Geothermal Energy

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COORDINATION OF GEOTHERMAL RESEARCH

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Crustal Studies
Division of Gravity, Geothermics & Geodynamics
Earth Physics Branch
Department of Energy, Mines and Resources
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This report covers meetings with B.C. Hydro and Power Authority (BCH) in late 1982, at which federal funds for continued work at Mt. Meager were requested by BCH, the meeting of the Sedimentary Panel on Geothermal Energy in January 1983, and the annual planning meeting of the project leaders of the Geothermal Programme, also in January 1983.

Request by B.C. Hydro and Power Authority

Early in October 1982 representatives of B.C. Hydro and Power Authority indicated their intention of seeking funds from Energy, Mines and Resources (EMR) in order to continue their drilling and testing programme at Mt. Meager. In order to obtain the information necessary to develop an EMR response, a fact-finding team consisting of the Renewables Task Coordinator R.P. Overend, J. Legg of Office of Energy Research and Development (OERD), J. G. Souther of Geological Survey of Canada (GSC), and the Geothermal Programme Coordinator A.M. Jessop assembled in Vancouver. This team attended a meeting at the offices of BCH on Friday 15 October and visited the drill site on Saturday 16 October.

The status of the work at Mt. Meager and the economic difficulties facing the geothermal team of BCH are summarised in a statement prepared at the time. This is attached as Appendix 1. The fact-finding team reported to a group of EMR management personnel on 26 October.

The changed attitude of BCH towards the funding of the geothermal programme at Mt. Meager results from fall in power demand and revenues rather than in any changed perception of the potential of the programme. BCH are finding that the environmental acceptability of geothermal development is much better than that of major dams and consequent flooding, and so their hydroelectric developments have also been drastically curtailed. The cut-back at Mt. Meager is thus prompted by general economic decline rather than any technical difficulty or change of policy.

The contention of J. Stauder, the leader of the BCH geothermal team is that the deep drilling at Mt. Meager needs one more year to give a definite answer about the potential at that site. Without this, the expenditure of M$26 to reach the present stage is partially wasted. After one more year the project could be shelved for a time, since the deep holes now in place would have yielded as much information as possible.

From the viewpoint of the Geothermal Programme it would also be most unfortunate if current momentum was lost before the proof of concept work was completed. It would be quite damaging to the research programme to have to wait 4 or 5 years before we decide one way or another on the Mt. Meager site. In fact, if the experiments are not brought quickly either to the point of declaring the geothermal promise to be adequate for B.C. Hydro to continue, or, to the point of declaring that that particular well site is dry, then the future B.C. Hydro research programme may be of reduced value. If this site is dry, then the future budgets would be better spent on another site altogether, for example the north side of Mt. Meager.

The BCH representatives were unable to be specific on the amount of financial support needed, but they were thinking in terms of a few million dollars. Typical expenses are:

(1) mobilisation of drilling if the present rig is removed by the contractor
    - $300,000

(2) drilling of offset holes from existing holes to intersect the permeable zones in more places
    - each $900,000.

A BCH team of J. Stauder and J. Milligan visited EMR in Ottawa on 27 October, 1982, and were met by K. Whitham, ADM responsible for OERD and R. Hollbach, ADM Conservation and Non-Petroleum Sector. The main points expressed by EMR were:

(1) EMR appreciates the work done by BCH of Meager Creek and agrees with the expressed need to complete the present phase of the work on technical grounds.

(2) Funds under the Federal-Provincial agreement on Conservation and Renewable Energy (CREDA) are effectively blocked by the Provincial Government, which is unwilling to make any further contribution to the development of geothermal resources of Mt. Meager.

(3) EMR has no source other than CREDA for direct funding of BCH at Mt. Meager. However, it is possible for a part of the OERD funds directed to the Geothermal Programme to be used for EMR studies that are integrated into the BCH programme. It was realised that this can be only a small contribution to the BCH programme, since the total EMR geothermal budget is at least an order of magnitude smaller than recent annual expenditures by BCH at Mt. Meager.

