KOOTENAY LAKE

COMMUNITY GEOTHERMAL PROJECT

PHASE ONE

GIS PROJECT SET UP AND DATA INTEGRATION

SUMMARY INTERPRETATION REPORT

Prepared For:
The Regional District of Central Kootenay –
Community Sustainable Living Advisory Committee (CSLAC)

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On behalf of
South Kootenay Lake Community Services Society

PHASE ONE - GIS PROJECT SET-UP AND DATA INTEGRATION

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1) Project Introduction

Geothermal heat and power have been extensively developed around the globe, however until recently, very minimal development has occurred in Canada. The United States leads the world in the amount of geothermal electricity generation. According to the US Energy Information Association, in 2020, there were geothermal power plants in seven states, which produced about 17 billion kilowatt hours (kWh), equal to 0.4% of total U.S. utility-scale electricity generation.

High temperatures are required for power generation, typically in excess of 120°C, however Direct Use geothermal heat applications successfully use much lower, more moderate temperatures for direct heating and other industrial or commercial processes.

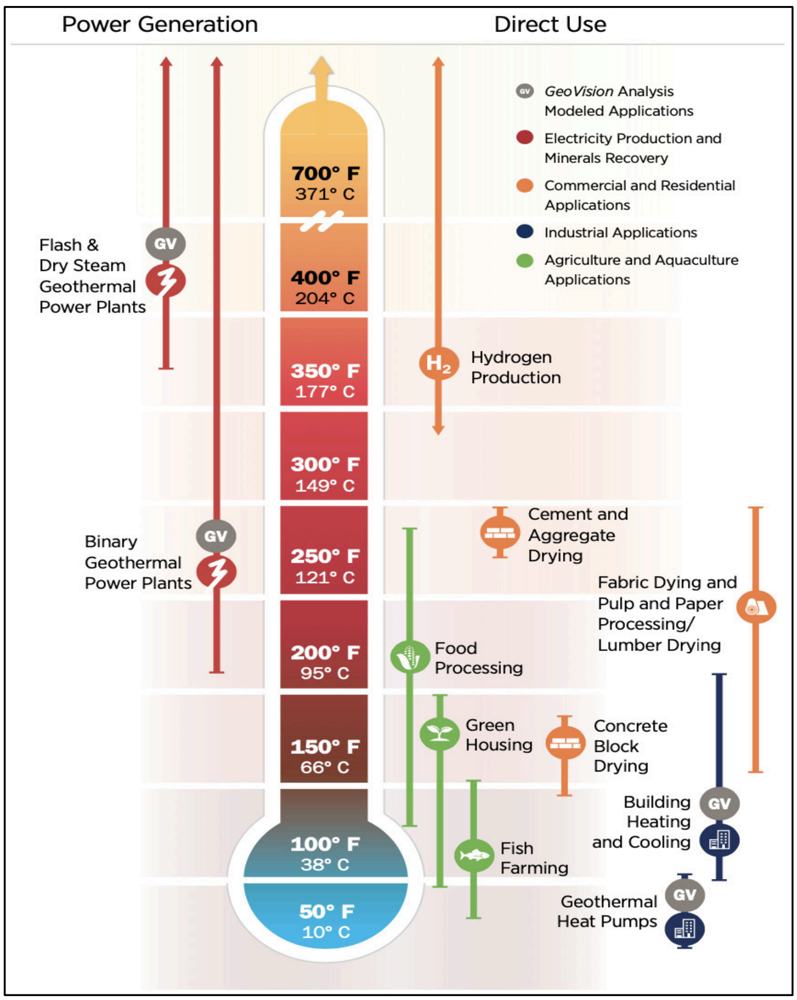


Figure 1 – Range of Geothermal Heat Uses (U.S. DOE)

The most common direct use applications utilize temperatures equal to or lower than 60°C for space heating, greenhouses, aquaculture, bathing, and snow melting / de-icing. The heat from geothermal fluids can be cascaded, meaning that a resource can be used multiple times for different purposes, until the temperature has been lowered to a point where it is no longer useful; thereby utilizing as much of the resource as possible, all the while utilizing a renewable resource and producing little to no GHGs.

A range of prospective outcomes is directly related to the depth and the temperatures encountered. Temperatures in the range of 38-80° C represent a viable source of geothermal heat for community direct heat applications. In Chena Alaska (near Fairbanks), a small hot spring (~80°C) was initially developed as a resort/hotel but now also supports a 7,000-sq. ft. greenhouse and a small-scale binary cycle power plant. This resort / facility, ultimately created some 35 fulltime jobs in the community and has attracted visitors from all over the world (over 32,000 overnight guests and 80,000 day visitors in 2015). It is believed that the potential for a Chena type of development also exists in the Kootenay Lake region of BC.

There are three documented hot springs offsetting Kootenay Lake at Ainsworth, Riondel and on Crawford Creek near Crawford Bay. Understanding the geological conditions which prevail in these three areas will help develop/ complete a geothermal / geological model for the area, as well as highlight key areas of potential for future work.

The first phase of this community geothermal project has utilized the skills of a fourth-year student from Selkirk College to source and compile all available public domain open-file data. This included remotely sensed data such as LiDAR and Infrared as well as, geological and geophysical data. Initial indications are that the data compiled have helped to better frame the numerous hydrothermal mineral deposits and showings in the Ainsworth/Riondel areas and create a local geological model for geothermal energy. This work may also allow for a high grading of areas for more detailed evaluation in the next phase of work. This could include a surface geological and geochemical assessment, in addition to further geophysical evaluation utilizing drones.

2) Geological Setting

The location of Phase One of this Community Geothermal Project is in the Central Kootenay's of British Columbia, specifically the Kootenay Lake region. Geologic processes, in particular plate tectonics, control the concentration of the Earth's heat in this region. The targeted project area is located along an ancient plate boundary, proximal to a deep-seated suture zone, making the project area somewhat unique geologically and many of the area hot springs occur in close proximity to this ancient suture line. Metamorphic rocks underlie much of the eastern and northern areas, while granitic and volcanic rock are dominant to the west. These two domains, come together where the ancient North America continental plate and ancient Pacific Islands oceanic plate met. These two domains are now welded together along a tectonic suture or ancient subduction zone (GSC, 2009).

Geological mapping shows that the area of southern BC generally exhibits an anomalous temperature signature at shallow depths (based on wells) in Figure 2 and is modelled to have high temperatures at depth as well (Figure 3).

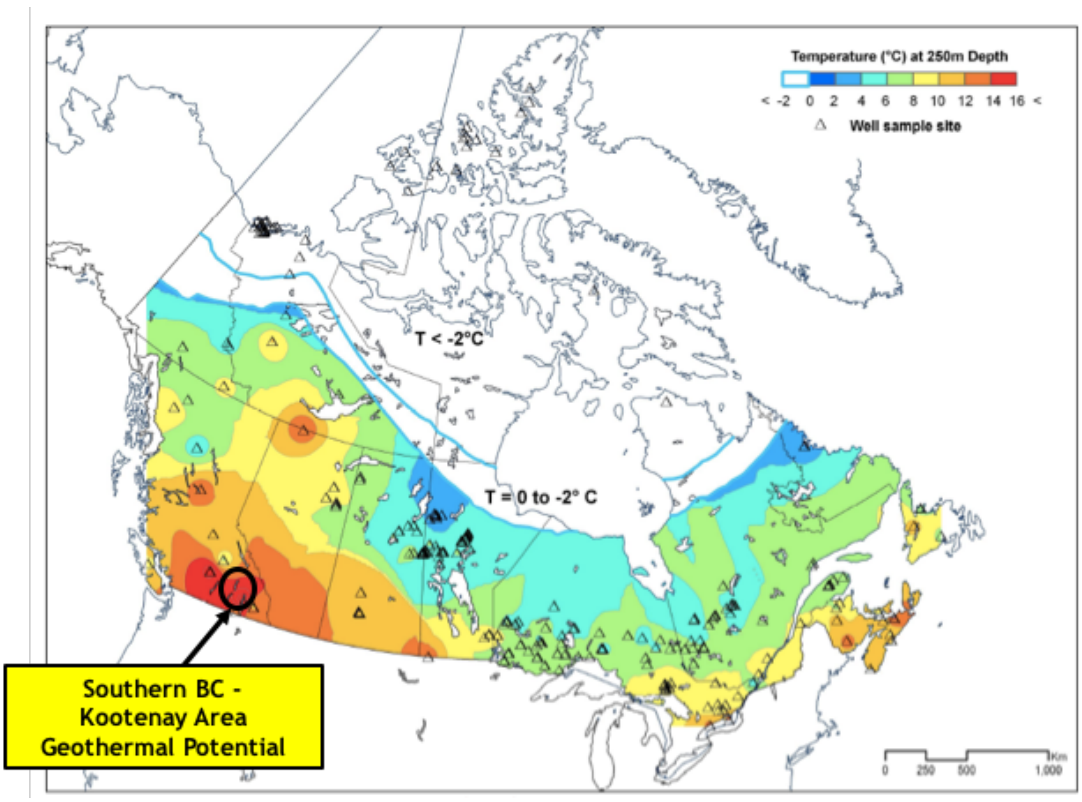


Figure 2 Temperature at 250m (GSC, 2012)

The hot springs in the Kootenay Lake area have produced temperatures up to 82°C at surface and flow rates of 7 liters per second (GSC, 1992). In Riondel, temperatures of 40°C and flow rates of 150 liters per second were encountered (GSC, 2016).

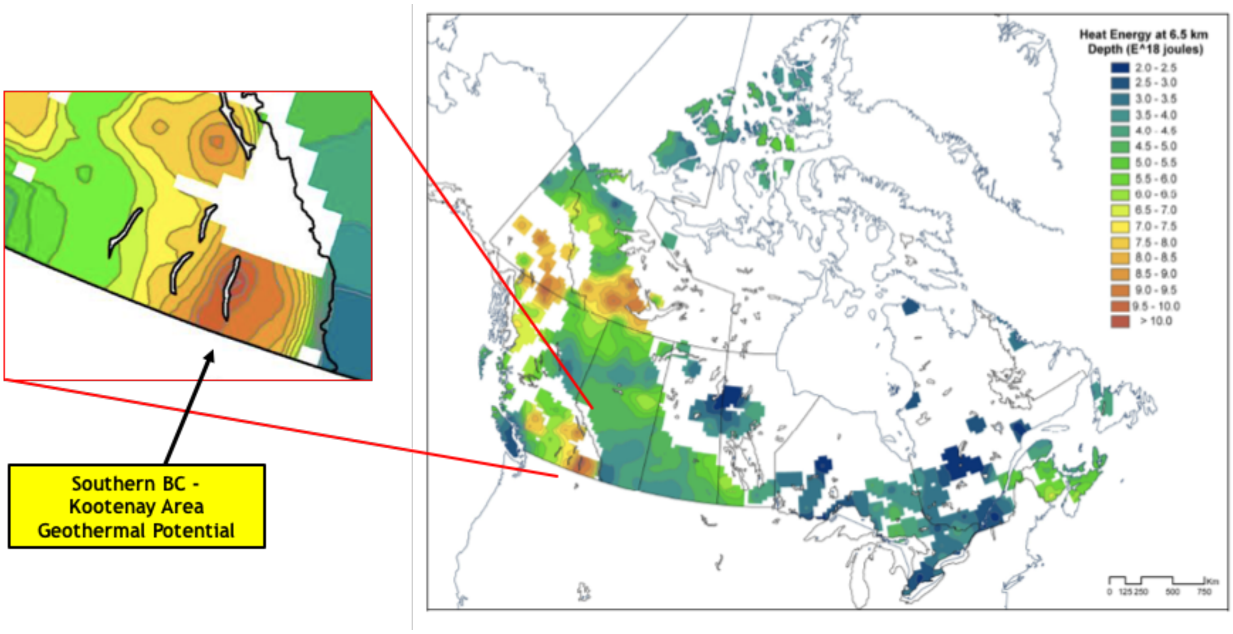


Figure 3 Map showing example of in-place geothermal energy for 6-7 km depth across Canada, Southern BC Area inset (GSC, 2012)

The Kootenay Lake region exhibits high heat flow and is also the site of an assemblage of highly metamorphosed rocks. According to Moynihan & Pattison (2013), the area contains rocks that were metamorphosed at approximately 25 Kms depth and at temperatures of >650C. Deep, heat energy mapping shows that the modeled heat energy in the Kootenay Lake area is approximately 25-40% higher than the generalized background within BC. In addition, the area of anonymously high heat flow is essentially coincident with the location of the most highly metamorphosed rocks - proximal to Kootenay Lake.

