Chapter 2: Introduction

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Nahanni National Park Reserve (NNPR) was established by the federal government as a park reserve in 1976, pending the settlement of aboriginal claims. In the mid-1980s, the park management plan identified three areas for expansion: Ragged Range, Tlogotsho Plateau and Nahanni Karst. These became the focus of study for this Mineral and Energy Resource Assessment (MERA). Changes to the NNPR boundary and establishment of this area as a national park will be addressed through the Deh Cho process. This MERA provides information to decision-makers involved specifically in the National Park establishment process and only for these three study areas. Any other areas that may be considered for this process will also require MERA assessments.

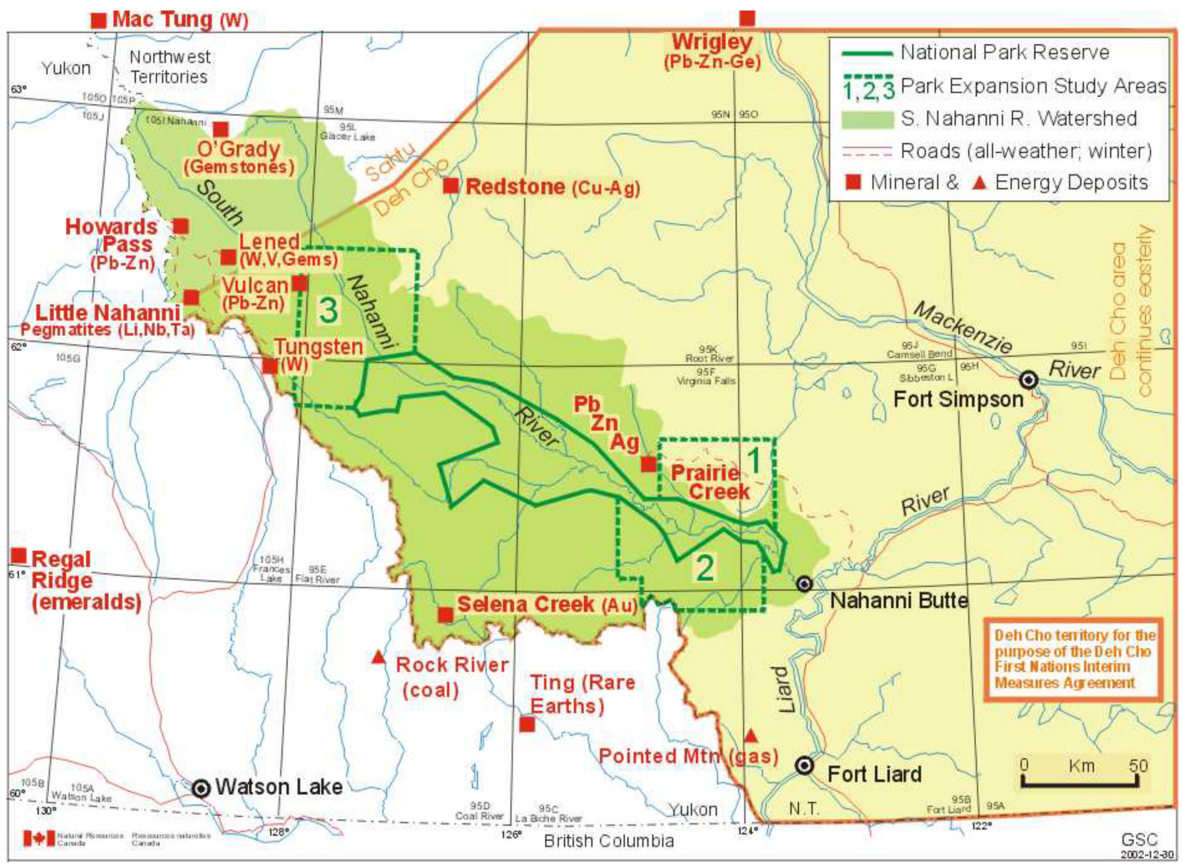

Figure 2.1. Geographic, political and economic context of the Nahanni National Park Reserve (NNPR) area. MERA (Mineral and Energy Resource Assessment) study areas for potential park expansion are: 1.– Nahanni Karst, 2 – Tlogotsho Plateau and 3 – Ragged Ranges.

Nahanni National Park Reserve (NNPR) is one of Canada's premier wild river national parks. The unique deep canyons, falls, white water and meandering reaches of this renowned northern mountain wilderness area resulted in national and international recognition as a Canadian Heritage River and as a UNESCO World Heritage Site, in 1987. The South Nahanni River region is also one of high known mineral potential with a long exploration and mining history, including traditional knowledge of lost gold that still excites the imagination. At the time NNPR was set aside, there was no process for consideration of mineral and energy potential before the establishment of new national parks, and the NNPR is considered to be grandfathered in this context. Any expansions to this original reserve are now, however, subject to modern science-based assessments for a range of attributes relevant to modern society, among these being mineral and energy potential as a contribution to sustainable development. This report provides mineral and energy resource assessments that are restricted to three proposed expansions to NNPR: Ragged Ranges, Tlogotsho Plateau and Nahanni Karst.