Following this decision by EMR, J. Souther (GSC, Vancouver) and A. Jessop (EPB, Ottawa) met with J. Stauder (BCH) in Calgary on the evening of 7 December. Mr. Stauder was asked to specify the work items that EMR could undertake by letting contracts, on the understanding that all work must be integrated with the BCH programme and be fully agreeable to BCH. As a result of this meeting a letter was addressed to Mr. Stauder, and this is attached as Appendix 2.

At a further meeting in Vancouver on 24 January, 1983 this request was repeated. However, Mr. Stauder remained vague about his wishes and seemed to be thinking in terms of a lump-sum transfer from EMR to BCH. As well as being impossible without Treasury Board approval, the EMR scientists involved are of the opinion that this style of support would not be in the best interests of EMR or of the Mt. Meager programme.

Calgary, January 1983

On 20 January 1983 the third meeting of the Sedimentary Panel on Geothermal Energy (SPONGE) was held at the Institute of Sedimentary and Petroleum Geology, by kind permission of Dr. W. W. Nassichuk. A preliminary record of this meeting is attached as Appendix 3.

It was unfortunate that, owing to budgetary restrictions, no representatives from British Columbia or New Brunswick could attend.

On 21 January the authors visited the offices of Petrocanada and met Mr. I.G. Bryden. Petrocanada is considering the merits of entering the geothermal scene, and may hire a person to work on the subject. Mr. Bryden has spoken with BCH representatives, and has been gathering information on the situation in Canada, both in the western mountains and in the sedimentary basins. The authors were able to provide him with a background history of geothermal research in Canada, complete with names of the chief participants.

Vancouver and Victoria

On 21 January the authors visited the offices of the GSC in Vancouver, and copied temperature data from the files of J.G. Souther for inclusion in the borehole data file in Ottawa.

On 25 January the annual planning meeting of the Programme Coordinator and Project Leaders was held at the Pacific Geoscience Centre (PGC) near Victoria. Present were M.J. Drury, L.K. Law, T.J. Lewis, J.G. Souther and A.M. Jessop.

A review of the work done in 1982-83 is included as Appendix 4. All work is completed or close to completion, except item 3.2 - Aquifer mapping, which has suffered a series of delays. It is now anticipated that a contract will be let in early March, to extend into the new financial year. It is unlikely that the funds reserved for this item will be fully spent, but, owing to a misunderstanding on the part of the Coordinator concerning the total funds available, the total expenditure will be very close to the allotment.

In planning the contracts and projects to be undertaken in 1983-84 the following points emerged:

(1) Provision had to be made for work at Mt. Meager, but in the absence of any response by BCH to our request for their priorities for EMR work, we could only use our own judgement and leave some flexibility to add further items later.

(2) Although this meeting was concerned with the earth science aspects of the programme, it was agreed that there is a need for the engineering studies to move from the general survey of possible applications towards addressing the geothermal potential of, for example, some of the mining properties in northern regions, in close cooperation with earth scientists, who must supply the resource data.

(3) Plans were put in place for the entire budget, although it was believed at the time that part of it would not receive approval until later in the year. It is now known that the entire operating budget will be available in April, the only part being deferred until later being the requested person-years.

On return to Ottawa it was found that the funds allotted to salaries had been slightly reduced from the previous year, so that the total amount of operating resources is slightly greater than was known at the meeting. Other small changes have been introduced owing to our ability to perform some operations in 1982-83 instead of in 1983-84. These changes have been incorporated into the plan for 1983-84, which is attached as Appendix 5.

Appendix 1

The Mt. Meager Geothermal Project

Technical Status of October 1982

A. M. Jessop 21 October, 1982

B.C. Hydro have now drilled three exploratory deep wells on the south side of Mt. Meager, each to depths of at least 3000 m. Testing and completion of the wells is still in progress, but preliminary results show that, although fracture permeability is less than ideal, two of the wells could probably be developed to a production capability by the additional drilling of offset legs to penetrate fault zones already encountered by the main wells.

Work at Mt. Meager began with the compilation of hot-spring geochemical data in 1972-73. The springs at Meager Creek showed evidence of flowing from a hot source reservoir associated with the Mt. Meager volcanic complex, which has a four million year history of violent Cascade type eruption. The last major explosive eruption took place about 2400 years ago. This site was selected by both EMR and B.C. Hydro as being worthy of detailed examination for geothermal potential because of its favourable geological character and its proximity to the energy markets of the lower Fraser Valley.

