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# Mineral and Energy Resource Assessment of the Tlogotsho Plateau, Nahanni Karst, Ragged Ranges and Adjacent Areas Under Consideration for Expansion of Nahanni National Park Reserve, N.W.T.

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# Chapter 1. Executive Summary: Mineral and Energy Resource Assessment of the Tlogotsho Plateau, Nahanni Karst, Ragged Ranges and Adjacent Areas Under Consideration for Expansion of Nahanni National Park Reserve, N.W.T.

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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.

The following areas of high or very high mineral or energy resource potential are located within or adjacent to the study areas:

1. Natural gas in three structures flanking eastern NNPR and the proposed Tlogotsho Plateau expansion, related to the Liard play.
2. Lead-zinc-silver on the western margin of Nahanni Karst and Tlogotsho Plateau, and in Ragged Ranges from Glacier Lake to Vampire Peaks (Vulcan deposit).
3. Tungsten around the Flat River valley near the existing CanTung Mine, Ragged Ranges.
4. Gemstones and rare element pegmatites near plutons throughout the Ragged Ranges.

The South Nahanni River crosses the structural grain of the eastern Selwyn Mountains and southern Mackenzie Mountains. These mountains expose mainly sedimentary rocks, including in very general terms: Neoproterozoic (about 800 Ma) to Late Cretaceous (about 100 Ma) platformal to shale basin sedimentary strata. Older rocks were intruded by minor Devonian (350 Ma) granitoid rocks and all were folded and thrust faulted during the Jurassic (~170 Ma) to Cretaceous collision of an island arc with western North America. During this collision the Selwyn and westernmost Mackenzie Mountains were intruded by major Cretaceous granitoid batholiths. Compressive and right lateral strike-slip adjustments continued throughout the Tertiary (~40 Ma), and to the present, e.g. the 1985 Nahanni Earthquake. This area was also the boundary region between mountain and continental glaciations, preserving an ice-free corridor during the last ice age.

Data for this resource assessment consist of i) updated and integrated bedrock geology, ii) mineral and energy occurrences in the region, including geochemistry of 100 bedrock samples from occurrences; iii) a regional geochemical survey of 484 stream silts, 400 heavy mineral concentrates (HMCs) from gravels and 100 HMCs from large silt samples; and iv) a regional geochemical survey of 114 hot, warm and cold springs. For minerals and coal the South Nahanni River region is subdivided into seven resource assessment domains (Figs. 1.1-1.3). For oil and gas, the area is assessed in relationship to the Liard Fold and Thrust belt that extends from the eastern part of the South Nahanni River region, south into northeastern British Columbia (Fig. 1.4).

The four above conclusions, together with the assessments for all other deposit types considered for the region, are expanded in the balance of this Executive Summary. Section 1.1 and Table 1.1-1.2 summarize the mineral and coal assessments. Section 1.2 and Figure 1.4 summarize the oil and gas assessment that is fully detailed in Chapter 8. Details of the MERA process, park values and these assessments are provided in the seven following chapters.

### *1.1. Mineral Resource Assessment of the Ragged Ranges and Nahanni Karst – Tlogotsho Plateau Study Areas, South Nahanni River Region.*

The study areas are transected by a number of geological domains that extend far beyond the areas of interest but provide a useful conceptual framework within which to compile mineral potential attributes and extrapolate beyond individual field sample points. Nevertheless, mineral potential is assessed only in the three specific study areas, because these are where field work was focused. The small size of even world-class deposits, and the strong variability of structure, stratigraphy and mineral deposit indicators in the study areas all require high density of modern geoscience information to make proper assessments. The mineral potential for domains beyond these three study areas can be confidently determined only with new field work similar to that reported here, in accordance with the MERA terms of reference for national park establishment. With this caveat, the domains and their mineral potential are summarized as follows, in alphabetical order.