2.1 Mineral and Energy[1] Resource Assessment (MERA)Terms of Reference

The MERA process in northern Canada has been described by Sangster (1983), Scoates et al. (1986) and continues to evolve (Jefferson, 1992). The process was formally established in published Terms of Reference (Government of Canada, 1995), although considerable flexibility is facilitated by active Working and Senior MERA committees that have interdepartmental membership. The purposes of MERA are:

(1) to ensure that the economic and strategic significance of mineral and non-renewable energy resource potential is duly considered in the national park establishment process in the Yukon and Northwest Territories;

(2) to ensure that, in making recommendations regarding withdrawal of land for park purposes, the Minister of Indian Affairs and Northern Development is advised on the balance between the values of the land with respect to park establishment criteria and the potential for the exploration, development and use of mineral and energy resources which may inhere in the land;

(3) to prepare an assessment of the mineral and energy resource potential of areas in the Yukon and Northwest Territories which are being considered for administration as national parks.

The first and second purposes are fulfilled by the Senior MERA Committee - the Assistant Deputy Ministers or Chief Executive Officers or Deputy Ministers of:

- Indian and Northern Affairs Canada (Chair)
- Parks Canada Agency
- Mineral and Metals Sector, NRCan
- Geological Survey of Canada, ESS, NRCan
- Appropriate agency, Yukon Government
- Appropriate agency, NWT Government.

A parallel MERA Working Group is directed by the Senior MERA Committee.

This Open File was prepared to fulfill the third purpose, by providing some of the critical information needed to meet the first and second purposes. The MERA method aims to upgrade the geoscience data base as much as possible as a basis for applying mineral deposit analogues such as summarized by Eckstrand (1984) and Eckstrand et al. (1995). The park establishment process includes on-going public and internal government consultations at local, community, territorial and national levels. The MERA results presented herein will contribute to the public information base for consultations on the proposed expansions to NNPR. The existing NNPR is also being considered for conversion to a fully established National Park through the Deh Cho process, and this report is being released at about the same time as DIAND announces a regional withdrawal of Deh Cho lands (Fig. 2.2), including much of the South Nahanni River watershed adjacent to the national park reserve. However the focus of this study, and its application for land use planning, are restricted to the three proposed park expansion areas illustrated in Fig. 2.1.

This report is published to serve as an objective scientific information source for a wide audience, as part of a public consultation process. Various data provided herein may be used by some stakeholders to support development, by other stakeholders to support preservation, and by yet others to manage land-use practices in an operational sense, such as planning within the existing NNPR. Any criticisms or additional information are welcomed by the first author and the MERA committees for the overall report, and by the first authors of each Chapter for technical aspects. Stakeholders should be confident that the MERA process is responsive, for example both Tuktut Nogait and Ukkusiksalik national park MERAs included second phases to respond to stakeholder concerns that were received by the Senior MERA Committee (Jefferson, 1994).

[1] Energy includes only non-renewable energy such as coal, oil and gas.