EMR carried out a small drilling experiment near the hot springs in the winter of 1974, and in the fiscal years of 1974-75 to 1977-78 research was pursued by both B.C. Hydro through their contractor Nevin, Sadlier-Brown, Goodbrand Ltd. (NSBG), and EMR. During this time electrical resistivity, magnetotelluric, geological mapping and other surveys were performed, the two agencies working independently but in close informal cooperation. In 1978-79

both agencies let interlocking contracts to NSBG for a coordinated programme of studies, as an embryo Federal-Provincial programme. In 1979-80 and 1980-81 the continuing research was financed under CREDA and was managed by B.C. Hydro with EMR scientists being involved in an advisory committee structure. During this time a temperature of 200°C was encountered at a depth of only 365 m, showing that strong localised hydrothermal circulation was taking place.

At the close of this phase it was considered that the time had come for the drilling of the deep proving well on the south side of Mt. Meager. Sufficient surface surveys and shallow drilling had been done, and the existence of a viable resource needed to be demonstrated by deep wells. The CREDA input having come to an end, B.C. Hydro decided to continue alone. They brought in KRTA Ltd., an experienced New Zealand company, to consult on the project, and a Westburne drill rig from Alberta, beginning in the spring of 1981.

Work on the north side of the Mt. Meager complex continued at a modest level of surface surveys and shallow drilling. EMR attention was shifted to Mt. Cayley, a similar volcanic complex to the south of Mt. Meager and to the eastern end of the Anahim volcanic belt in the Thompson River area.

From July 1981 to July 1982 three deep wells were drilled from a site on the south side of Mt. Meager, in the Meager Creek valley a few kilometres above the hot springs. The well-heads are within about 30 m of each other, but each well is turned to its own direction, in order to examine its own source zone. Directional drilling was necessary to penetrate zones beneath the rugged flanks of the mountain, and it was considered to be preferable to rely entirely on directional drilling rather than to face the costs and difficulties of preparing level sites and moving the rig in difficult terrain.

Well MC1 was directed to the northwest and was drilled to a total length of 3000 m. Five hundred metres of drill pipe were lost in the bottom, and the well was completed with slotted casing to 2500 m, where the temperature was 217°C. On testing the well heated up quickly and became artesian after a few weeks. It initially produced about 20 tonnes/hr of water and steam with an intermittent geyser-like action. Production is believed to come mainly from the Meager Fault where it is crossed at the 1300 m point in the well, at a temperature of about 190°C. This well has returned drill cuttings and other solid material in the flow, showing that some plugging occurred during drilling and that flow channels were being cleaned out. A flow rate of 39 tonnes/hr has now been obtained from this well, after a 24-hour airlift operation, having an electrical potential of approximately 1/3 MW. Bottom-hole temperature has increased to 227°C.

Well MC2 was directed to the northeast and was drilled to a total length of 3500 m, with a bottom-hole temperature of 260°C. Due to the damage of the casing at 190 m depth, which was producing substantial cold fresh water inflow, production was not possible. Since then the casing has been repaired and the well is now under testing.

Well MC3 was directed to the west-northwest and was completed to a total length of 3500 m in July 1982. Substantial circulation-loss problems were encountered in the drilling of this well, indicating significant permeability. Testing showed considerable formation damage by circulation-correction material and drill cuttings, and much of this material has returned to the well. The lower part of the hole was at one time filled by this material reinforced by precipitated silica. At the time of the EMR visit on 16 Oct. 1982 testing was continuing. Air-lifting was in progress at about 1000 to 1200 m, and the flow showed intermittent bursts of

discolouration, showing that solid material was still being cleared out from the permeable flow channels. Periods of good flashing have been obtained from this well, and a steady production capability is anticipated as the condition of the permeability is improved. Although two wells were flowing to the atmosphere at the time of the EMR visit, there was no perceptible smell of gas impurities. In particular, hydrogen sulphide was not noticed at any time while walking round the site or standing within a few metres of the wells.

