YUKON ENERGY CHARRETTE

A DISCUSSION OF GEOTHERMAL RESOURCES and THEIR POTENTIAL FOR UTILIZATION IN THE YUKON TERRITORY

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Background on Geothermal Resources

The term "geothermal energy" refers to the natural heat of the earth. This heat is present world-wide beneath the earth's surface and it increases with depth at rates which vary from place to place. Although this heat is a component of the near-surface heat utilized in ground source heat pump systems, part of that resource may also be of solar origin and, in spite of its practical applications in space and process heating, it is not pertinent to the one under discussion: the generation of electrical power. The temperatures required for electrical generation are much higher than those available from ground source geothermal heat pump systems – but the interior of the earth is hot and there are many places where this heat is able to access the near-surface environment.

On average the rate of temperature increase with depth is about 25℃ per kilometer but, where geothermal resources are present, this value may be substantially higher – possibly well over 100℃ per kilometer. These rates are termed "geothermal gradients" and high geothermal gradients imply elevated temperatures in rocks at shallow or intermediate depths beneath the earth's surface. Areas where this occurs are of commercial interest because geothermal heat has a number of applications if it can be accessed, recovered and utilized in a cost effective manner.

The geothermal heat in these areas is generally attributed to:

1) The passive flow of terrestrial heat from deep within the earth.
2) volcanic activity and
3) radioactive decay of elements such as uranium, thorium and potassium in crustal rocks.

Unlike most other sources of renewable energy, geothermal resources must be identified and quantified by geological, geophysical and geochemical exploration methods much like those employed in the mineral industry. This generally involves developing an understanding of the geology of the particular area of interest normally beginning with recognition of surface manifestations of geothermal activity. These include hot and warm springs, fumaroles, geysers and active or recently active volcanoes but other more subtle indications of their presence are also possible. These may include:

1) sinter or tufa deposits – which are surficial rocks deposited by precipitation of minerals dissolved in hot or warm groundwater;
2) occurrences of rocks that have been altered by hydrothermal activity – essentially by contact with hot water and steam;
3) areas where vegetation is either stunted or unusually prolific as a result of elevated sub-surface temperatures and
4) seasonal phenomena such as local melting of ice and snow including areas of open water in winter conditions.

In addition, because geothermal fluids by their nature need to circulate through channels in the earth's crust, the configuration of major fractures or fault systems may play an important role in influencing their locations.

Resource Capacity

Geothermal resources are a well-established source of electrical energy in many countries including the U.S. where installed geothermal capacity in excess of 3000 MW is currently supplying electricity from 77 operating plants in 15 states including California, Nevada, Utah, Hawaii and Alaska among others. Much of the electricity used in San Francisco, for instance, and most of the power in Reno, Nevada is generated from geothermal resources. There is no production in Canada although geothermal exploration has been carried out in B.C. and a small pilot plant was operated there during the 1980s.

Although geothermal exploration has been carried out in B.C., the Yukon, and Northwest Territories, actual utilization in Canada is confined to recreation at hot spring resort sites and to space heating – and, other than low-temperature applications such as those at Mayo and Haines Junction, the Takhinni Hot Spring near Whitehorse is the only geothermal site currently utilized in the Yukon.

Potential Energy Production

Until a high-enthalpy resource has been identified and characterized in the Yukon any estimate of the potential for electrical generation would be entirely speculative. Geothermal Power plant capacities elsewhere, however, tend to lie in the range from a few megawatts to a few tens of megawatts. Current U.S. developments include Nevada Geothermal Power (49 MW; northern Nevada); Stillwater (47 MW; northern Nevada) and Thermo (10 MW, Utah) among others. California is the largest geothermal producer with over 2500 MW capacity: Nevada is second at 433 MW. Plants are typically assigned a life of 25 or 40 years but, depending on resource management practices, the resource itself can be expected to persist almost indefinitely. The Larderello geothermal field in Italy, for instance, has been producing energy since 1905!

