ABANDONED MINING EXPLORATION EQUIPMENT IN NUNAVIK

Methods to Identify and Locate Potential Sites

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Abstract Since the 1950s, the territory of Québec has been the site of important mining and exploration works. Prior to 1976, mining companies were not required to clean up exploration sites, and consequently there are a large number of abandoned mine and exploration sites where outdated equipment and empty drums has been left, just as the presence of oil and chemical wastes has become of concern for the Inuit populations due to healt and environment hazards. The main challenge of the inventory project has been to develop methods which has enabled the location of the abandoned sites. The paper present the different approaches to the problem, with details about techniques which have turned out to be effective.

Keywords: Resource exploitation, mine sites, exploration, remote sensing, areal survey, observers, key informants, photographic record

1. PROBLEM

During the 1950s, the territory of Québec situated north of the 55th parallel was the site of important mining exploration works. The deposits of Asbestos Hill (asbestos), Raglan (nickel) and Katinniq (nickel) were discovered in the Ungava Trough. It was only at the beginning of the 1970s that these intensive works were slowed down. Although they started during the 1940s, similar works were pursued in the southern Labrador Trough. The exploitation of iron mines starting from the 1950s led to the establishment of Schefferville and the construction of the railway linking the latter up to Sept-Iles, located on the

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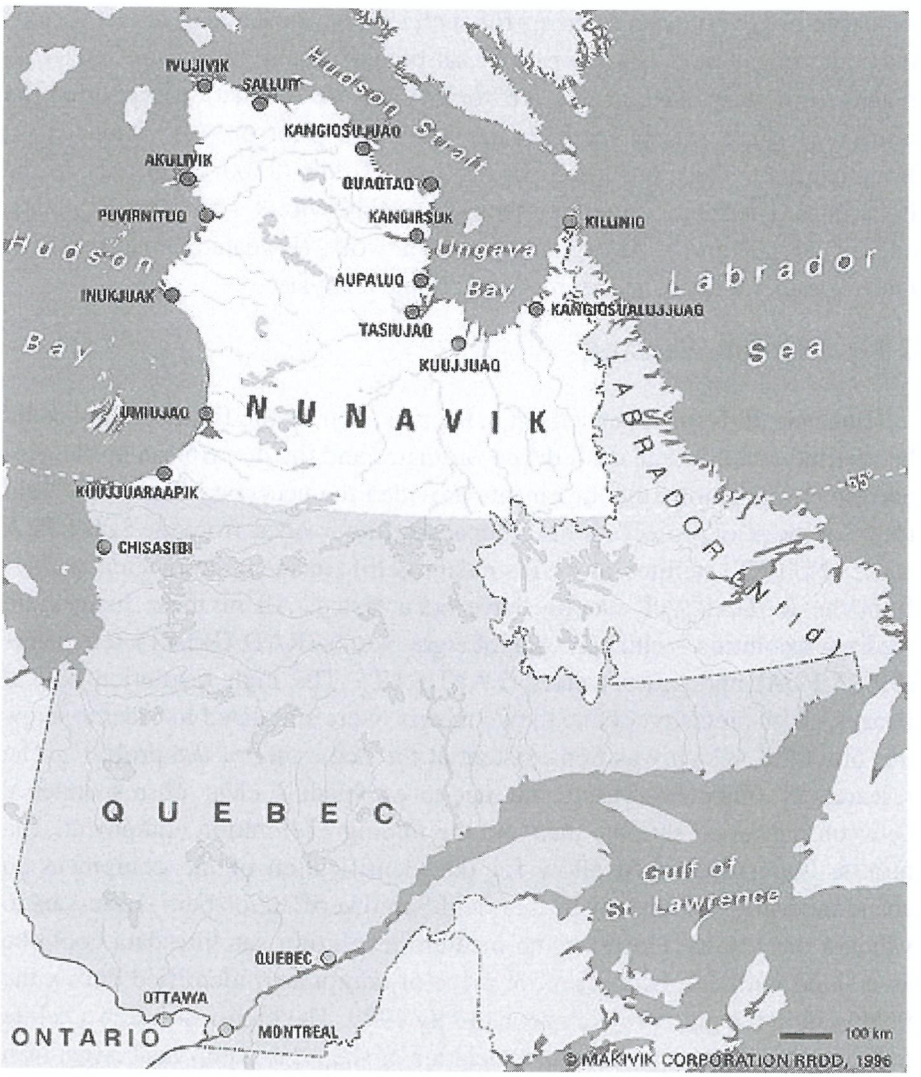
St-Lawrence Gulf. The extraction of iron ore will stop at the beginning of the 1980s. On the Hudson Bay shores, prospecting works were also undertaken, but only for a shorter lapse of time. They had been limited to the coastal areas, mainly in the South.