The main conclusions to be drawn from the work so far are as follows:

1. A zone of elevated temperature exists at an easily accessible depth below the southern flank of Mt. Meager. Without natural permeability this would be a hot dry rock resource of temperature over 260°C.
2. Significant permeability exists in the hot zone in major fault and shear zones, but permeability in fractures and in brecciated zones has been sealed by mineral deposition by hydrothermal action.
3. Wells MC1 and MC3 penetrate zones of potential production of flashed steam, but each well needs offset legs to increase the volume of source rock penetrated, and in particular to penetrate the known fault zones at more places. Offsets are commonly added to geothermal production wells at many sites.
4. The Mt. Meager project is close to demonstrating a viable geothermal resource on the south side of Mt. Meager. The drilling of offset legs to existing wells will either confirm the flashing hot water resource or show the area to be of hot dry rock potential only owing to limited permeability in the zones tested.
5. Environmental problems related to dissolved solids and escape of gas should be small.
6. Continuing work on the north side of Mt. Meager shows further targets that will probably merit the sinking of large exploratory wells.

7. EMR work at Mt. Cayley indicates that further surface and shallow drilling surveys are merited, and that Mt. Cayley shows potential at least as good as Mt. Meager did at a similar stage of research.

Appendix 2

December 8, 1982

Mr. J. Stauder
British Columbia Hydro and Power Authority
Vancouver, British Columbia
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Dear Joe:

As a result of your meeting with senior levels of Energy, Mines and Resources and myself in Ottawa on 27 October, it was established that EMR has no objection in principle to Geothermal Energy R&D funds being once more applied to the demonstration project on the south side of Mt. Meager after a break of four years. This is at present the only step that EMR can take to further the project, since Federal CREDA funds are effectively blocked by the Provincial Government and EMR has no other source that might be tapped for this purpose.

At the same meeting, and during our visit immediately preceding, it was agreed that the project has so far been generally successful in achieving its aims, and that it has been shown that geothermal energy, has definite potential in British Columbia, at a price that is economically reasonable, and at a high level of public acceptance. EMR would thus like to see the Mt. Meager project continue, and is prepared to make what small effort it can to support this.

As you know, the Geothermal Energy R&D budget is at least an order of magnitude smaller than the annual expenditures that you have been making at Mt. Meager, and in addition to anything that we do at Mt. Meager we must also continue our R&D programme in other geological settings and other parts of Canada. Our financial effort will thus be relatively minor, but we hope that our willingness to suspend or delay other parts of our R&D programme for this purpose will demonstrate our wish to see the Mt. Meager project continue and our faith in the potential of the area and the work done so far.

In order to make the most of our limited resources we should, over the next two months, agree on one or more specific tasks that can be undertaken by consultants or others under contract to EMR within the general project management of British Columbia Hydro. These tasks must be designed to form a component of British Columbia Hydro's reduced work plan but be within the capabilities and interests of EMR and its contract managers. Contractors must also be chosen to achieve the maximum continuity and coordination with British Columbia Hydro plans and previous work. Federal policy is to use Canadian contractors in order to establish a Canadian expertise in geothermal exploration and technology.

I believe that we should take the following specific steps:

1. British Columbia Hydro should establish a small technical coordinating group to include at least Jack Souther and myself from EMR.

2. British Columbia Hydo should provide us both with copies of all reports pertaining to the Mt. Meager project that we do not already have.

3. The coordinating group should meet to define EMR activities and to establish our role within the Mt. Meager project. The final decisions probably cannot be made until mid-January, since our 1983-84 budget is not yet approved by Cabinet or Treasury Board, and it could still be cut substantially.

4. In continued close contact our two agencies will negotiate and let our contracts for the work of the 1983 season.

We hope that our limited financial support to this project, our continued R&D programme in all aspects of geothermal energy in Canada and our continued scientific interest and support of the Mt. Meager project will demonstrate our strong wish to see the Mt. Meager project continued to a logical and successful conclusion.

Yours sincerely,

Alan M. Jessop
Geothermal Programme Coordinator
Earth Physics Branch

AMJ:ja

Appendix 3

Sedimentary Panel on Geothermal Energy

SPONGE

Record of meeting of 20 January, 1983

Institute of Sedimentary and Petroleum Geology

Calgary

A meeting was held at the Institute of Sedimentary and Petroleum Geology on Thursday 20 January 1983 to review activities during 1982 and to discuss the future of geothermal energy research in sedimentary basins.