At most geothermal sites heat is transported to the near-surface environment by hot water that has circulated through channels in hot rocks. The availability of the resources ultimately depends on the configuration of these channels which are created by faults and fractures that allow circulating water to access the hot and generally deep sub-surface environment. Geothermal waters are commonly meteoric (rain and snow) but may also be connate (water entrapped in sedimentary deposits), juvenile (water derived from magma) or metamorphic (water produced by the alteration of hydrous minerals). In areas where there is little or no water, however, the evolving technology of Enhanced Geothermal Systems (EGS) may also have a role in future geothermal development. This technology is predicated on drilling into naturally occurring hot dry rock and, if required, fracturing it to enhance or create artificial permeability then circulating water through it to recover its heat. The cost of recovery, however, increases with the depth of the resource ultimately limiting the utility of deep stores of heat. Under some circumstances, however, geothermal recovery economics can be enhanced if deep wells drilled for other purposes, such as petroleum and natural gas exploration, can be exploited.

Electricity is generated from geothermal resources by drilling wells into sub-surface reservoirs of hot water or, in special cases, steam. The hot fluid is extracted and used to drive either a conventional steam or binary turbine which, in turn, drives an electrical generator. In some cases residual heat from the turbine may be used in secondary applications such as space heating or for recreation. The cooled water is then re-injected into the reservoir.

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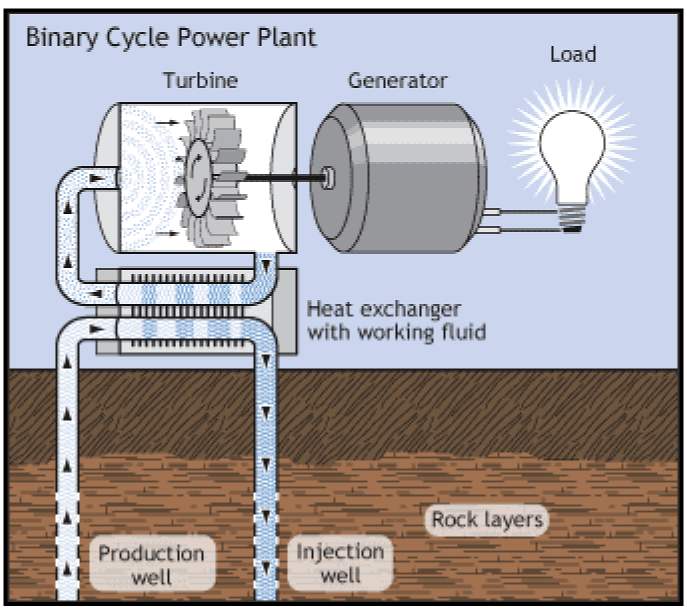
Flow Testing a Geothermal Well in B.C.

Geothermal steam turbines such as those used in northern California operate efficiently at temperatures in excess of 180°C. They use either dry steam directly from the reservoir or very hot water which is flashed to steam and passed through a condensing turbine which drives a generator.



Modern binary or Organic Rankine Cycle (ORC) plants can exploit geothermal resources at temperatures in the range between about 90 and 180°C but are most cost effective at temperatures in the 120 to 160°C range. These plants utilize the hot water from the geothermal reservoir, through use of a heat exchanger, to heat and vaporize a binary fluid – normally an organic fluid that boils at a lower temperature than water. The resulting pressurized vapour, which is confined in a closed circuit, then drives a turbine which drives a generator to produce the electricity. The vapour is cooled and condensed to a liquid at the turbine's outlet then reheated and re-cycled continuously. Efficient condenser cooling is important and, in hot and/or dry regions, production can be seriously impaired by insufficient cooling capacity. This is not expected to be a problem here.

Low temperature resources, those below temperatures of about 80℃, are useful in a number of applications such as space and process heating, recreation and fish farming among others. In special circumstances, however, electrical energy can be produced from +/-80℃ fluids, higher temperatures are normally required. These resources are commonly associated with hot and warm springs or shallow wells.

