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Subject: MGT – Trip Report - Geophysical Investigations

Date: November 4, 2010

To: Steven K. Chick
State Conservationist, NRCS
Lincoln, Nebraska

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Purpose:

At the request of the Panhandle RC&D and the Northern Cheyenne Tribe, an electromagnetic induction (EMI) survey was conducted to identify the burial area of tribal members killed during the “*Cheyenne Outbreak*” from Fort Robinson, Nebraska, during the winter of 1879. In addition, the site of the *Dear’s Trading Post* (circa 1873 to 1881) at the Red Cloud Agency was indentified and mapped using EMI.

Participants:

Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Eva Foot, Northern Cheyenne Tribe, Lame Deer, MT
Robert Little Wolf, Northern Cheyenne Tribe, Lame Deer, MT
Ronald Moore, RC&D Coordinator, Panhandle RC&D, Scottsbluff, NE
Edna Seminole, Northern Cheyenne Tribe, Lame Deer, MT
Terry Steinacher, State Preservation Archaeologist, Nebraska State Historical Society, Crawford, NE
Winslow White Crane, Northern Cheyenne Tribe, Lame Deer, MT
Gilbert White Dirt, Northern Cheyenne Tribe, Lame Deer, MT

Activities:

All activities were on September 30 and October 1, 2010.

Summary:

1. Members of Northern Cheyenne Tribe from Lamb Deer, Montana, were present to observe the EMI survey of the *Saw Mill* site. A shaman or “medicine-man” provided an opening prayer and later consecrated the suspected burial area identified by historical documents, photographs and the results of the EMI survey.
2. An EMI survey of the *Saw Mill* site revealed a likely location. However, resolution was poor and identification required other sources of available information. Presently, it is uncertain if any remnants of the burnt-down saw mill structure remain or have been either washed away or buried beneath deep deposits of recent alluvial materials. The general area identified by the results of the EMI, however, was accepted as the most probable location of the former saw mill.
3. In the past, for a vast majority of the archaeological EMI surveys the quadrature phase response (apparent conductivity) alone was typically used. The newly-developed EM38-MK2 meter simultaneously records both conductivity and susceptibility data for two penetration depths. As a consequence, both sets of data are now available to archaeologists. As shown in this report, the use of both apparent conductivity and susceptibility data can improve interpretation. At the *Dear’s Trading Post* site, compared with the conductivity data, the susceptibility data provide more impressive and informative results.



4. An Excel worksheet containing all geo-referenced EMI data have been forwarded to Terry Steinacher (State Preservation Archaeologist) for importation into GIS.

It was the pleasure of Jim Doolittle and the National Soil Survey Center to work with members of the Northern Cheyenne Tribe and the Nebraska State Historical Society and be of assistance in this project.

/s/ David Hoover, Acting

JONATHAN W. HEMPEL
Director
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cc:

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Technical Report on EMI investigation at Fort Robinson on September 30 and October 1, 2010.

Jim Doolittle

Background:

In 1877, members of the Northern Cheyenne tribe were extradited from their northern Plains homeland to a Southern Cheyenne reservation located in what is now Oklahoma. In 1878, more than 350 Cheyenne under the leadership of chiefs Dull Knife and Little Wolf broke free from the reservation and began a trek northwards to their northern Plains homeland. In Sand Hills of Nebraska, the group under Dull Knife decided to separate from the group and seek refuge at the Red Cloud Agency. Unknown to the Northern Cheyenne, the Agency was occupied by soldiers. An army patrol seized this party (about 149 Northern Cheyenne) and took them to Fort Robinson, where they were confined in cavalry barracks. On the night of January 9, 1879, the Cheyenne broke out of the barracks intent on escaping and returning to their homeland. This event has been referred to as the "*Cheyenne Outbreak*". During this attempted outbreak, several members of the Northern Cheyenne tribe (fourteen men, nine women, and four children) were killed and their bodies brought back to Fort Robinson. Two historical accounts tell that the bodies were brought back to the fort's saw mill. However, the fate of these bodies was never recorded in military documents. The winter of 1879 was exceptionally cold and the ground was frozen. As a consequence, excavating grave site(s) was unlikely, and it is possible that the bodies were buried in the saw mill's pit. Twenty years after the event, a scout, who was at Fort Robinson at the time of the *Cheyenne Outbreak*, recounted that the bodies were buried in the sawmill pit.

The saw mill and pit have long since disappeared. Documents reveal that the saw mill was burned to the ground. No details are available as to the disposition of the tools associated with the mill or the composition of the burnt debris. Today, the approximate location of the saw mill has been roughly estimated from older Army photographs taken at a distance from the fort. However, the identified area is spatially, rather large. The identified area is next to the White River, which has experienced several known catastrophic episodes of flooding. As a consequence, remnants of the saw mill, if present, are believed to be buried beneath about 2 to 3 meters of recent alluvium. It is unknown whether debris from the fire had been carried away by earlier flood events. The objective of this survey was to use electromagnetic induction and global positioning systems (GPS) to locate and georeference the likely site of the former saw mill and pit. Members of the Northern Cheyenne Tribe are interested in locating the burial area, obtaining closure, protecting the burial area, and erecting a monument.

An additional EMI survey was conducted on the grounds of the Red Cloud Agency to situate and georeference the former *Dear's Trading Post* (circa 1873 to 1881). Established in 1873, the Red Cloud Agency was a supply distribution point for the Sioux, Cheyenne and Arapaho. Structures at the Red Cloud Agency included a large warehouse, blacksmith shop and stables, offices, homes, and two trading posts; one was the *Dear's Trading Post*.