A review of the deep well data, acquired from the Canadian Geothermal Energy Association (CanGEA) highlights one key deep data point, the Moyie #1 well which was drilled to a depth of 3,476m in early 1987. A reliable downhole temperature reading of 108°C was acquired at a depth of 3,017m providing a geothermal gradient of 0.33 degrees per meter. On Figure 4 below the 'surface' Heat-flow data and Moyie #1 well data have been summarized. Overlain on this map is the Deep (6.5 Kms) Heat Energy mapping completed by the Geological Survey of Canada (2012). Note – Figure 3 shows the regional perspective of the overlain GSC, 2012 heat energy data). Although these come from two different data sources (with different heat energy units) it is apparent that there is a significant increase in heat flow moving from the best deep well control at Moyie #1 (located approximately 22 km South of Cranbrook), west into the Kootenay Lake area.

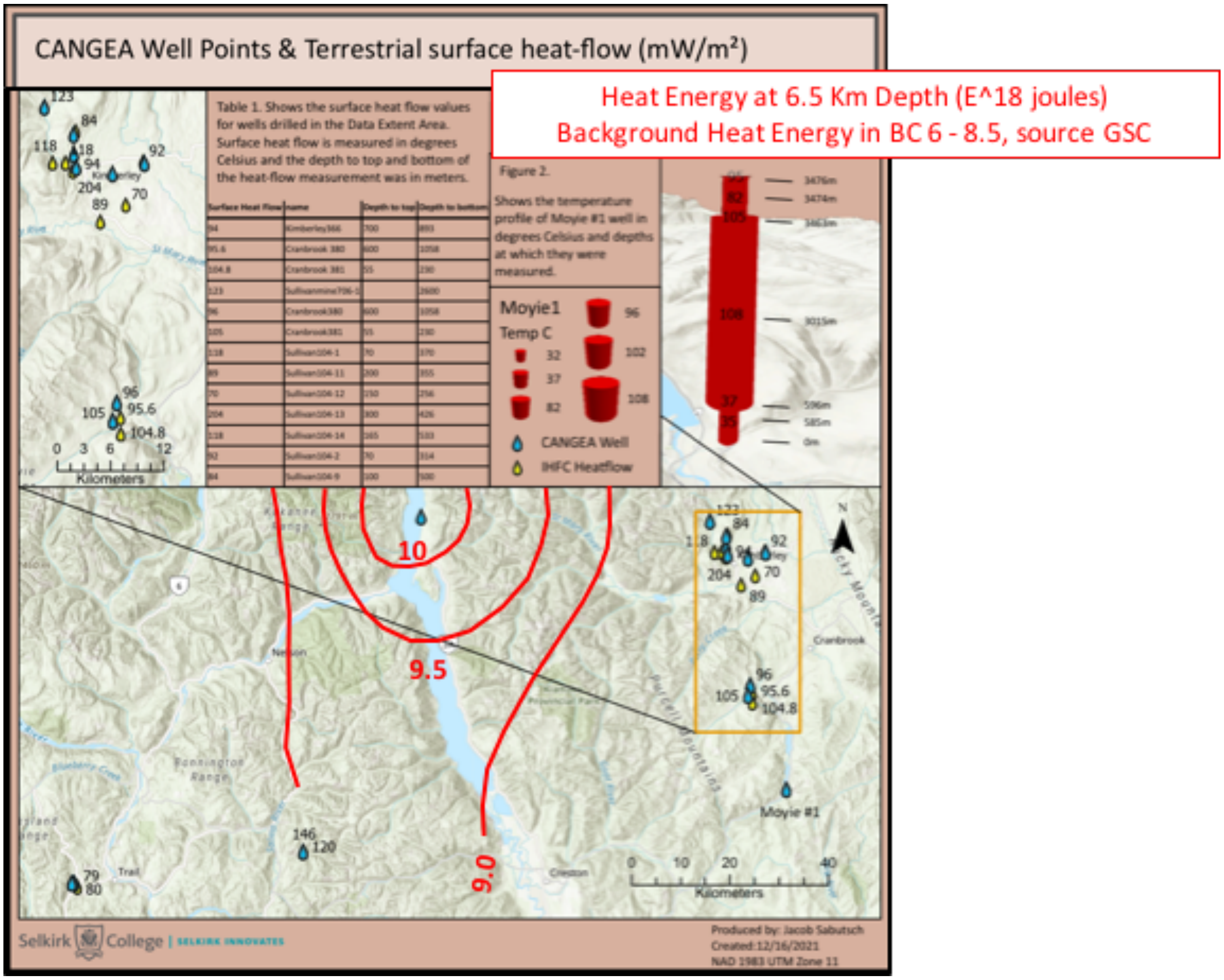


Figure 4 Map showing CanGEA Terrestrial Surface Heat Flow (Selkirk 2021) **with Deep Geothermal Energy for 6-7 km Depth, overlain in red** (GSC, 2012)

Demonstrated higher than average heat flow is one of the two most critical and contributing factors necessary for any geothermal project, the second is fluid flow potential. In the Kootenay region, the main conduit for flow will be within fractured reservoirs. Fracture networks not only allow hot fluid to migrate vertically from depth, but also provide the capacity for sustained flow rates through a network of extensively fractured reservoir rock. Fractures are generally created through faulting resulting from regional stress conditions.

Much of the mountain building process in the region resulted from compressional stresses, generally applied in a west – east direction. Fracturing created under these conditions can be closed or even mineralized as compressional stress continued. There are however, periods of relaxation which are a result of two or more areas pulling apart. This is often referred to as a period of extension. Faulting under extensional stress conditions can create vertical movement (i.e. normal faulting) as well as strike-slip (lateral) movement where one area moves past another. Faulting and fracturing created during periods of extension stand a better chance of creating open or partly open fracture systems. It is well documented that the Central Kootenay's did see a period of extension during the Eocene, 56-35 million years ago (Mya).

The initial proposed model for the Kootenay Lake area has more localized wrench or 'tear' faults related to regional, Eocene strike-slip faulting. These more localized faulting transect the subsurface between two regional, deep seated fault systems. Kootenay Lake, is in fact the site of convergence of two major, more regional fault systems.

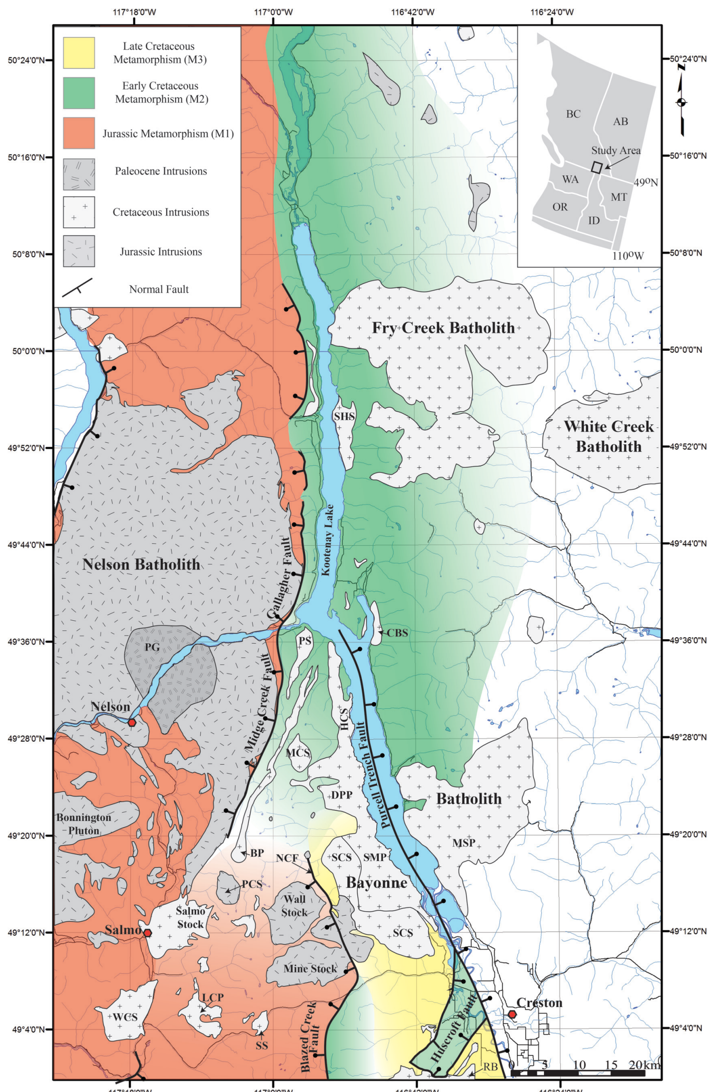


Figure 5 Map illustrating different age domains of regional metamorphism, Kootenay Lake BC, regional normal faults highlighted (Webster & Pattison 2018)

The Purcell Trench Fault (PTF) is a 'down to the east' normal fault that extends from Coeur D'Alene, Idaho, north, to the west arm of Kootenay Lake. Leclair (1988), believed that there was approximately 25 km of movement along the PTF at the latitude of southern Kootenay Lake. (This would suggest that the west shore moved about 25kms north relative to the east shore). Just west of the PTF is the Midge Creek / Gallagher Fault complex which extends from the Salmo area in the southwest to north of Kaslo on the west side of Kootenay Lake. Moynihan and Pattison (2013) interpreted the Midge Creek fault, which is down to the west, to be part of a larger Eocene fault complex that encompasses the Midge Creek, Gallagher, Lakeshore, and Josephine faults. See the relative position of these regional faults (in black) on Figure 5 (above).

It is possible that the position of these regional faults and the area where they converge, could help to create a unique set of geological conditions that are of particular interest to geothermal exploration. Increased fracture density generated by intersections between multiple overlapping fault strands can substantially increase the host rock permeability, facilitating enhanced hydrothermal (geothermal) fluid flow.

> *"Step-overs (relay ramps), terminations, intersections, and accommodation zones in fault systems correspond to long term, critically stressed areas, where fluid pathways are more likely to remain open in networks of closely-spaced, breccia dominated fractures."* (Faulds & Hinz 2015)

In Figure 6 below, the most obvious NW faults, shown in red, were recognized in early geological mapping and are even visible on Google Earth. These fault traces are highlighted on the topographic map (left). When compared to a Lidar image from Phase One (right), an extensive network of multiple conjugate faults is clearly evident. These faults would not be visible without the ability of Lidar to essentially remove the vegetation and image the actual ground surface, as in this displayed Digital Elevation Model (right).