Prior to 1976, mining companies are not legally required to clean up exploration sites. Some of them do it. But other companies abandoned everything right there, from the prospecting equipment to the facilities for the workers. Others were more selective: only the outdated equipment (empty drums, out of service equipment) or in surplus was abandoned. This decision was furthered by the high transportation costs, resulting from the lack of any road infrastructures. Oil products are quite often part of those surpluses. On the other hand, the abandonment of drills, even if they are out of service, is rarely added on. During the 1990s, the presence of oil and chemical wastes that had been abandoned became of concern for the Inuit populations: the storage conditions fell into decay. Hunters point out regularly the harmful impacts on the environment. In the absence of an inventory of these sites, some large-scale impacts are apprehended, giving rise to great concern.

In 1997, following from the setting up of a cleanup program for the Ungava Bay region, some municipal corporations include some abandoned mining sites in their list of activities. Priority is given to sites that are seen as threatening. Among these sites, some are located far away from the villages and consequently, this increases the operation costs. Above all, a minimal number of mining sites that were known sites by the Inuit has been cleaned up. In 1998, a conclusion is acknowledged: (i) nor the number of abandoned mining sites (ii) neither their harmful repercussions on the environment and territory are known. At the beginning of 1999, we set up a project in collaboration with the northern villages to obtain the required information about the nature and extent of the problem. The following operational objectives were then defined: (i) to determine the number of sites with abandoned equipment, (ii) to identify their exact location, and (iii) to identify equipment, material and toxic substances present on those sites. The period aimed by the project is prior to 1976 during which the first Québec law on environment (Loi sur la qualité de l'environnement) was adopted by the government.



Map 1: Nunavik Territory

2. METHODS

The territory to be surveyed is vast, it is to say 500,000 km2. Locating such equipment is therefore a difficult task. Given that there was no funding

available in government agencies for such survey, we decided to test various methods: no method is known to be as both efficient and cost-effective in regard to the large size of that territory. A private foundation supported the initiative. Three survey methods are used in a pilot project conducted in Kangiqsujuaq. They are tested in a 50 by 50 km (2500 km2) area in the hinterland. These are: (i) remote sensing, (ii) interviews with key informants, and (iii) aerial survey. At the end of the fieldwork, (iv) data from a corpus on Quebec mineral deposits are integrated to the analysis.

2.1 Remote Sensing

Because of the tests carried out in the two other methods, this option could be verified at a minimal cost: the co-ordinates and the description of the sites and the equipment by the informants provided the necessary basis, the "field truth" of the pilot project's zone. Optical satellite images, from the SPOT PLA and LANSTAT satellites, as well as radar satellite images (summer and winter) from the RADARSAT satellite have been tested. All of these images are medium resolution - with precision of eight metres (RADARSAT), ten meters (SPOT PLA) and thirty meters (LANDSAT). The high resolution optical images - with precision of one to two meters, were simulated in order to know this potential, which was non-existent at the beginning of the project[1] . The researchers' objective was to attempt to establish a clear correspondence between the tested satellite data and the mining exploration equipment. The results, if positive, must allow for the identification of the equipment on abandoned sites without any further field-based verification being necessary to validate the results. However, no medium-resolution satellite data could be associated with any equipment, or piece of equipment, identified during the fieldwork in the pilot project's zone in July 1990. The high-resolution satellite data did, however, allow for the association of shapes to equipment larger than one to two square meters: buildings of different sizes and transportation equipment are easily distinguished.