Geothermal production drilling costs are comparable to those for oil and natural gas wells: a completed geothermal well can cost from a few hundred thousand to several million dollars. Recent U.S. estimates for a deep production and injection well doublet are reported to be about $10,000,000 – and not all are successful producers. In addition, unlike petroleum and natural gas development, a geothermal discovery will require construction of a surface plant *at the site of the resource*. Contemporary geothermal installation costs are on the order of +/-$4,000,000 per MW installed. Reported 2007 break-even electricity costs were about $0.054/kWh. More recent U.S. utility prices are reported to range from about 8 to 12 cents/kWh.

Depending upon the characteristics of the resource, productive capacity of geothermal plants normally varies from less than 200 kilowatts (kW) to several hundred MW but, for most current applications, it generally lies in the range of a few tens of megawatts. This places certain constraints on the siting of geothermal power plants: they must be located close to energy markets or infrastructure such as an electrical grid because small to intermediate sized plants cannot generally support the cost of long transmission lines. Typical power line costs for, say, a 10MW plant may be expected to exceed $300,000 per kilometer and, depending upon terrain, infrastructure and capacity, could range on up to $2,000,000 per kilometer.

As an alternative to conventional energy sources geothermal resources are attractive in large part because they usually provide "base load" energy which means that, once in service, they operate steadily. Unlike wind, solar and run-of-river hydro they are not influenced by natural variations in wind strength, sunlight or stream flows and there are no fuel costs.

Status of Geothermal Energy Exploration and Research in Yukon

No electricity is currently produced from geothermal resources in the Yukon. There are, however, a number of areas within the Territory and parts of adjacent B.C. where there is geological evidence of the type of geothermal resource that might be used to generate electricity. Direct indications include:

1) areas of Recent volcanism
2) hot and warm springs

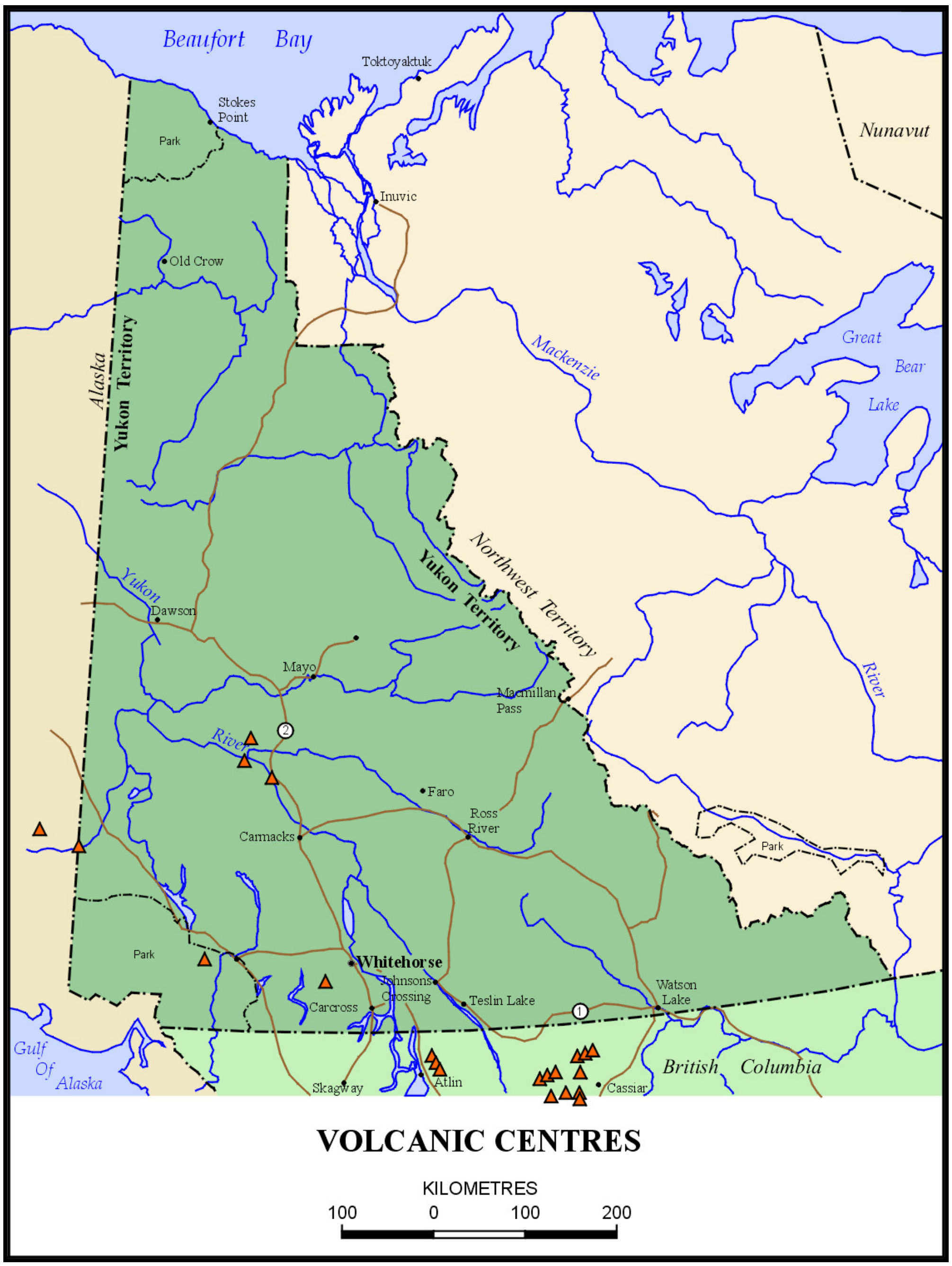
Areas with geothermal potential but with no direct indications include:

3) regions of elevated terrestrial heat flow and
4) major fault structures

Exploration work has been initiated in several of these areas but continued effort will be required.

Volcanic Areas

Volcanic activity is an excellent geothermal resource indicator. The most recent volcanic activity in the Yukon occurred at aptly named Volcano Mountain near Fort Selkirk - just north of the confluence of the Pelly and Yukon Rivers. The last eruptions here are estimated to have happened less than 3000 years ago. Although the lava is thought to have been derived from a very deep source, the volcanic activity was long lived and there is a reasonable possibility that an active heat source remains beneath the complex.



View of Volcano Mountain

An older, but still comparatively young volcanic complex lies just southeast of Whitehorse in the Alligator lake area. Volcanic activity here between 3 and 9 million years ago was the source of the Miles Canyon basalts. So far no evidence of near-surface heat has been found in this area.

Another area of volcanic activity lies further south in the Yukon – B.C. border area. It is referred to as the Northern Cordilleran Volcanic Province. In B.C. it contains volcanic centres such as Mt. Edziza and Level Mountain, among others. These volcanoes have been active in the recent past and hot springs associated with them indicate that they are still hot. The volcanic province appears to extend into the southeastern Yukon but no strong geothermal targets have yet been identified there.

Thermal Springs

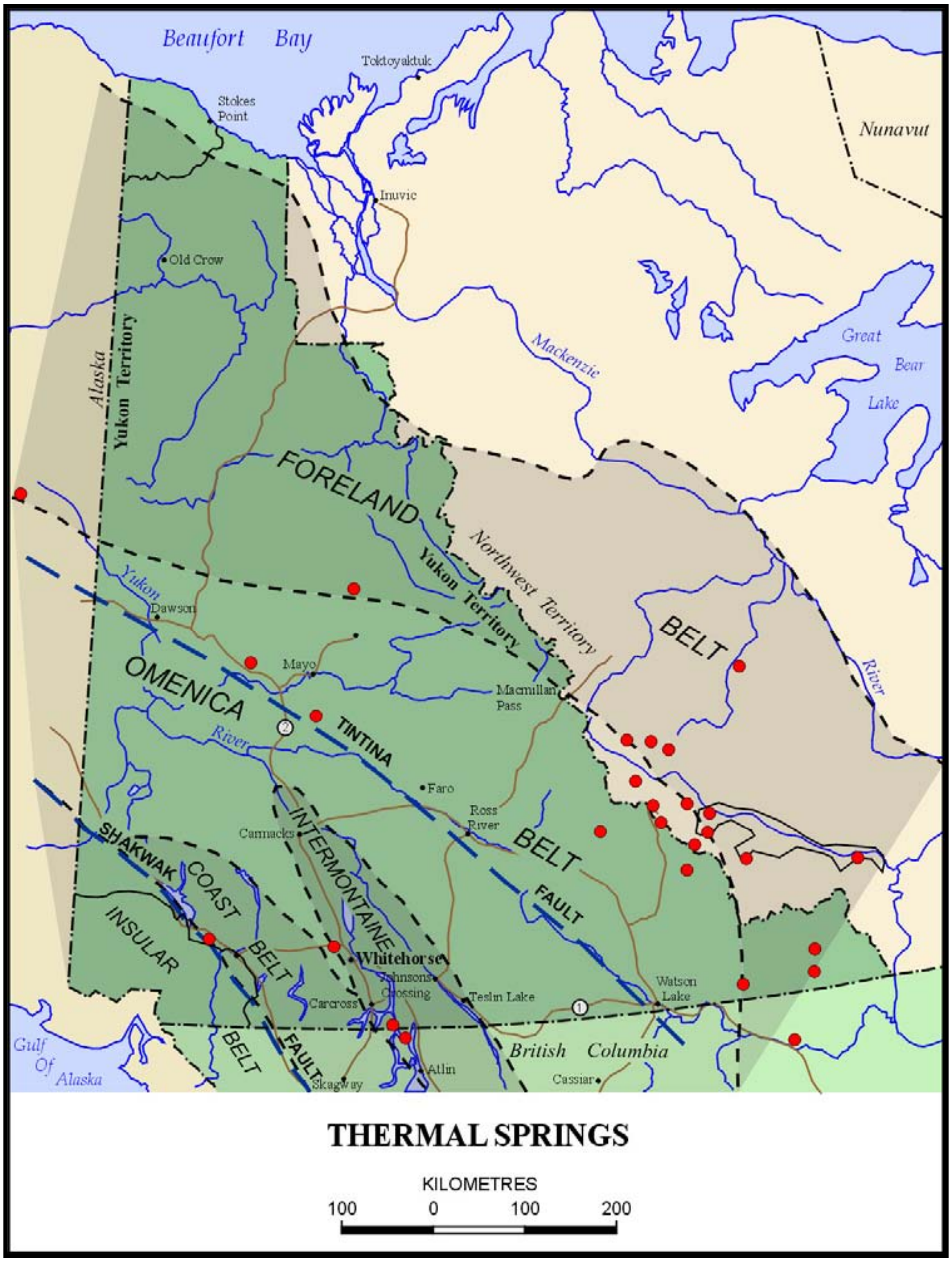
A total of about a dozen thermal springs have been reported to occur in the Yukon. These springs appear to fall into three broad categories:

1) those associated with the folded and faulted sedimentary rocks of the Mackenzie Mountain fold belt;
2) those associated with granitic intrusive rocks in the Omenica crystalline belt;
3) those associated with fault systems.

Springs related to Recent volcanic activity have yet to be discovered in the Yukon but several are present south of the border in northern B.C.