The Kootenay Lake area has higher than normal geothermal heat flow, so if fault induced fracturing can be verified within an appropriate geological model, then the East Shore of Kootenay Lake should be very well situated to serve as a pilot project to test the feasibility of developing a geothermal heat source for renewable direct heat.

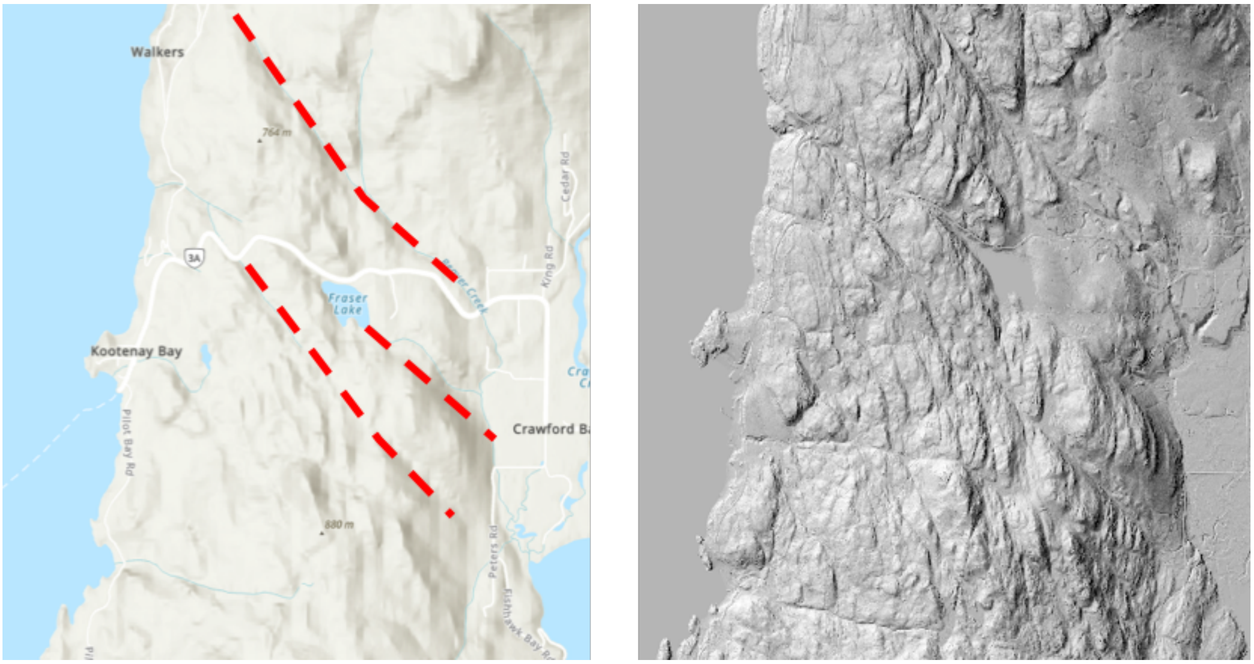


Figure 6 – Topographic Surface Vs. Lidar Digital Elevation Model (DEM)

3) Phase One – Scope of Work

Phase One utilized the skills of a GIS student from Selkirk College Geospatial Research Centre to build out an ArcGIS project for the Kootenay Lake region. The primary focus area established for most of the data is shown in red in Figure 7 (below). A larger more regional study area (shown in blue), was chosen for certain geophysical data such as Aeromagnetic & Gravity data, given the capacity of this data to demonstrate more regional structural elements and tectonic features.

The goal of this project has been to aggregate all relevant available, open file surface and subsurface, geological, and geophysical data from public and private sources. An ArcGIS geodatabase was created to host organize and aggregate all the data compiled. This geodatabase and a series of digital maps are key outputs of the student's work on this project, some of which are shown in this interpretative summary report.

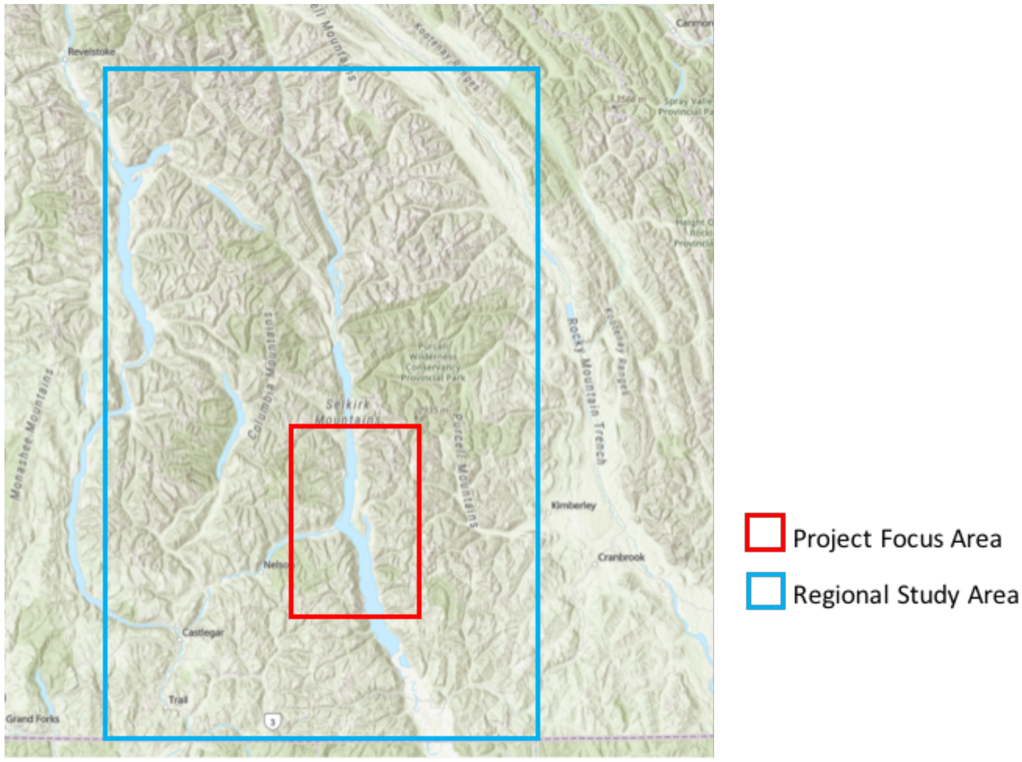


Figure 7 – Data Focus Area, Kootenay Lake

4) Data Sets Utilized

A complete summary of all data sets that were accessed and included in the geodatabase are outlined in the Selkirk Student Report (attached in the Appendix). Table 1 below was extracted from the student report to be displayed here.

Dataset	**Original Data Type***
Alteration-Mineral ASTER	.PNG
ASTER Geoscience BC	.HDF
ASTER & Landsat Google Earth Engine	.TIFF
CANGEA Geothermal Database & Provincial Resources Estimate Maps: BC	.KMZ
CANGEA well	.CSV
Crawford Bay Geological Survey of Canada Map	.PDF
Geological Faults & Bedrock	.SHP
Geoscience BC	.SHP

Ground water wells	.SHP
International Heat Flow Commission: Global Heat Flow Database	.CSV
LiDAR BC (Digital Elevation Model)	.TIFF

**Description of file formats:*

.HDF (Hierarchical Data Format Files) standardized format for scientific data storage, .PNG (Portable Network Graphic) uncompressed raster image format,
.TIFF (Tagged Image File Format) graphics container that stores raster images, .CSV (Comma Separated Values) is a file delimited text file that uses commas to separate value,
.KMZ (Kehole Markup Language) file that consists of a main KML file and more supporting files that are packaged using a Zip,
.PDF (Portable Document Format) a file format to present documents with text formatting and a
.SHP (Shapefile) is a format for storing geometric location and attribute information of geographic features.

Table 1. Show a list of the datasets acquired for the purpose of the project and the format of the original datasets, (Selkirk Report, 2021).

5) Description of Key Data Elements

a) Geoscience BC Surface Bedrock Geology and Faults

The Geoscience BC bedrock and fault datasets were integrated into the geodatabase. This data outlines the type of bedrock present in the area of interest, the stratagraphic age and names of the formations encountered. Major, surface detected faults were also mapped by Geoscience BC and incorporated into this mapping.

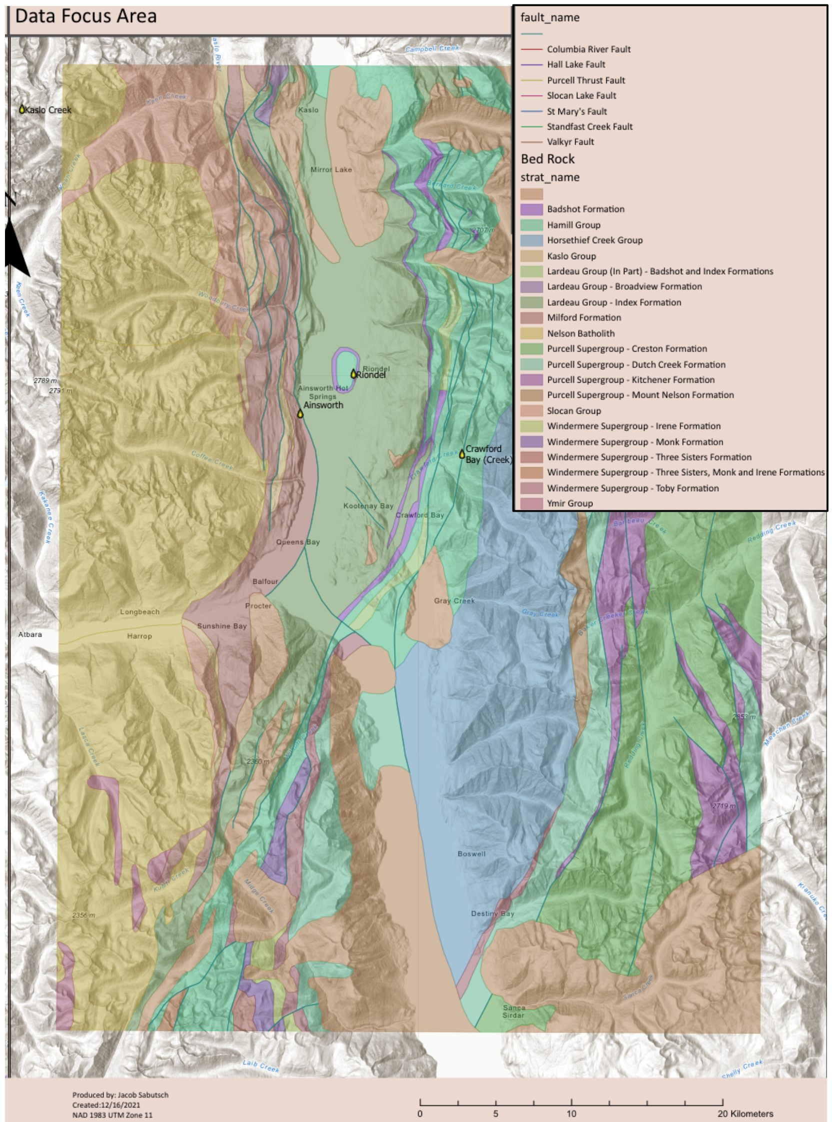


Figure 8 – Geoscience BC, Surface Bedrock Geology with Major Faults and Hot Springs (Selkirk Report 2021)

b) Light Detection and Ranging Data (Lidar)

Lidar is a technology used to create high-resolution models of ground elevation with a high degree vertical of accuracy (approximately 1 meter accuracy in the case of the BC data).