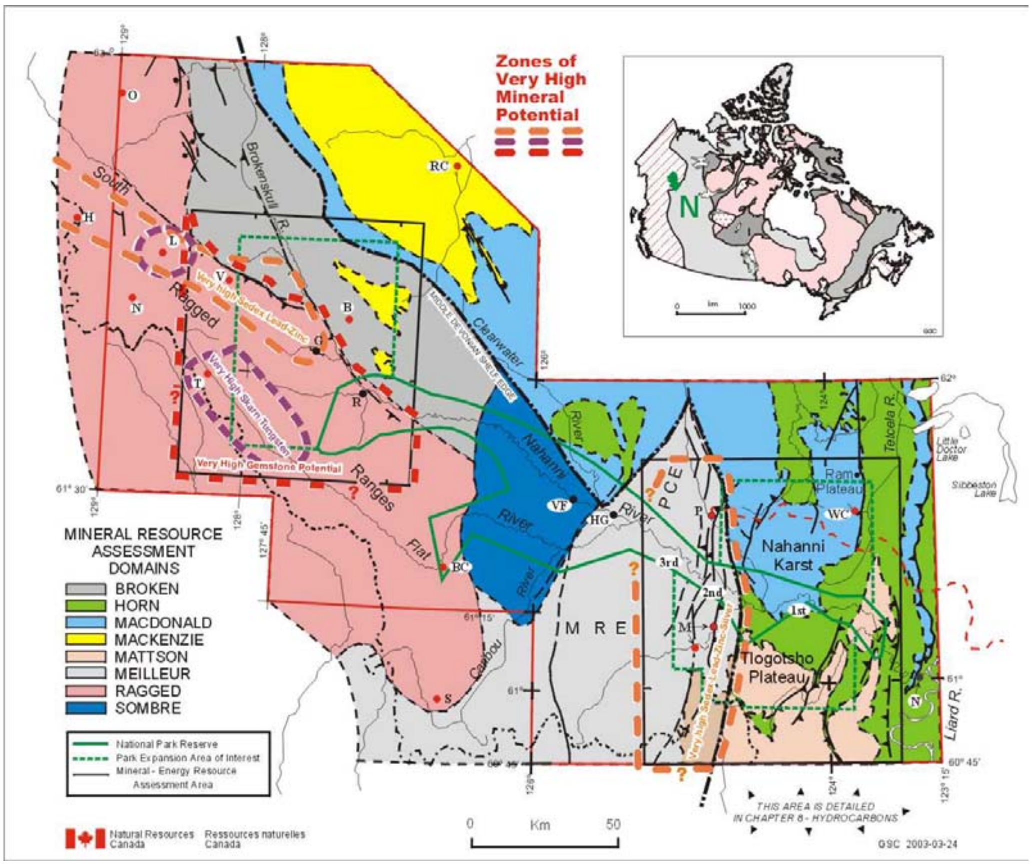


Figure 1.1. South Nahanni River resource assessment overview. Hydrocarbons (SE corner) are detailed in Figure 1.4. Very high potential for specific mineral deposit types is outlined by coloured dashed lines, related to deposit types as labeled. Ratings apply only to study areas, except NW of Ragged Ranges which includes new orientation data.

MRE = Meilleur River Embayment, PCE = Prairie Creek Embayment, SS = Sombre Salient. Localities (black dots) and mineral sites (red dots) are: 1st, 2nd, 3rd = Canyons of NNPR; B = Broken Skull; BC = Bennett Creek placer gold; G = Glacier L., H = Howards Pass zinc-lead; HG = Hells Gate; L = Lened tungsten; M = Meilleur River hot springs; N = Nahanni Butte community; O = O'Grady gemstones; P = Prairie Creek silver-lead-zinc; R = Rabbitkettle Hot Springs; RC = Redstone copper; S = Selena Creek placer gold; T = CanTung Mine and Hot Springs; V = Vulcan zinc-lead; VF = Virginia Falls; WC = "Wretched Creek" (inf.) placer gold. MINERAL RESOURCE ASSESSMENT DOMAINS are explained in text.

