Climate Change and the Arctic Archaeological Record: An Archaeo-Geophysical Approach to Assess Site Stability and Predict Future Impact

Report on Work Conducted Under Nunavut Archaeological Permit No. 2014-22A

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Cover photo: Dr. Ian Ferguson (Department of Geological Sciences, University of Manitoba) and David Landry (PhD Candidate, Department of Anthropology, University of Manitoba), establishing the grid to conduct an archaeogeophysical survey of Area 5 at the LdFa-1 site, Mingo Lake, NU.

Introduction

This report describes archaeogeophysical fieldwork activities conducted on July 15, 2014 at the LdFa-1 site under Nunavut Archaeologist Permit 2014-22A. This research was carried out in conjunction with a larger ongoing investigation of archaeological sites and chert toolstone source locations in the deep interior region of southern Baffin Island (see Milne NAP report #2014-24A). Dr. Brooke Milne (CEOS, Anthropology, University of Manitoba) is the principal investigator on both projects. Project co-investigators include: Drs. Robert Park (Anthropology, University of Waterloo), Mostafa Fayek (Geological Sciences, University of Manitoba), and Douglas R. Stenton (Culture and Heritage, Government of Nunavut). In 2014, Dr. Ian Ferguson (Geological Sciences, University of Manitoba) joined the research team to oversee the archaeogeophysical survey at the site.

Permits

Other relevant permits and exemptions were acquired by Milne in advance of this research from the following agencies:

- Nunavut Scientific Research License no. 01 028 14N-M (Nunavut Research Institute)
- Qikiqtani Inuit Association Land Use Exemption Permit no. Q14X006

Acknowledgements

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Project Objectives

It is unequivocal that the earth is warming and that this warming is occurring in the Arctic at a rate three times faster than the global average. Increases in the annual average surface air temperature (SAT) in the Arctic are nearly twice those recorded for the rest of the world and are predicted to further increase by 4 to 7° C over the next 100 years. Permafrost is a fundamental feature of the Arctic environment and it is known that increases in SAT result in increased permafrost temperatures, which, in turn, lead to accelerated permafrost thaw and degradation. Moreover, active layer depths (i.e. the layer of ground that thaws and freezes annually) are correlated to warming surface air temperatures and can be sensitive indicators of permafrost stability. A deepening active layer (AL) due to warming will have major impacts on biogeochemical, hydrological, ecological, and pedogenic processes since they occur within the active layer of the soil. It will also lead to soil consolidation and surface subsidence as ice contained within the soil melts.

All of these effects of warming are relevant to Arctic archaeology because stable Arctic permafrost has until now facilitated the unparalleled preservation of millennia-old sites and artifacts, to a degree almost unmatched anywhere else in the world. The Arctic region of the North American continent has seen some of the most fascinating and demanding human adaptations anywhere. The impact of global climate change is expected to have catastrophic impacts on the Arctic archaeological record precisely because it spans the AL and underlying permafrost.

This research aims to use a multi-instrument archaeo-geophysical approach to examine AL depths and permafrost stability at an at-risk archaeological site—LbDt-1—located on the Hone River, 110 km inland from Iqaluit, NU. Our investigative methodology combines surface (i.e. terrestrial LiDAR) and subsurface remote sensing technologies (i.e. ground penetrating radar (GPR), electrical resistivity (ER), and electromagnetic conductivity (EC)) and will collect a range of complementary data to address three objectives: (1) evaluate the current stability of the permafrost across the entire LbDt-1 site and determine if it varies with the natural and cultural topography, in order to gauge whether any areas of the site are at differential risk; (2) use the information acquired from objective 2 to develop a predictive model identifying the most vulnerable parts of similar sites; and, (3) collect data on permafrost stability from an area not presently monitored by climate scientists.

An archaeogeophysical approach like the one proposed in this study has not been previously executed in this region of the Arctic; therefore, another important objective of this study is to test the instrumentation in the field to determine its suitability for this kind of on-the-ground research into AL depths and permafrost stability, and for future archaeological site prospection.

Activities in 2014

Milne, Fayek, and Landry identified LbDt-1 in 2013 and based on preliminary investigations of the site, the research team agreed to return again in 2014 to further explore the site’s occupational history and geology. It was further agreed the site would be ideal to execute a pilot study investigating AL depth and permafrost stability given its complex topography, prominent structural features (e.g. tent rings, hearths), and expansive lithic debitage scatters. These characteristics would allow us to assess if AL depths and permafrost stability varied in relation to these natural and anthropogenic features.