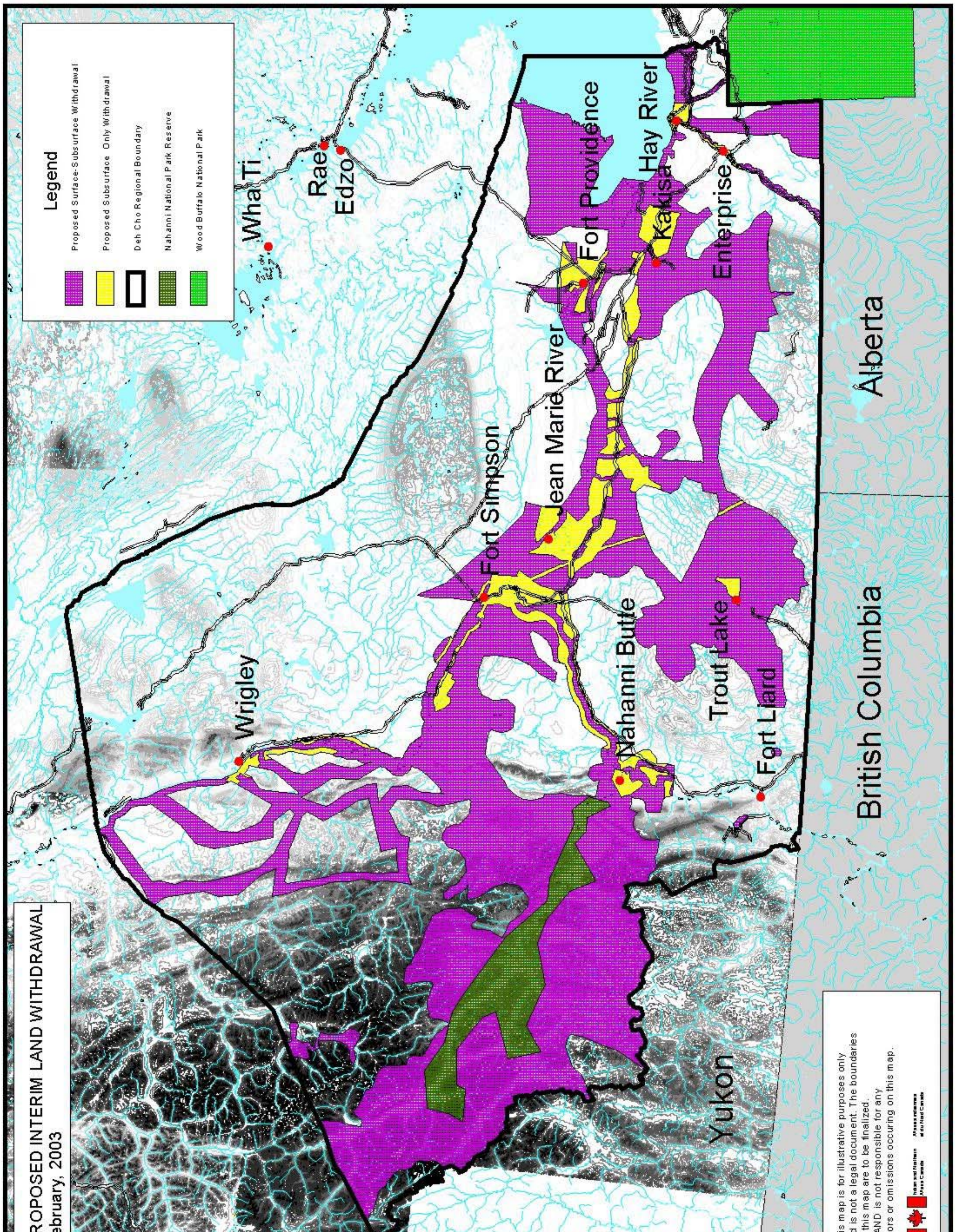

Figure 2.2. Proposed interim land withdrawal, draft as of February 2003, for illustrative purposes only, from Deh Cho Process negotiations.

2.2. Geographic Setting, MERA Study Areas and Features of National Park Interest

NNPR is located in the southwestern corner of the Northwest Territories, straddling the South Nahanni River (Fig. 1.1), extending from 61º to 62º North Latitude and covering 4,766 square kilometres. The South Nahanni River transects the southern Mackenzie Mountains (northern three quarters of Fig. 2.1)and lies just north of the Liard Plain that is along the Yukon - British Columbia border.

The three study areas being considered as extensions to NNPR (Fig. 2.1) extend the region of interest from 60º 45' to 62º 30' North Latitude and from 123º 15' to 128º 30' West Longitude. The original proposed Ragged Ranges Extension covers an area of about 55 x 70 km. The mineral resource assessment study area of 80 x 85 km around the Ragged Ranges Extension was designed to capture context and allow for minor variations in boundary shape once the various studies and consultations are completed. The Tlogotsho Plateau proposed extension, covering an area of sandstone-cored gentle ridges and broad shaley valleys, is about 30 by 60 km, and the Nahanni Karst extension is some 40 by 50 km. The Tlogotsho and Nahanni Karst areas are embraced by a single rectangular resource assessment study area about 105 x 85 km, again designed to capture context and allow for minor variations in boundary configurations once the studies and consultations are completed.

The National Park Reserve and its proposed extensions encompass a spectacular region of waterfalls, canyons, rapids, caves, mountains, valleys, plateaus, karst topography and mineral and thermal springs in the lower three quarters of the South Nahanni River Basin, NWT. The South Nahanni River watershed drains 37,000 square kilometres, from icefields near the Yukon-Northwest Territories border, extending 540 kilometres eastward through the southern Mackenzie Mountains into the Liard and, eventually, Mackenzie rivers.

Regional information on flow dynamics, physiography and chemical compositions of surface waters in this watershed are provided by Halliwell and Catto (1998). They have determined that the waters and/or natural fine particles of minerals suspended in the waters are regionally and naturally enriched in elements such as aluminum, cadmium and zinc. Some of these elements are also elevated in the aquatic life that appear to be adapted to this ongoing, natural condition. Geologically, this is understandable because the waters drain rocks that contain natural and regionally elevated contents of these elements that are released during normal weathering. The ecosystem is built upon this geological foundation, so all life that draws its nutrients from plants, groundwaters and surface waters will reflect the regional and local compositions of the bedrock. Interestingly a number of the cold and hot springs in the region that contain salts, also contain elevated metals (see Chapter 5), and there are abundant signs that large animals come to these springs (such as Meilleur River hot springs) to drink, thereby enhancing the process of enriching their bodies in these elements.

The NNPR area and proposed extensions transect the southern Mackenzie Mountains fold and thrust belt, which is the most complex in Ragged Ranges. Details and illustrations of the bedrock geology of each study area are provided in Chapter 3. In general, shaley rocks form wooded and grassy slopes on the backs of, and at the feet of mountain ridges (e.g. Yohin Ridge and Nahanni Butte extending up to Little Doctor Lake area; also mountain pastures in Ragged Ranges). Sandstones, limestones and dolostones form cliffs and extensive ridges.

Extensive karst topography comprising solution channels, gushing cold springs from underground drainage, caves and sinkholes, some containing beautiful isolated small lakes (poljes), is developed in the naturally soluble carbonate rocks of the region, particularly in the Nahanni Karst (Ram Plateau) area, but also in carbonates found in Ragged Ranges, due to dissolution of the carbonates by rainwater and snow-melt. The spectacular gorges of the South Nahanni River and its tributaries are also hosted by dolomites and limestones that preserve evidence of ancient dolomitization, brecciation and solution collapse ("Manetoe Facies" of Morrow and Aulstead, 1989). These processes created oil and gas reservoirs some 350 million years ago.

Granites with their mantles of thermally altered sedimentary rocks core the highest peaks (9000' / 2700m) in Ragged Ranges, Logan Mountains, some of which still support alpine glaciers, as well as ice-cored rock glaciers. The Logan Mountains are an attractive destination for mountaineers (e.g. Hubbard, 1957), the Cirque of the Unclimbables formed a backdrop for filming part of the Clan of the Cave Bear film. Caribou use the mountain pastures for their summer range.