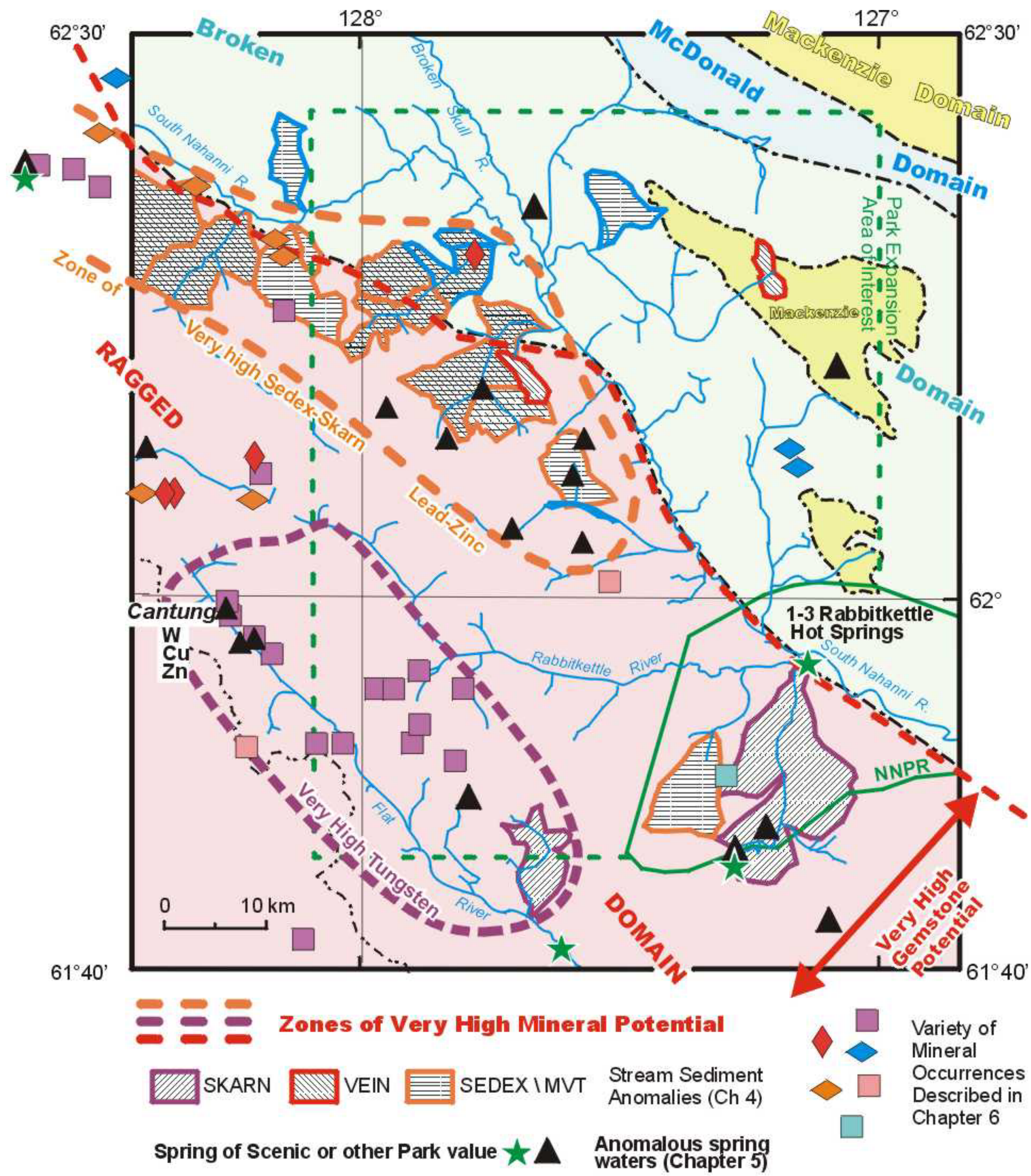


Figure 1.2. Summary of resource assessment domains (large pastel coloured zones, shown regionally in Fig. 1.1) and mineral potential indicators of the Ragged Ranges study area. Shaded polygonal areas represent selected stream catchment basins for which geochemical data are highly anomalous in one or more elements typical of the mineral deposit types represented here (cross hatching indicates two at once). Heavy dashed lines outline zones of very high potential for tungsten (purple) and lead-zinc (orange). Simplified from, and further details summarized in, Chapters 4, 5, 6 (Fig. 6.2), and deposit type assessments of Chapter 7 that are summarized in Table 1.1.

