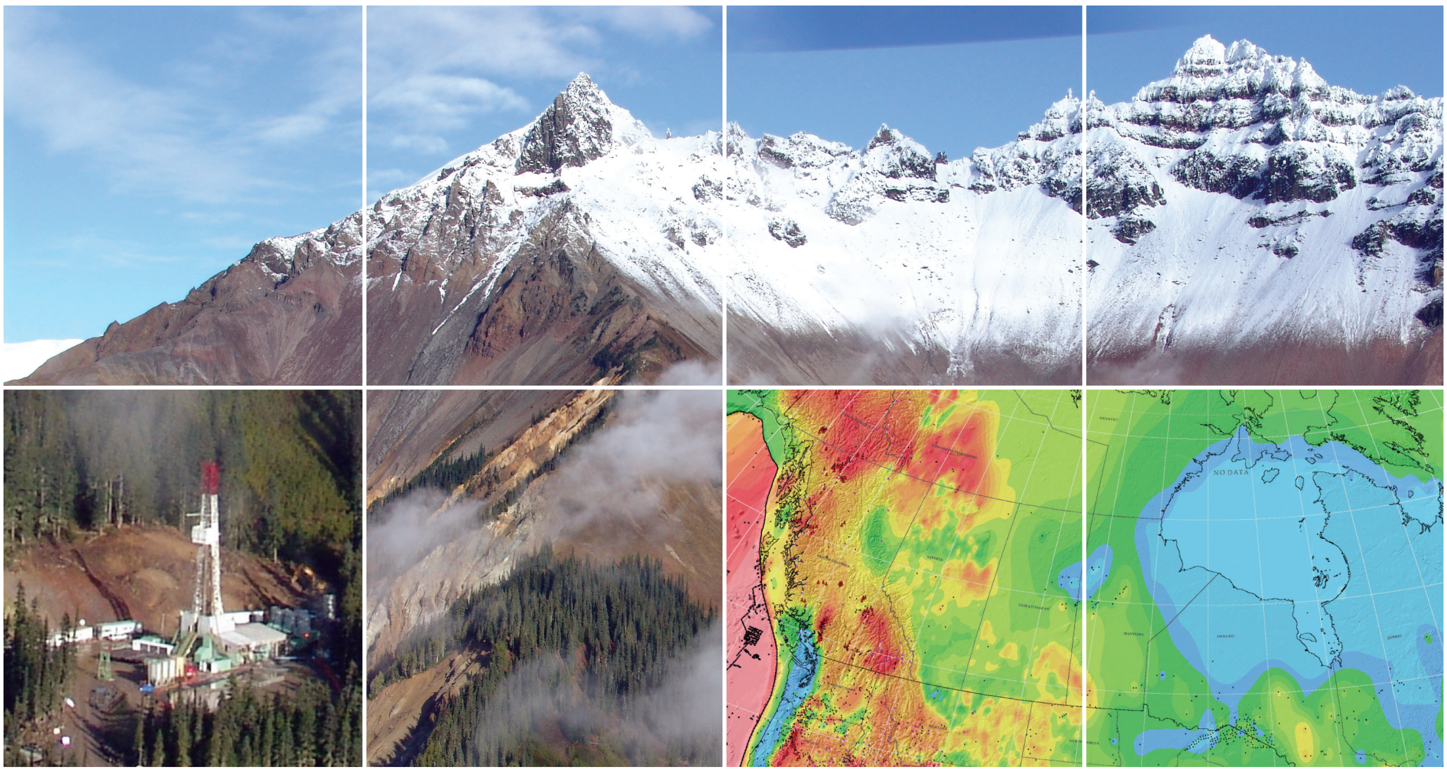
Geoscience Needs for Geothermal Energy Development in Western Canada: Findings and Recommendations

Petroleum Geology Open File 2009–03



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Geoscience Needs for Geothermal Energy Development in Western Canada: Findings and Recommendations

BC MEMPR–NRCan-GSC–CanGEA Workshop
October 16–17 2008, Vancouver B.C.

Report co-prepared by British Columbia Ministry of Energy, Mines and Petroleum Resources and Natural Resources Canada–Geological Survey of Canada

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Front Cover Images:
Photo: Mount Meager geothermal exploration project. Photo credit - Western Geopower Corporation, used with permission.
Graphic: Geothermal Map of North America. Red and pink colors depict high or very high heat flow (Southern Methodist University Geothermal Laboratory website, 2008).

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Ministry of Energy, Mines and Petroleum Resources

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ACKNOWLEDGEMENTS

The organisers would like to thank all of the participants for their generous contributions throughout the two days of this workshop. We are particularly indebted to the Canadian Geothermal Energy Association; their encouragement of their membership to attend this event resulted in an excellent group of expert participants.

Vic Levson (BC MEMPR) and Daniel Lebel (NRCan-GSC), co-chairs of the organising committee, wish to acknowledge the dedication and time of the workshop organising committee staff of BC MEMPR, NRCan-GSC, and CanGEA. We are especially grateful to Ron Smyth, who had the initial idea for this workshop. We wish to add our best wishes on the occasion of his retirement, which occurred over the course of organising this workshop. Ron served over a long career with the BC government and the geoscience community in Canada, and the first payoff of his geothermal geoscience foresight is contained in this report.

EXECUTIVE SUMMARY

The goal of the workshop was to assess the geothermal geoscience needs of western Canada and the appropriate role of government geological science agencies in supporting geothermal energy exploration and development. The focus was on using moderate- to high-temperature geothermal systems for direct heat or electricity generation.

Geothermal energy is a natural source of heat contained within the earth. It can be extracted and used either indirectly to generate electricity or directly for heating applications. Geothermal energy represents a viable but largely untapped renewable energy supply at a time when western Canada is facing a future electricity supply shortfall. There is also an opportunity for Canada to consider geothermal electricity and direct heat as a carbon abatement measure, as is presently done in several other countries, including the United States, Iceland, and Australia.

The workshop was focused on defining geoscience needs in order to steer future geoscience programming in response to the above policy drivers.

The workshop was facilitated by presenting three key questions to the participants:

1. What are the key geothermal energy resources and tools?
2. What is the geoscience needed to support geothermal energy development?
3. What is the appropriate role of a government geological science agency in addressing these geoscience needs?

The main recommendations from the findings presented in this report are as follows:

Recommendation 1: Develop a national geothermal resource assessment.

Key geothermal resources of western Canada need to be well defined and inventoried in order to encourage exploration and facilitate the raising of capital. The 2008 United States Geological Survey (Williams, 2008) provides a good example.

Recommendation 2: Compile regional or national geothermal-related geoscience databases to support geothermal energy exploration with pre-competitive geoscience.

The first step in meeting this recommendation should be government-led compilation of existing geological information. Recent efforts started by the British Columbia Ministry of Energy, Mines and Petroleum Resources (BC MEMPR) and the Geological Survey of Canada (GSC) are positive steps that should be continued. Databases need to be continuously maintained and updated as new data are generated by exploration and geological surveys.

Recommendation 3: Acquire new targeted geoscience information for geothermal exploration in areas with the highest potential for development.

Assessing the areas of highest potential for development can be challenging due to complex technical difficulties as well as land-management and regulatory issues. To reduce the time and effort involved, task focus areas should be jointly defined by technical advisory committees comprised of members of the geothermal industry, major electric utilities, and government geoscience agencies.

Recommendation 4: Hold other forums and undertake policy analysis to advance geothermal energy in Canada.

Other topics that need to be addressed at a provincial or national level include industrial incentives (tax breaks, risk reduction for drilling, green power pricing incentives) and geoscience needs for low-temperature systems (e.g., geoexchange). Organising partners for the workshop (BC MEMPR, NRCan-GSC, and the Canadian Geothermal Energy Association [CanGEA][1] agreed to explore how these recommendations could be implemented.