Active alpine glaciation has sculpted the mountain peaks and valleys, producing high-elevation cirques, and U-shaped valleys with lateral and terminal moraines in Ragged Ranges. Much of the glacial till along the east side of Nahanni Karst and Tlogotsho Plateau is terminal moraine from the Laurentide ice sheet. Tills and glaciolacustrine clay deposits border or mantle valley floors within the South Nahanni River Basin. Eastward, in the Liard River valley, drumlin fields are oriented northwest-southeast in the northern half of the area and east-west in the southern half of the area. The various glacial deposits have been locally reworked into ancient and modern river sands and gravels, some of which contain minor amounts of placer gold. The silt and clay fractions reworked from these tills continue to be carried downstream, suspended in the turbulent Nahanni waters. River erosion is actively changing the shapes of the stream beds and banks in the South Nahanni River Basin, in places destroying man-made edifices. Details and illustrations of the distribution, compositions and interpretations of the surficial deposits are provided in Chapters 3 (Geological Setting) and 4 (Regional Surficial Geochemistry).

A range of high and low-volume, cold, warm and hot springs are associated with fracture systems and locally produce edifices such as the picturesque tufa mounds of the famous Rabbitkettle Hot Springs, as well as providing soothing bathing pools. The distribution, classification and chemical composition of spring waters are described and interpreted in Chapter 5, with some illustrations provided in Chapter 3.

The climate of NNPR is cold continental, with wide annual temperature and precipitation variations, and a sub-zero ambient temperature. Summer and fall are dominated by westerly air currents from the Pacific Ocean, whereas arctic air streams predominate in winter and spring. The eastern end of NNPR tends to be cooler and wetter, and chinook winds are common throughout the winter (Halliwell and Catto, 1998). An Environment Canada weather station was installed near the South Nahanni River above the Virginia Falls water survey station in 1994 to characterise weather conditions on a data-deficient area and to monitor weather conditions for forest fire management in the Park and nearby areas (ibid.). Discontinuous permafrost was observed throughout the South Nahanni River area, and where ice rich, degradation locally causes slumping and slope failure.

Moore (1980) provides an account of the human side of winter life in the Nahanni from the perspective of one pair of southern tourists. Parks Canada has facilitated collection of traditional knowledge, and the reader is referred to the NNPR office in Fort Simpson for an extensive bibliography. Graham (1972) and Abel (1980) are examples of studies related to the lands, legends and socio-economic issues related to NNPR region. One legend in particular has a living connection, in that Nahanni Butte elders maintain an oral record of the small gold rush, in the vicinity of Deadman's Valley, and the origin of that name. An account of that gold rush was also published by Lambard (1937) and later summarized by Lord (1951).

Access to the NNPR region (Fig. 1.1) on the east is by highway to Fort Liard and Fort Simpson, and thence by air or boat to Nahanni Butte. A winter road that transects the northern part of Nahanni Karst and an air strip provide potential access to the Prairie Creek mine site that is proposed for rehabilitation (Canadian Zinc news release, May 2002), subject to permitting. An all-weather road and an air strip provide access to and from the reactivated CanTung mine site (Ednie, 2002). Travellers into NNPR must make advance arrangements with Parks Canada staff based in Fort Simpson. Canoeists coming down the South Nahanni River must register on-site with park staff based at Rabbitkettle Lake. Air traffic within NNPR is restricted. A series of newsletters (e.g. Parks Canada, 1983a, 1984a,b and 1985) provide considerable information related to park management.

2.3. History and Method of NNPR MERA Studies

"Nahanni was set aside as a 'reserve for a national park, subject to a settlement of any right, title or interest of the people of native origin' when the National Parks Act (of Canada) was amended in 1974" (Parks Canada 1983a, p.1). When the original park reserve was established, "Nahanni's current boundaries were not based on a systematic evaluation of resources and constraints. It was understood that as detailed studies of the region became available, the park's boundaries could be modified to take this new information into account." (Parks Canada, 1984a, p. 14). This is a factor in the concept of change that is discussed in Section 2.4 - Confidence in this assessment.

In 1983 Parks Canada (now Parks Canada Agency) began a management planning program to guide the development, management and operation of NNPR (Parks Canada 1983a, b). This led to a decision to expand the park in three areas containing specific natural resources of interest (Parks Canada 1984a). GSC was then requested to provide mineral and energy resource estimates of the study areas according to the MERA process which was later formalized by the Government of Canada (1995). Consultation between officials of Parks Canada, DIAND, the NWT Government and then Energy Mines and Resources (now NRCan) led to the definition of three MERA study areas and a three-year plan of office and field work to upgrade the geoscience data base.

In 1985, the first year of the study, we compiled available data, including personal interviews, from previous workers such as Aranoff et al. (1986); Ballantyne (1991; pers. comm. 1985), Bonham-Carter and Goodfellow (1984, 1986), Goodfellow (1980, 1982, 1983), Gordey (1978, 1980, 1981), Gordey et al. (1981, 1982, 1983), Morrow (1984), Morrow and Cook (1987), Morrow and Aulstead (1989), Morrow et al. (1990), and numerous industry reports (cited in Appendix 1), guided firstly by the Archer Cathro mineral occurrence database. Gordey et al. (1983) included a thorough assessment of mineral deposit types and settings in the Nahanni map sheet that is located adjacent and west of the Ragged Ranges Study Area, and covers the headwaters of the South Nahanni River. Goodfellow (1982) provides a regional geochemical reconnaissance of the same area. These two sources were particularly helpful in designing this resource assessment. A comprehensive geological legend (Table 3.1) was compiled showing the stratigraphic relationships based on previous regional government mapping (references cited in its caption) and the above consultations.