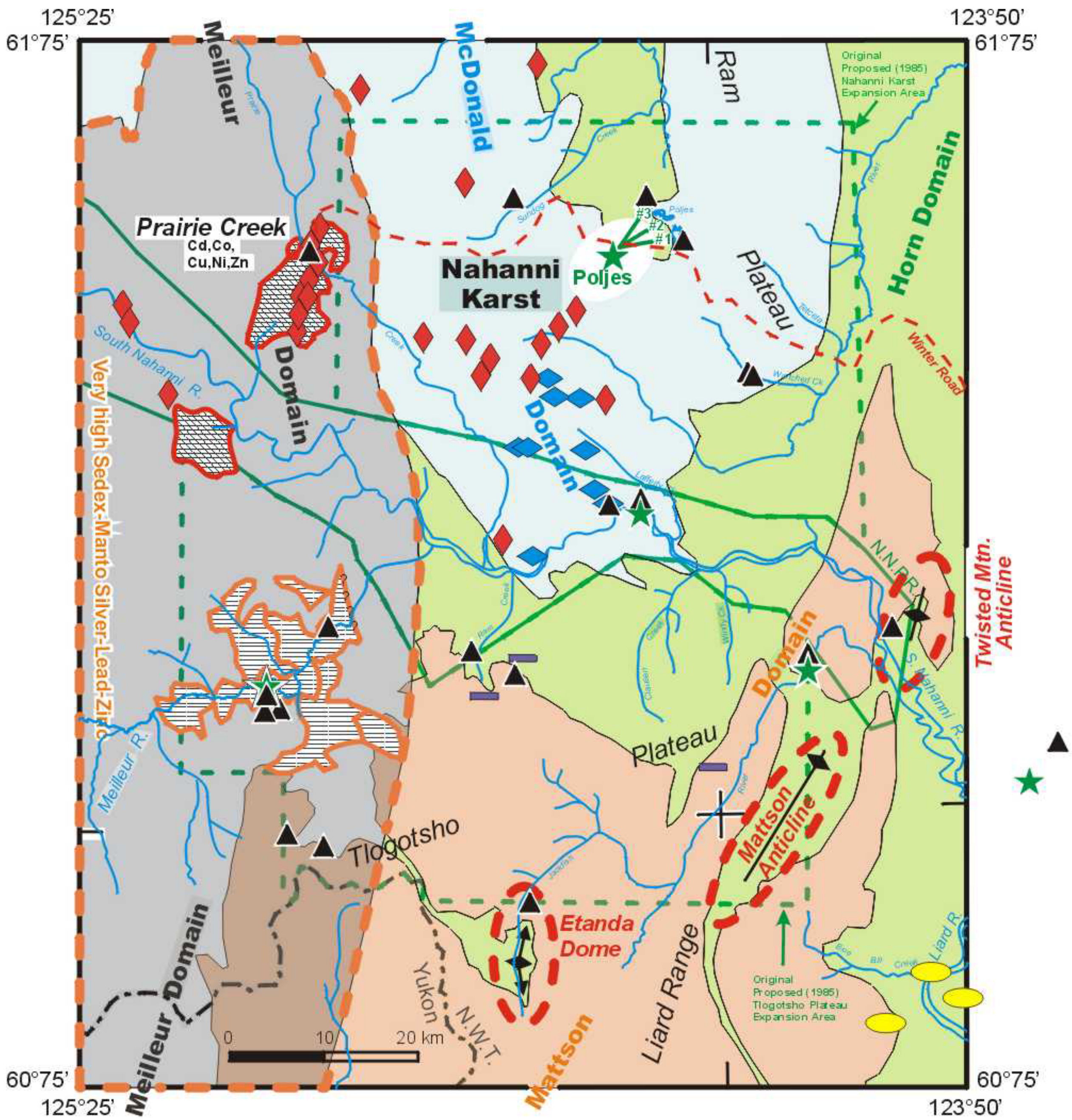


Figure. 1.3. Summary of resource assessment domains (irregular large pastel coloured zones, shown regionally in Fig. 1.1) and mineral potential indicators of the Nahanni Karst and the Tlogotsho Plateau study areas. Symbols and legend as in Fig. 1.2. Heavy dashed orange line outlines the area of very high lead-zinc-silver potential of Meilleur Domain. Meilleur Domain extends beneath Mattson Domain on the west side of Tlogotsho Plateau as shown by mixed pink-grey shade. Etanda Dome, Mattson Anticline and Twisted Mountain Anticline are discussed in the hydrocarbon assessment, Section 1.2. Simplified from, and further details summarized in, Chapters 4, 5, 6 (Fig. 6.3), and deposit type assessments of Chapter 7 that are summarized in Table 1.1.