A Digital Elevation Model (DEM) was created using the Lidar data and since it has the capability of effectively 'seeing through' vegetation it has provided an accurate depiction of the surface of the earth. As a result, the surface geology including faults are quite apparent allowing for rapid interpretation of surface geological features in many locations. Figure 9 (below) shows an image of the

Lidar DEM taken from the focus area along with a preliminary fault interpretation. Abundant faulting is evident with different faults showing different orientations and those general orientations depicted in different colors (images below cover an approximately area of 12 Sq. Km.).

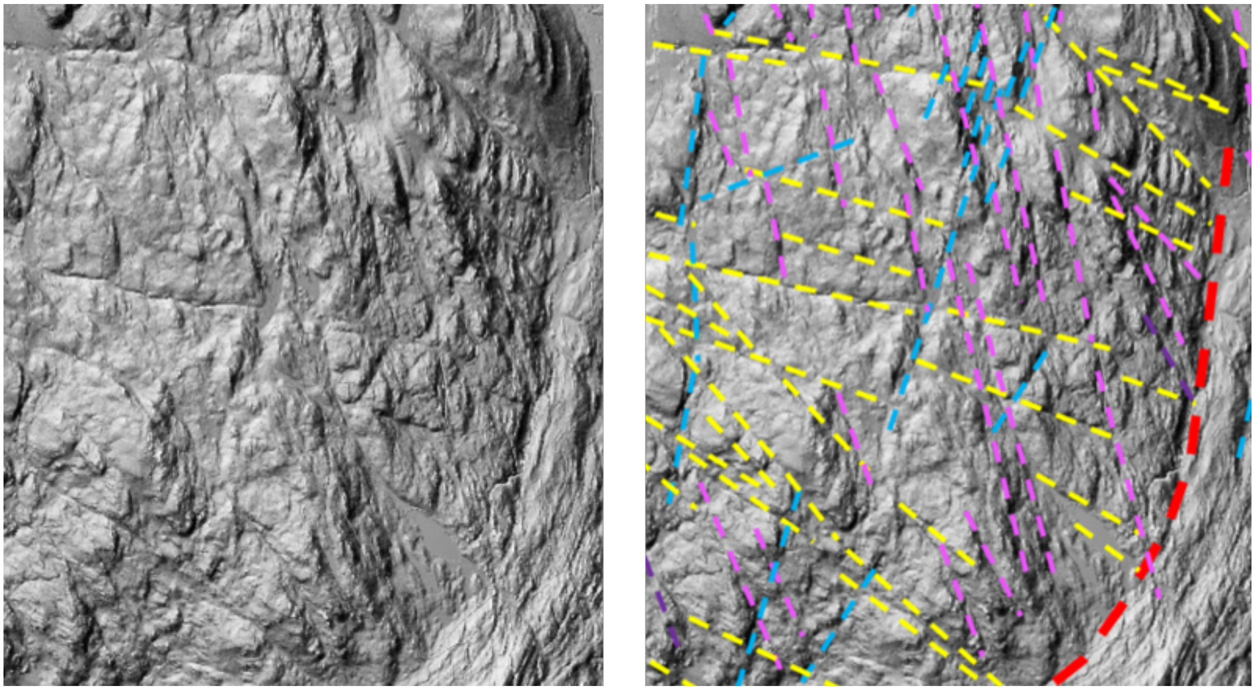


Figure 9 – Lidar DEM Hill Shade Image (left) with Preliminary Fault Interpretation (right), location central Pilot Bay Peninsula

Generally speaking there are two key components of a successful geothermal project 1) higher than normal heat flow and 2) the potential of the reservoir to produce fluid at substantial and sustainable flow rates. To achieve 2) or flow, the desired reservoir in the targeted area would need to be significantly fractured and since faulting is key to fracturing, then the high degree of surface faulting evident at several locations within the project area, is an encouraging sign.

Further work will be needed to tie the different fault orientations to episodes in the structural history of the area and correlate faults evident near existing hot springs to this structural history. There will be further discussion of some of the observed relationships in section 6) Preliminary Interpretation.

c) ASTER Data (Advanced Spaceborne Thermal Emission and Reflection Radiometer)

Geoscience BC acquired the ASTER Satellite imagery and have made this data available but in the original unprocessed format. Alteration-Mineral images were also acquired from Geoscience BC and while these images have been processed the documentation on what was done to the data was not available.

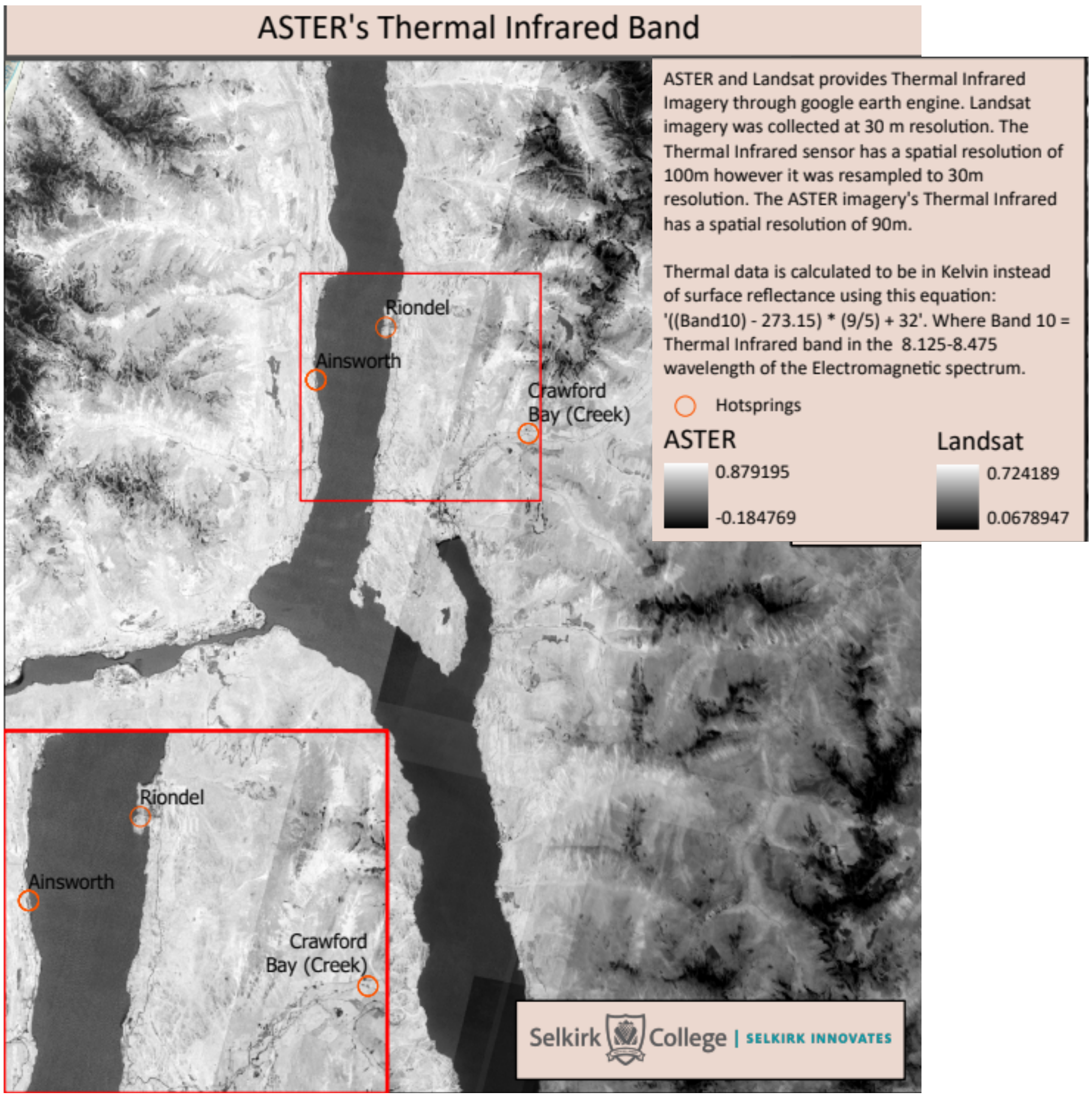


Figure 10 – Thermal Infrared Average Values for Data from Summers of 2010-2021 Aster Image (Selkirk Report 2021)

Close examination of the satellite and alteration-mineral images do exhibit some compelling lineaments which are consistent with interpreted fault lineaments from the Digital Elevation Model (DEM). Note the highlighted trend in Figure 11 which is consistent with a well-defined NW trending fault. It should be noted however that these observed lineaments, in the Aster data are rather weak and generally inconsistent over longer distances. It is believed that this is a limitation of the satellite data, how it was acquired and /or processed.

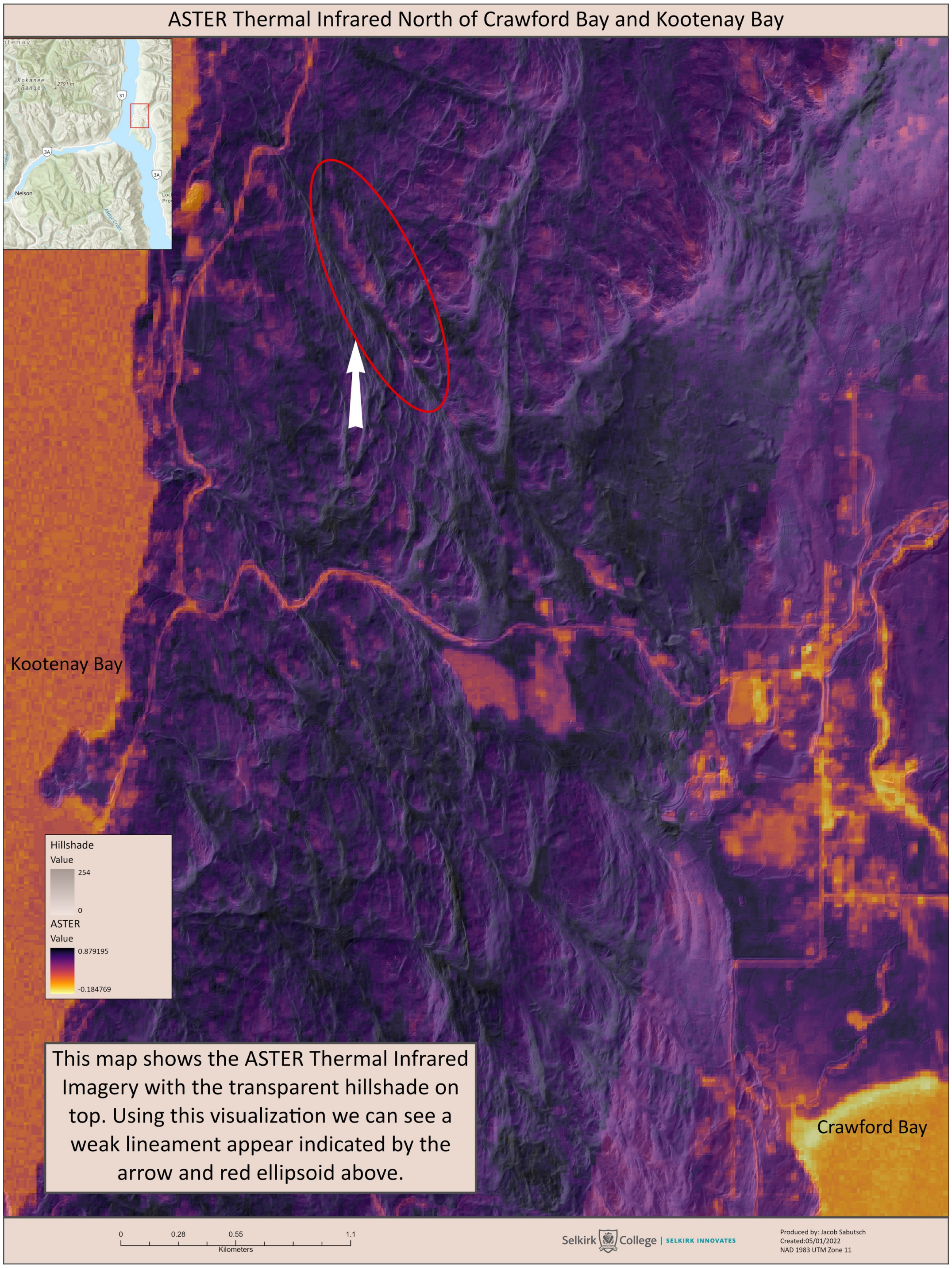


Figure 11 – ASTER Thermal Infrared Imagery with transparent DEM Hillshade
(Selkirk Report 2021)

