis with integrated core data provided an excellent analytical tool for understanding the reservoir. However, the thin section work and X-ray diffraction (XRD) analysis provided the most important insights. Diagenetic and hydrothermal processes have transformed the reservoir properties. The
dissolution of primary minerals and the precipitation of secondary minerals altered both the basal clastics and the basement rock. Six thin sections were cut and analyzed (1 thin section in the Winnipeg, 2 in the Deadwood and 3 in the Precambrian). The porosity in the Deadwood samples had been occluded by the precipitation of hematite by up to 29% in one thin section. The altered Precambrian now contains abundant illite of up to 40% as determined by XRD analysis. Microfractures observed in a Precambrian thin section demonstrate a porosity up to 5.6%. The formation micro-image (FMI) logs indicate surprisingly little fracturing through the Winnipeg and Deadwood Formations, despite pervasive fracturing throughout the underlying Precambrian. This low fracturing was particularly surprising given the drilling fluid losses caused by fracturing in the overlying Yeoman section.

Figure 5: The DEEP Border-01 well head with tank farm during the flow and build-up test

The well was shut-in in December 2018 and the borehole temperatures were able to equalize. In August 2019, Production Logging Tool (PLT) logging and a flow and build-up test were completed on the Border-1 well. The bottom hole temperature measured during PLT logging was 124.6°C. The well was produced using an electric submersible pump (ESP) at a constant rate of 500 cubic metres per day into a tank farm of thirty 64 m³ tanks. During the flow and build-up test, the downhole pressure was monitored and samples of brine, gas, and precipitated solids were collected to be analyzed for determination of the composition of the produced brine.

After the three-day flow test, the well was shut-in for 23 days during which time the pressure in the well equalized and was recorded by downhole gauges. The data from the test was analyzed and modeled utilizing reservoir pressure transient analysis (PTA) software. The resulting pressure-transient analysis showed significant skin (near bore hole formation damage) and a dual porosity system. Fracture contribution from the weathered Precambrian and matrix contribution from the lower Deadwood sands best fit the derivative plot curves. The extrapolated flow rates after well stimulation modeled to rates sufficient for project viability.

The flow and build-up test evaluated the entire open hole section and although the modelling clearly demonstrates a dual porosity system, it is impossible to derive a unique solution. Assumptions are required regarding the characteristics of the fractures and uncertainty exists as to which zones contribute and the relative contribution of each zone. Additionally, the reason for the high skin factor is not fully understood. Given these uncertainties the Border-01 well was further tested in Q4 2019. The slotted liner covering the zones of interest was removed from the well bore to enable zonal injection and fall-off testing. These tests were completed over the identified potential reservoir zones to provide unique zonal permeability, reservoir damage and relative contribution data as well as insight into absolute contribution, flow rate and reservoir performance. Injection and fall off testing is a pressure transient well test that obtains reservoir data by measuring reservoir pressure response after injecting fluid into the formation. The injection fluid was carefully prepared with a chemical and filtration treatment and then pumped into the formation at a constant rate while recording pressure for a test period calculated based on known reservoir parameters. There were 4 zones of interest that were isolated and tested using inflatable packers. These zones are the Winnipeg, the upper and lower Deadwood and the Precambrian.
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7. FUTURE PLANS
The data from the well injectivity and fall off test acquired in the Border-1 well will be analyzed and modelled using PTA test software. The understanding of the permeability, skin, reservoir pressure and relative flow contribution of each zone will be utilized to support the design of future wells and overall development scheme of the project.

A second well (Border-02) will be drilled from the same surface location directionally with a bottom hole location approximately 1,500 m to the southwest. Because the integrated analysis of all data from Border-01 suggests that the bulk of the hot fluid contribution was sourced from the Precambrian, the Border-02 well will target the Precambrian fractures with the intermediate casing point immediately above the Precambrian. The well is designed to penetrate 200 m into the Precambrian. Once Border-02 has been drilled and completed, a 30 - 60 day well doublet test will begin with fluid produced from Border-02 and injected into Border-01. This data will be utilized in a suite of geothermal modelling tools to understand the reservoir diffusivity and thermal breakthrough parameters for the final field well space design.

Hydraulic fracturing for EGS is being investigated as a possibility for the basal clastics and Precambrian.

8. CONCLUSIONS
High risk exploration drilling and the subsequent testing and data analysis is an exciting process full of surprises and learnings, DEEP’s experience with the Border-01 well is an example of this. The exploration program was successful in identifying a potential geothermal resource, the first in of its kind in the Williston basin, Saskatchewan and Canada. Further testing and drilling will determine the economics for geothermal power generation in Southeast Saskatchewan. Early indications are positive.

Basin centers are attractive when prospecting for geothermal opportunities as they tend to have the highest available temperatures in sedimentary reservoirs. However, as observed in DEEP’s first geothermal well, processes such as thermal alteration can have a negative impact on reservoir quality and should be considered during project risk assessment. Fractures in both target reservoir zones, and the constraining units should be assessed as fluid contribution from fracture networks could be a significant factor in project success.

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