The conference room was made available by kind permission of Dr. W.W. Nassichuk, Director of the Institute.

A.M. Jessop acted as chairman. A list of participants, with addresses is appended to this record.

1. Record of the last meeting

The record of the last meeting had been circulated to all who had attended. The error in the address of Mr. Young was noted, and the corrected address is added to the list below. No further points were raised by those present.

2. Review of existing projects

The chairman asked those present to describe current projects relevant to geothermal energy research.

Walter Jones of the University of Alberta is continuing the compilation and analysis of temperature data from industrial sources. A total of 55,000 temperature data from 28,000 wells have been compiled in Alberta, and a temperature gradient map based on averages on a grid of 3 x 3 townships and ranges was shown. Various ways of averaging, smoothing and mapping the data are being examined. A similar data compilation for the provinces of Saskatchewan and Manitoba has been completed, but analysis work has concentrated on Alberta. The Hinton and Edmonton areas had been chosen for detailed study because of the coincidence of good temperature gradients and potential markets for heat energy. A four-unit divided bar system was being set up in order to be able to determine thermal conductivity of rock cores, and thus to differentiate between conducted and water-borne heat and to understand the thermal regime of the areas under examination.

Funding for this work has come from the Alberta Energy Research Fund (ERF), Earth Physics Branch contracts, and an NSERC operating grant. An NSERC strategic grant has been obtained for the coming year, but the ERF grant is coming to an end.

H. L. Lam showed how the temperature gradient map may be correlated with the topographic relief map, the high gradient areas corresponding to relatively low elevation, as a result of ground-water recharge and discharge. Some exceptions to this general rule are apparent, for example the Hinton anomaly and areas near the B.C. border in N.E. Alberta. In response to a question concerning the Fort McMurray area, the gradient is high at about 36 mK/m, but since the depth of sediments is only of the order of 500 m, the highest possible aquifer temperature is only about 25°C.

Jacek Majorowicz showed how he has calculated gradients, again by the square window method, but using two depth intervals to allow for constants in thermal conductivity. The separating boundary chosen was the contact between the Palaeozoic and Mesozoic strata. Owing to poor distribution of data with depth, some surface intercepts are too high or too low, but reasonable values of surface temperature may be used to constrain the calculated gradients. Temperature continuity on the contact surface may also be used to prevent gross errors. Net rock data, previously collected by Sproule Associates Ltd., under contract to EPB, has been used to derive estimated conductivities. It is found that the total integrated heat flow over the study area, which is Alberta townships 1 to 60, is different above and below the boundary by a factor of 1.8, the higher value being below the boundary.

Walter Jones presented some data on hot water production potential from several wells in the Hinton and Calgary areas. Potential water flow ranged from 4 to 5000 m^3/hr at temperatures of about 113°C at 300 m in the Hinton area. It was pointed out that the flow data refer only to the short section tested, and that they illustrate the difficulty of estimating flow water from available data. This is the most difficult of the essential geothermal factors for which to find good data. A report of this work has been submitted to the Alberta Government ERF office.

Lawrence Vigrass reviewed the progress of the Regina demonstration project. The first well was drilled in 1979 to a depth of 2215 m, with the intention of using the heat in a large sports building. The well encountered 110 m of reservoir rock of good permeability, but temperature was not as high as expected. The well seems to be the coolest in the area, and this is not fully understood. The content of dissolved solids was 110,000 ppm, rather less than expected, and the water yielded 1.6 m of gas at atmospheric pressure

per 100 m of water. This gas was mainly nitrogen, with about 5% helium and minor amounts of methane and carbon dioxide. The presence of 20 ppm hydrogen sulphide and 1 ppm oxygen was a surprise. The well is designed to supply water at 100 m^3/hr.

Approval in principle for the second well was received well over a year ago from the Provincial Government, which will be using CREDA funds, of which 50% is supplied by the Federal Government. During this time the University has completed a usage study, and has performed work on corrosion, maintenance of the well and theoretical studies on reservoir behaviour and well spacing. It has been concluded that well separation can be reduced to 1000 m, thus avoiding the expense of crossing the Trans-Canada Highway with the pipe. The usage study has showed that four buildings could use the heat, with a return temperature of 20°C. The use of this energy is economically attractive to the University, but would not be if they had had to pay for the drilling of the wells. Economics in regions of higher aquifer temperature will be more reasonable.