Stakeholders from the geothermal industry welcomed the renewal of partnerships between government energy-policy agencies, their counterparts in geological science agencies, and CanGEA to address policy and knowledge gaps and advance geothermal energy in Canada.

[1]CanGEA is a non-profit association promoting the development and use of sustainable geothermal energy in Canada. Their focus is moderate- to high-temperature resources (above 70 °C) for power production. http://www.cangea.ca/about-cangea/

INTRODUCTION

WORKSHOP GOALS, CONTEXT, AND PARTICIPANTS

The principal goals of this workshop were to assess the geothermal geoscience needs of western Canada and determine the roles of government geological science agencies in geothermal energy exploration and development.

The two-day workshop was well attended by approximately 50 geologists, academics, economists, energy regulators, industry professionals, and federal and provincial government scientists and policy makers. The attendees represented a wide range of perspectives on complex technical issues and the broad geoscience needs for geothermal energy development. The agenda of the meeting is attached in Appendix 1. The list of participants and the organising committee members are included in Appendix 2.

The workshop focused on three key questions:

1. What are the key geothermal energy resources and tools?
2. What is the geoscience needed to support geothermal energy development?
3. What is the appropriate role of a government geological science agency in addressing these geoscience needs?

To orient the participants, the workshop discussions were initiated by a series of presentations. The main purpose of the presentations was to provide background information for the discussions and to offer the opinions of leading geothermal experts on the three key questions for the workshop. The presentations were followed by break-out groups to enrich the lead presenters' opinions with those of the other attending experts. There was no priority setting of the geoscience needs, but a lead reporter for each break-out group presented a summary to the whole workshop group. A general discussion was then held on the relative importance of the geoscience needs and on the possible roles of geological science agencies in addressing these needs. The results of these discussions are synthesized in this report, and recommendations have been developed based on participants' suggestions.

The presentations are listed in Appendix 3. They are available in PDF format on the disk included with this publication, and are publicly available at the Canadian Geothermal Energy Association web site (www.cangea.ca).

On behalf of the organising committee, Daniel Lebel outlined the goals of the workshop and the key questions to be addressed. He provided for the participants some key background information on geothermal potential.

Garth Thoroughgood (A/Director, Geothermal Resources, BC MEMPR) outlined the issues being addressed by the current BC government geothermal policy review by the Geothermal Task Force.

Steve Grasby of the GSC outlined the results of the federal government National Geothermal Program (1975–1986); possible future program undertakings by the GSC were also briefly described. Current work by BC MEMPR toward a geothermal geoscience database for British Columbia was presented by Cassandra Lee to open discussion on possible future work on western Canada geothermal geoscience databases.

Craig Dunn of CanGEA made a general presentation on the opening of the second day, outlining CanGEA's mission, its present undertakings, and its views on the three key workshop questions.

Break-out Group 1 focused on high-temperature volcanic belts and hydrothermal systems; this topic was introduced by Tim Sadlier-Brown (Appendix 4). Break-out Group 2 focused its attention on geoscience needs for geothermal development in the western Canada sedimentary basins, which were introduced by Jacek Majorowicz's presentation, "Geothermal Potential of Sedimentary Basins in Western Canada". Break-out Group 3 discussed geoscience needs for the advancement of enhanced geothermal systems and hot dry rocks, as introduced in presentations by Michal Moore and Dan Yang. Break-out Group 4 focused on databases, geoscience products, exploration tools, and data integration, as introduced in presentations by Frank Monastero and Cassandra Lee.

GEOTHERMAL ENERGY: WORLD SUPPLY AND POTENTIAL FOR WESTERN CANADA

Geothermal energy is used worldwide to supply direct heat to buildings and to generate electricity. Geothermal electric power plants presently supply more than 9 GW (gigawatt) worldwide (Tables 1 and 2) and have a potential estimated between 60 and 250 GW depending on the assessment method (Table 2). The USA is the leading country in geothermal electricity generation at over 2.5 GW.

Sitting on the Pacific 'Ring of Fire' (Figure 1), western Canada has high volcanic and non-volcanic geothermal potential. This is illustrated by the heat flow map in Figure 2.

The Canadian mining and energy exploration industries are supported by geoscience and engineering professional communities, which are well versed in mineral and energy resource development. Canadian electricity utilities have a wide experience in bringing a varied mix of electricity supplies to the market. BC Hydro and Yukon Energy are aware of geothermal development taking place abroad and are also interested in seeing this development take place in Canada. This has been shown with capital investment

TABLE 1: WORLD TOP 10 INSTALLED GEOTHERMAL ELECTRICITY GENERATION CAPACITY BY COUNTRY, WITH INSTALLED GROWTH PER YEAR AVERAGED OVER THE PERIOD 2000–2007.*

World Top 10 Installed Geothermal Electric	1990 MW	1995 MW	2000 MW	2007 MW	% of top 10	Growth per year 2000-2007
USA	2774.6	2816.7	2228	2,687	29%	2.94%
Philippines	891	1227	1909	1,970	21%	0.46%
Mexico	700	753	755	953	10%	3.75%
Indonesia	144.8	309.8	589.5	992	11%	9.75%
Italy	545	631.7	785	811	9%	0.47%
Japan	214.6	413.7	546.9	535	6%	-0.31%
New Zealand	283.2	286	437	472	5%	1.14%
Iceland	44.6	50	170	421	5%	21.09%
El Salvador	95	105	161	204	2%	3.82%
Costa Rica	0	55	142.5	163	2%	2.06%
Total top 10	5692.8	6647.9	7723.9	9208	100%	2.74%

*As a reference, Canada's total electricity generation capacity was 111,000 MWe (megawatt potential for electric generation) in 2000, and none from geothermal. (US Senate Committee on Energy and Natural Resources website, 2007), (Canadian Electricity Association website, 2008).

TABLE 2: INSTALLED GEOTHERMAL CAPACITY FOR ELECTRICITY GENERATION, AND FUTURE POTENTIAL BY CONTINENT.*

	Installed Capacity (MWe 2005)	Potential (MWe)	Installed Capacity (% of World Total)	Potential (% of World Total)
North America	3,517	30,000	39%	20%
Asia	3,290	42,000	37%	28%
Europe	1,124	15,800	13%	11%
Oceania	441	9,000	5%	6%
C. & S. America	424	38,000	5%	26%
Africa	136	14,000	2%	9%
World Total	**8,933**	**148,800**		

*(CERM3 website, 2008), (Planete energies website, 2008).

by BC Hydro and geothermal exploration companies to support the development of the Mount Meager geothermal system.

Geothermal industry stakeholders and observers have claimed that success in electricity generation is within reach (e.g. Ghomshei et al., 2005). The Mount Meager play is often cited as having great potential for profitable development, and it has been the focus of much research, exploration, and development investment. It has been reported on the Western GeoPower web site that "since the late 1970s, the geothermal resource potential of the Meager volcanic complex has been investigated using various exploration techniques, including geology, geochemistry, geophysics, and the drilling of numerous temperature gradient wells (slim-diameter wells used to measure subsurface temperature), deep slim wells, and several full-diameter wells." During one flow test, one of the full-diameter wells drilled by BC Hydro was used to supply a 20 kW pilot geothermal power facility. Western GeoPower claims that "if exploration and development is successful at the South Meager Project it will utilize dual-flash turbine technology with two standard 55 MW (gross) generating units. This type of plant installation has been used at many geothermal projects worldwide." (Ghomshei et al., 2005)