**Table 1.1.** Resource potential ratings of 5 and above for assessment domains located only within Ragged Ranges and Nahanni Karst-Tlogotsho Plateau study areas. Domains are outlined and only the highest ratings are shown on Figures 1.1, 1.2 and 1.3. Ratings (1 Very High through 7 Very Low) are defined in Table 1.2. Deposit types are described in Chapter 7 after Eckstrand et al. (1995). Host rock units are listed in Table 3.1 and summarized in Chapter 3. Domains are summarized in text here and in Chapter 3.

| **Domain** | Rating | Deposit Type with **Commodities** | **Potential Host-Units, Comments** |
|---|---|---|---|
| **Broken** | 1 | Sedex **zinc-lead-silver** | 3,5; Road River and Earn groups |
| | 4 | Distal skarn **lead-zinc-silver** (also veins?) | 8,1,3; carbonates in shales |
| | 4 | Sedimentary **nickel** sulphides | 3,5; Road River and Earn groups. |
| | 5 | Mississippi Valley-type **lead-zinc** | 4; Sunblood & Sombre formations |
| **Mac-Donald** | 3 | Mississippi Valley-type **lead-zinc** | 4; Manetoe Facies; Arnica - Headless |
| | 5 | Placer **gold** (possible tourist interest) | 9; creeks, 145° structures Ram Plateau |
| **Mattson** | 5 | Placer **gold** (possible tourist interest) | as above in Yohin Ridge |
| | 5 | **Coal** | 7; Mattson Formation (CPm) |
| **Meilleur** | 1 | Vein (Manto) **silver-lead-zinc** | 4; Whittaker Fm, fault at Prairie Creek |
| | 3 | Sedex **zinc-lead-silver** | 3,5; Road River and Earn groups. |
| | 4 | Sedimentary **nickel** sulphides | 3,5; Road River and Earn groups. |
| **Ragged** | 1 | Skarn **tungsten** | 8,1,3; in carbonates at shale facies change intruded by 2-mica plutons. |
| | 1 | Sedex **zinc-lead-silver** | 3,5; Road River and Earn groups. |
| | 1 | **Emeralds** associated with skarns | 8,1,3 in miarolitic veins cutting skarns |
| | 2 | **Elbaite and other gems** associated with plutons | 8,1,3 associated with hornblende granodiorite |
| | 3 | **Lithium** & other **rare elements** in pegmatites | 8, dykes and pods of 8 in 1,3 |
| | 3 | Skarn **lead-zinc-silver** | 8,1,3; carbonates in shales near plutons |
| | 3 | Placer **gold** | 9, alluvium |
| | 4 | Lode **gold*** | 8,1,3 Yusezu, Rabbitkettle, Steel fms. |
| | 4 | Sedimentary **nickel** sulphides | 3,5; Road River and Earn groups. |
| | 5 | Vein **silver-lead-zinc** | 8,1,3, carbonates in shales near plutons |

* Lode gold includes, for the sake of simplicity, disseminated replacement and a broad family of vein-gold-bearing ores that are spatially and genetically linked to magmatic (volcanic and/or plutonic) systems at shallow crustal levels. See Chapter 7.

**Table 1.2.** Explanation of mineral and energy potential rating categories (after Jackson and Sangster, 1987 and Jefferson et al., 1988), based on the application of deposit-type[1] models (Eckstrand et al., 1995) to data bases that include only geology, mineral occurrences and reconnaissance geochemistry.

| RATING | POTENTIAL | CRITERIA |
|---|---|---|
| **1** | Very High | - Geologic environment is very favourable<br>- Significant deposits[1] are known<br>- Presence of undiscovered deposits is very likely |
| **2** | High | - Geologic environment is very favourable<br>- Occurrences[2] are known<br>- Presence of undiscovered deposits is likely |
| **3** | Moderate to high | - Intermediate between moderate and high potential<br>- Reflects greater uncertainty due to fewer data |
| **4** | Moderate | - Geologic environment is favourable<br>- Occurrences may or may not be known<br>- Presence of undiscovered deposits is possible |
| **5** | Low to moderate | - Intermediate between low and moderate potential<br>- Reflects greater uncertainty due to fewer data or inferred greater depth of buried resources |
| **6** | Low | - Some aspects of the geologic environment are favourable but are limited in extent<br>- Occurrences generally not known.<br>- Presence of undiscovered deposits is unlikely. |
| **7** | Very low | - Geologic environment is unfavourable.<br>- No occurrences are known.<br>- Presence of undiscovered deposits is very unlikely. |

[1]"Deposit" refers to a mineral resource of a size that could be developed.
[2]"Occurrence" refers to a drilled or exposed mineral resource that may or may not be part of a hidden deposit.