Keith Hutchence described his calculations of water flow patterns in a uniform formation having a geothermal well doublet, and showed examples of calculation of water temperature at various times, including the time of onset of declining temperature at the producing well. Calculations are done by finite-difference numerical technique, and include the heat contribution from the solid rock, but do not include any vertical transfer from neighbouring impervious strata. Some diagrams showed evidence of model instability around nodal points, but serious errors were not anticipated. Regional water migration is slow compared with induced flow. A report on part of this work is in preparation.

Brian Hitchon described a recent major paper on thermal effects of ground-water dynamics. He showed the diagrams of the paper and described how low gradient areas could be related to topographic highs, and vice versa, on a range of scales. The strength of such anomalies depends on the depth to which water can penetrate through formations. This paper has been submitted to the Bulletin of the American Association of Petroleum Geologists.

Garth van der Kamp reviewed a report that he prepared under contract to EPB concerning the thermal effects of water on rocks of all kinds. He showed how dispersion can given an apparent enhanced vertical conductivity, even when flow is horizontal. He found it possible to explain observed anomalies beneath the prairies on a scale up to a few hundred kilometres, but not over thousands of kilometres, since the needed flow rates would be too high.

Michael Price described sedimentary geothermal research in the United Kingdom. Shallow heat flow holes to a few hundred meters have been drilled in the Wessex, Lincoln, Carlisle and Cheshire Basins, in the Midland Valley of Scotland, and in Northern Ireland. A deep well was drilled at Marchwood, just outside Southampton to 2400 m. Temperature was found to be 73°C, but transmissivity was limited to 5 to 7 Dm, giving a potential drawdown of 350 m at a production rate of 100 m^3/hr. An energy output of 4 to 5 MW would need 250 kW of electrical pumping power.

A well at Larne, Northern Ireland, has been drilled to 2700 m, but has encountered little permeable aquifer potential.

A well has been drilled in Southampton, 1.9 km from Marchwood, to supply heat to a new building complex. The target formation was the Trias, which will supply 100 m^3/hr of water at 76°C with a drawdown of 400-500 m after 20 years. The chemical nature of the water is very similar to that found at Regina.

Malcolm Drury briefly reviewed the status of work in the Atlantic region. It has been possible to collect data from 52 wells onshore, compared with 28,000 in Alberta. However there are a few places where further work may be justified.

3. Future directions

The chairman raised the question of mapping of potential geothermal aquifers, so that a potential user could refer to some map that would show him in a general sense whether there was any point in performing detailed studies of his area. Mr. Gorell pointed out that it would be very expensive to do this for the whole of the inhabited Prairies, because of the large number of wells that would have to be examined and the difficulty of obtaining good data on permeability and pay-zone thickness. Temperature data is filed at the University of Alberta, but permeability data is not collected, it has to be interpreted from drill-stem tests, and it usually represents only a small part of any aquifer zone.

Mr. Gorell suggested that the 224 wells of the net-rock compilation could be used as a starting point, to identify the probably aquifers on a regional basis and to produce a small-scale general map. Jacek Majorowicz said that maps of isotherms of temperature maps at specific depths or elevations could be produced. Brian Hitchon pointed out that some minimum criteria were needed, for example 50°C for temperature. Malcolm Drury suggested that the first map needs to be based on geological data rather than on potential markets, but markets will dictate the areas to be studied in detail.

Brian Hitchon suggested that known aquifers such as the Viking could have temperature data plotted fairly easily, and Lawrence Vigras said that he would like to extend his original work on the Winnipeg formation.

It was generally agreed that the order of steps should be:

1. use 224 wells to define units to be examined;

2. examine formation units one by one;

3. potential users do site-specific studies.

The meeting closed at about 3:00 p.m., with agreement to hold a further meeting in about one year.