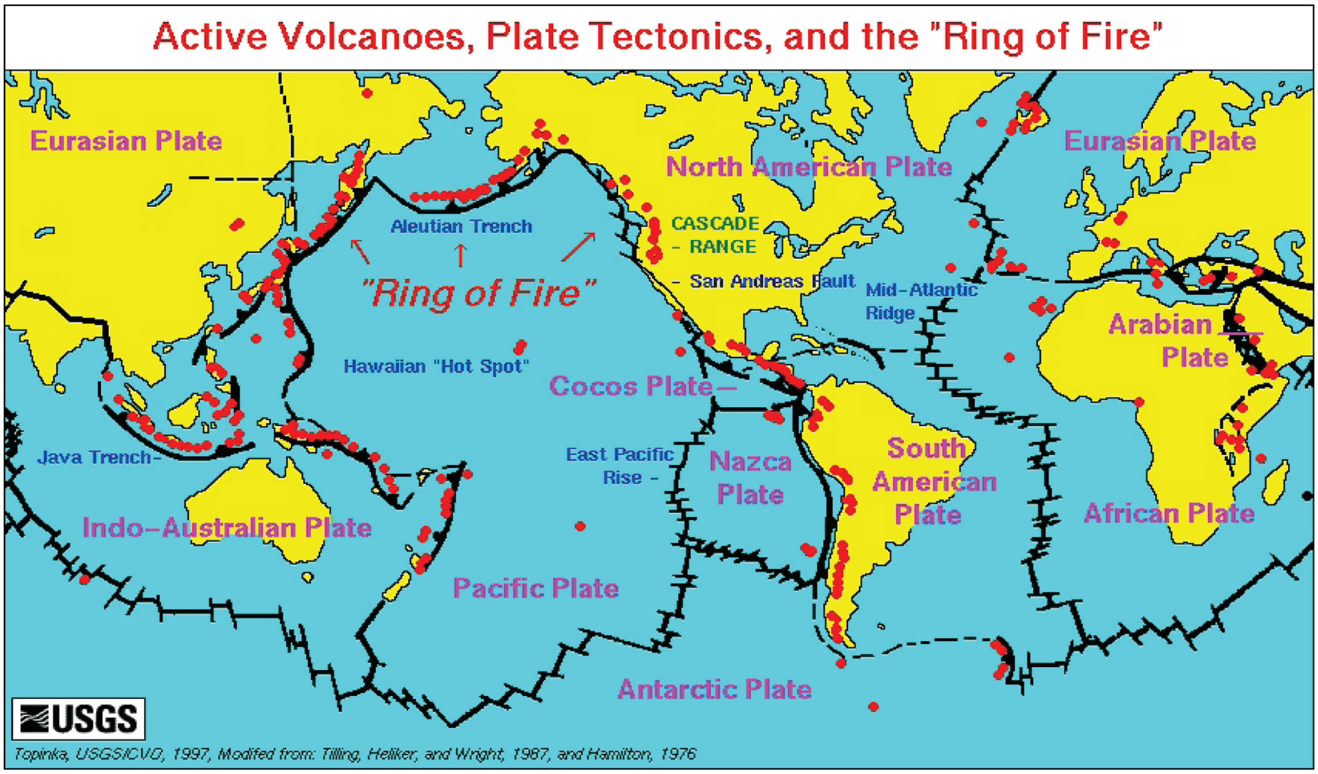

Figure 1: World geological 'hot' features (volcanoes in red), and western Canada portion within the Pacific Ring of Fire and other plate tectonic features. USGS website, 2008.

POLICY CONTEXT

British Columbia is facing an impending electricity shortfall (Figure 4), and geothermal energy represents a viable yet largely untapped energy supply for the region. The federal and provincial governments are also actively engaged in an ongoing policy drive to address climate change through a range of low–carbon-emission energy supplies and carbon abatement measures.

Even though BC shows great potential for geothermal energy, there has yet to be a functioning geothermal energy plant in Canada. The geothermal policy review in BC and a recent study by CanGEA have examined how growth of geothermal development in other countries frequently followed initial government support through a mix of policy and tax incentives, including pre-competitive geoscience and a clear regulatory regime. It remains to be demonstrated how these policy measures may be applicable in BC and elsewhere in Canada. Industry observers have suggested that government support for the geothermal industry through various incentives would create a critical and positive investment climate for US and Canadian companies. This support should be maintained even in times of economic difficulty (Silcoff, 2008).

With the above in perspective and to address more precisely the topic of this workshop, a presentation by Steve Grasby of the Geological Survey of Canada outlined the achievements and legacy of the 1980s National Geothermal Energy Program. The federal government geothermal program was a response to the oil crisis of the 1970s and was abruptly terminated in 1986 when the price of energy dropped. Current GSC activities have limited resources that are focused on compiling data to create a digital database, generating depth-temperature, heat flow, heat content, and resource potential maps, and raising awareness of geothermal potential in Canada. Future projects might include data collection, heat flow and temperature fields of sedimentary basins, petrophysical data integration, Tertiary volcanic history, adapting methodologies for resource assessment, and a national scale resource assessment. The GSC has extensive tools and capacity to contribute to geothermal energy development but does not have a current geothermal group.

Canada has a very active direct-heat geothermal industry that makes use of heat drawn from shallow underground using low-temperature geo-exchange systems for residential and district heating. These systems have their own geoscience needs; the workshop did not address these systems.

CanGEA conveyed that geothermal energy:

- can provide base-load electricity (greater than 95% capacity factor),
- is a domestic resource,
- is technologically mature and cost-competitive,