Based on our previous experience at LbDt-1, the decision was made to access the sites daily using a Twin Otter aircraft rather than a helicopter. This larger aircraft would enable us to more easily transport the LiDAR system and suite of geophysical instruments intended for use in our site investigations. All of this equipment is bulky and heavy, and easily exceeds the stowage capacity of a helicopter. As such, Milne arranged for daily Twin Otter flights to access the site from Iqaluit from July 14 – 21, 2014.

Much to our disappointment on the first day of fieldwork (i.e. July 14), the pilots could not find a suitable landing spot for the aircraft at LbDt-1 despite more than an hour of searching (see Figure 1). The research team returned to Iqaluit on July 14 and Milne requested to amend the archaeology permit to shift the project's focus to LdFa-1—a site located on the northwest shore of Mingo Lake that has been accessed by Twin Otter more than a dozen times in previous fieldwork projects.

With the amended permit, the research team set out on July 15, 2014 to access LdFa-1. Once again, the pilots circled the site for approximately 30 minutes after deeming landing areas used in previous years unsuitable. Eventually a very rough landing spot was identified and given the difficulties encountered, the pilots were not willing to return to LdFa-1 in subsequent days. Therefore, our research efforts in 2014 were restricted to a single day and a mere eight hours on the ground.

Figure 1. Overhead view of the upper component at LbDt-1 taken from the Twin Otter as the research team circled looking for a suitable landing spot.

Archaeogeophysical Survey

Knowing there was limited available time to conduct any kind of survey, the research team set out to establish a 20 x 20 m grid with a horizontal line spacing (x-axis) of 0.5 m in Area

5 of LdFa-1 (see Figures 2 and 3). The instruments transported to the site on July 14 included a magnetometer/gradiometer and EM31 Profiler, both of which are used in electromagnetic surveying. Area 5 was chosen for the survey since in 2008, Park excavated two test units in this part of the site, which yielded abundant lithics and faunal remains. Therefore, we knew past populations had used the area even though there was no discernible evidence for it on the surface. The goals of the survey were to test the feasibility of the geophysics instrumentation in this Arctic environment and to see if any measurable differences in magnetic levels associated with the disturbances created by the subsurface testing and/or past human activities could be detected.