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Appendix 4

Status of Projects in 1982-83

Project 1.	Identification and assessment of geothermal resources in non-volcanic terrain.		
1.1	Geological and radiometric mapping of Coryell syenite, contracted as a graduate student project - project postponed for lack of suitable student		
1.2	Gravity survey of the White Lake Basin - preliminary in-house survey showed that full survey was unlikely to yield adequate results		$ 2,000
1.3	Shallow drilling; a continuation of the shallow-hole programme of 1981-82 - 15 holes completed, extending the previous line across the Garibaldi Volcanic Zone		70,000
1.4	Multi-frequency magneto-telluric survey at Mt. Meager - field work completed and awaiting report		16,000
1.5	Shallow drilling in the Alert Bay volcanics of northern Vancouver Island - 8 holes completed		36,000
	Operational support and related expenses		26,000
		TOTAL	$150,000
Project 2.	Identification and assessment of geothermal systems associated with recent volcanic activity.		
2.1	Drilling for temperature gradient at Mt. Cayley - one hole completed at site accessible only by helicopter		100,000
2.2	Mercury and Arsenic trace-element survey around Mt. Cayley - work postponed		
2.3	E-Scan survey at Mt. Cayley - field work completed and awaiting report		60,000
2.4	Multi-frequency magneto-telluric survey in Anahim Volcanic Belt - Phoenix system used in field and awaiting report		46,000

	2.5	Schlumberger resistivity survey in Anahim Volcanic Belt - field work completed and awaiting report	17,037
	2.6	Potassium - Argon dating of selected volcanic centres - contract let and work in progress	8,760
	2.7	Geological mapping at Mt. Meager - small contract let to complete earlier work. Field work done and awaiting integrated report	3,600
	2.8	Geochemical water survey at Mt. Cayley - contract let to NSBG, field work completed and awaiting report	7,600
	2.9	Data processing - contract let for organisation and storage of accumulated data. Work in progress	4,000
		Operational support and related expenses	3,003
		TOTAL	$250,000
Project 3.		Geothermal energy from sedimentary basins.	
	3.1	Temperature and net-rock data synthesis - contract let to University of Alberta. Work in progress and reported on at SPONGE	40,000
	3.2	Aquifer mapping - contract under negotiation, to extend into next financial year	50,000
	3.3	Measurement of thermal conductivity of sedimentary rocks - contract let and work in progress	34,900
	3.4	Isotope analysis of subsurface waters of Hinton area - contract let and work in progress	10,500
		Operational support and related expenses	13,600
		TOTAL	$149,000

Project 4.	Geothermal resources of the Atlantic region		
4.1	Aquifer study of Cumberland Basin - postponed until adequate data source is identified		
4.2	Resistivity study of Cumberland Basin - postponed pending availability of equipment		
4.3	Data collection in region - contract let, work in progress		8,000
4.4	Drilling in granites - drilling completed and measurements in progress		37,500
4.5	Management of drilling programme - work completed and awaiting report		25,000
4.6	Rock fracture study - awaiting report		17,000
	Operational support and related costs		8,500
		TOTAL	$ 96,000
Project 5	Applications and transfer of foreign technology		
5.1	Contracted application study - contract let and work in progress		70,000
5.2	Laboratory testing - work in progress		30,000
		TOTAL	$100,000

SUMMARY

Expected expenditures:

Project 1	$ 150,000
Project 2	$ 250,000
Project 3	$ 149,000
Project 4	$ 96,000
Project 5	$ 100,000
TOTAL	$ 745,000

Funds Available

Original Panel	$ 360,000
NEP	$ 243,000
Supplementary	$ 124,000
TOTAL	$ 727,000

The over-expenditure results from the Coordinators misunderstanding of the sum available, and will be supplied from A-base funds, or balanced by reduction in 1982-83 expenditure in item 3.2.