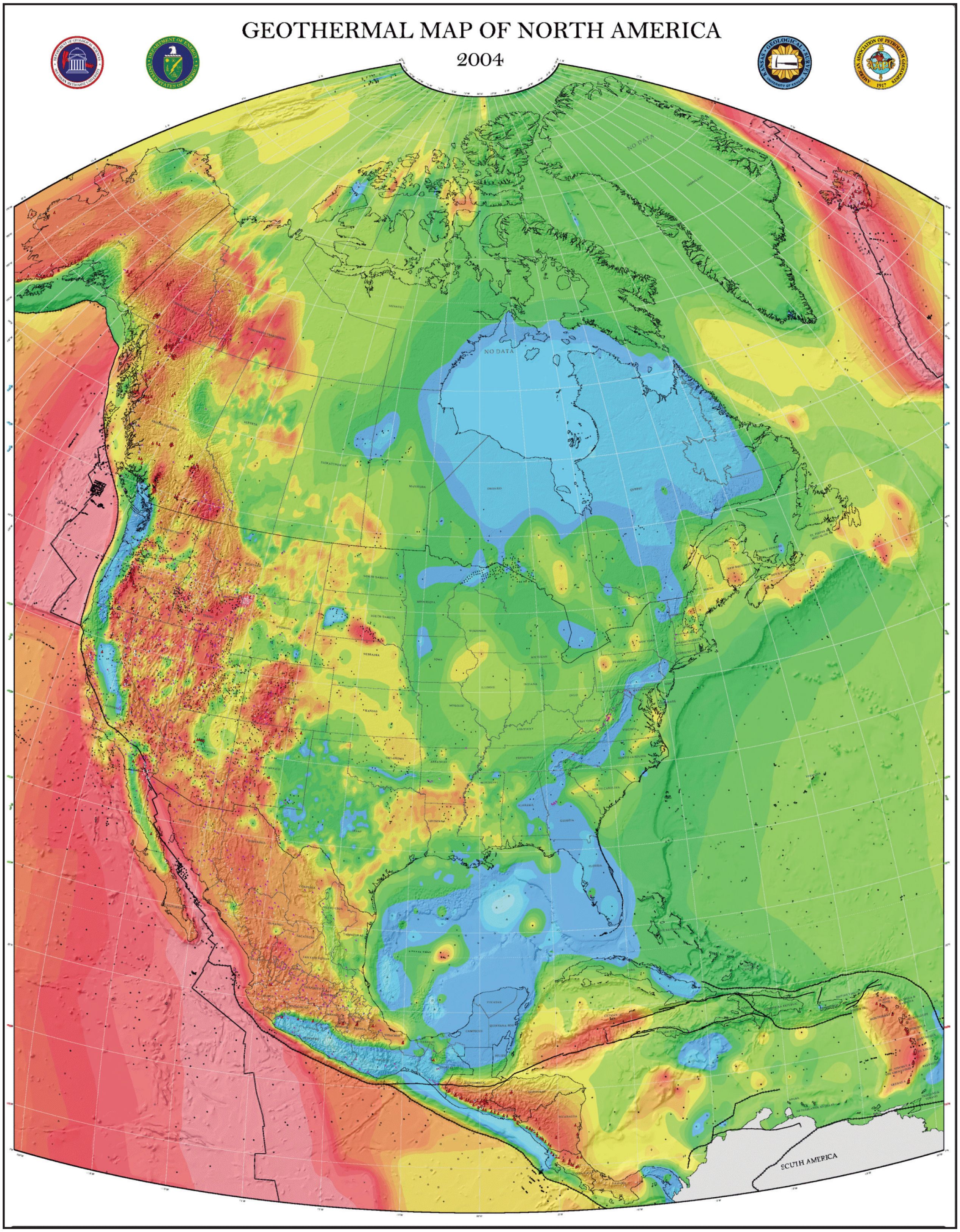

Figure 2: Geothermal Map of North America. Red and pink colors depict high or very high heat flow (Southern Methodist University Geothermal Laboratory website, 2008).

- produces near zero greenhouse gas emissions,
- has a small environmental footprint,
- is a sustainable resource (renewable energy), and
- is the lowest long-term cost of all energy alternatives.

Studies on geothermal energy and the reduction of carbon emissions have been published for other countries, such as Australia (Australia Government – The Treasury website). The workshop participants were not aware of a Canadian study on the potential of geothermal energy (as compared to other alternative energy sources) as a carbon abatement measure. Such a study might be useful for climate change mitigation policy development.

MEETING FINDINGS

The findings of the meeting have been placed in the same order as the key questions to participants.

QUESTION 1: WHAT ARE THE KEY GEOTHERMAL ENERGY RESOURCES AND TOOLS?

In addition to shallow geothermal resources tapped through geo-exchange systems, participants agreed that there are several types of geothermal resources in western Canada that could be supported through provision of pre-competitive geoscience knowledge:

- high-temperature volcanic belts,
- sedimentary basins,
- crystalline basement,
- deep fluids systems (crustal circulation, thermal springs, etc.), and
- hot dry rocks.

Participants also agreed that the following tools and technologies are possible areas of geoscience application:

- geoscience knowledge integration, exploration tools (e.g., borehole geophysics development), and geoscience mapping,
- enhanced (engineered) geothermal systems (or heat mining), and
- geothermal information products, management, and systems.

Within the geothermal systems, crucial variables to understand as they relate to geoscience needs are

- heat (resource),
- water (medium), and
- flow and permeability.

CORDILLERAN GEOTHERMAL AND DEEP FLUIDS SYSTEMS

Sadlier-Brown (Appendix 4) pointed to the Coast/Cascade Volcanic Belt as the most attractive to geothermal development, noting the occurrence of hot springs on northeast-trending faults in this area (See Figure 3 for the division of Cordilleran belts). The Omineca Belt and its alkalic intrusive rocks are a potential source of geothermal energy for enhanced geothermal systems (EGS) and possibly radiogenic heat. Some participants suggested that no one really knows what the geothermal potential of the Cordillera is in western Canada. A geothermal map of the Canadian Cordillera was produced in the 1990s by the GSC and is well known to the group. The recently published reviews of the Cordilleran phase of the program (Jessop, 2008b) provides a comprehensive summary, including references, of work done on geothermal projects in the Cordillera since about 1974.

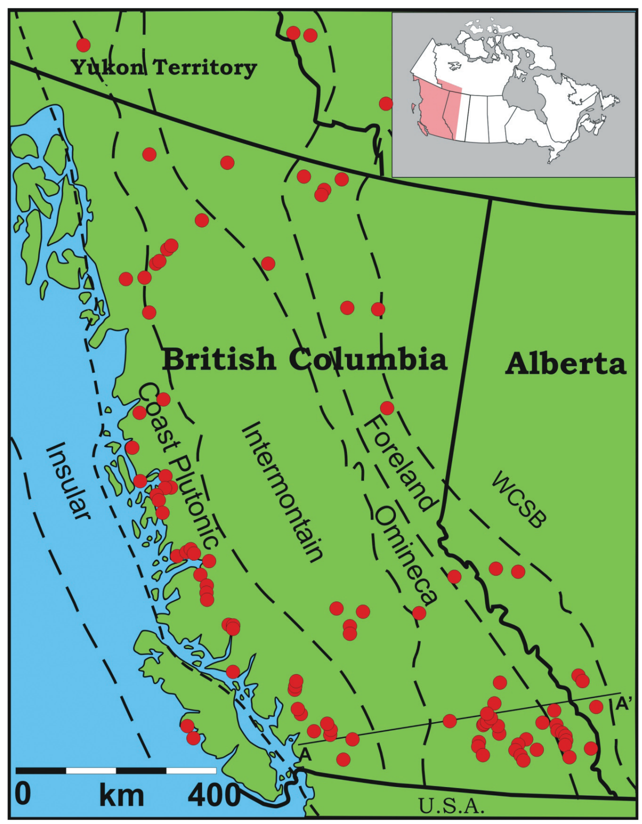

Figure 3: Known thermal springs in western Canada. Source: Geological Survey of Canada.