d) Geophysical Data

The geophysical data covering our area of interest was made available through Natural Resources Canada and consisted of multiple generations, or vintages, of airborne magnetic and gravity surveys collected by the Geological Survey of Canada over the previous decades -the survey of our area of interest is thus represented by composite, undifferentiated datasets that are a merged product of numerous smaller surveys. After review, it was determined that of the available datasets only the 200m aeromagnetic survey had sufficient spatial resolution to support the project's imaging efforts. Both the airborne gravity and the 1,000m aeromagnetic data were too low-resolution to provide useful information for the project,

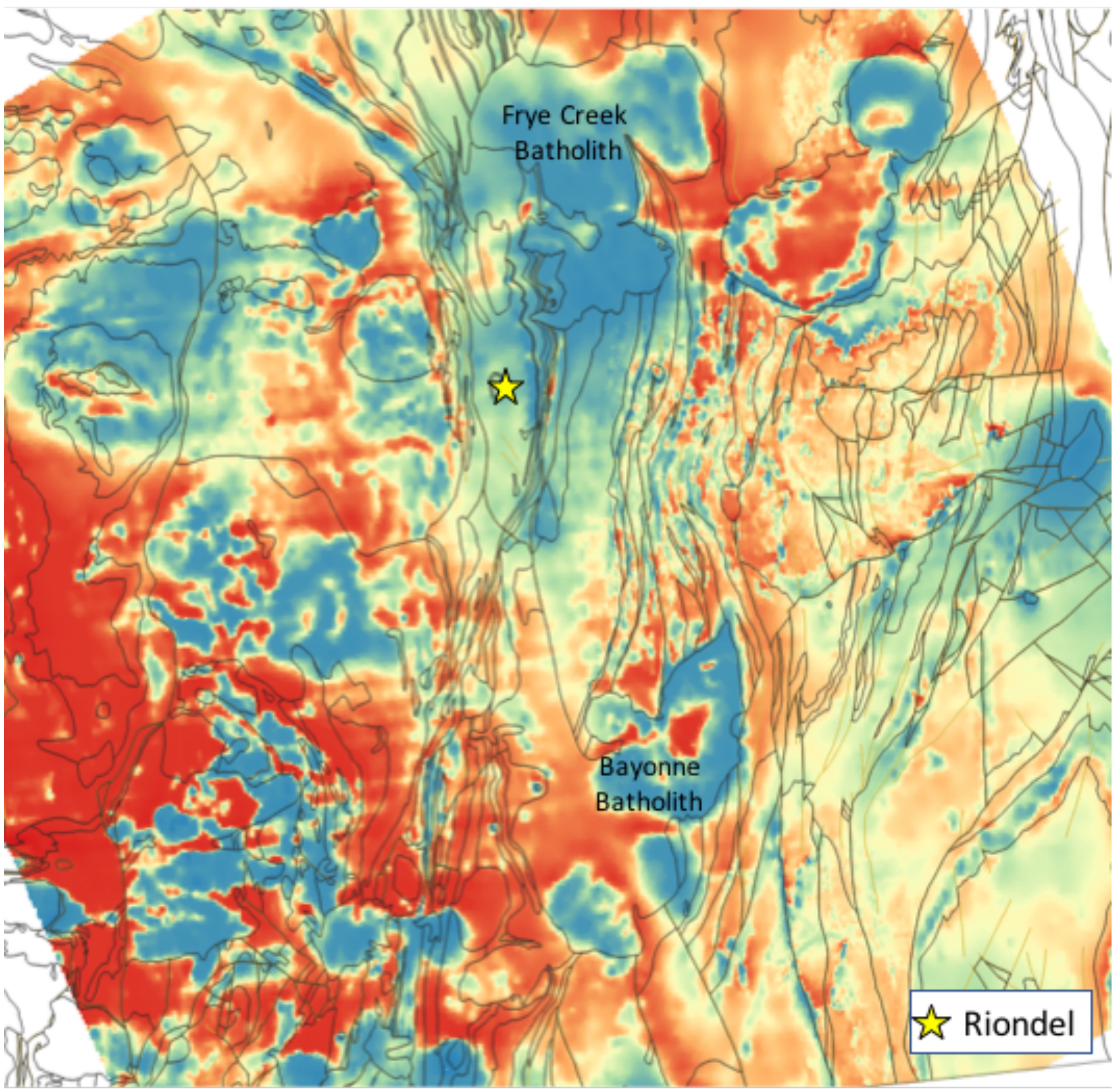


Figure 11 – NRCan Aeromagnetic Data – 200m Derivative

On the 200 m residual data, as with any magnetic survey, what's being measured are variations in intensity of the regional or local magnetic field. These variations, or magnetic anomalies, are directly related to compositional variations in the local geology, typically changes in the concentration of ferromagnetic minerals. In the case of the 200 m aeromagnetic data, overlaying this survey on a map of the BC Bedrock geology shows a significant correlation between the shape and intensity of the local magnetic field and the underlying geology; of note is the level of agreement between the mapped plutonic intrusions or batholiths and the broad, positive geomagnetic anomalies expressed as blue fields on the map shown in Figure 11 (note position of Fry Creek and Bayonne Batholiths).

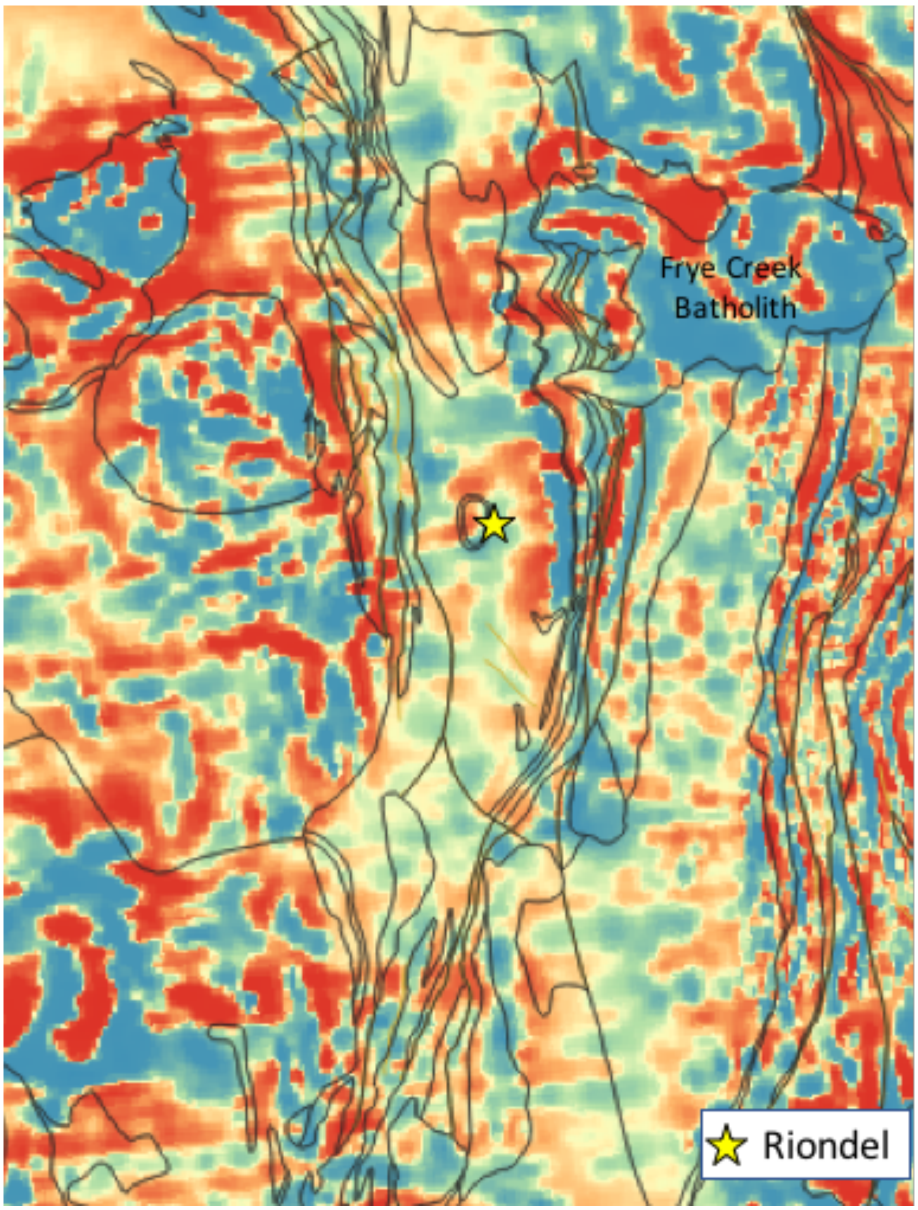


Figure 12 – NRCan Aeromagnetic Data – 200m Vertical Derivative

The mapped pluton or batholith edges and changes in magnetic field strength are in strong agreement. Linear magnetic anomalies also serve to highlight mapped geologic trends and can be used to infer their continuation where a mappable surface expression becomes problematic, due to overburden or standing water issues.

In addition to the 200m residual data, a first vertical derivative of the aeromagnetic data was also available over the survey area. The first vertical derivative of the magnetic field is the rate of change of the magnetic field in the vertical direction. The first vertical derivative enhances shorter wavelength components of the magnetic data at the expense of longer wavelengths, producing a dataset more sensitive to abrupt changes in magnetic field strength. This tends to enhance imaging related to abruptly changing or closely spaced anomalies, typically indicating increased subsurface complexity. The vertical derivative data also serves as an edge-detector, being sensitive to lateral changes in magnetic character.

In the case of this project area of interest, the efficacy of the first vertical derivative data can be seen in Figure 12, near Riondel and Crawford Bay where the residual map shows a relatively smooth blue-to-white expression of the local magnetic field. In comparison, the increased sensitivity to small scale changes of the First Vertical Derivative map for this same area shows more detail relatable to mapped geologic and structural features (note position of NW trending faults near Kootenay Bay). Indications of structure at this level of resolution may be used as a focal point for further higher-resolution micro-surveys in a later stage of the project.