In August 1985 a ten-day field program oriented the first author to logistics and feasibility of different types of geochemical survey. Standard stream silts, bulk gravels for heavy mineral analysis, and surface waters were sampled in the upper South Nahanni River and Prairie Creek areas that contain significant mineral occurrences (e.g. Prairie Creek Mine, Lened and Vulcan, Figs. 1.1, 2.1) and provide analogues located close to the study areas for proposed park expansion. In addition, we examined confidential exploration geochemical data acquired from private companies who had explored parts of the study areas.

Two graduate theses were then designed as part of a comprehensive field program for 1986 and 1987, to compile, integrate and resolve uncertainties in the previously mapped geology of the NNPR corridor, and to collect systematic geochemical base-line data in the most cost-effective ways, while training young scientists. The graduate studies culminated in M.Sc. theses on stream-sediment geochemistry (Spirito, 1992) and hydrogeology-geochemistry (Hamilton, 1990) that are reworked here as chapters 4 and 5 respectively. Methods of these studies are outlined in detail in each chapter.

Field programs during the summers of 1986 and 1987 also included geological mapping of surficial deposits in order to better understand glacial and fluvial processes that contributed to the geochemical signatures. Bedrock mapping extended new information from the Nahanni map sheet (Gordey et al. 1983) into the Ragged Ranges study area, and helped us to familiarize ourselves with the Prairie Creek Embayment (Morrow and Cook, 1987) and its extensions into the Nahanni Karst and Tlogotsho Plateau study areas.

Examinations of known mineral showings (with K.M. Dawson in 1986) were coupled with reconnaissance and follow-up geochemical sampling of bedrock. In the Nahanni Karst study area, we reviewed the setting and metallogenesis of the Prairie Creek (formerly known as Cadillac) Ag-Pb-Zn vein hosted by laminated limestone and dolostone of the Sombre Formation. In the Ragged Ranges area we reviewed the Lened (Forster, 1979; Glover and Burson, 1986) and Tungsten (Mathieson and Clark, 1984) skarns, the Vulcan shale-hosted stratiform Zn-Pb-Ba deposit (Mako and Shanks 1984) and numerous smaller prospects as shown in Goodfellow (1982).

The 1986-87 field work was based on our 1985 experience and on consultations with GSC and industry personnel experienced in regional geology (D. Morrow, S.P. Gordey), exploration geochemistry (e.g. B. Ballantyne, D. Paré, R.G. Garrett, W.D. Goodfellow, G. Hall, J. Lynch, F. Michel, W. Shilts and others at the Geological Survey of Canada) and mineral deposits of the region (e.g. K.M. Dawson, I.R. Jonasson, T. Muraro, D.F. Sangster, W.D. Sinclair, B.E. Taylor). This work was incorporated in the geological summary (Section 3 of this report), and Section 6 on mineral occurrences and geochemical anomalies.

Selected initial results of the stream sediment geochemical surveys and analytical data were reported by Hall et al. (1988), Spirito et al. (1988), Jefferson and Paré (1991), Spirito (1992) and several oral and poster presentations such as Jefferson et al. (1987, 1989). Similarly, different facets of the spring water survey were reported by Hamilton et al. (1988 and 1991), Hamilton (1990), Timlin (1991) and Bowman (1990). These reports all made reference to the MERA process, and offered preliminary comments on mineral potential. A separate hydrogeological investigation of the Rabbitkettle Hot Springs (Gulley, 1993) was conducted as part of a Parks Canada study of this feature.

Completion of this Nahanni MERA study was put on hold by the first author, in order to focus GSC resources on the MERA process for other northern national park proposals at Wager Bay - Ukkusiksalik (Jefferson et al. 1991, 1993), Darnley Bay - Tuktut Nogait (Jones et al., 1992, Jefferson et al., 1994) and northern Bathurst Island (Anglin et al., 1999) that were given higher priority by Senior MERA Committee. Other NRCan priorities were also addressed.

This study was reactivated in 2002 at the request of the Senior MERA Committee because progress is being made on the Deh Cho Process. The field and laboratory database is here re-interpreted in light of more recent mineral deposit models (e.g. Eckstrand et al., 1996), and renewed exploration in the South Nahanni River region. This Open File publication of the MERA studies is designed for public review and for consultation as part of these proposals.

Two other resource assessments related to this Nahanni MERA provide important regional context. Fonseca (2001) summarized a resource assessment workshop for the Yukon which involved five well respected mineral deposit experts, and assigned their highest mineral potential ratings overall to a number of tracts, one of which is located adjacent to Ragged Ranges on the west. Specific high assessments for gold and Nick-type sedimentary platinum-nickel are located in adjacent tracts located west and south of Ragged Ranges. Fonseca noted that the importance of Sedex lead zinc potential overwhelms that of most other deposit types, nevertheless it is shown here that a number of other deposit types also have high potential in the South Nahanni River region.

A second resource assessment is under way under the auspices of the DIAND Northern Affairs Program, addressing the need for very broad regional mineral resource potential information related to the Deh Cho lands (Lariviere, pers. com. 2003). The first author of this report has kept in close communication with Lariviere to ensure full transfer of relevant information between the two assessment projects.