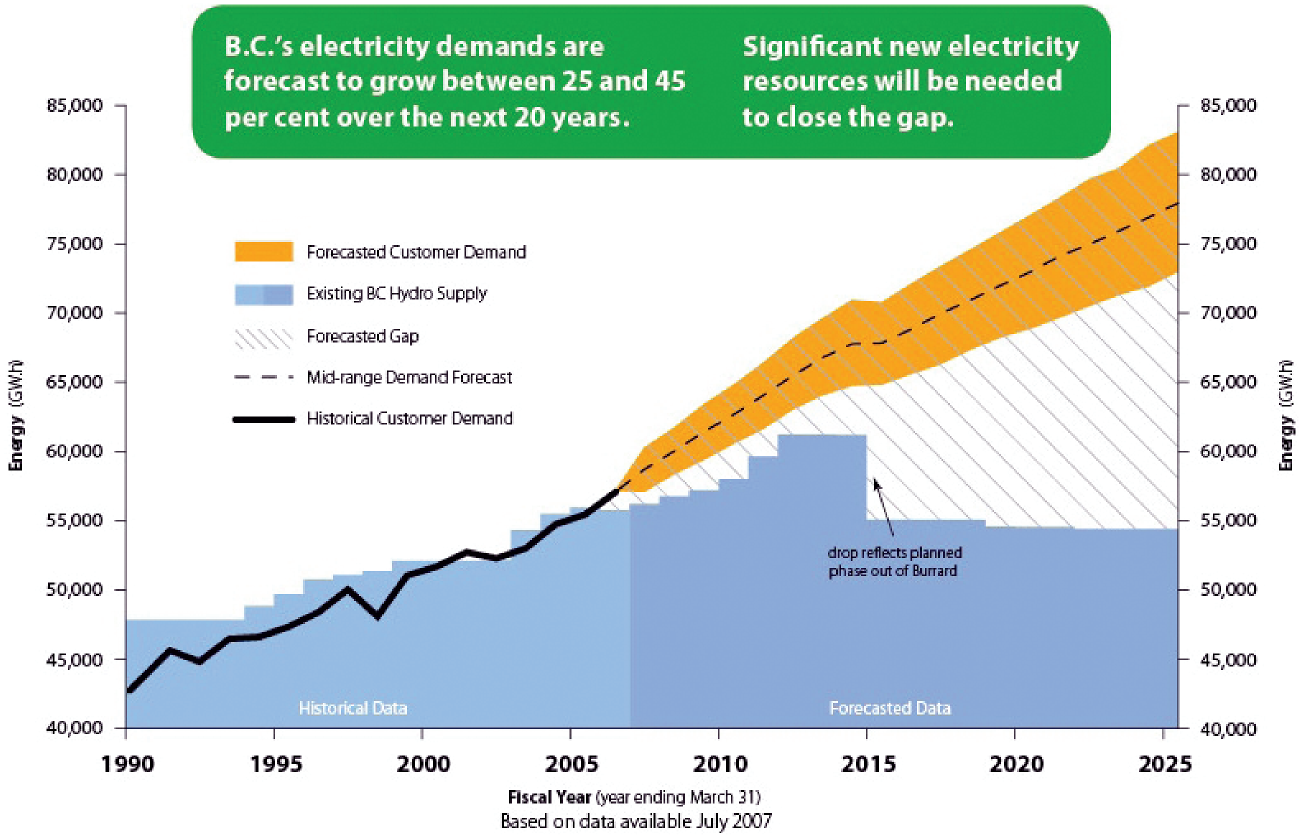

Figure 4: Forecast of energy shortfall for the province of British Columbia (BC Hydro, 2008).

SEDIMENTARY BASIN AND CRYSTALLINE BASEMENT

Jacek Majorowicz underlined that the North America Heat Flow Map shows high heat flow from BC to Yukon and NWT in the Cordillera but relatively low heat flow in the Western Canada Sedimentary Basin. He outlined past work by himself and recent compilations of work from the former National Geothermal Program, such as the recent review of the sedimentary basins phase of the program (Jessop 2008a).

In order to obtain high temperatures in the Western Canada Sedimentary Basin, it is necessary to drill through the sedimentary cover to varying depths. An impressive heat flow anomaly exists in the crystalline basement of the Canadian Shield in the Northwest Territories in the area closest to Alberta; temperatures greater than 150 °C are anticipated within a range of 2 to 4 km. This anomaly appears to be an extension of a broad anomaly extending across Yukon from the Pacific coast. Heat flow data available for the Cordillera and northwestern Canada are very sparse, and these broad anomalies need more data to be confirmed as extending over such a wide area. A modified Canadian heat flow map will soon be released by Majorowicz in collaboration with Steve Grasby of the GSC. Majorowicz noted that geothermal potential should be broken down into shallow (geothermal heat), mid-depth (low-enthalpy geothermal heating systems), and deep heat for electricity (EGS). He also noted that there is potential for geothermal electricity production in the Western Canada Sedimentary Basin through the exploitation of the large assets of existing oil and gas wells. Temperatures between 50 and 100 °C are regularly encountered and could be exploited if sufficient fluid flow could be found between neighbouring wells and heat extracted from fluids co-produced with oil and gas; this could be done using binary cycle electric generation technology, which has been successfully tested in the United States (JPT website, 2008). Ormat quotes an estimate by US Senator Mike Enzi of Wyoming that in the United States alone, oil fields could provide an additional 5,000 MW of electricity through this technology. In addition to providing power to oil fields, some binary power plant companies have proposed plans to feed this generated electricity into the grid, essentially putting oil and gas companies in the geothermal business.

The break-out groups did not add more substantial elements to this outline of sedimentary basin and crystalline basement geothermal potential characteristics.

ENHANCED GEOTHERMAL SYSTEMS AND HOT DRY ROCKS

Michal Moore summarised economic models that show how EGS can be very competitive with other alternative energy resources. Dan Yang summarised EGS experiences through deep drilling projects in Europe that have demonstrated that having a temperature anomaly is not the limiting or contributing factor in the success of an EGS project. Drilling costs have escalated for several projects and led to abandonment. One ill-placed site induced limited seismicity that caused damage to property and became a political issue. As the learning curve is steep for drilling technology, it is more economical to drill many holes at once. Switzerland is working on standards in geothermal risk analysis that will be valuable to the entire industry.

QUESTION 2: WHAT IS THE GEOSCIENCE NEEDED TO SUPPORT GEOTHERMAL ENERGY DEVELOPMENT ?

The following summarises key and immediate geoscience needs identified by the participants for the various types of geothermal resources:

- Establishment of a national or western Canadian map and comprehensive assessment of geothermal potential. The recent USGS report Williams et al., 2008) focused on geothermal resources in western states was cited as a key example of what needs to be published in Canada.
- Establishment and standardization of databases with basic information from existing sources: location and geochemistry of hot and cold springs; geochemistry of rocks; drill hole locations and logs; heat flow and temperature gradients.
- Investigation, development, or compilation of new geoscience maps and knowledge bases, including:
  - Geochemical geothermometry data, including isotopic water geochemistry (^{3}He and ^{4}He isotopes)
  - Accurate digital map of hot spring locations
- Initiation of geophysics and geology studies to understand crustal dynamics and geothermal reservoirs:
  - Establishment and maintenance of a regional seismic network; regional GPS and InSAR studies; a neotectonics atlas of the Cordillera with fault ages and types; regional strain information; radiometric ages and geochemistry of young volcanics; crustal thickness; geophysical surveys; airborne electromagnetics; heat flow; temperature gradient data; alteration; structural geology; etc.

The following sections describe the geoscience needs pertaining to specific geothermal resource types.

CORDILLERAN GEOTHERMAL AND DEEP FLUIDS SYSTEMS

To support the discussion on geoscience needs, Francis Monastero offered a very inspiring and experienced view of the various geoscience tools available for geothermal exploration and development. He demonstrated how data integration can be a powerful instrument for geothermal exploration and resource discovery. Monastero's primary experience is with volcanic and deep fluid systems in the western US. He presented examples of success from Nevada, where there are many geothermal facilities online. He noted that this success was due to programs that supported the industry, including the establishment and standardization of databases with the location and geochemistry of hot and cold springs, rock geochemistry, drill hole locations and logs, atlases of temperature, heat flow, temperature gradients and bottom hole temperatures, etc. He described Nevada's program of compilation, calibration, quality control, and maintenance of relevant data sets (geological maps, geophysical surveys, hydrogeology, aerial and satellite photos). He noted the importance of crustal dynamics in geothermal exploration and the contribution of a regional seismic network and GPS and InSAR studies. This information best serves the industry if it is digitized and available on the internet. Digital mapmaking and database integration have proven to be powerful tools in Nevada.

Discussions in the break-out groups yielded geoscience needs for Cordilleran volcanic and deep fluid systems, put the proposed elements by Monastero in the Canadian geological and geothermal exploration context, and added many possible new elements.

The following elements were suggested:

- new field work in isolated and unexplored areas
- geochemical analyses of areas of high potential and He isotope studies to determine juvenile fluid content
- a neotectonic compilation of the Cordillera, with more geodynamic information (strain, faults), ages, and differentiation between ductile and brittle faults
- age and geochemical data of young volcanics and further studies of young volcanic belts
- maps of geological drillhole locations
- geological maps that include accurate hot spring locations
- crustal thickness data
- databases that compile all existing information and are available on the web
- investigations of geothermal potential on a large scale
- benchmarking of other countries with existing geothermal programs

- new exploration techniques and methodologies
- partnerships with academia, industry, and other countries

SEDIMENTARY BASINS AND CRYSTALLINE BASEMENT

The lead speaker of the session, Jacek Majorowicz, and the break-out group stressed that we need to increase our knowledge of geothermal fields in the Western Canada Sedimentary Basin, including lithology and structure, aquifers, fractures, and stress fields. Such datasets would be ideal to pinpoint target areas, draw from related databases, and produce an atlas of geothermal resources. Such geoscience datasets would support the creation of demonstration facilities. It was noted that John Cassidy of the GSC just published regional stress field information for western Canada.