2.2 The Recognition by Observers Aboard a Seaplane (Or Aerial Survey)

A series of flights aboard a seaplane flying at an altitude of 300 metres and at a speed of 100 miles/hrs, and following parallel and equidistant flight lines

one kilometre apart were carried out. Two observers posted at the back side windows were in charge of taking photos, writing down the co-ordinates as they were picked up and displayed by the Global Positioning System (GPS), and briefly describing the abandoned equipment. Two 35mm cameras, one of which with a 38-140 mm zoom lens, were used for the photography. The observers in the front side windows - including the pilot- ensured constant observation of the ground below. The first ground observation (generally) would allow the pilot to slow down and begin the necessary turns in order to pick out the geographical co-ordinates with the GPS as well as to take photographs. After this, with everyone's agreement, the pilot would bring the seaplane back to the flight line in progress in order to continue the observation. Each person, equipped with binoculars, had to observe and scrutinise the surface on a distance of 500 metres from the side of the plane. In all, 46 records of site position were completed during the aerial surveys.

2.3 Interviews with Key Informants

With the help of topographical maps, these interviews emphasise the knowledge of hunters carrying out their activities in the hinterland. At first, the project was presented during a preparatory meeting. It aimed at raising awareness about the various sites associated with the mining exploration and their equipment, products, and typical wastes. Next, during individual meeting, each informant was invited to indicate and detail an abandoned site that he could provide the exact location on the 1 : 50 000 and 1 : 250 000 topographical maps from the Canadian Department of Resources and Mines: every site is then pointed and marked by the informant on a map, and the researcher give a code to every marked site by writing it down on the map. This code is also written down at the top of a separate identification card, made for this purpose, allowing for the collection of information on the abandoned equipment and the condition of the site. This procedure was applied to each site known by an informant. In the pilot project's zone, thirty (30) sites associated with the abandonment of mining exploration equipment had been located.

2.4 the Database on the Mining Deposits

Since our survey aimed specifically at collecting data on mining sites from the period prior to 1976, the archivists from the Québec government's Service

du développement minier examined carefully a former computerised database called COGITE that was used before the setting up of the geo-mining information system called SIGEOM - in 2000, COGITE was still partially integrated (64%) to SIGEOM. The data collected by the archivists forms a corpus that gathers all of the index cards of mining deposits codified in the Catalogue des gîtes miniers du Québec, indicating the state of the deposit: showing (I), prospect (P) and deposit (G). Each of these categories refers to the nature of the work conducted during the exploration: (i) the showing had never been the object of any work, (ii) the prospect gave rise to works allowing for the obtaining of some dimensional parameters without evaluating the tonnage, and (iii) the deposit was the object of works aiming at the evaluation of the tonnage[2] . In 1999, it was only the identification and the location of these three kinds of sites that had been accessible and integrated into the pilot project. In 2000, it was possible to get access to the content of the index cards that include information spread out in eight (8) main headings, such as: "historical background of the works" and "bibliography"[3] . In all, in 1999, 23 mining sites had been located in the pilot project's zone.

2.5 The Analysis of Data by Individual Method and by Cross-checking

In 1999, the systematic taking of photos of the sites during the aerial survey conducted by the observers aboard a seaplane on the one hand, and, on the other hand, the preliminary characterisation of a sample of sites were determining in both the validation of the results and the final choice of methods for the inventory in 2000. By using the aerial survey, besides the location by the GPS and the nature of equipment, the spatial delimitation of every observed site could be regularly determined with a relative reliability. This was made possible by the systematic presence of barrels of petroleum (capacity of 45 gallons) and drilling pipes (three meters), both constituting standard equipment. Furthermore, the preliminary characterisation that was made by both seaplane flights and on foot, starting from lakes to sampled sites, allowed, however, at shedding light on the limits of the aerial survey. Two sites of a significant size (diameter of 10 to 20 meters) had been discovered: the black and white and dusted equipment merged totally with immediate surroundings, preventing them of being identified by aerial observation.