Broken Domain (Figs. 1.1 and 1.2) comprises a heterogeneous linear array of shale dominated sedimentary rocks, packages 1 to 5, bounded on the northeast by Devonian (~350 Ma) limestones near the Clearwater River, on the southwest approximately by the South Nahanni River, on the southeast by Sombre dolostones that underlie Virginia Falls, and on the northwest by a zone of granitoid intrusions that are part of the Ragged Domain.

Horn Domain (Figs 1.1 and 1.3) comprises several separate irregular areas of thin Devono-Mississippian shales of rock-packages 5 and 6 that drape underlying carbonates of the MacDonald Platform. This domain underlies low topographic areas and hosts the Kraus iron- and sulphur-rich hot springs.

MacDonald Domain (Figs 1.1, 1.2 and 1.3) is dominated by Paleozoic carbonate strata of the Mackenzie to MacDonald platforms which extend from northern Mackenzie River to northeastern British Columbia. In the study area it extends from South Nahanni River to Ram Plateau and hosts the famous Nahanni Karst terrane with sinkholes, caves, disappearing lakes (poljes), underground streams and many small lead-zinc showings.

Mackenzie Domain (Figs. 1.1 and 1.2) comprises Late Proterozoic strata in the core of Redstone and Mackenzie Arches. It contains significant resources of sediment-hosted copper and iron-formation which are located well outside the proposed park expansions and are unlikely to extend into it. The southwestern part of this domain transects the northeast corner of the Ragged Ranges study area.

Mattson Domain (Figs 1.1 and 1.3) comprises Carboniferous to Cretaceous continental sandstones of rock-package 7 which contain common coal seams. Soft ridges and bluffs of the Tlogotsho Plateau expose wind-sculpted sandstone cliffs above soft shale valleys with iron-rich hot springs.

Meilleur Domain, (Figs 1.1 and 1.3) similar to the Broken Domain, comprises rock-packages 3, 4, and 5 which are repeated in a north-trending fold-and-thrust array on the shale side of the Devonian facies boundary. This domain contains the Prairie Creek mine (closed but undergoing exploration by Canadian Zinc) which is part of an extensive northerly trending silver-lead-zinc-quartz-carbonate vein system. The Meilleur Hot Spring, which was discovered by this survey, is a beautiful and fragile resource in its own right, surrounded by a specialized flora of fleabane and wild mint, but also, with other springs and sediments in Meilleur River Valley, a source of evidence for buried lead-zinc-silver sulphide deposits.

Ragged Domain (Figs 1.1 and 1.2) comprises rock packages 1 to 5 (shales dominate over carbonates) and 8 (~ 100 Ma Cretaceous intrusions). Many mineral showings have been discovered in Ragged Ranges, especially the world class CanTung tungsten skarn deposit, and gemstones have been found in very similar rocks located northeast of the Ragged Ranges study area. This domain also contains the highest peaks in the region, with alpine glaciation features, hot springs at CanTung, and a strong variety of other topographic features and hotsprings, such as the tufa mounds at the mouth of Rabbitkettle River.

Sombre Domain is an oblong exposure of Ordovician carbonate rocks, the Sunblood and Sombre dolostone formations, that extend across the middle of Nahanni Park Reserve just above the confluence of the Flat and South Nahanni rivers. Road River Group shales border the west side, southern end, and form its eastern margin along the Caribou River. Sunblood Dolostones host Virginia Falls. This domain is outside the study areas, therefore resource assessments of this domain are not included.

### *1.2. Oil and Gas Resource Assessment of the Ragged Ranges and Nahanni Karst – Tlogotsho Plateau Study Areas, South Nahanni River Region.*

Oil and gas potential is interpreted to be low to moderate within Nahanni Karst and Tlogotsho Plateau study areas, although very high potential is assigned to three structures adjacent to the east and south, along the Fort Liard trend, described below. The highly metamorphosed and deformed Ragged Ranges study area has very low potential.

The following synopsis shows important reservoirs having been breached by normal erosion in the cores of the proposed Nahanni Karst and Tlogotsho Plateau park expansion areas. These exposed reservoirs are excellent for geological research, and are buried toward the east and south in the Twisted Mountain Anticline, Etanda Dome and Mattson Anticline (Figs 1.3 and 1.4) immediately adjacent to NNPR and Tlogotsho Study Area respectively.