Summary of key geoscience needs from the break-out group:

- Development of a database of existing data (this was identified as the most urgent and important need).
- Encouragement for oil and gas companies to collect more data that would be relevant to geothermal. This can be done through regulations or incentives. There may be resistance to regulations; incentives would be the preferred option.
- Capacity-building of highly qualified personnel for geothermal. Funding for universities and university students is needed; government labs with qualified personnel need to be redeveloped; experienced professionals are needed to maintain databases. This requires constant financial support as opposed to fluctuating support.
- Development of demonstration projects. Participants were divided about whether a demonstration project is advisable, and if so, the type of project that would be useful. People feared that failure to invest sufficiently in a demonstration project might lead to a failure that would handicap later exploration and tarnish the reputation of geothermal in Canada. Exploration risk for geothermal energy can be compared to mineral and oil and gas exploration, where drilling tens of wells is necessary before a discovery is confirmed and developed. There is no lack of successful mid- to high-temperature geothermal projects in the world. This must be balanced against the possible benefits of a demonstration project in Canada.
- Improvement of geophysical surveys. Partnerships with oil and gas companies are necessary. Vast datasets of seismic and borehole data could be mined; targeted borehole or seismic surveys could also be done.

ENHANCED GEOTHERMAL SYSTEMS

Michal Moore, one of the lead authors of a recent US Department of Energy (DOE) funded Massachusetts Institute of Technology (MIT) study, offered that the role of government could be to provide incentives to industry by supplying evidence that geothermal resources can be exploited through EGS and for identifying where EGS is most accessible and needed. A demonstration EGS project that connects geothermal power to the grid would establish costs and show that the project is feasible. Moore suggested that the geological surveys should compile a report similar to the MIT study (MIT, 2006) (with Canadian realities) and contribute to a North America geothermal potential map. Yang and several other participants countered that a cautious approach is necessary for Canada. If we undertake deep drilling projects for EGS, in complex geological terrains, we need to consider lessons learned in the EU, where many variables had to be considered when exploring. In that context, it might not be prudent for government to invest heavily in developing large geoscience databases to target deep geothermal resources in complex geological terrains. Instead, people suggested watching international development and waiting for favourable economic conditions to foster development of deep geological targets (greater than 5 km depth), where heat always exists but where permeability and porosity conditions are hard to predict. It is worth waiting until the technology has had a chance to develop and costs become lower. Some participants suggested that EGS might be used in Canada for small load centres, district heating applications, and small remote communities. Developers will not be looking at EGS as a first priority but will focus on hydrothermal. We can continue to build resources that will lend themselves to EGS development in the future. The GSC could play an educational role by developing information products and a Geoscape-style poster for EGS (and all of geothermal).

Participants felt that Canada should first be focusing EGS application on conventional hydrogeothermal systems, where there is a need to enhance flow in plays with poor permeability using technology such as hydrofracturing. There is an opportunity to apply for funding through the US Department of Energy for possible R&D or demonstration EGS projects in Canada. There are opportunities to use as EGS sites the thousands of dry oil wells in western Canada. Geoscience needs would have to be defined against these opportunities once an EGS project is undertaken, possibly by a consortium of industry, academia, and government.

DATABASE DEVELOPMENT

The participants in the database break-out group developed a list of ten priorities for database development:

- create a comprehensive online directory of existing data sets
- accurately locate hot springs and geothermal boreholes
- make available relevant data and quality control information on other drill holes
- conduct hot water geochemical analyses and make them available
- create a description of methodologies for sampling and data acquisition
- make sure all data is accompanied by metadata
- preserve legacy data
- publish existing heat generation data
- formalize multi-organizational communication and input for database
- digitize the basics

QUESTION 3: WHAT IS THE APPROPRIATE ROLE OF A GOVERNMENT GEOLOGICAL SCIENCE AGENCY IN ADDRESSING THESE GEOSCIENCE NEEDS?

Participants had difficulty separating the role of geological science agencies from those of other government agencies in supporting the development of geothermal energy in Canada. Governments are involved in resource assessment, regulations, clean energy and greenhouse gas policy, reducing economic risks, and reducing the environmental risks of resource development. Government can also support industry in creating databases and maps or atlases of geothermal potential, developing technology and methodologies, integrating and supporting university research, and by benchmarking leading countries. Many of the observations in the break-out groups and in the leading presentations touched on government roles that fall beyond the role of geological science agencies or pertain to non-geoscience needs. The participants did not distinguish the respective federal and provincial geological science agency roles and assumed that the portioning of responsibilities is well understood or would be established through discussions between these agencies[2]. These needs have been captured here nonetheless.

Break-out group participants and the lead presenters offered a generous array of proposed roles for the geological science agencies that would be valuable to the geothermal energy sector. The most important role would be to develop and lead national or provincial geothermal programs that would address the geoscience needs outlined for question 2.

These programs should include the following:

- providing centres of expertise and facilities to support industry (for example, labs)
- housing a web portal for databases and a compilation of geothermal resources
- ensuring maintenance (compilation, quality control, and update of datasets supporting exploration: geologic maps, geophysical surveys, hydrology data, aerial and satellite photos)
- learning from other countries or regions with existing geothermal programs
- developing new exploration techniques and methodologies
- partnering with academia, industry, and other levels of government
- providing public education about geothermal energy
- building capacity in geothermal exploration

Governments should be the keepers of data and be able to foresee what might be needed next and have a role in interpreting data. Governments also need to keep evolving with industry. More linkages need to be established between geoscience and policy people. There is a need to provide information in a way similar to how the government provides information to oil and gas and mining. A geothermal resource assessment should be a priority.

The presentation made by Craig Dunn of CanGEA clearly outlined key elements that should be a priority for the geological surveys. The geothermal industry needs a jumpstart, and this could come in the form of unbiased third-party estimates of MW potential, the partnering of industry, government and academia, and support in drilling, education, and information. Someone also needs to compile and house geothermal information.

BC MEMPR is beginning to develop a database for BC geothermal information. Existing geothermal data are being sought. Data that are not yet available in digital form are being digitized. Data from other industries, such as oil and gas, that can be useful for geothermal exploration are also being collected. Some of the data do not belong to MEMPR, and permission must be obtained before they are released.

[2] The respective role of geological surveys in Canada is well established through the Intergovernmental Geoscience Accord, renewed in 2007 for a third five-year term.

OTHER KEY ISSUES RAISED IN THE MEETING

Although the focus of the workshop was on geoscience needs for geothermal energy development, several related issues were raised that warrant attention if geothermal energy is to become viable for western Canada.

Many participants urged BC MEMPR and other jurisdictions to develop roadmaps for geothermal energy development. Such a roadmap has been developed by NRCan and partners to support the development of carbon capture and sequestration and has led to policy uptake and an early start for this geologically-based technology to reduced carbon emissions.

It would be valuable to learn from countries and jurisdictions that have successful government geothermal energy programs or have recently undertaken a similar process (Australia, Nevada, France, Germany, and Iceland).

There was support from some and opposition from others for the concept of a government sponsored demonstration project. Participants were divided also on the issue of partnerships and cost-sharing for drilling between industry and government. Some participants felt this would help establish the industry by reducing the financial risk to companies.

RECOMMENDATIONS

The main recommendations of the workshop are as follows:

RECOMMENDATION 1: Develop a national geothermal resource assessment.

Key geothermal resources of western Canada should be better defined and inventoried in order to encourage exploration for the resource and facilitate the raising of capital. The 2008 United States Geological Survey (USGS) report1 on US geothermal resources is an example.

RECOMMENDATION 2: Compile regional or national geothermal-related geoscience databases to support geothermal energy exploration.

This recommendation must be met through government-led compilations of geological databases. Recent efforts started by the BC MEMPR and GSC are positive steps that should be continued. Databases need to be continuously maintained and updated as new data are generated by exploration and geological surveys.

