435 Ki;pling St.
Victoria,BC. V8S 3J9
Email: mdoodyj@gmail.com
phone: 250-388-4046

The CRD Parks Committee
Victoria, BC

Notes on Presentation to Members of the Parks Committee on February 21, 2018

From the many concerns around this proposal for 1980 Fairfield Place, this letter focuses on aspects your may not have thought of. I write on behalf of the trees, who cannot talk, to present some scientific factors about building next to a dedicated park and Garry Oak sanctuary cluster.

Apparently, the owners "did not intend any harm to the park" and probably neither does the board. Efforts happened to keep the number of tree removals down, to either 5 (in the letter) or 7 (on the plan). The proposal papers were often inaccurate and inconsistent. The following concerns arise:

- Science has proved that removing trees hastens climate change and creates a swath of damage to the trees around the removal area. (See attached documents with summaries.*) This means that trees in that area will weaken and die faster ver a certain time.;
- Building activities, including truck movements, cause disruption and add damage.to weakened trees.
- P. 2.1 showing the basement reveals the need for considerable blasting. ($300,000 worth);
- Building larger on rock for a view and then blasting a basement are irrational precedents.
- The trees in the whole area of the park would be impacted all around. With accumulated blasting, the weakened trees would be hastened to their end and healthy trees affected.
- Garry Oaks as endangered, are often removed in building projects. Also, removal of trees in a grove means that the those left can less resist natural forces, like winds;
  - A tree sanctuary park needs all the protection it can get and all the park trees would be affected.

Private views here lead to a damaged park and dying 100-year old trees, allies for many benefits.

Victoria staff showed myself and another citizen how close the lot was to Oak Bay but said nothing about the CRD's Trust Conditions and the necessity to notify Oak Bay as a sharing steward. Every agency involved seems to have shown either ignorance or negligence, both requiring correction. I urgently ask the Parks Committee to begin to break this unhappy cycle with the following actions:

1) Take seriously the dangers for this park and send grave concerns about the variances and their impacts to the Board of Variance and to Victoria Mayor and Council.
2) Recommend to the Regional Board to begin the process detailed by Brad Atchison in investigating and repairing the park and begin to use existing accumulated funding ($14 million);
3) Recommend that the Regional Board contact the lot's owners to acquire it as part of the park.

Mary E. Doody Jones

Mary E. Doody Jones
Dip. of Cultural Conservation (UVic)

* Trevor J. Lewis is a geophysicist on the International Panel for Climate Change (winning the Nobel prize). He sent his CV and two studies on tree removal as sample science.

Trevor J. Lewis

1107 Maple Road
Sidney, B.C. V8L 5P5
(250)-655-2949

Education:

B. A. Sc.	1963	U. of British Columbia (Eng. Physics)
M. Sc.	1965	U. of British Columbia (Geophysics)
Ph. D.	1975	U. of Western Ontario (Geophysics)

Memberships and Offices:

-Geological Ass'n of Canada, American and Can. Geophysical Unions, APEGBC

-former director of the Can. Geothermal Energy Ass'n., Honorary Member

-former secretary of the International Heat Flow Commission of IASPEI

Employment:

-Employed (33 years) with the Federal Government as a Physical Scientist and a Research Scientist (Geological Survey of Canada)

-Head of the Cordilleran Geophysics Section for several years, and Acting Director of the Pacific Geoscience Centre for a year

Publications:

-over 70 publications, 37 in refereed journals (Bibliography available)

-Marine heat flow measurements for hydrocarbon exploration and development, a short course, Houston, 2001.

-a chapter on groundwater flow in Fluids in Tectonically Active Regimes of the Continental Crust, an MAC Short Course

-editor of a special issue of Global and Planetary Change: Climatic Change Inferred from Underground Temperatures

-Contributor to the Inter Governmental Panel on Climate Change, 1995.

Applied Work:

-Measuring the heat flow in the Queen Charlotte basin and modelling deep temperatures, for use in hydrocarbon maturation studies and determinations of maximum depths of earthquakes

-Measuring heat generation in sediments and modelling past temperatures on the eastern North American continental margin, showing the effect of not allowing for the heat generation in sediments.