The Liard Fold and Thrust Belt structural gas play includes all gas fields and prospects that occur predominantly in Devonian and Carboniferous strata that are antiformally trapped in folded and faulted Laramide diastrophic structures. These plays are defined by regionally extensive reservoir and cap rocks, as well as favourable structural features that are broad and predictable.

This definition is essentially the same as the Canadian Potential Gas Committee's "LFP1 – Liard Fold Belt" play (Procter and Newson, 2002) and it is a field level treatment equivalent to the Geological Survey of Canada's 1992 two-pool based analyses. The National Energy Board of Canada has also studied the region.

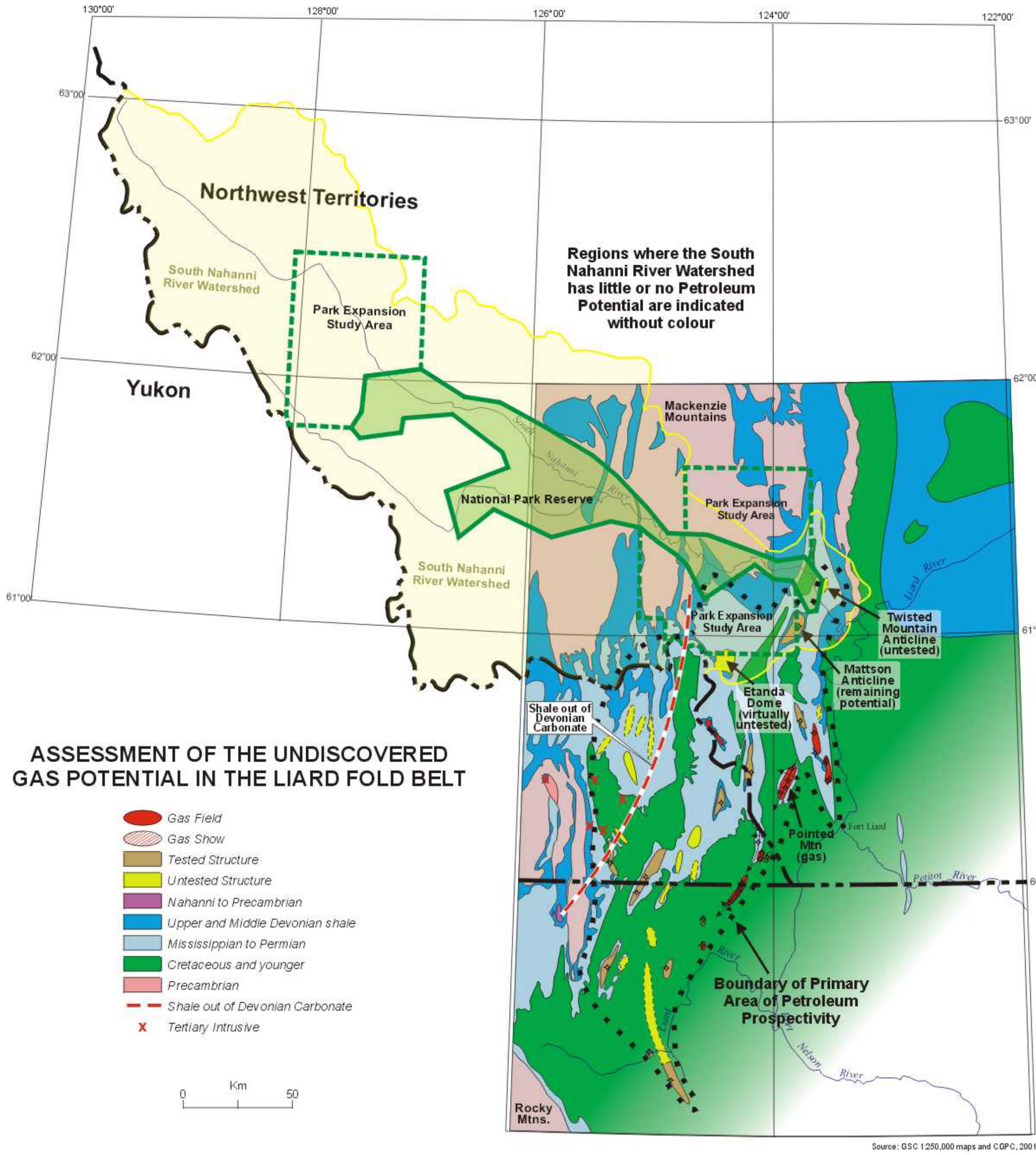


Figure 1.4. Play area map showing the location of the three structures, Etanda Dome, Twisted Mountain Anticline and Mattson Anticline that have high potential for natural gas (Following Procter and Newson, 2002). These structures are shown in more detail in Figure 1.3.