RECOMMENDATION 3: Acquire new targeted geoscience information for geothermal exploration in areas of highest potential for development.

Due to the complex technical difficulties and land-management and regulatory issues faced in assessing the areas of highest geothermal potential, focus areas should be jointly defined through technical advisory committees comprised of members from the geothermal industry, major electric utilities, and geological surveys.

RECOMMENDATION 4: Hold other forums and undertake policy analysis to advance geothermal energy in Canada.

Other topics that need to be addressed at a provincial or national level include industrial incentives (tax breaks, risk reduction for drilling, green power pricing incentives) and geoscience needs for low-temperature system (e.g., geo-exchange). Organising partners for the workshop (BC MEMPR, NRCan-GSC, and CanGEA) agreed to explore how these recommendations could be implemented.

CONCLUSIONS

All the participants at the workshop, and in particular the geothermal industry representatives, are very keen to see geothermal energy move forward in western Canada. Industry felt that geoscience may not be enough to spawn large investments in geothermal exploration and investments. The current policy review in BC is welcome by industry, because they feel that many projects are currently held back by provincial land tenure issues. Once these regulatory concerns are resolved, it is likely that there will be rapid development of this fledgling industry, and availability of pre-competitive geoscience would create a positive investment climate.

There was consensus on the urgent need for a regional (western Canadian or national) geothermal energy potential map that outlines key targets and comes from honest brokers, such as geological science agencies. This would support industry in pinpointing targets, attracting investors, and raising capital. There are geoscientific data that would aid geothermal development, and these would best serve industry if they were available in a free, standardized and centralized form on the internet. It was also recognized that in developing a geothermal program in western Canada, it would best serve the industry to look to countries and regions that have successful programs, such as the US (Western States), Germany, Iceland, and Australia. It is important to note that in these countries, the development of geothermal energy has come with government incentives and support before industry became self-sufficient. Without government support, exploration capital will continue to flow to areas where there are resources more readily available, such as the Western USA. Providing geoscientific support to geothermal energy development will not just support an industry but will contribute to meeting Canada's future energy needs and greenhouse-gas reduction targets.

Participants were pleased to have had the opportunity to participate in the workshop and encouraged the GSC, BC MEMPR, and other geological science organizations to organise a similar workshop to get further input on geoscience needs for geothermal potential, possibly focused on geo-exchange and shallow aquifer geothermal resources.

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APPENDIX 1: AGENDA

Geoscience Needs for Geothermal Energy Development
in Western Canada

October 16–17, 2008 Vancouver B.C.

Boardrooms B and C, 2nd Floor, 401 Burrard Street

Convened by the BC Ministry of Energy, Mines and Petroleum Resources, in partnership with the Canadian Geothermal Energy Association (CanGEA) and the Geological Survey of Canada

Who should attend: *Geoscience and geothermal experts from industry, government and academia that can advise on geoscience needs to support geothermal energy development*

AGENDA

DAY 1

October 16th AM Overview talks

8:00–8:30 Registration/coffee

Setting the stage

8:30–8:45	Introductions
8:45–9:00	Key questions for participants and workshop expectations
9:00–9:15	Garth Thoroughgood, A/Director, Geothermal Resources (BC MEMPR): "Geoscience Needs for Geothermal Exploration and Development in British Columbia—Why this Workshop?"
9:15–9:45	Stephen Grasby (NRCan-GSC): "National Geothermal Energy Program, Past and Present"
9:45–10:00	Health break

High temperature volcanic belts and sedimentary basins

10:00–10:30	Tim Sadlier-Brown (Sadlier-Brown Consulting Ltd.): "Geothermal Potential of the Cordillera"
10:30–11:00	Jacek Majorowicz (Northern Geothermal Consult): "Geothermal Potential of Sedimentary Basins"

Geothermal prospecting tools

11:00–11:30	Francis Monastero (Magma Energy Corp,US):
	"Needs for Geoscience Tool Development and Data Integration for Geothermal Exploration"
11:30–12:00	Break-out group process description
12:00–1:00	Lunch

October 16th PM

Break-out groups on geoscience needs

1:00–3:00	
	Group 1 High temperature volcanic belts and hydrothermal systems
	Group 2 Sedimentary basins
3:00–3:15	Coffee
3:15–4:30	Report from breakout groups
6:30	Dinner event organised by CANGEA
	Industry Guest Speaker: Gary Thompson (CEO of Sierra Geothermal Power Corp.)
	Tickets available in advance from CANGEA

APPENDIX 2: LIST OF WORKSHOP PARTICIPANTS

Name	Affiliation
Allen, Diana	Simon Fraser University
Aspinall, Craig	Western GeoPower Corp.
Baumann, Frank	Magma Energy Corp.
Chisholm, Doug	Danforth Oil & Gas Ltd.
Deibert, Lee	Meridian Environmental Inc.
Ghomshei, Mory	University of British Columbia
Grobe, Matthias	Energy Resources Conservation Board, Alberta Geological Survey
Hanova, Jana	BC Hydro
Hartling, Alf	BC MEMPR
Hill, Rod	Yukon Geological Survey
Holowaty, Nadja	BC Hydro
Ince, Martin	M.K. Ince and Associates Ltd.
Jessop, Alan	NRCan-GSC (retired)
Johnson, Elizabeth	BC MEMPR
Kantrowitz,Ted	Canadian GeoExchange Coalition
Lewis, Trevor	Sidney Geophysical Consultants Ltd.
Lowe, Carmel	NRCan-GSC
MacLeod, Kenneth	Western GeoPower Corp.
MacRaild, Fiona	BC MEMPR
Majorowicz, Jacek	Northern Geothermal Consult
Monastero, Francis	Magma Energy (US) Corp.
Moore, Michal	University of Calgary, Institute for Sustainable Energy, Environment and Economy (ISEEE)
Moormann, Denis	Trans Pacific EnviroEnergy Inc.
Parks, Kevin	Director, Alberta Geological survey
Robertson, Paul	Christopher James Gold Corp.
Sadlier-Brown, Tim	Sadlier-Brown Consulting Ltd.
Semaine, Zak	Alberta Environment
Thompson, Alison	Canadian Geothermal Energy Association
Thompson, Gary	CEO, Sierra Geothermal Power Corp.
Thoroughgood, Garth	BC MEMPR
Witter, Jeff	Sierra Geothermal Power Corp.
Woodbury, Al	University of Manitoba
Woodsworth, Glenn	Tricouni Geological
Yang, Daniel	Shell Canada
Yehia, Ron	Ormat Technologies, Inc.

APPENDIX 2 CONTINUED

Workshop Organising Committee (also workshop attendees)

Dunn, Craig	Canadian Geothermal Energy Association
Ellerbeck, Mike	NRCan-GSC
Grasby, Steven	Research scientist, NRCan-GSC
Lebel, Daniel	Director, Northern Canada Division, NRCan-GSC; Organising committee co-chair
Lee, Cassandra	BC MEMPR
Levson, Vic	Director, BC MEMPR; Organising committee co-chair
Reynen, Bill	Director, Calgary Division, NRCan-GSC
Riddell, Janet	BC MEMPR
Smyth, Ron	BC MEMPR (retired)
Ulmi, Malika	NRCan-GSC
Walsh, Warren	BC MEMPR (could not attend)
Arvind Anand	NRCan-GSC (could not attend)

APPENDIX 3: WORKSHOP PRESENTATIONS

Presentations by Lebel, Thoroughgood, Grasby, Majorowicz Monastero, Dunn, Moore, Yang, and Lee are available in PDF format on the included disk.