Two statements could then be made from the observation experiences, aerial and on foot, in the pilot project zone. The first statement is linked to the nature of the ground of the arctic hinterland: it is an uneven ground and difficult for walking, where there is practically no trees and little vegetation and sediments - we can cover no more than 1000 feet in five minutes by walking. This datum justifies in itself the use of helicopters or tracked vehicles for the transportation of men and equipment for the exploration works. This led us to adopt an arbitrary rule for the identification of the potential sites: a site includes all pieces of equipment between which an adult can walk in under five minutes on this terrain - that is, under 300 meters (1000 feet).

The second statement follows from the preliminary characterisation: hundreds of empty drums of brine with calcium chloride that compounded most of the equipment discovered in two sites during the examination on foot escaped the aerial survey. Consequently, the sites first indicated by key informants and which were missed by the aerial surveys during the following days remain relevant: the equipment that was sought could have been mixed up with the various elements of the surrounding landscape.

In 1999, a certain number of sites were put aside during the final enumeration. Whether they were not abandoned or they had been merged with another - to make a unique site - in accordance to the proximity rule of 300 meters. In the first case, those sites were located in the northern part of the pilot project's zone. The latter is characterised by the presence of a road network structured around an east-west road linking the Falconbrige company's sites. The positions of many exploration and exploitations sites had been recorded there. They were active, some works being undergone, or they had been recently occupied - the latter sites reveal an exemplary maintenance: equipment put in order, absence of debris. Most of them were at the end or close to a penetration road for the trucks.

In regard to the second case, the examination of the photographs taken during the aerial surveys allowed for the discovery of some large sites at the position where many sites had been identified following from the recording of positions during the aerial survey. The merging of the positions of these sites was made in accordance to the rule of 300 meters. The determination of the distances was facilitated by the omnipresence of barrels on the ground. During the pilot project, this integration had been applied to the sites noted during the aerial survey, or indicated by the key informants as well as to the mining deposits located on the Quebec government's maps[4] .

Photo 1 : Site K-25 seen from seaplane.

Photo 2 : Site K-60 determined by examination on foot

In all of these cases, the evaluations were carried out on maps having a scale of 1 : 50 000 on which the co-ordinates had been transposed. Then, the merging of sites allows for evaluating the potential of mining deposits, the pinpointing of equipment as well as the precision of the location in accordance to the various methods.

However, in 2000, the access to the content of index cards of the mining deposits called into question the precision of the inscriptions of the Quebec government's services miniers. For every site, by comparing the co-ordinates that we picked up from the 1982 map to the ones, when we got access to it in 1999, to the ones included in the file of the database COGITE, we found out a discrepancy with a variation of 50 to 1000 meters in the north-south axis as well as in the east-west axis. All the mining deposits of the pilot zone were affected. This discrepancy called into question our objective to carry out the integration of all of the sites located during the 2000 inventory: if the governmental services could produce such gaps in locating sites on topographical maps with a scale of 1 : 250 000, the indications provided by the key informants from the villages could reveal similar margin of imprecision. This is why the location and identification of the potential sites that were plotted during the interviews in 2000 had been kept as they were without integration.

3. RESULTS

During the survey works in 1999, 101 records of site positions had been taken on the territory of the pilot project's zone. The repartition of sites in accordance to the applied survey techniques can be found in the table hereinafter under "Survey". Next, after a first examination of the photographs taken during the aerial survey, 21 records of site positions have been removed, following mainly from the results of the aerial survey (14) and the use of the maps and catalogues of the Quebec's services miniers (7): they were considered as active because of the on-going exploration works or exploitation works at that time.

The next step consisted in the merging of the records that could be integrated, that is, to apply the proximity rule of 300 meters to the close records of site positions and the equipment by using the photographs taken during the aerial survey.