2.4. Confidence in this Assessment

In the MERA process (Government of Canada, 1995), Phase 1 assessments involve primarily literature research, application of mineral deposit analogues to the compiled data, and assessment of data gaps (equivalent to the 1985 portion of this study). Phase 2 assessments involve collection of substantial amounts of new data by field work and subsequent laboratory analysis (Scoates et al., 1986).

Early non-renewable resource assessments by the Geological Survey of Canada were mainly Phase I in nature (Scoates et al., 1986). New field and laboratory data specifically published with the assessments were obtained coincidentally by also fulfilling other activities of the Geological Survey (e.g. Jackson and Sangster, 1987; Jefferson et al., 1988; Roscoe et al., 1987).

This and the Wager Bay assessment (Jefferson et al. 1991, 1993) were the first for which additional funding was provided on a three-way cost-shared basis by Parks Canada (then Environment Canada, Parks), Indian and Northern Affairs Canada and the Geological Survey of Canada. This funding was extended by use of M.Sc. student projects (Hamilton, 1990; Spirito, 1992), internal GSC laboratory test projects (e.g. Hall et al., 1988) and by logistical support from Polar Continental Shelf Project. The NWT Mineral Development Agreement provided additional funds in 1988 to support further analysis of heavy mineral concentrates by Consorminex (Jefferson and Paré, 1991). From the beginning therefore, this work featured partnerships that supported research on methods in exploration geochemistry and training of highly qualified personnel while acquiring abundant high-quality resource assessment data.

This assessment involved considerable field and laboratory work as outlined in section 2.3 above. This brought our level of knowledge up to that of a Phase 2 assessment, equivalent to a grass-roots industry exploration program. The MERA process does not progress further than this – drilling and sampling that would be required to develop truly quantitative resource inventories (see Chung et al., 1992) are in the realm of the private sector.

Many of the conclusions here were reached by literature study and review, although the new field data enhanced our understanding of the metallogenic history of the area (that part of the geological history pertaining to the development of ore deposits and the accessory features of those deposits that provide clues to their existence) and improved our confidence. The geochemical sampling and prospecting done for this assessment were relatively intense compared to previous MERAs (see Scoates et al., 1986) and although write-up was shelved for a considerable length of time, this study set the minimum standard for the field component of subsequent GSC resource assessments by emphasizing the importance of new field data..

Even though we consider our data base to be the best possible given the time and resources available to do the assessment, the data points are of variable density because of the large size, variable bedrock exposure of the study area, variable shapes and slopes of catchment basins, and erratic distribution of spring waters. Given these challenges, a focus of this study was to use the best possible means to determine which geochemical results are anomalous. The compromises made in terms of sample density, and types of analyses and data manipulation are presented in the "Methods" sections of chapters 4, 5 and 6. Much of chapters 4 and 5 are devoted to understanding population characteristics of the stream sediment and spring water geochemical data sets.

The assessments presented herein are based on current knowledge of geology and mineral deposit types (e.g., Eckstrand, 1984, 1995; Cox and Singer, 1986; Sheahan and Cherry, 1993). Some deposit types, such as Sedex (layers of sedimentary base metal sulphide minerals) are more predictable based on quantitative geochemical and petrochemical study of large systems than others. Vein gold, and skarn tungsten deposits on the other hand, are formed by a variety of much less constrained processes, operating in much more variable systems. In the eastern South Nahanni River region, sedimentary rocks underlie the entire study area, whereas in much of Ragged Ranges the geology is dominated by relationships between granitoid intrusions and sedimentary rocks. Methods of field work and the interpretations were tailored to these differences. Mineral occurrences were sampled and re-analyzed to see if any geochemical elements are present that might not have been considered economic or were undetected in previous exploration times (e.g. germanium).

A major geological history feature in all of the study areas is the sedimentary environment known as Selwyn Basin. It is named for carbonaceous shales that record an ancient deep water (~350 million years ago) sea in which anoxic conditions favoured the preservation of organic material and metallic sulphide deposits. This deep quiet water environment was flanked on the east by the McDonald Platform which featured carbonate environments similar to coral reefs of today. These platformal strata have been affected by both ancient and modern karsting, with the ancient being favourable hosts for lead-zinc and hydrocarbon accumulations. For these reasons, much effort went into understanding field relationships and lithogeochemical prospecting of potential host rocks such as favourable stratigraphic horizons and interfaces between plutons and sedimentary rocks.

As noted by Brobst and Goudarzi (1984) and Scoates et al. (1986) all assessments are inferences, "best guesses" at the time, and are subject to change as new information becomes available, such as: geoscience data, concepts and deposit types, mineral uses and extractive technologies, and economic-social parameters. Areas should thus be reassessed periodically.