-Mineral exploration research in an Industrial Partners Program (GSC) project with Cominco near the Sullivan mine, Kimberly (1996-7)

-Geothermal energy exploration at Meager Mountain, B.C.

-Design of a pulsed needle probe to measure the thermal conductivity of materials

-Detecting water flow through a proposed radioactive waste disposal site at Whiteshell, Manitoba

-The necessary thermal conditions to find diamonds: Slave province

-Analysis of more than 2,000 heat flow measurements for offshore hydrocarbon exploration in over 35 countries.

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GLOBAL AND PLANETARY CHANGE

The effect of deforestation on ground surface temperatures

Trevor Lewis *

Geological Survey of Canada: Pacific, P.O. Box 6000, Sidney, B.C. V8L 4B2, Canada

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Abstract

Recorded ground surface temperatures (GSTs) over a period of a year at closely spaced sites in a temperate area (almost no snow or ground freezing) show that forested sites and one with a high water table have colder average temperatures relative to other terrains. At sites in southern British Columbia where trees have been logged and in the southern Yukon where they were burned down by a forest fire, the ground surface temperature increased at the time of deforestation. Borehole temperatures are used to show this since no GSTs were recorded. At these sites there has been no subsequent reforestation, and the ground surface temperature has remained nearly constant since deforestation. The times since deforestation range from 5 to 52 years, and the average increase in ground surface temperature is 1.8 K on northern Vancouver Island and 1.2 K in the southern Yukon. The heat required for transpiration in a forest is about 10% of the net radiative heat flux at the ground surface. If this amount of heat is surplus due to deforestation and if the earth is considered to radiate heat like a black body, then the expected increase in the GST is of the order of 1 K.

Keywords: global warming; geothermics; borehole temperatures; forestry; ground temperatures

1. Introduction

We present in this paper both observed ground surface temperatures (GSTs) and GSTs modelled from borehole temperatures beneath previously deforested terrains. We claim that the differences in observed GSTs over a period of a year at closely spaced sites are due to differences in the terrain or ground cover. The GST in forested areas is cooler on average than in cleared areas. Consequently, previously forested areas should have experienced an increase in GST when deforested, whether by logging or by forest fire. In such areas where the forest did not grow up again, this would result in a permanent increase to the average GST at the time of deforestation. The purpose of this presentation is to show the influence forests have on GSTs. Undoubtedly this is related to many factors, but the largest is evaporation (transpiration) of water. We show that the amounts of heat involved are sufficient to change the average GST by the observed amount.

The GST observation sites are located on southern Vancouver Island, in the temperate zone of Canada's southern west coast. The borehole sites are in previ-

* Corresponding author. Tel.: +1 250 3636510. Fax: +1 250 3636565. E-mail: lewis@pgc.nrcan.gc.ca

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Geothermal evidence for deforestation induced warming: Implications for the climatic impact of land development

Trevor J. Lewis and Kelin Wang
Pacific Geoscience Centre, Geological Survey of Canada, Sidney, British Columbia

Abstract. Analyses of temperatures from boreholes in previously forested areas in western Canada disclose sudden increases of one to two degrees in ground surface temperature at the times of deforestation at each site. This is the first clear evidence for deforestation induced warming. These findings suggest that any land development changing climatic parameters such as the amounts of water evaporated from the earth's surface contributes to regional climatic change. A warming of the ground surface over a large area of central Canada, synchronous with the deforestation of southern Ontario and neighbouring regions in the nineteenth century, may be an example of climate change linked to the widespread creation of agricultural lands. Such a warming also affects the surrounding regions.

Introduction

General circulation models include processes by which regional deforestation may significantly affect the temperatures of the earth's surface (increasing albedo, decreasing soil moisture, etc.). The theoretically predicted effects on regional climate are dependent on location and circulation pattern [*Henderson-Sellers et al.*, 1993]. In the Amazon forests climatologists have measured elevated air temperatures in clearings [*Gash and Nobre*, 1997]. The important influence of forests on climate has been long suspected [*Geiger*, 1965], and increased ground surface temperatures (GSTs) detected using underground temperatures have been attributed to deforestation previously [*Hyndman and Everett*, 1968; *Cermak et al.*, 1984; *Lewis and Wang*, 1992; Majorowicz, 1996]. However, because there are no surface temperature records spanning long enough periods before and after deforestation, direct evidence of deforestation-caused temperature change was missing.