6) Preliminary Interpretation

a. Geology of Existing Area Hot Springs

As previously mentioned there are three documented hot springs within this project focus area; namely Ainsworth, Riondel (Bluebell Mine) and Crawford Creek. These hot spring occurrences have documented measured temperatures of 44°C, 40°C and 29°C respectively.

Major faults mapped by Geoscience BC express themselves at the surface near both the Ainsworth and Crawford Creek hot springs and depending on the geological interpretation utilized, there is also a major fault near Riondel. In fact, this fault would be the main reason that the Hamill/Badshot formations are superimposed on top of the younger Lardeau formation at this location. In addition to the established regional mapping of more regional faults, near all of these hot springs, there is also a range of minor cross-cutting faults or conjugate, oblique faults evident on the Lidar data.

The more extensive regional faults have been interpreted as being either thrust faults, formed under generalized east-west compression or normal faults created during periods of extension / relaxation. Younger faults are more likely to be active and permeable (Blewitt et al, 2002) and are often the target of geothermal exploration programs. Younger, extensional faults have a better chance of being open, as the rocks are effectively pulled apart during extension and therefore have the ability to more readily transmit hot fluids vertically. It is very likely that a combination of faults, have conspired to bring hot geothermally heated fluids up close to the surface at the three locations highlighted above. See one possibility shown schematically in Figure 13 below.

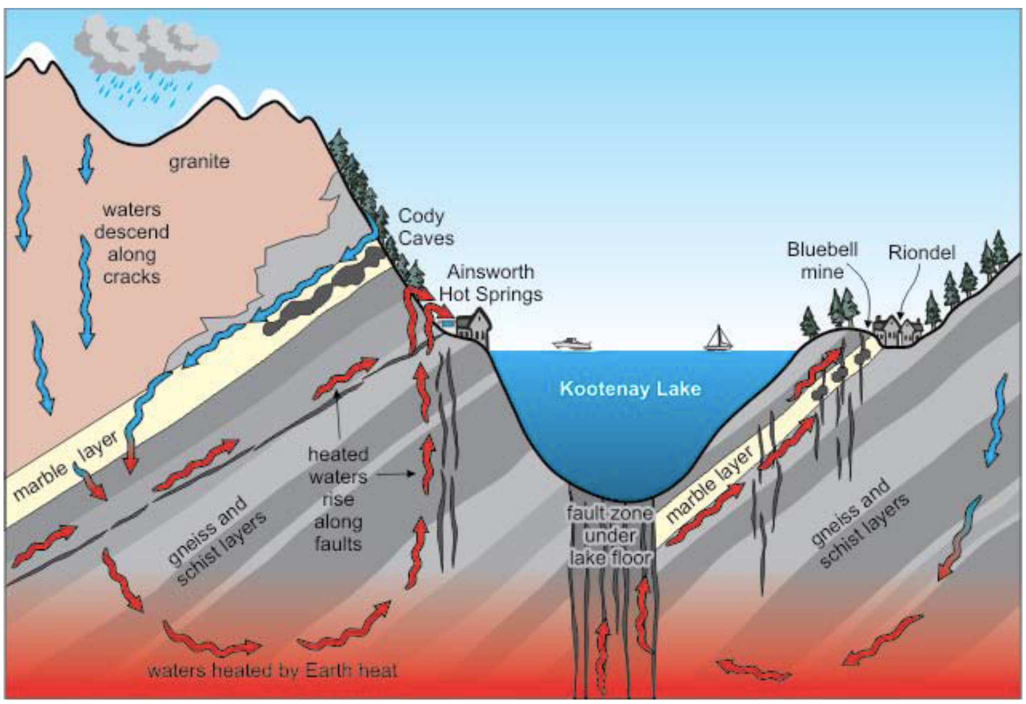


Figure 13 – A schematic cross section across Kootenay Lake near Ainsworth and Riondel, showing a possible configuration of faulting that could feed Ainsworth hot springs. GSC (2009)

Figure 14 (below) shows the mapped and interpreted faults near Riondel. The smaller faults interpreted from Lidar are west-northwest near the town and mine site as well as up the mountainside east of Riondel. There is also a pronounced north-south trend and a northwest fabric accentuated by Hendryx Creek and between the creek and the town of Riondel. Either or both fault systems could have contributed to the vertical movement of geothermal fluids which were eventually encountered in the Bluebell Mine (Kootenay Chief Zone).

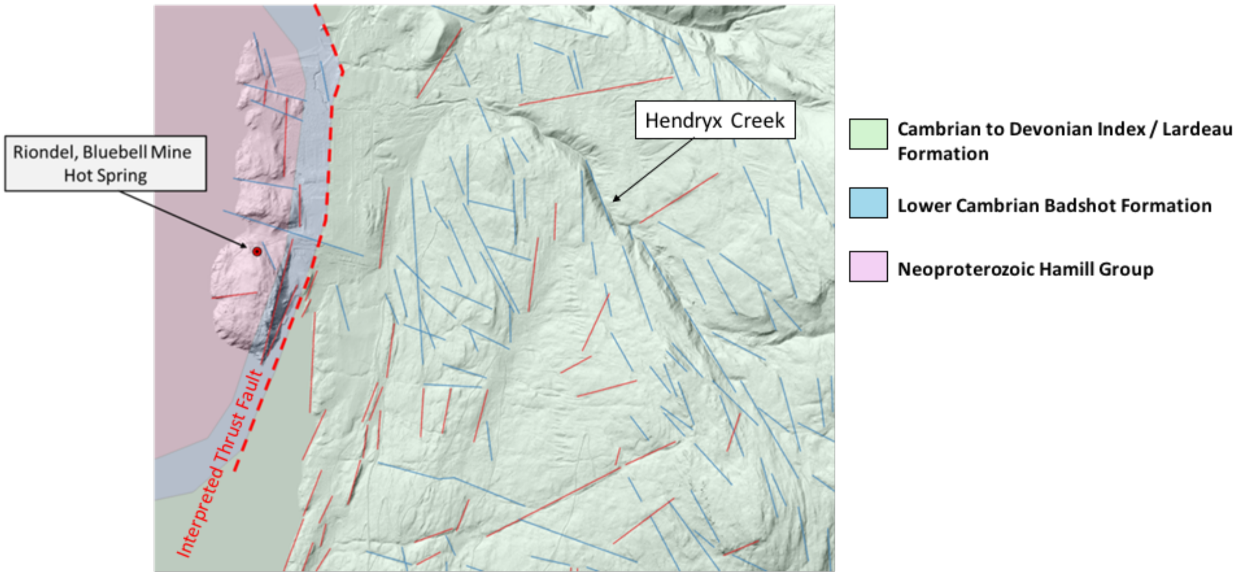


Figure 14 – Lidar DEM image with bedrock geology including mapped and interpreted faults at Riondel

In the GSC Report on the Riondel hot spring, Desrochers (1992), there is a detailed description of faults extracted from detailed geological descriptions within the mine workings - "*a major north trending fault extending the length of the mine is described in the footwall rocks immediately below the Badshot limestone.*" This major fault is shown as a red dashed line in Figure 12. The report also indicates that "*ore zones are localized at the intersection of limestone* (Badshot, shown in blue on map above) *with steep cross fractures that trend northwestward and dip 85° north*."

This same west-northwest orientation is evident in a short fault on the surface near the hot spring, (Kootenay Chief area), as well as on the slope just east of the town site. Below in Figure 15, Moynihan and Pattison (2011) compiled a summary section to display the relationship between WNW fractures and the ore bodies. This detail shows very closely spaced fracturing, especially in the Kootenay Chief mine where the greatest influx of hot (40°C) geothermal fluid occurred.

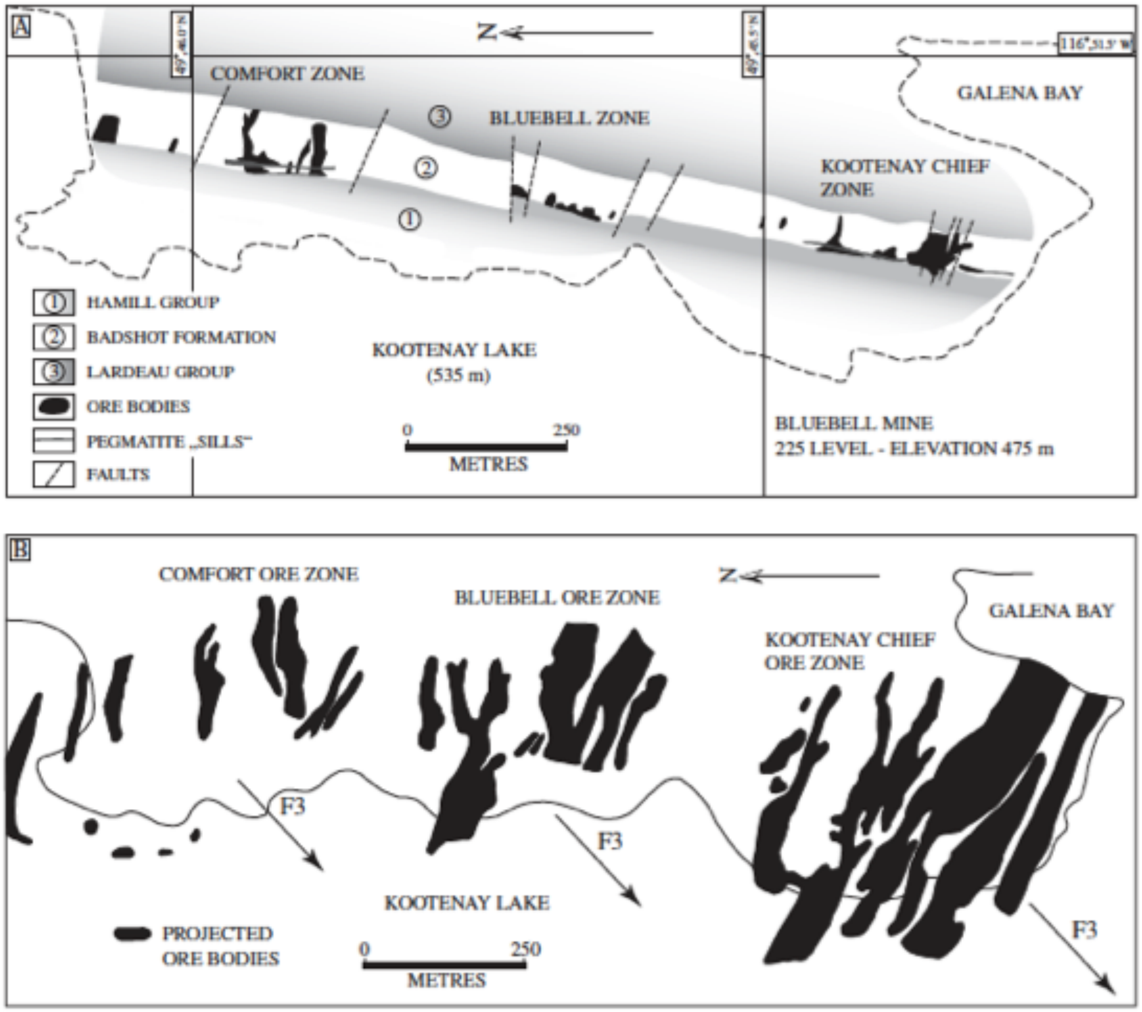


Figure 15 A) Plan of the 225 level of the Bluebell mine. The outline of the Riondel peninsula is also shown. Adapted from Irvine (1957).
B) Plan of the Bluebell mine showing the projection of orebodies onto the surface, from Shannon (1970). (Moynihan and Pattison, 2011)

Moynihan and Pattison (2011) state that *"Abundant systematic fractures in the rocks at Bluebell and elsewhere provided conduits for fluid movement into the geochemical trap provided by the carbonate rocks. The high spatial density of deposits and early Tertiary intrusions in the Ainsworth-Bluebell area presumably reflects enhanced development of fracture networks in the area. Development of this fracture network took place independently of earlier folding processes."*

As we know the Bluebell mine, primarily in the Kootenay Chief area, but also noted in other areas of the mine generally, geothermally heated water was encountered. The water influx at Kootenay Chief was measured at 40°C but the 1992 GSC report suggested the water temperature would likely increase further with increased depth.