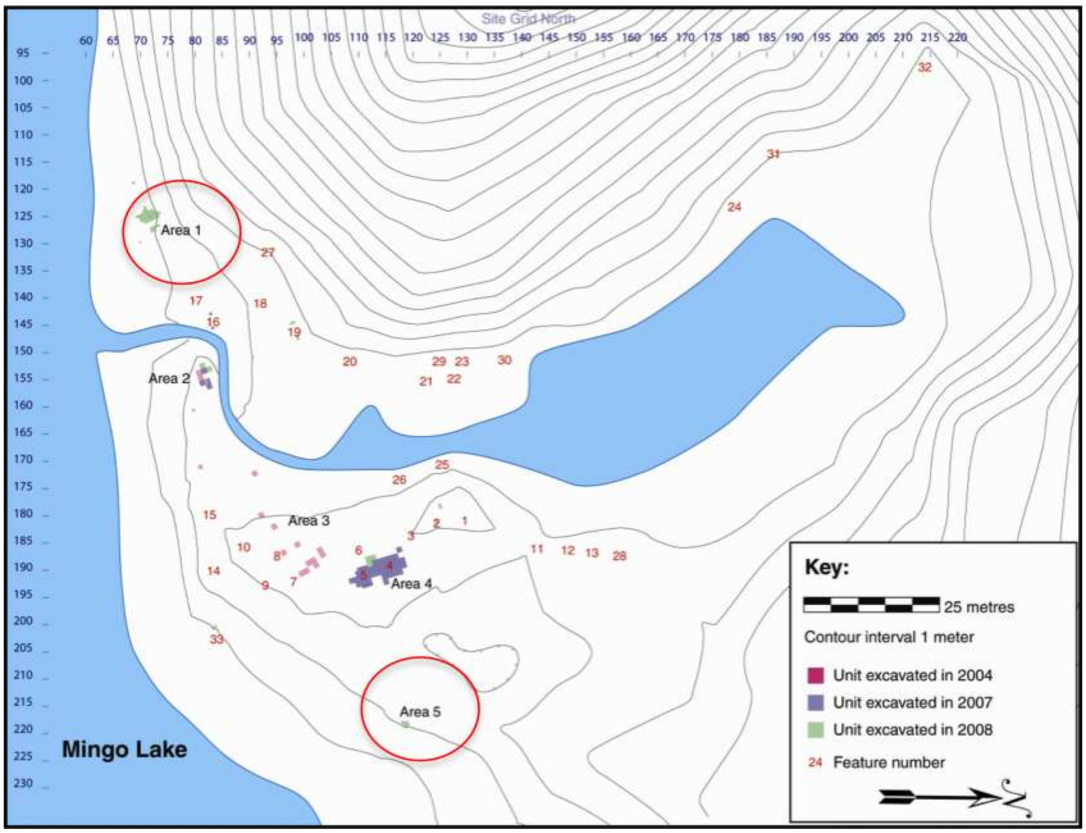

Figure 2. Map of LdFa-1 site indicating five discrete areas of investigation. Test units in 2014 were excavated in Area 1 while an archaeogeophysical survey was conducted in Area 5.

Measurements of the magnetic susceptibility were taken every 20 cm along the vertical axis (y-axis) to provide greater Y-axis resolution (see Figure 4). A local base-station was set up and used to correct for diurnal fluctuations in the Earth's magnetic field along with a vertical gradient to correct for any isolated changes. The corrected survey results illustrate gradual/natural changes in soil and bedrock susceptibility from the northwest corner of the grid down to the southeast corner, which is lowest point of elevation in the survey area.

What is of particular interest are the higher levels of magnetic variation observed around the test pits. The magnetic levels in this area may be attributable to two factors. One possibility is that activities relating to burning or cooking may be creating these levels of remnant magnetism (i.e. the original site occupants had a fire of some kind in this location). It is also possible the 2008 test excavations had an effect on the soil in this area since such disruptions can increase or decrease the magnetism at the surface. In all likelihood, both scenarios are correct since excavated faunal remains from the tests yielded evidence of subsistence activities and the test excavations did indeed cause disturbances to the soil.

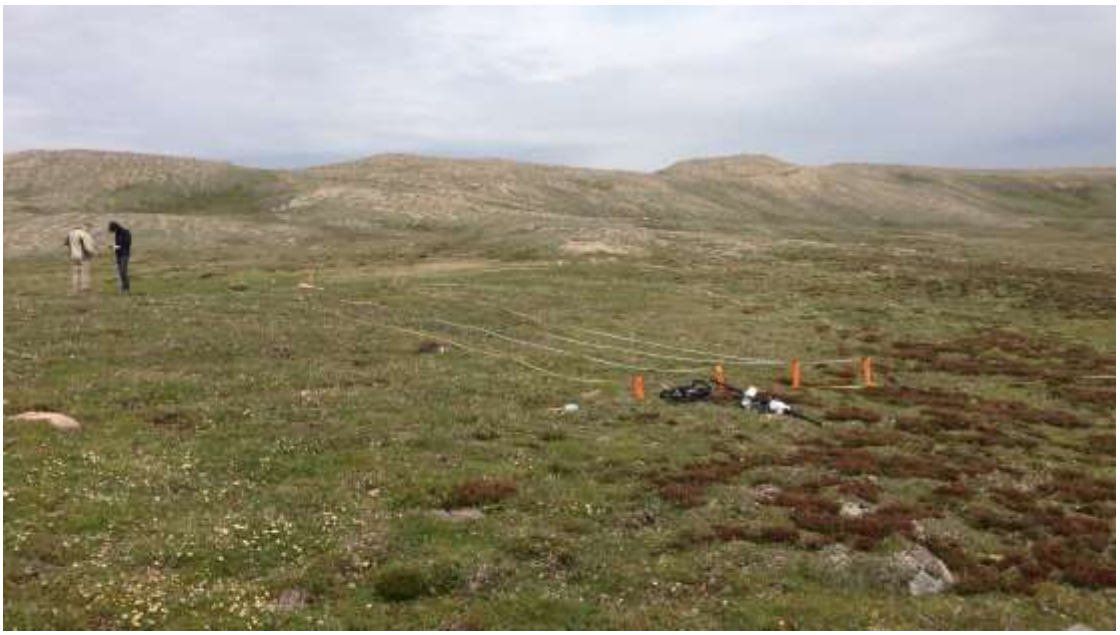

Figure 3. Ferguson and Landry establishing 20 x 20 m survey grid in Area 5 at LdFa-1.

Figure 4. Ferguson and Landry using the magnetometer/gradiometer to survey Area 5 at LdFa-1.