Such evidence should be preserved in subsurface temperature-depth profiles. With a constant ground surface temperature (GST), the subsurface temperature is in a steady state, increasing with depth. Any changes in the GST propagate downward, causing disturbances to the otherwise steady state temperature profile. A GST change caused by deforestation decades ago should appear in temperatures measured in a borehole as a disturbance reaching a few tens of meters depth. Inversion of borehole temperatures has been used by many researchers to estimate past regional GST histories [e.g., *Lewis*, 1992; *Shen et al.*, 1996]. Large contrasts in annual average GSTs between closely located sites with and without trees have been directly observed (e.g., *Lewis, in press*). However, a site-specific causal relationship between deforestation and GST change has not been established because we generally do not have the detailed knowledge of deforestation history of specific borehole sites.

We found areas in western Canada where deforestation histories are known and boreholes are available for temperature measurements. Borehole temperatures at each site indicate a sudden increase in GST which correlates well with the time of deforestation. This leads us to consider the effect of regional land development on past climate change.

Geothermal data and analysis

On Vancouver Island, British Columbia (Fig. 1), we obtained temperatures in 15 boreholes in June, 1992, at sites where timber was previously harvested (clear cut) at times ranging from 5 to 52 years before. In the Clear Lake area, southern Yukon (Fig. 1), a fire destroyed the forest 23.1 years before temperature measurements in 8 boreholes in July 1992. Trees have not been replanted within tens of meters of these borehole collars; dimensions of the deforested areas vary from 500 m to kms. The temperatures were measured to an absolute accuracy of 20 mK and a relative accuracy of 3 mK. The boreholes on Vancouver Island, drilled for geothermal studies, are 100 m deep [*Lewis et al.*, 1997]; at Clear Lake where holes were drilled for mining exploration, they are up to 470 m deep [*Bentkowski and Lewis*, 1994].

Obvious in each borehole temperature profile from Vancouver Island (Fig. 2) is a decrease in the geothermal gradient near the top. A similar shape is found in many

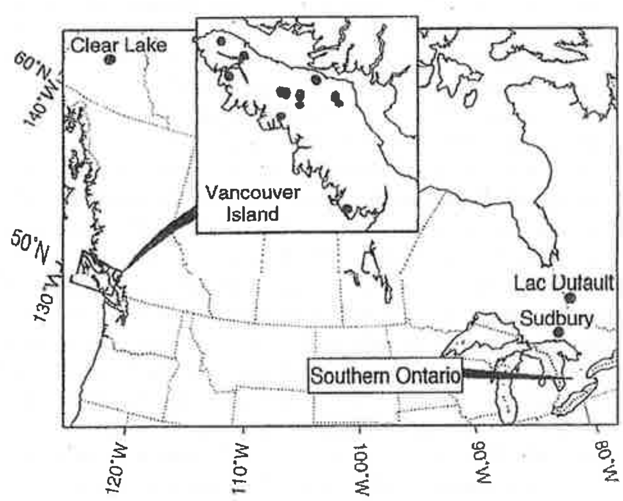

Figure 1. Locations of borehole sites, (Vancouver Island, Clear Lake, Lac Dufault and Sudbury,) and southern Ontario where early agricultural development is documented.

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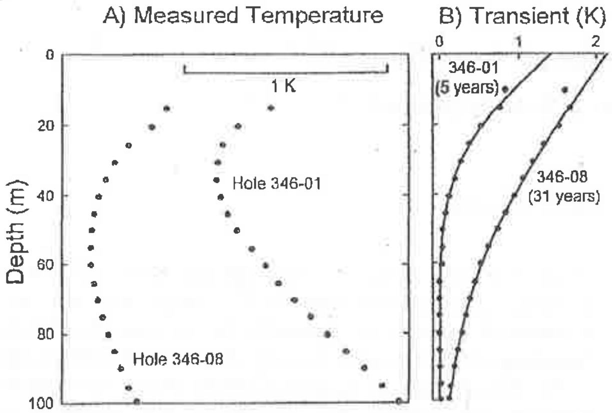