Daniel Lebel (NRCan-GSC): Organising Committee: Introduction and Context for the Workshop

Garth Thoroughgood (BC MEMPR): “Geothermal Review in British Columbia Government”

Stephen Grasby (NRCan-GSC): “National Geothermal Energy Program; Past, Current and Future Geothermal Research at the Geological Survey of Canada”

Tim Sadlier-Brown (Sadlier-Brown Consulting Ltd.): “Geothermal Potential of the [Canadian] Cordillera”

Jacek Majorowicz: “Geothermal Potential of Sedimentary Basins in Western Canada”

Francis Monastero (Magma Energy (US) Corp.): “Products, Geoscience Tools, and Data Integration Necessary for Successful Geothermal Development”

Craig Dunn (Canadian Geothermal Energy Association): “CanGEA views on key questions for the workshop”

Michal Moore, University of Calgary: “Enhanced Geothermal Systems” [An overview of potential for electricity generation in Canada and the US]

Dan Yang, Shell Canada: “Mining Deep Heat: Geoscience Needs”

Cassandra Lee, BC MEMPR: “A Geothermal Geoscience Database for British Columbia”

APPENDIX 4: TEXT OF PRESENTATION "GEOTHERMAL POTENTIAL OF THE CORDILLERA"

By Tim Sadlier-Brown, Sadlier-Brown Consulting Ltd.

The obvious manifestations of geothermal resources include hot and warm springs, sinter or tufa deposits, and volcanoes or volcanic terrains. In the western Canadian cordillera, well over 100 thermal springs have been reliably reported to occur, and at least 6 Holocene, very young, volcanic terrains are known. Within these terrains are many discrete volcanic centres characterized by large volcanoes, cinder cones, lava flows, and hot springs.

Most hot spring or hydrothermal waters are of meteoric origin—rain or snow that has percolated into the subsurface and been heated by one or more of several natural processes:

1) near-surface volcanic activity;
2) deep circulation through fault and fracture systems or other permeable structures in regions of normal or slightly elevated geothermal gradient;
3) circulation through rocks heated by decay of radioactive elements (U, Th, K).

Worldwide currently exploited geothermal resources are mainly hydrothermal fluids, including

1) steam and high temperature hot water (over 150 °C), which are commonly used to generate electricity;
2) moderate temperature water (90 to 150 °C), which can be used for space heating, other industrial and recreational purposes and, increasingly, for electrical generation through the use of advanced binary turbines, such as those produced by UTC and Ormat.
3) low temperature waters (less than 90°C), which can have applications in space heating (such as greenhouses) or other direct uses, such as commodity drying, recreation and, in some settings in cold climates, electrical generation.

Advances in drilling and drill-related technologies have also made it possible to exploit heat in hot dry rocks using engineered or enhanced geothermal systems (EGS), where water is pumped into wells drilled in hot rock, circulated through induced fractures in the rock where it is heated, then returned to the surface for industrial use.

Potential for high- and low-temperature hydrothermal and EGS resources related to volcanic activity, deep circulation, and natural radioactivity exists in many parts of the western Canadian Cordillera.

The Cordillera has been divided into five elongate northwest-trending, geologically discrete "belts", often referred to as accreted terrains:

1) the Insular Belt along the west coast;
2) the Coast Range/Cascade Belt adjoining it to the east;
3) the Intermontane Belt traversing the central part of BC;
4) the Omineca Belt to its east; and
5) the Rocky Mountain Belt in the BC–Alberta border area.

Distinct manifestations of geothermal resources occur in each of these terrains.

Insular Belt:

Hot springs such as Maquinna Point and Ahousat on Vancouver Island and Hotspring Island in the Queen Charlottes. These are probably attributable to deep circulation, but radioactive decay may play a part. Their development potential is compromised by their remoteness from electrical or industrial load centres.

Coast Range/Cascades:

Numerous hot springs extending northwest from Harrison Lake in the south and possibly into the southern Yukon. The hydrothermal systems producing these springs are, in some instances, readily attributable to volcanic activity associated with the Cascade Volcanic Belt. This includes the Garibaldi terrain in southwest BC, the most actively explored geothermal area in the province and probably the most economically attractive one as well owing to its proximity to the lower mainland power market.

Other hydrothermal systems in the Cascade/Coast Range region are remote from the Recent and Holocene volcanoes and appear to be related to a sub-parallel belt of older eroded volcanic centres known as the Pemberton Volcanic Belt. These waters are probably heated by deep circulation in fault systems in a geological terrain characterized by elevated terrestrial heat flows. In southeast BC there is an apparent relationship between many of the springs and 1) northeast-trending fault or fracture systems and 2) alkaline plutons.

Intermontane Belt:

This belt is host to several large volcanic complexes, such as the Anahim/Ilgachuz Belt west of Quesnel and Mount Edziza, Level Mountain and Heart Peaks volcanic complexes in the Telegraph Creek–Stikine River area of northern BC, and also possibly the Wells Gray–Clearwater volcanic area. Geothermal development in these areas may be compromised by remoteness and the fact that at least two of them are within parks.

Omineca Belt:

A cluster of hot springs in southeastern BC, including those near Nakusp and Ainsworth/Kootenay Lake. Many of these springs appear to be associated with Mesozoic granitic intrusive terrains and may owe their elevated temperatures to radioactivity occurring within the host rocks. Some of these springs are in areas that could be (or have been) commercially developed and may be appropriate for EGS assessments.

Rocky Mountain Belt:

The most celebrated hot springs in Canada occur in the Rocky Mountain Belt. These include those developed as resorts at Banff, Jasper (Miette), Radium, and Fairmont as well as a number of lesser known sites, such as Lussier, near Fairmont, those in the Liard River area and the Rocky Mountain Foothills of northern BC and the Nahanni River area of the NWT.

For the most part these springs appear to be heated by deep-seated fault systems in the rocks of the Rocky Mountain fold belt, and preliminary tests suggest that their source reservoirs may not achieve the temperatures required for uses other than recreation.

From a geological standpoint the most attractive geothermal resource areas in the Cordillera are:

1) hydrothermal systems associated with the major volcanic centres and
2) inferred high-temperature hydrothermal or EGS systems associated with major faults and fractured alkaline intrusive terrains.

By the standards of BC Hydro's power plants (commonly several hundred and up to two thousand MW capacity) most geothermal plants are small—normally from 10 to 150 MW. This means that construction of hundreds of kilometres of transmission line to get the energy to market is not practical. The plant must therefore either be near the market or near an existing transmission line. It may not need to be in the lower mainland, of course, as smaller communities and isolated industrial users such as mines may be attractive energy markets.

Examples of areas that would appear to be attractive geothermal development sites are

1) the Garibaldi volcanic terrain;
2) the Pemberton volcanic terrain;
3) the West Kootenay area.

The magnitude of the geothermal resource potential of BC is currently unknown, but as I have been asked to come up with an estimate I propose a "comparable" approach. Other jurisdictions that share at least some geological characteristics with BC but that have been more intensely explored and developed include California, Nevada, Oregon, Idaho, and Washington.

California's installed geothermal capacity is currently 2,555 MW, but a substantial component of this is derived from the Geysers Field, which is arguably unique.

Nevada's current capacity is 318 MW, and additional near-term potential has been estimated at 1730 to 2170 MW (average, say 1100 MW near-term) but, like California, it is probably unique because of its high basin and range heat flow regime.

Oregon is reported to have between 297 and 322 MW (average 310 MW) in development, and Idaho from 251 to 326 MW (average 289 MW) also under development. Washington's potential has been estimated at up to 600 MW, although on the basis of limited data.

Past estimates of the BC potential vary from a few hundred to several thousand MW but, as BC is about the same size as Nevada, Oregon, Idaho, and Washington put together, all other things being equal and with equivalent effort, we could have 2299 MW on line and in development! If, however, because of Nevada's distinctive geology, its potential is arbitrarily discounted by 50%, the number becomes ± 1750 MW, on line and in development! This is clearly not a rigorously derived figure—it completely ignores a lot of fundamental geological differences and market considerations—but it's a start.

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