Approximately 59,480 to 65,130 x $10^6 m^3$ (2105-2305 BCF) of natural gas have recently been discovered in 7 anticlinal fields of the Liard Fold and Thrust Belt structural gas play, primarily in Devonian Manetoe dolostone and Carboniferous Mattson clastic reservoirs.

Historically this play (also known as "Beaver River - Devonian and Carboniferous" has one of the best exploratory well success and reserves addition rates in all of the Foreland Belt of the Cordillera. The play area extends across more than 2 million hectares in the Yukon, Northwest Territories and British Columbia.

Two major approaches have been used to assess gas potential and its field-size distribution: geo-anchored and geologically constrained volumetric, as discussed above.

The total petroleum potential of the Liard Plateau structure play is between 181,211 x $10^6$ $m^3$ (6413.1 BCF) and 112,681 x $10^6$ $m^3$ (3987.8 BCF) of initial in-place gas, probably located in 15 to 128 accumulations, including the seven existing discovered fields.

Recent petroleum exploration activity and changes in development strategies have resulted in a renewed interest in this play and the identification of a significant in-place energy resource potential that represents about 1-2% of the national gas reserve and it has a probable value of between $40 Billion and $25 Billion at 2001 export prices.

Recent development activities on structures tested by wells that were previously abandoned also indicates that earlier drilling may not be diagnostic of potential due to reservoir heterogeneities and compartmentalization.

Three large structures are relevant to the Nahanni Karst and Tlogotsho Plateau study areas (Figs. 1.3 and 1.4). The untested Twisted Mountain Anticline lies on the eastern boundary of NNPR and crosses the South Nahanni River. Etanda Dome is located on the south-central margin of the Tlogotsho Plateau Study Area.. The geology of these structures is consistent with each containing initial natural gas resources of 2.8 to 8.5 x$10^9$ $m^3$ (between 100 and 300 BCF), some 2-9 % of the entire play. Between these two structures, the Mattson Anticline has also been tested by a single well. Recent developments in the Liard Field have shown that early exploration tests may not be diagnostic and that the Mattson Anticline retains potential for commercial gas production.

In general the Park Reserve and its proposed extensions cover areas where the burial of the primary reservoir targets is reduced, compared to most of the prospective region of the play. Erosion has reduced the potential for effective top seals on the reservoirs and decreased formation volume factors for gas, within NNPR and its proposed extensions, except for the three structures noted above.

The same rocks that provide some of the most spectacular scenery in the eastern NNPR (Nahanni Karst and the three gorges of South Nahanni River) are the primary reservoirs for petroleum in the subsurface. Scientific and engineering study of these rocks could be conducted in ways that contribute to both efficient sustainable development of the resource outside of the Park Reserve boundaries and an improved educational experience for visitors to the Park Reserve. Additional government-funded research, up to and including the acquisition of seismic data and the drilling of an exploratory well to determine the potential immediately east of the proposed Park expansion, would provide better data to fully understand the implications any land withdrawals covering these prospects.

### *1.3. Caveats*

In regard to "Final" boundaries, this assessment is based on the best information and resource analogues that are currently available, but these tools and our economic environment inevitably change through time (examples in Chapter 2), thus requiring periodic re-assessment. In the case of NNPR, exploration has discovered many showings but coverage is still sparse. The work reported here was begun in 1985. Preliminary assessments were made by 1990, before the project was put on hold because of higher priorities under the MERA process.

Today, with only new contextual data, some of the assessments are much changed (hydrocarbons on the southeastern margin, in Liard Fold Belt among the highest potential in Canada; new gemstone potential in Ragged Ranges; placer gold potential decreased. Some assessments remain unchanged (e.g. very high for lead-zinc-silver in the Meilleur River and Prairie Creek areas). Stakeholders are encouraged to comment and provide any new information or ideas to the authors and MERA committees as outlined in Chapter 2.