Some areas that have little identifiable resource potential at one time may contain undiscovered new types of mineral deposits. Experience in conducting resource assessments (e.g. at Tuktut Nogait; Jefferson, 1992) has taught us that such new deposits (or known deposit types in new environments) may be recognizable and exploitable in the very near future, or well into the distant future. Such changes for Nahanni are illustrated by the following examples, each of which on its own may have a huge impact on the economic future of this region:

- Our interpretation of gold anomalies in the Nahanni Karst and Tlogotsho Plateau areas is here revised downward from Jefferson and Paré (1991). This was influenced most strongly by the discovery of world class kimberlite-hosted diamond deposits in the Slave geological province, north of Yellowknife (Fipke et al., 1995). The linkage between gold and diamonds is detailed in Chapter 4.
- Our assessment of zinc potential in the Meilleur River and Prairie Creek areas (Spirito et al., 1988; Hamilton et al., 1988) began high, and has been reinforced by the continued exploration and development of the Prairie Creek silver-lead-zinc vein, to which a Mississippi Valley type lead-zinc lens has been added, according to Canadian Zinc press releases. (known to previous operators and K.M. Dawson, pers. comm. 2003, as a manto component).
- The mineral potential in the Meilleur River area is inferred indirectly, because no mineral showings are exposed there (see Chapters 4, 5 and 7). We are encouraged because experience has shown that even superior geoscience databases in well explored and long-inhabited terrains of southern Canada and other parts of the world cannot be considered definitive. The Lisheen zinc-lead-silver deposit in south-central Ireland exemplifies this hidden nature of mineral resources. This part of Ireland has been relatively densely inhabited for thousands of years, but the concept that an economically viable buried base metal deposit might be found here was only imagined in the 1960's, and the search for buried base-metal deposits of this type began in earnest only in 1984 (Hitzman, 1992). Lisheen is a silver-lead-zinc deposit such as might be present at depth in Meilleur River valley.
- In the Selwyn Basin itself, a new nickel-platinum deposit type (Hulbert et al. 1992; Hulbert 1996) was discovered and interpreted as a type of sedimentary exhalative deposit after we had completed our field work. An alternative, meteorite impact hypothesis is also being discussed in the literature (Goodfellow, 2002) and presents different implications for resource assessment. Now we are able to consider empirical clues to the Nick deposit type, whereas if we had completed the MERA report in 1989 or 1990, it would have been omitted as a factor in both nickel-platinum and gemstone potential.
- The Selena Creek placer gold deposit with many accessory elements (Appendix A-1.7) was known when this MERA project began,

but has not been followed up by industry. Nevertheless, the proposed analogy with the world class Carlin deposits has been recently fortified by research summarized by Poulsen (1995) and resource assessments of adjacent tracts in Yukon Territory (Fonseca, 2001).

- When this study was initiated, a volume on mineral deposit types of Canada (Eckstrand, 1984) had just been published, and was the standard for teaching, exploration, and resource assessments. Eleven years later, a much more comprehensive update was published (Eckstrand et al., 1995) which includes more deposit types and improved parameters and understandings for many. The latter provides the mineral deposit analogues used in this resource assessment.

- Although Eckstrand et al. (1995) is extensive, none of the deposit type descriptions apply readily to the Prairie Creek silver-lead-zinc vein. That deposit constitutes its own unique analogue for assessment of Prairie Creek Embayment. On the other hand, Dawson (pers comm. 2003) feels that it is an expression of a distal manto deposit type.

- Emeralds were recently discovered in nearby Yukon Territory (e.g. Groat et al. 2001) and gem potential of the region has been assessed in a preliminary fashion (Groat et al., 1995; Groat and Ercit, 1996; Walton, 1996). None of this information was readily available from Canadian sources in the 1980s, although there was interest in lithium pegmatites, and Brazilian examples existed. Groat's research and gemstone extraction are actively ongoing, two relevant papers were just published (Ercit et al., 2003 and Groat et al., 2003) which outline many questions, therefore new information will be continuously available in the near future. A recent publication on beryllium (Grew, 2002) has not been considered in this assessment.

- An early unpublished hydrocarbon resource assessment was prepared by T. Bird in 1988, showing a general southeastward increase in potential within Tlogotsho Plateau, based on information available at that time. Now, with knowledge derived from the recent discovery of huge gas reserves in the Fort Liard area (10 percent of Canada's total), both a large regional area of high potential and three specific structures are identified as having high potential. In addition, continually evolving quantitative statistical hydrocarbon assessment methodology have been used in our completely new hydrocarbon assessment (Chapter 8). The quality of the geoscience knowledge in this area is also continuously improving because of new mapping (Fallas, 2002; Hynes et al., 2003; Lane and Hynes, 2003).

- The availability of nearby energy from the Liard gas play, as well as the likelihood of a future Mackenzie Valley oil and gas corridor and the changing status, and evolving priorities of the Deh Cho First Nations and local communities have changed the economic setting of the Nahanni region. The exploration industry and land managers are thus re-examining their interests in base metal prospects such as the Prairie Creek silver-lead-zinc, Redstone copper-silver and Howard's Pass lead-zinc, and skarn tungsten deposits such as CanTung (Appendix 1), and discovering new geological information.

This resource assessment and all but the last example of change above are focused on geological criteria which do not take into account numerous economic factors such as politics, local cultures, proximity to market, operating costs versus technology, and high northern salaries which are known to change dramatically over time.

Social and economic considerations are appraised as part of the MERA process (Government of Canada, 1995) but not by the writers of this report. Policy staff of MERA partner agencies, and other stakeholders involved in public consultations will address such considerations. Such economic assessments have been informally discussed during public consultations, but have not been published for northern national park proposals in Canada.

In contrast, British Columbia and United States resource assessment agencies publish estimates of economic values of inferred mineral resources that are then used in public consultations (e.g. Drew, 1997). Such estimates are commonly referred to as “quantitative”, even though they are simply an extension of the inference process, and cannot possibly be derived by a mathematically quantitative method, as proven by Chung et al. (1992). This is because the statistical databases on mineral deposit types, sizes and grades are incomplete, deposit type classifications are still in a state of flux, we lack statistical data on the regional geological context of deposit types, and the economic valuations begin with educated guesses by experts regarding the number and sizes of deposit types in the assessment regions. Therefore, we are confident that the qualitative geological assessments provided here are as good as can be, given the state of knowledge at hand. If communities require a sense of economic analogues, actual operating mines of the given deposit type provide realistic economic, social and environmental scenarios at the present time.