The springs in Category 1 are attributed to deep circulation of meteoric water in a region of moderately elevated terrestrial heat flow. They tend to be of moderate temperature ~ 40 to 50℃ and have only limited prospect of higher temperatures at depth. They are also remote from electrical infrastructure.
The Category 2 springs appear to have potential for moderate-to-high temperatures at moderate depths. They are attributed to circulation in deep open fault or fracture systems probably in areas of

elevated geothermal gradient. The Takhini hot spring and the geothermal resource driving the only operating geothermal plant in the northern North America, which is located at Chena Hot Springs in Alaska, may fit into this category.



THERMAL SPRINGS

The Yukon is traversed by several major faults. One of these, the Denali – Shakwak fault system in the western part of the Territory has been historically active. Several warm water occurrences (+/-18°C) are present along its trace. These temperatures may have direct use applications and they may be indicative higher values at greater depths. The source of this water has been partially investigated by YEC but results to date are inconclusive. Several thermal springs are also reported to occur associated with the Nahlin fault in the southern Yukon and northern B.C.


Warm Spring at Jarvis River

Heat Flow

A number of studies done in the past by Geological Survey of Canada personnel have identified regions where terrestrial heat flows and geothermal gradients are higher than normal. These are attributed to heat generation produced by decay of radioactive elements in crustal rocks and/or by the presence of high temperature regions or "hot spots" in mantle rocks beneath the earth's crust. For the most part, however, these are regional features and more effort will be required to develop specific targets for exploration within them.

Fault Systems

The Denali-Shakwak Fault in the western Yukon and the Tintina Fault which traverses the territory from Watson Lake to Clinton Creek are targets for geothermal exploration. Warm springs in the Shakwak Valley have been partially evaluated by geophysical and geochemical surveys and drilling.

The Tintina fault, which is aligned with the Rocky Mountain Trench fault system to the south, is of particular interest. It is a major break in the earth's crust and the focus of over 400 km of right lateral displacement accompanied in some intervals by vertical movement. This has produced segments along its strike where elongate blocks of rock in the fault zone have been displaced downward to form bedrock depressions or "grabens" which have been filled by later alluvial and sedimentary deposits. The presence of grabens implies the possibility that the region has been subjected to extensional tectonic forces which could produce the type of open fractures and faults that host geothermal resources in other comparable terrains – such as northern Nevada. In southern B.C. several hot springs with geothermal potential are associated with faulting in the southern Rocky Mountain Trench.

Summation

No electricity is currently produced from geothermal resources in the Yukon but there are a number of areas with geological evidence for the type of geothermal resource that could be used to produce electricity.

Until a resource has been identified and quantified in the Yukon any estimate of the cost of production would be very speculative. In other jurisdictions, however, electricity is produced from geothermal resources at a cost ranging from $40 to $80/MWh.

Prevailing plant construction costs are reported to range between $2.5 and 4.5 million per megawatt installed – of which a substantial component (up to about 50%) is for exploratory and development drilling.

Geothermal resource extraction is independent of seasonal, diurnal and meteorological factors. It is essentially a base load electricity supply.

There are no fuel costs other than the cost of identifying and maintaining the resource.

Geothermal resource developments are well suited to development of complimentary applications such as space and process heating assuming that the resource is reasonably convenient to a market for the heat.

Development of a geothermal resource is entirely dependent upon a successful exploration program which could take years depending upon factors such as funding, the level of effort and compliance with regulatory provisions. Actual plant construction, however, is straightforward and, depending on the size of the plant, construction may be expected to take two to three years once the resource has been quantified.

Geothermal plants are being constructed and operated throughout the world. The technology, while innovative in some respects, is not radical. Accordingly, the completion risk is expected to be on par with that for any other energy project.

In the Yukon there is no legislation governing geothermal title or regulating geothermal engineering and environmental practices. There are, however, many examples from other jurisdictions and there appear to be no issues that would preclude geothermal development in the Yukon.

Geothermal energy is very “green” – no or minimal emissions, no combustion, small pant footprint. In some areas, however, extraction of water from geothermal reservoirs has been linked to seismicity. This has been an issue in densely populated regions such as in Europe.

Geothermal electricity would be expected to qualify for carbon credits.