2014 Survey Results and Research Plans for 2015

The magnetic and magnetic susceptibility survey identified subsurface anomalies that positively correspond to the locations of Park's 2008 test units (see Figure 4). Moreover, they identified an approximately 4 m diameter, roughly circular arrangement of igneous boulders that resemble the outline of a Palaeo-Eskimo tent ring feature. Based on these results, future testing at the site can be effectively focused to ground truth these areas resulting in the possible identification of structural remains that are otherwise invisible on the surface.

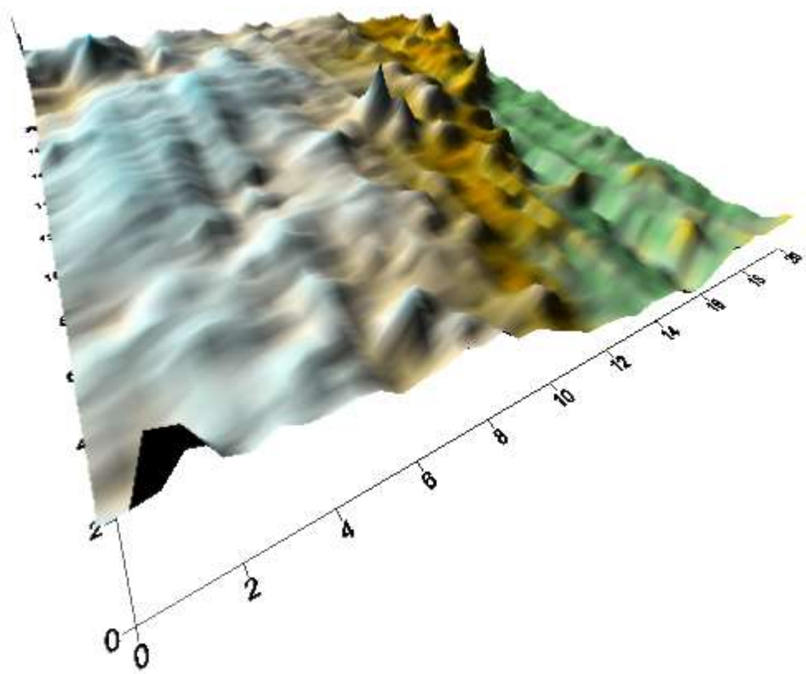

Figure 4. Illustration outlining those locations exhibiting higher levels of magnetic variation within the 20 m x 20 m survey grid in Area 5 at LdFa-1. Those locations with the highest readings are located between 10-14 m on the x-axis and 7-10 m on the y-axis. This is where the 2008 test units are also located (figure from Landry et al. 2015).

These results demonstrate the effectiveness of using non-invasive remote sensing technologies to delineate the structure and organization of archaeological sites. It would take days to weeks to excavate the equivalent area at the site to achieve the same information, which would also invariably result in the destruction of the deposit.

The use of magnetic and electromagnetic methods has contributed to our overall understanding of the lithogenic responses and subsurface properties at the site. For example, we now have an improved understanding of the range of magnetic features that can be identified in this complex geological environment. They also revealed that the soils at the site are highly resistive and thus ideal for future studies at LdFa-1 that aim to use ground penetrating radar (GPR) and multiprobe resistivity meters. These instruments will provide complementary, high-resolution data against to compare the results for the 2014 survey. The research team intended to use these instruments during the 2014 field season but could not given the logistical problems encountered.

Overall, this brief survey provided valuable information for our planned investigations at the site in 2015, which will use all of the instrumentation noted to conduct a thorough assessment of the larger LdFa-1 site area. Perhaps most importantly, we know in advance that the instrumentation, especially the GPR, will work given the local soils and geology of the site; therefore, the data acquired in 2014 met the fourth objective outlined for this study.

The 2015 survey will be well positioned to collect the data needed to tackle the remaining three objectives. Given the uniqueness of LdFa-1 as a multi-component archaeological site in the deep interior of southern Baffin Island, the 2015 survey will provide important baseline information on the site's AL depths and permafrost stability.

A detailed discussion of the 2014 archaeogeophysical survey at LdFa-1 can be found in Landry et al. (2015).

Artifacts

The investigative activities covered by this archaeological permit did not involve any subsurface testing or surface collection of artifacts or related materials. Therefore, there is no artifact catalogue associated with this permit and no loan request to borrow materials from LdFa-1.

References Cited

Landry, David B., Ian J. Ferguson, S. Brooke Milne, and Robert W. Park
2015 Combined Geophysical Approach in a Complex Arctic Archaeological Environment: A Case Study from the LdFa-1 Site, Southern Baffin Island, Nunavut. *Archaeological Prospection* DOI: 10.1002/arp.1505