Figure 2. Examples of borehole temperatures from Vancouver Island: A) measured temperatures, and B) the transient component, fitted (line), and measured (symbols), after subtracting the steady state contribution. Large annual temperature variations penetrating to a depth of about 10 m are not modelled. The difference in the penetration depths of the transient perturbations is due to the different times of deforestation at the two sites. The time (in years) prior to temperature measurement is shown for each site in B).

boreholes in eastern and central Canada and other parts of the world such as Alaska's North Slope. This common feature has been understood to be caused by recent climatic warming [*Lachenbruch and Marshall*, 1986; *Wang and Lewis*, 1992]. In central and eastern Canada warming began in the mid-19th century. Our previous results [*Wang et al.*, 1994] showed much less and much later warming in British Columbia. We now realize that many western Canadian sites that we analysed earlier were disturbed by surface vegetation changes, and that the regional differences in climatic warming were even larger than what we concluded. At the many sites from which we have data in British Columbia, detailed studies of site specific causes indicate little regional climatic warming. In any case, the perturbations shown in Fig. 2 cannot be caused by a uniform regional climatic warming; if they were, they would occur at very similar depths. The fact that the anomalies occur at various depths at different sites is consistent with the causes being site-specific.

It is most likely that deforestation, either by timber harvesting or fire, causes the warming. If this is so, the GST should have increased suddenly when the trees were removed, and the effect can be represented by a step change in the GST at time t prior to the temperature measurement. Therefore, we consider a simple GST history that involves a step increase. Since the dimensions of the deforested areas are much greater than the depths of the boreholes, for each site the step change on the surface can be assumed spatially uniform. Major geological boundaries that could cause lateral conductivity contrasts are absent near the borehole sites. Therefore, the calculations were done in one dimension (vertical). Since the increase in the GST due to forestation at each site is unknown, the magnitude of the step change A was left as a free parameter.

The measured thermal conductivity, diffusivity and heat flow were used in the calculations. The thermal conductivities were measured on core samples using a pulsed needle probe technique [*Lewis et al.*, 1993], the accuracy of individual measurements being ± 15%. The rock penetrated was well represented by over 400 samples chosen at vertical spacings of 10 m or less. The thermal conductivities were high due to mineralization and quartz content. Since the thermal capacity of most rocks is nearly constant, we have accurately estimated the diffusivity from the thermal conductivity of core samples from the upper section of each borehole (1.0-2.1 m^2/s).

For a preliminary calculation, we simply took the known time of deforestation as the time t of the step change and adjusted the magnitude A until the calculated subsurface temperature profile (Carslaw and Jaeger, 1959) best matched the borehole data. With reasonable A values (0.5 - 2.5 K), we were able to reproduce the observed thermal disturbances [*Lewis, in press*]. We then used a more rigorous method: a directed Monte-Carlo search inversion to determine simultaneously the values of t, A, the heat flow and the surface intercept temperature that give the best fit to the borehole data in the least squares sense. For most boreholes, the average misfit of the data was 0.02 K (Fig. 2). Calculated temperatures differed the most from those measured in sections of deep holes in a mineral deposit. We omitted results from two of the 8 boreholes at Clear Lake because we thought the sampling inadequate to represent a large thermal conductivity variation in and near a massive sulfide deposit.

The remarkable agreement (Fig. 3) between geothermally determined times of step changes and known times of deforestation clearly demonstrates that the subsurface temperature disturbances were caused by deforestation. The magnitudes of the step change are 0.5 - 2.7 K. The undisturbed heat flows in shallow holes on Vancouver Island are similar to values from nearby, deeper holes.

The correlation between the times of deforestation and the geothermally determined t values is good in spite of the approximations in our simple analysis. We assumed a