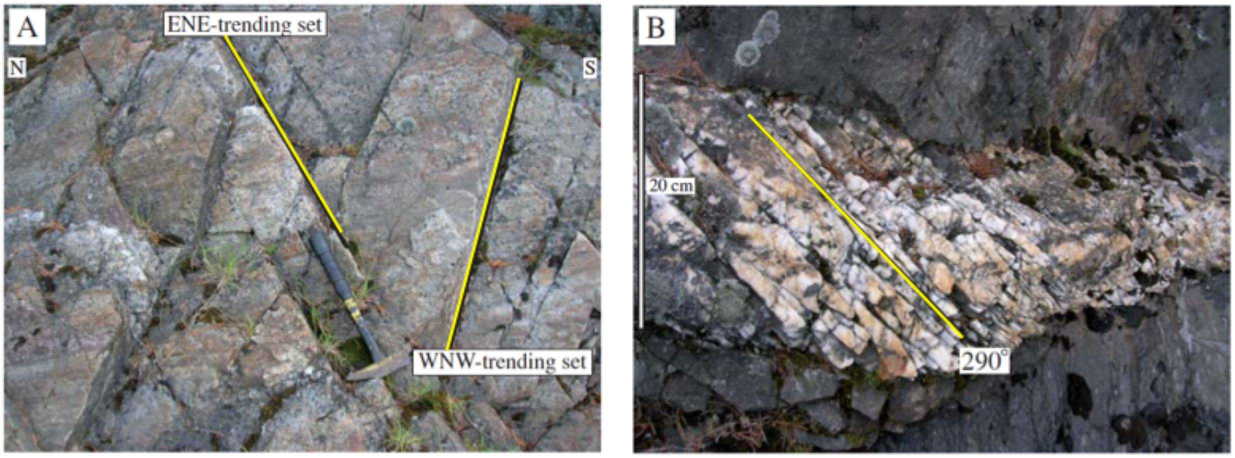


Figure 16 A) Photograph of the two dominant sets of fractures in quartzite of the Hamill Group on the Riondel peninsula. Looking east onto S2/S0. Hammer for scale. B) Quartz vein occupying southeast-dipping fracture cut by west northwest– trending fractures. (Moynihan & Pattison D.R.M., 2011)

The ENE and WNW trending conjugate fracture set highlighted in Figure 16 seem to be consistent with faults prevalent on Lidar, from the Riondel area. However these same fault orientations are also observed throughout the area. It is believed that this is representative of a more regional stress condition which produced these fracture systems. If ENE and WNW trending fractures can transmit geothermally heated water at Riondel in would seem reasonable to think that fractures of a similar orientation could repeat these results elsewhere in the area.

A review of the fault interpretation derived from the Lidar (Hill shade) data does in fact show one of more oblique faults near the hot springs at Riondel and Ainsworth, however there is a gap in the Lidar data over the Crawford Creek location not permitting the interpretation of minor oblique faults at this time. In the future, geological field study of the Crawford Creek hot spring site may reveal other fault possibilities; beyond the major Orebin Creek fault near where the hot springs occur.

b. Preliminary Indications

When reviewing the geological indicators evident at or near existing hot springs within the Phase One study area the following criteria are considered important:

- Evidence of a major, more regional fault
- Clear indication of multiple cross-cutting faults (especially NW trending)
- Increased fault density with more than one primary orientation
- Preliminary infrared indications pointing to possible correlation with faults
- Direct or indirect evidence of hot springs

When considering the above five criteria, three high-graded areas within the Phase One study area become apparent – 1) Pilot Bay peninsula west of Crawford Bay, 2) East of Riondel where NW trending faults/fractures are prevalent and 3) the area around Crawford Creek hot springs.

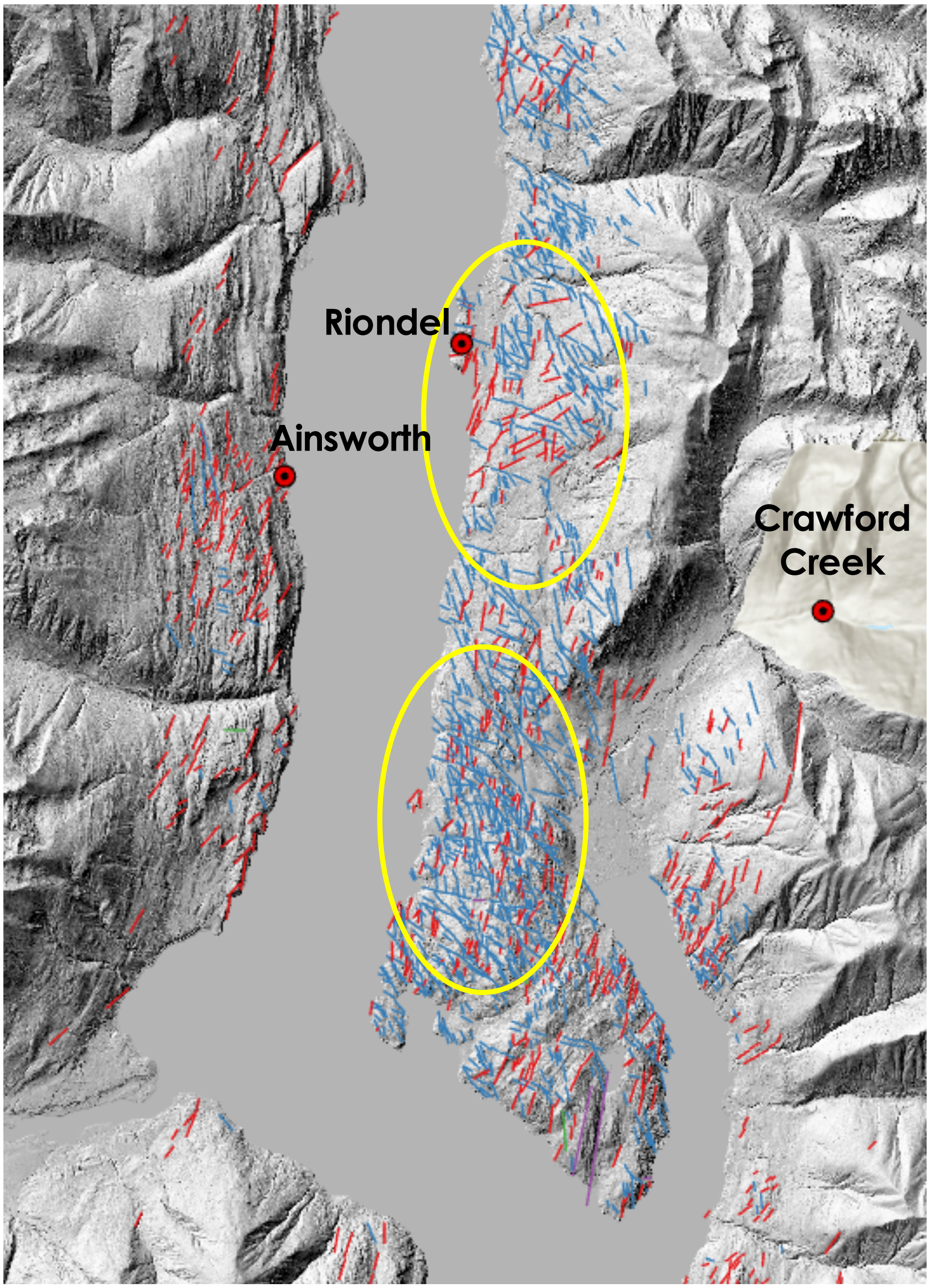


Figure 17 – A Lidar image of the Kootenay Lake East Shore, showing interpreted faults and suggested fracture density a) Riondel Area and b) Pilot Bay Peninsula

The faults shown on Figure 17 (above), provide a good overview of different potential stress conditions and how the fault or fracture density changes from one area to the next. In the area around Riondel there is an observed fault density which is considerably less than the high apparent fault density in the area west of Crawford Bay on the Pilot Bay peninsula.

One factor potentially effecting the appearance of higher fault density on the Pilot Bay peninsula is post faulting glaciation. Peters (2012), recognized the impacts of Pleistocene glacial movement through the region. Peters demonstrated that the direction of glacier flow through the area and across the peninsula would have been SSE. The pattern seen on Lidar, particularly the NNW faulting, may have been exaggerated by glacial plucking of low dipping meta-sediments in a preferential direction. It is speculated that the relatively low relief topography and position of the peninsula within the valley, relative to glacial flow, could have increased the areas exposure to this type of mechanical erosion.

Figure 18 (below) summarizes some of the key attributes of the first area of interest and why is should be considered for detailed evaluation in Phase Two.