Techniques/Steps Sites	Survey	=>	Withdrawal (activity)	=>	Potential
Key Informants:	30 records				30 records
Aerial Survey:	46 records				32 records
Examination on foot:	2 records				2 records
Mining deposits (map):	16 records		23 records		
Total	101 records				80 records

Techniques (unique record)	Potential Sites	Techniques (multiple records)	Potential Sites
A. Key Informants	16	**B + B**	5
B. Aerial Survey	16	**A + B**	5
C. Examination on foot	2	**A** (2) + **B**	1
D. Map on Mining deposits	13	**A + B** (2)	1
		A + B + D	1
		A (2) + **B + D**	1
		A (3) + **B** (2) + **D**	1
Total	47	Total	12

The large surface area of certain sites, many hundred of meters, is discovered at that time. These sites include many records resulting from diverse techniques, except the examination on foot. At the end, we get 59 potential sites that can be classified in two different ways: the sites with an unique record (47), that cannot be merged in accordance to the proximity rule of 300 meters, and the sites combining two records of site positions or more (12), still in accordance to the same rule.

3.1 Comments on the Sites Identified by the Key Informants

The observations of the sites with an unique record, except two, and the ones of the ten (10) of the twelve (12) sites with multiple records still have to be validated, that is, they have to be characterised in order to verify the presence of the equipment identified by the informants. Until now, in looking at the details in terms of equipment provided by informants, few of the sites are

characterised with an evaluation of the potential quantity of equipment - except some sites that had been the object of a filming on videocassette (2 with unique record and 2 with multiple records). For most of the sites, the informants limit themselves to the identification of some items (barrels of petroleum, camp, helicopter, tracked vehicle, tripod). Regarding the sites with multiple records, seven (7) records are combined with positions noted during the aerial survey where we find the equipment of the products mentioned during the interviews. There is only one site that regroups records (2) where the detail of the equipment does not fit with the observations noted aboard the seaplane. Then, in the absence of a visit, the regrouping of the records of site positions provided by the key informants that are located unless than 300 meters does not validate, nor invalidate the presence of the equipment detailed during the interview. Meanwhile, (i) it may have been missed during the aerial survey, (ii) it is the margin of error of the location of a site, the one to which it is combined and which was observed during the flight lines, or (iii) it is a mistake made by the informant.

3.2 Comments on the Sites Identified by the Aerial Survey

Among the 16 sites with an unique record located by the aerial survey, the examination of photos allows for observing that their surface areas vary from 2 to 100 meters of diameter, the majority (13) having a surface area with diameter of 40 meters and less. Among the latter, nine (9) are characterised by the presence of 1 to 3 pieces of equipment - standard barrels of petroleum, drilling pipes, piece of fibreglass, canoe, and piece of plywood - , two (2) are characterised by the presence of 10 barrels of petroleum, one (1) characterised by the presence of two barrels and 35 piles of samples of rocks, and, finally, the thirteenth is characterised by the presence of nearly 50 barrels of petroleum of standard format. Regarding the three (3) sites with a diameter of 100 meters, two are located at a distance of 500 to 550 meters from the closest site identified by an informant - the third being at 1,3 km from a site identified as well by an informant. Two contain standard barrels of petroleum (11 and 18) in addition to 1 to 2 pieces of equipment (drilling pipes, cabins, debris on the ground). The last is characterised by the presence of some barrels of petroleum of standard format that were used as signs for a runway and, close to them, an amount of an hundred of empty barrels of brine (chlorine calcium), indicating a drilling site.

Among the 12 sites with multiple records of positions having been identified, the diameter of their surface area varies from 10 meters to 1,35 km. Among them, there are only two (2) that are not regrouped with a site identified by a key informant - rather, they are regrouped with a aerial survey site. But, for one of them, the second closest site identified by an informant is located at a distance of 800 meters and, for the other site, the distance is of many kilometres. Seven (7) sites are characterised by the presence of 1 to 2 pieces of equipment - standard barrel of petroleum, drilling pipe, piece of plywood, cabins - for quantities varying between 4 to 100. Five (5) sites are characterised by the presence of 4 to 8 types of equipment or products - in addition to the equipment mentioned above, we should add: construction (structure), metallic scrap, debris (dry material), gas tanks, drums (chloride calcium) and bottles (chemical products). The sites (2) with 5 to 7 types of equipment are characterised by the presence of gas tanks, many cabins and of 150 to 1150 standard barrels of petroleum.