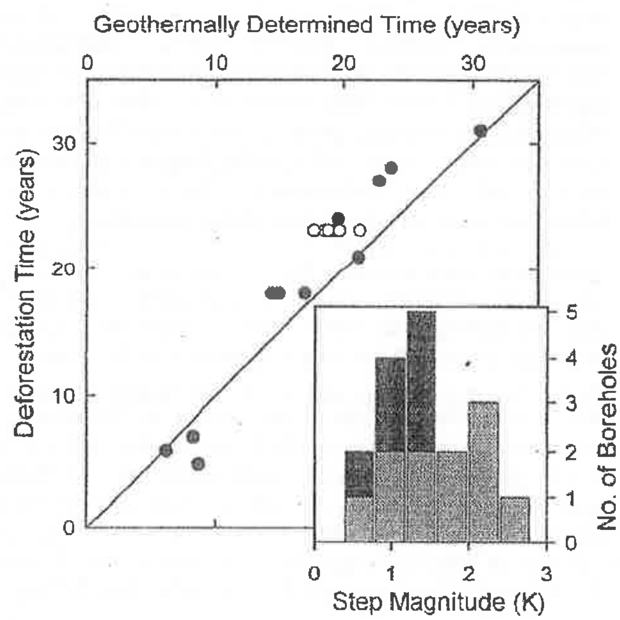

Figure 3. Known times of deforestation compared with the times from fitting a step GST change to the observed borehole temperatures. The insert shows a histogram of the amplitudes of temperature change for Vancouver Island (light bars) and the Clear Lake (dark bars).

constant rock diffusivity with depth for each site; in reality, the diffusivity of the overburden, e.g., 0.5×10^{-6} m^2 s^{-1} [*Putnam and Chapman*, 1996; *Moench and Evans*, 1970], is much less than that of rock, and probably varies annually with the water content. The overburden thickness is generally not well known. Its effect should be negligible where it is less than a few meters thick. For greater thicknesses, ignoring it would cause the estimated t value to be smaller, consistent with the slight systematic mismatch seen in Fig. 3. At Clear Lake where overburden is 5-25 m thick, the modeled time is 19.2 ± 1.2 yr for six boreholes affected by the same forest fire 23.1 yr before measurement. The response time of a rock formation of thickness L and diffusivity α to a step temperature change at the surface, called here the thermal time constant, is $L^2/4\alpha$. The difference between the time constants of 18 m thick layers of overburden and of rock equals the observed delay.

The average magnitudes of the step change for Vancouver Island and Clear Lake are 1.84 ± 0.63 and 1.24 ± 0.60 K, respectively. The local variation in magnitude from hole to hole within a group may be associated with the specific environment of individual sites, such as the density of trees, water table, terrain effects, etc. The regional variation in magnitude between Vancouver Island and Clear Lake could be attributed to many factors, but the latent heat of freezing ground water keeps the ground warmer than the air during cold winter months [*Judge*, 1973; *Lewis and Wang*, 1992], causing the deforestation-induced warming to be smaller than the surface air temperature (SAT) increase at Clear Lake.

It is important to note that deforestation did not cause just a short period of higher GST: the GST after deforestation has remained constant at each site.

Attribution of warming

We attribute the GST warming to the change in heat budget at the earth's surface in the deforested areas. One of the largest energy fluxes at the earth's surface is that due to evaporation. Heat is absorbed by trees for transpiration of fluid, and it is later released into the upper atmosphere. The fluid involved is the groundwater flowing up the trunk of the tree. Increased annual runoffs from deforested areas in the Amazon support this attribution (Bruijnzeel, 1996). Using nominal values for rates of biomass production ($3m^3$ of fibre per hectare year on Vancouver Island) and for transpiration (300 litres of water per kilogram of fibre), the heat used, averaged over the year, is 3.5 W/m^2, or approximately 10% of the net radiation contribution to the total heat budget at the ground surface. After deforestation, the heat is no longer required for transpiration. This amount of heat is of the same order as that required to produce a change in the GST of 1 K, assuming a simple black body radiation model for the earth's surface. To put this in perspective, this equals the increase in heat per unit area attributed to the increased direct radiative forcing of the long-lived greenhouse gases since the beginning of the Industrial Revolution [*Houghton et al.*, 1996]. However, albedo and other factors also contribute to this net observed effect (e.g., *Gash and Nobre* [1997]).

Other activities such as drainage of wetlands, lowering of the water table, conversion of grasslands to farmlands, and extensive overgrazing also cause the ground surface temperature (GST) to increase. The amounts of water vapour produced from groundwater and released into the atmosphere are decreased by each of the processes.