Appendix 5

Projects planned for 1983-84

Sub-programme 4.5.1 Exploration technology and regional resource assessment

Project 1 Identification and assessment of geothermal resources in non-volcanic terrain

Project Leader T.J. Lewis

Items

1.1	Drilling of hole near PGC, in granites	$ 10,000
1.2	Drilling from the shallow holes to augment work of 1982	28,000
1.3	Hydrological study of White Lake Basin	16,000
1.4	Detailed analysis of magneto-telluric data from Anahim Volcanic Belt acquired in 1982	5,000
1.5	Casing for boreholes drilled for other purposes as opportunity arises	5,000
1.6	Shallow drilling in Anahim Volcanic Belt	60,000
	Operating and DSS charges	6,000
	TOTAL	$ 130,000

Other items not included in budget

1.x2	Mapping of bedrock geology of Coryell syenite	$ 20,000
1.x3	Drilling in southern Queen Charlotte Islands	$ 250,000

Project 2 Identification and assessment of geothermal systems associated with recent volcanic activity

Project leader J. G. Souther

Items

2.1	Multi-frequency magneto-telluric survey in Mt. Cayley area	$ 40,000
2.2	Regional water chemistry and hydrology of Mt. Cayley area	$ 10,000
2.3	Drilling of new resistivity anomaly near Mt. Meager	$ 90,000*
2.4	Water chemistry in the Stikine Volcanic Belt	$ 10,000
2.5	Seismic monitoring in the Anahim Volcanic Belt	$ 56,000
2.6	Potassium-Argon dating of selected volcanic centres	$ 10,000
2.7	Chemical analysis of rocks and data processing	$ 6,000
2.8	Demonstration of the E-Scan system as a geothermal prospecting tool in a northern mining area	$ 20,000
2.9	Geothermometry of spring water - update of inventory	$ 10,000
2.10	Soil geochemistry studies	$ 10,000
2.11	Chemistry of fluids produced from Mt. Meager wells	$ 10,000*
2.12	Purchase of terminal to assist in data handling (Capital)	$ 2,000
	Operating and DSS charges	6,000
	TOTAL	$ 280,000

* Items related to BCH work at Mt. Meager

Project 3 Geothermal Energy from sedimentary basins

Project leader A.M. Jessop

Items

3.1	Analysis of temperature and heat transport in the Western Canada Sedimentary Basin	$ 55,000
3.2	Aquifer mapping, continuation of work started in 1982-83	$ 50,000
	Thermal measurement equipment (Capital)	$ 18,000
	Operating and DSS charges	$ 7,000
	TOTAL	$ 130,000

Project 4 Geothermal resources of the Atlantic region

Project leader M. J. Drury

Items

4.1	Hydrological and isotope study of Magdelen Basin	$ 35,000
4.2	Multi-frequency magneto-telluric survey in P.E.I	$ 10,000
4.3	Drilling for temperature gradients	$ 65,000
	Operating and DSS charges	$ 5,000
	TOTAL	$ 115,000

Sub-Programme 4.5.2 Extraction Technology

Project leader Brian Larkin (National Research Council)

The items for this project have not yet been decided, since the major contract of 1982-83, with Acres Ltd., is not yet completed.

Allocated Funds $ 125,000

Sub-Programme 4.5.3 Systems

Project leader A. M. Jessop

Funds for this sub-programme will probably be used on some project, to be requested by B.C. Hydro, at Mt. Meager.

Allocated Funds $ 50,000*

Sub-Programme 4.5.4 International Collaboration

Project leader A. M. Jessop. If personnel resources are approved, a new project leader will be recruited.

Funds for this sub-programme will be used for establishing international contacts. However, if recruitment of a project leader is not approved, most of the funds will be available for work at Mt. Meager.

	Allocated Funds	$ 20,000

Summary of Sub-programme 4.5.1

Proposed expenditures

Project 1	$ 130,000	
Project 2	$ 280,000	
Project 3	$ 130,000	
Project 4	$ 115,000	
TOTAL	$ 655,000	

Funds available

Operating	$ 635,000	
Capital	$ 20,000	
TOTAL	$ 655,000	

Summary of Geothermal Programme

Sub-programme 4.5.1

Operating	$ 635,000	
Capital	$ 20,000	
Personnel	$ 30,000	
Personnel deferred	$ 60,000	$ 745,000

Sub-programme 4.5.2

Operating	$ 125,000	
Personnel deferred	$ 30,000	$ 155,000

Sub-programme 4.5.3

Operating	$ 50,000	

Sub-programme 4.5.4

Operating	$ 20,000	
Personnel deferred	$ 30,000	$ 50,000
TOTAL		$1,000,000