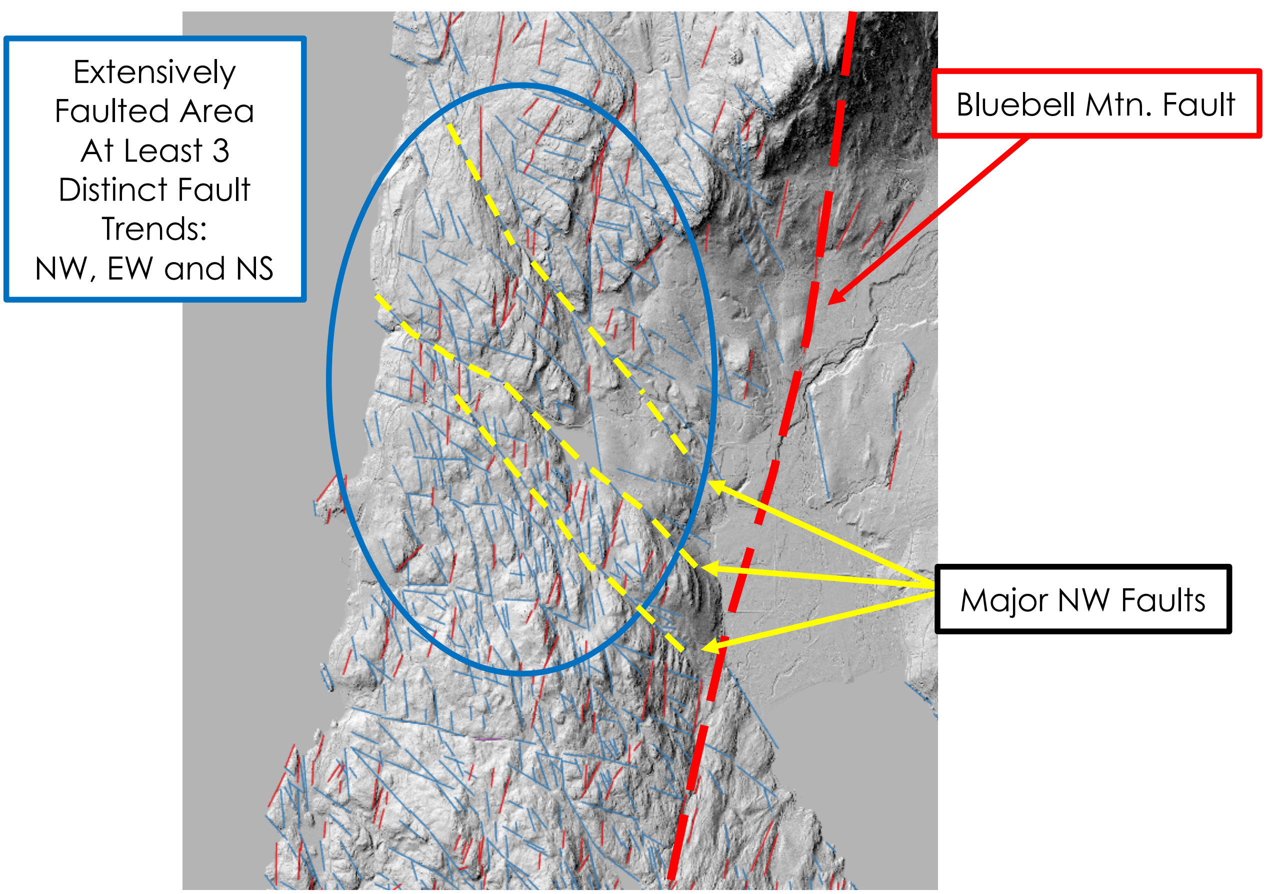


Figure 18 – A Lidar image of the area immediately west of Crawford Bay with key structural attributes highlighted.

In addition to the above highlighted structural elements, the area is at the center of high modelled geothermal heat energy (GSC, 2012) as well as being proximal to the most highly metamorphosed rock in the area. Although there is no direct evidence linking this to geothermal potential it does show that the rocks which were subjected to the highest temperature (and pressure) and now located on the surface reflecting very significant up welling in this immediate area.

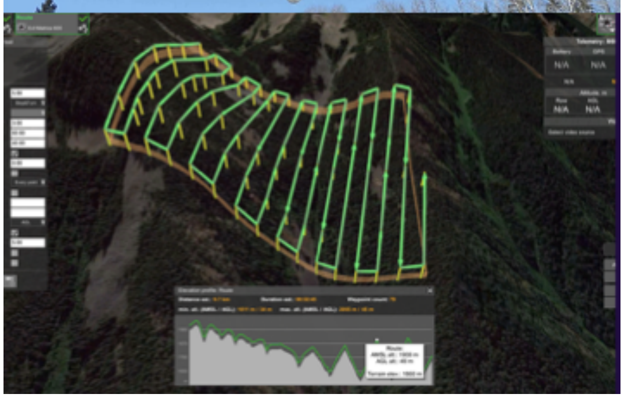
The other two areas have one or more of the five criteria highlighted above however, other mitigating factors such as data availability, access, structural complexity, target reservoir(s) and potential stress conditions tend to decrease their estimated potential at this early stage. If initial field observations in 2022 cause a shift in priorities this will be taken into consideration at that time potentially resulting in a shift in location of any detailed geophysical evaluations.

7) Recommendations for Further Work, Phase Two (2022)

In Phase Two, a short geological field program will include geological mapping, surface temperature data collection and directed geochemical sampling across a broader area of interest, such as the area surrounding Pilot Bay peninsula. This will be followed by a geophysical program which could include Multispectral Infrared and Thermal Imaging (TIR) via drones.

During Phase Two, geological field work, carried out by a geology student would include outcrop mapping to understand bedrock lithology as well as structure and incorporate bedding inclination, carefully noting observed fractures and the orientation of different fracture sets. Several fracture sets are evident in the picture of an outcrop on the Pilot Bay peninsula, (Figure 19). Geological field work will also include geochemical sampling of relevant surface water bodies. The student will be furnished with simple equipment to gather temperature and conductivity readings from the water bodies as they are being sampled. Laboratory analysis of water samples collected will follow.

This detailed drone work will be focused over a specific area, recognized to have increased potential. The survey can be conducted quickly, safely and effectively with minimal environmental impact.



The planned geophysical activity in Phase Two will be conducted by Selkirk College students using their drone (Figure 20a). It is anticipated that the drone program would focus of a specific area covering up to 15 Sq. Kms. The drones will carry geophysical remote sensing equipment such as Multispectral Infrared, Total Infrared (TIR) and potentially Magnetotellurics (MT).

A detailed program would see drone flight lines every 50 meters in a tight grid as depicted in Figure 20b. It is estimated that this work will be carried out over a five to seven-day period towards the end of the summer under the most favourable weather conditions. The exact location of the drone program can be determined after some of the preliminary geological field work confirm certain baseline assumptions.

Finally, a scoping operational assessment could be included in Phase Two; to determine potential cost considerations for additional future work in a third phase - including the testing of priority drill areas. Drilling a test well to a maximum depth of 1,000 to 1,200m should be sufficient to confirm geothermal conditions (temperature and flow rates) as well preliminary scoping economics of setting up a full pilot project utilizing direct heat from a successful well. A maximum drill depth of 1,200m was established, based on the area temperature gradient and a depth sufficient to encounter a minimum of 60°C. Under optimal geological conditions, the desired temperature however could be encountered at a much shallower depth with vertical fractures bringing hotter fluids closer to the surface.

A detailed Phase Two plan and budget is currently being prepared so that appropriate funding partners can be identified and secured well in advance of launching the summer 2022 field campaign planned, for the period of May to August.

8) Conclusion

The regional and localized data continues to highlight the anomalous earth energy or heat flow conditions which prevail in the Kootenay Lake area. This heat is well documented and in January 2015, Geosciences BC commissioned a study to provide an assessment of the economic viability of geothermal energy in British Columbia (for electrical power development). The ‘favourability analysis’ included a review of eighteen prospective geothermal sites across British Columbia. Three of the eighteen sites considered were situated in the Kootenay region.

In the final analysis, eight of the eighteen sites received favorable ranking as potential locations for geothermal power generation - two sites located in the Kootenay’s received a favourability ranking. In fact, one of the two favourable Kootenay sites is on Kootenay Lake itself. The heat flow data presented in the Selkirk 2021 report and contained herein, also confirms the anomalous heat flow conditions around Kootenay Lake. The remaining question is what conditions are required to bring this heat closer to the surface so that it can be utilized for commercial purposes that would benefit the communities in the area.

Much of the focus in analyzing the data during this project and in this report has been to understand the geological conditions which created the observed faulting and what type of faulting has led to fracturing of host reservoirs. Previous detailed work around the Bluebell Mine in Riondel has helped to establish the framework for the faults and fracturing that resulted in the placement of the ore bodies found there. Understanding the conditions that created the ore also contributes to our understanding of the role fracturing played in allowing the movement of hot geothermal fluids up to the shallow depths of the mine.

An examination of the fracture orientation, at the level of the Bluebell mine and an evaluation of fault orientation in the immediate area shows that the faults have a very similar orientation to the fractures which helped introduce geothermal fluids into the mine. Furthermore, that same fault pattern is observed along the East Shore becoming even more attenuated around the Pilot Bay Peninsula west of Crawford Bay.

It is now believed that having observed these relationships and reached this level of understanding, the proposed pre-project geological model has in part been verified. The work proposed in Phase Two will be targeting further validation of this geological model by confirming surface geological conditions and fracture orientations across the east shore; from just north of Riondel to the southern tip of Pilot Bay Peninsula. This, on the ground field work will provide an opportunity to take direct fracture measurements as well as collect geochemical samples for laboratory analysis. The mineral composition of surface waters can provide a reasonable proximity indication of potential geothermal activity in the vicinity of the water sampled.

In addition to the proposed critical field work, it is believed that focused thermal measurements using drones has the potential to not only validate indications from this Phase One, but to also verify the findings expected from early field activities during Phase Two. Thermal evaluation of the surface using drones could further high-grade areas for testing or even pin-point locations for verification of geothermal commerciality within a Phase Three and the drilling of a potential test well.

9) Acknowledgments

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11) Appendix

a) Selkirk Student Report, 2021 (attached)

b) Geothermal and Greenhouses (summarized from the Canadian Geothermal Energy Association https://www.cangea.ca/)

Understanding the Direct Use of Geothermal Heat

The direct use of geothermal heat implies that geothermal energy is used for heating and other industrial or commercial processes. Direct use operations often involve drilling and bringing hot fluids to the surface to extract the heat. After the heat is extracted, the lower temperature liquid is returned to the earth so that it can be reheated and utilized again.

The most common direct use applications utilize temperatures equal to or lower than 60°C for space heating, agriculture, aquaculture, bathing, and snow melting & de-icing. The heat from geothermal fluids can be cascaded, meaning that a resource can be used multiple times for different purposes until the temperature has been lowered to a point where it is no longer useful, thereby utilizing as much of the resource as possible, all the while utilizing a renewable resource and producing little to no GHGs.

Kirchweidach, Germany: Jobs, GDP, and No GHGs

The geothermal heat project in Kirchweidach, Germany provides a useful case study for potential Canadian applications, as Germany is known to have similar geology to parts of Western Canada (sedimentary basin). The Kirchweidach project is most famous for the 12-hectare greenhouse that is heated by the direct use of geothermal heat; annually the company saves approximately 6.5 million liters of fuel or approximately 2,150 million tonnes of CO2. Additionally, the greenhouse employs 150 local, full-time staff.

The Netherlands: The Power of Geothermal Heat

The Dutch have a different perspective when it comes to utilizing their geothermal resources. Unlike other countries worldwide, whose focus is on geothermal power generation, the Netherlands have focused their energy on the direct use of geothermal heat for greenhouses and industry. Of the 12 active geothermal projects in the Netherlands, 11 are horticultural projects.

The Netherlands have become the second largest global exporter of food by dollar value after the U.S., with only a fraction of the land, and have also become the world leader in in tomato production. The Netherlands has recognized that geothermal energy is an important alternative to natural gas and strives to reduce 0.3 megatons of CO2 emissions annually through the use of geothermal heating for greenhouses.

New Mexico: The US' Geothermal Greenhouse State

New Mexico is the leading US state with regard to developed geothermal heated greenhouses. A useful example to illustrate the benefits of a geothermal heated greenhouse is the New Mexico State University's 28-acre greenhouse, which has created 250 full-time jobs, with an estimated payroll of $3.7 million per year and estimated sales of $13.4 million. New Mexico has a total of 50 acres of geothermal greenhouses, which represents $5.6 million in payroll and $20.6 million in sales, which the majority are made to out-of-state buyers. It is also worth noting that the greenhouses pay royalties for geothermal production.

Geothermal Agriculture and Aquaponics Model

Generally, the necessary temperature for a geothermal heated agriculture or aquaponics project is around 70°C. 21 acres of greenhouses generate net revenue of $5.2 million USD annually, cost approximately $15-$20 million USD, which equals a payback of approximately 3 to 4 years. Moreover, a project of this size generates approximately 8 jobs per acre, which equals 168 fulltime jobs for 21 acres. (Source: Economics of Heat vs. Power Only, Jerry Smith, NREL 2015)

https://www.energy.gov/sites/prod/files/2015/07/f24/03-The-Importance-of-Shifting-Exploration-Models---Jerry--Smith_0.pdf