Cultural evolution is changing the boundary considerations for resource assessments. Communities continuously evolve in their interests in and requirements from the land, many of which are related to geology and mineral-energy potential, including plant and animal life, environmental issues, employment and economic development. At this time, mining companies are the main high-technology, highly paid employers in the north, however stakeholders can change their perspectives in favour of, or against mineral development as their boundary conditions and cultures change. Similarly, the needs for protected areas change over time, with parks having different values in different places and times. Concerns about protecting water quality, animal and plant life (ecosystems) and scenic values vary with cultures, times and scientific advances.

With respect to mineral potential outside of the three resource assessment study areas of this report, only scattered data have been acquired, insufficient to document mineral potential for the purpose of determining park boundary configurations or other types of long-term land withdrawals. Nevertheless, in the process of analysing geological information, inferences from known mineral deposit indicators located within a given geological domain can be extended along stratigraphic and structural trends into lesser known areas. Hence mineral occurrences that are located outside of the Nahanni study areas, but within domains that transect the study areas, can provide information that is relevant to the study areas.

Such inferences are a necessary part of any resource assessment. In addition, information gathered in the course of assessing the study areas can be applied where they overlap the existing NNPR whose boundaries have not been finalized and “were not based on a systematic evaluation of resources and constraints” (Parks Canada, 1984a). This is technically feasible because geologic / metallogenic domains extend across both NNPR and the study areas into open land, because the adjacent areas of NNPR are so small compared to the study areas, and because geochemical data had to be collected within NNPR in order to determine base-line conditions and in order to obtain access to catchment basins that overlap NNPR and the study areas.

Nevertheless, any such applications of assessments presented herein, to areas outside of the field study areas, would entail a higher degree of uncertainty than within the study areas because the new geoscience data are located mainly within these study areas. A new regional assessment being conducted by DIAND (Lariviere, pers. comm. 2003) is addressing the need for information on areas outside of the proposed expansion areas.

On the other hand, oil and gas potential (Chapter 8) is assessed in a different areal manner, based only on the known regional geology and the buried extent of two recent main plays, "Beaver River - Devonian and Carboniferous". These have been among the most successful exploratory plays within the Cordilleran Foreland Belt, as measured by the number of cubic metres of initial raw gas in place discovered per metre of new field and new pool wildcat exploration borehole drilled. The Nahanni Karst – Tlogotsho Plateau study area is on the northern fringe of these two plays. The Liard Fold Belt that contains the plays overlaps only the southern part of Tlogotsho Plateau and Nahanni Butte. Based on known high metamorphic grade, the Ragged Ranges study area was not considered at all in this study.

Not all data sets collected by or available to this study have been thoroughly analysed, due to resource constraints. One or more thesis studies could statistically assess these data. Examples include lithogeochemistry of plutons from Garrett (1973, 1992), neutron activation analyses of heavy mineral concentrates from bulk stream silts (Appendix 3.2), an experimental procedure developed for this study (Jefferson and Paré, 1992), and heavy mineral grain counts (Appendix 3.2).

For all the above reasons, this assessment represents the best we can do with the best available information at this time. It is almost a certainty that in the future, say 2013, one or more factors will have changed and this assessment will become less relevant to the land management needs of the South Nahanni River area. Although decisions must be made on national park proposals, and this assessment will be one factor in making such decisions, further reassessment of this area will be warranted as our geoscience knowledge and economic context change

2.5. Organization of this report and Responsibilities of the Authors

This report reviews existing data from published sources, presents results of field and laboratory studies conducted in 1985-1992, interprets these data with reference to published mineral deposit analogues from Eckstrand et al. (1995), and provides qualitative assessments of mineral potential at the Phase II level (see Section 2.4 above) in the three study areas.

The Executive Summary (Chapter 1) was compiled by the first author and Osadetz, derived mainly from Chapters 3, 7 and 8. The first author was responsible for designing and managing the overall project, compiling and producing this report. This Introduction (Chapter 2) and the Geological Setting (Chapter 3) familiarize the reader with the South Nahanni River region and its MERA context and were prepared mainly by Jefferson with contributions from all co-authors. Detailed studies of stream sediment geochemistry (Chapter 4) were headed by Spirito, with additional contributions by Paré and Jefferson on heavy mineral grain counts, placer gold grains and neutron activation analysis of heavy mineral concentrates from silts. Spring water geochemistry and hydrogeology (Chapter 5) were led by Hamilton with guidance by Michel. Mineral occurrences (Chapter 6) were compiled by Hamilton and Jefferson, synopses prepared by Power-Fardy and Jefferson; lithogeochemistry compiled and interpreted by Jefferson. Mineral resource assessment (Chapter 7) was spearheaded by Jefferson, with important contributions from Chapters 4, 5 and 6. Coal assessment was taken by Jefferson entirely from literature sources provided by L.Lane (GSC Calgary), although coal was observed in the field. Hydrocarbon resource assessment (Chapter 8) was led by Osadetz; Chen provided statistical analysis and Morrow the geological context, with assistance by staff at GSC Calgary.

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