3.3 Comments on the Mineral Deposits

Among the sites with an unique record, on the 13 records of site positions of mineral deposits, there are 10 mineral deposits of type "showing", 2 of type "prospect" and 1 of type "deposit". Among the positions of type "showing", 9 are at distance varying between 1050 to 4850 meters from the closest site identified by one of the three techniques of survey - the tenth being at a distance of 450 meters from the site identified by a key informant. In other words, any equipment or product has been observed on one of these exploration sites by a key informant or the aerial survey. The two positions of type "prospect" are at a distance of 650 meters from their respective closest site, both having been identified by a key informant. Finally, the position of type "deposit" is located at a distance of 950 meters from the closest site identified by the aerial survey. But, this is the largest site of the pilot project whose limits could not have been completely established given the lack of time to visit it. The mineral deposits included in the sites with multiple records are all of type "prospect". In summary, among the prospects (5) and the deposit confined in the pilot project zone where the abandoned exploration sites were concentrated, five of them were close to a site identified by a key informant - with a distance varying from 200 to 650 meters.

4. CONCLUSION

The main challenge of the inventory project is the current location of the abandoned equipment by the mining industry at the time of their exploration works during the period prior to 1976. The use of various techniques allows for the validation of the results (by comparing them) that were obtained from each of these techniques. Unfortunately, remote sensing is a technique that is not yet completely settled to locate the exploration sites in the hinterland. On the other hand, the aerial survey was determining at that step: the collection of both geographical co-ordinates and photographs of sites with equipment provided the "field truth" that allowed for evaluating the other corpus of data, including the data on mineral deposits that became accessible at the end of the pilot project.

The integration of the data by using the proximity rule of 300 meters allowed for giving an overview of the results according to one's choice of a particular method. It appears, at first, that nearly all of the sites with multiple records have been identified by the key informants and the aerial survey - adding up three (3) of the six (6) mineral deposits where exploration works have occurred (types "prospect" and "deposit"). Next, if we compare the results of the category sites with an unique record, we find that, on the one hand, the results from the aerial survey show that ten (10) of the thirteen (13) sites are compounded of a small quantity of equipment -and among the three remaining sites, there is one site with 50 barrels of petroleum that has not been identified by the key informants. On the other hand, among the sixteen (16) sites with an unique record identified by the key informants, the potential content remains important: camps, helicopter, tracked vehicle, gas tanks - all of theme escape aerial survey.

The choice of the researcher team for the 2000 inventory was based on the following techniques: (i) interviews with key informants and (ii) data collection of the mineral deposits. All of the sites where the key informants mentioned the presence of chemical products and barrels of petroleum in plenty have also been retraced by the aerial survey - including the sites where the presence of cabins (workshop) or shelters (dwelling) has been pointed out. With the documentary data on the mineral deposits of type "prospect" and "deposit", we dispose of complementary techniques to carry out a large-scale inventory at a reasonable

cost. In 2000, this method was applied to cover the whole territory - with "unexpected spin-offs": following the results of the pilot project and inventory, government agencies decided to support the completion of the project. A first characterisation phase was realized in 2001 in the Northwest zone. The second phase in 2002 will cover the Southern and remaining zone. Moreover, governments are looking to fund a five-years cleanup program in Nunavik, involving local workers.

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NOTES

1 A satellite of this kind, called IKONOS-2, was launched on September 24, 1999, during this project. It covers Nunavik. However, its potential applied to sites of the covered area in 1999 is currently assessed by students from Laval University.

2 [1], p. 3.

3 Other headings: "identification", "location", "geological description", "mineralogical description", "genetic model", "other information" and "preparation" (date of the update and its author).

4 See [2].