In regions where forests were destroyed and wetlands were drained to create agricultural lands in the last century, an increase in GST lasting from the time of development until now is to be expected. The development of agricultural lands in southern Ontario, just north of Lake Erie and Lake Ontario, started about 1820 AD, and by 1900 AD, two-thirds of the land was classified as "improved" (Fig. 4; *Taylor et al.*, 1986). Individuals probably continued to clear portions of their land in the 30 - 50 years after it was first classified for tax purposes as improved, making the time when most of the area was cleared very approximately 30 years later.

Since early nineteenth century air temperature observations are scarce, and such observations can be unrepresentative of large, forested areas [*Lewis, in press*], results from inversions of borehole temperatures were used to define the warming history. Analyses of borehole temperatures from central and eastern Canada reveal a large warming over the last two centuries (e.g., *Wang et al.*, 1992; *Beltrami et al.*, 1992). Although there are no suitable borehole data from within the basin area of southern Ontario to define the past GST, there are some in the surrounding areas. We present inversions from two sites (Fig. 4). They indicate approximately the same

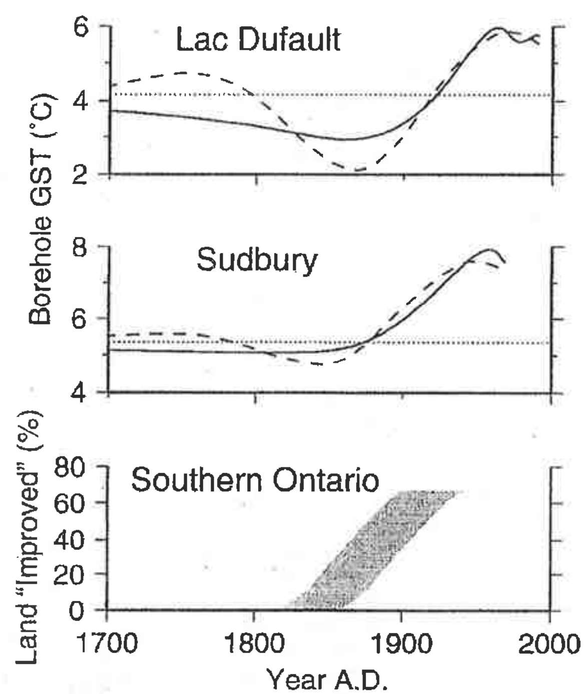

Figure 4. The past GST from two sites near southern Ontario (see Fig. 1 for locations), and the timing of production of agricultural land ("improved land") in southern Ontario. For the GST history at each site, the dotted line represents a well constrained long term average value, and the dashed line represents the GST history using our preferred inversion; using a more conservative a priori expectation of thermal conductivity variations produces the past GST histories shown as solid curves (27). The width of the gray band represents a period starting at the time a farmer's land was classified as improved and ending 30 years later when we assume most of the land might have been cleared.

timing of warming over this large region, and the same approximate amplitude of warming. The inversion techniques used for these longer records were designed to estimate "smooth" GST histories, not steps such as deforestation produces; also, the earth itself acts as a low pass filter. Although previous inversions have been done on data from many sites surrounding this region, there are possible terrain effects at most of the sites. From the seven sites which we know are free from such disturbances, the total increase in the GST over the last two centuries is 2.6 ± 0.5 K [*Wang et al.*, 1992]. However, the temperatures two centuries ago were abnormally cold, and the increase above the well-defined long term average GST is slightly less than 2 K.

Can deforestation have caused warming over a much larger region than the deforested area? Although circumstantial, the evidence is convincing. In Ontario and the surrounding regions, the warming over the last two centuries occurred at the time when large-scale deforestation to create agricultural lands took place. And the warming extended to undeveloped areas surrounding the deforested region. Results from general circulation modeling of large scale deforestation in South America also show climatic disturbances extending well beyond the deforested area [*Henderson-Sellers et al.*, 1993].

Although the effects of deforestation and other land development are only some of the factors influencing the climate, they cannot be ignored. Inversion of borehole thermal measurements is an excellent method for obtaining past GSTs to investigate the effects of past land development.

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T. J. Lewis and K. Wang, Pacific Geoscience Centre, 9860 West Saanich Road, Sidney, British Columbia, Canada V8L 4B2. (e-mail: lewis@pgc.nrcan.gc.ca, wang@pgc.nrcan.gc.ca)

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