Equipment:

The EM31 and EM38MK2 meters (Geonics Limited; Mississauga, Ontario) were used in the investigations¹. These meters require no ground contact and only one person to operate. These meters are typically used to measure the apparent conductivity (EC_a ; measured by the quadrature component) of soils and earthen materials. Apparent conductivity is typically expressed in milliSiemens/meter (mS/m). Though infrequently used in the past for soil and archaeological investigations, both meters can measure the apparent magnetic susceptibility (inphase component; ratio of secondary to primary magnetic fields). The apparent magnetic susceptibility of earthen materials depends on the magnetic concentration,

¹ Manufacturer's names are provided for specific information; use does not constitute endorsement.

composition (type of minerals) and grain size (Dalan, 2007). Susceptibility is the ratio of the secondary to primary magnetic fields and is expressed in parts per thousand (ppt). Differences in magnetic susceptibility have been used as indicators of human occupation and soil disturbance.

The EM31 meter weighs about 12.4 kg (27.3 lbs), has a 3.66 m intercoil spacing, and operates at a frequency of 9,810 Hz. When placed on the soil surface, the EM31 meter has nominal penetration depths of about 3.0 and 6.0 meters in the horizontal dipole (HDO) and vertical dipole (VDO) orientations, respectively (McNeill, 1980). In either dipole orientation, the EM31 meter provides measurements of both EC_a and susceptibility for one depth interval. McNeill (1980) describes the principles of operation for the EM31 meter.

The EM38-MK2 meter operates at a frequency of 14,500 Hz and weighs about 5.4 kg (11.9 lbs). The meter has one transmitter coil and two receiver coils, which are separated from the transmitter coil at distances of 1.0 and 0.5 m. This configuration provides nominal penetration depths of about 1.5 and 0.75 m in VDO, and about 0.75 and 0.40 m in the HDO. In either dipole orientation, the EM38-MK2-2 meter provides simultaneous measurements of both EC_a and susceptibility for two depth intervals. Operating procedures for the EM38-MK2 meter are described by Geonics Limited (2007).

A Trimble AgGPS 114 L-band DGPS (differential GPS) antenna (Trimble, Sunnyvale, CA) was used to georeferenced EMI data collected with the EMI meters.² An Allegro CX field computer (Juniper Systems, North Logan, UT) was used with the meters to record and store both GPS and EMI data¹. The RTM31 and RTM38MK2 programs (Geomar Software, Inc., Mississauga, Ontario) were used with the EM31 and EM38-MK2 meters, respectively, to display and record both GPS and EMI data on the Allegro CX field computer.²

To help summarize the results of the EMI surveys, the SURFER for Windows (version 9.0) software (Golden Software, Inc., Golden, CO) was used to construct the two-dimensional simulations shown in this report.² Grids were created using kriging methods with an octant search.

Survey Areas:

Saw Mill Site:

The approximate location of the former saw mill (about 42.6584 N. Latitude, 103.4624 W. Longitude) is in overgrown grassland with numerous cottonwood and willow trees. An uneven ground surface with dense grasses, brambles, trees and tree limbs made the EMI survey difficult and arduous. Some areas were missed. The survey area is border by and located near the confluence of Solider Creek with the White River. The site has been mapped as Glenberg fine sandy loam, channeled, frequently flooded (1031). The very deep, well drained Glenberg soils formed in stratified calcareous alluvium on flood plains and low terraces. Glenberg is a member of the coarse-loamy, mixed, superactive, calcareous, mesic Ustic Torrifluvents family.

Dear's Trading Post:

The approximate location of the former *Dear's Trading Post* was in the southwest corner of the Red Cloud Agency (42.6584 N. Latitude, 103.4624 W. Longitude). Low native grasses cover this site. While this site was more accessible to EMI, uneven ground surfaces still made the completion of the survey difficult and arduous. The site has been mapped as Sarben fine sandy loam on 9 to 30 % slopes (6093). A small unit of Jayem loamy very fine sand on 6 to 9 % slopes is in the southeast corner of the survey area. The very deep, well drained Sarben soils formed in reworked loamy and sandy sediments in sand-loess transition areas. Sarben is a member of the coarse-loamy, mixed, superactive, nonacid, mesic Aridic Ustorthents family. The very deep, well to somewhat excessively drained Jayem soils formed in

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sediments weathered from noncalcareous sandstone. Jayem is a member of the coarse-loamy, mixed, superactive, mesic Aridic Haplustolls family.

Survey procedures:

Random surveys were conducted across both sites with EMI meters. The EMI surveys were completed by randomly walking across all more open and accessible areas of each site with a meter held in the VDO (exploration depth of about 0 to 5 m for the EM31 meter (held at hip-height), and 0 to 150 cm for the EM38-MK2 meter (held about 5 cm above the ground surface)). Because of flood-related recent deposits, the deeper-sensing EM31 meter was used at the *Saw Mill* site. An EM38-MK2 meter was used to locate *Dear's Trading Post*.

Results:

Saw Mill Site

At the *Saw Mill* site, soil materials had an average EC_a of about 28 mS/m with a range of about -111 to 136 mS/m. However, one-half of the measurements collected at this site were between about 37 and 58 mS/m. The apparent magnetic susceptibility average about -1.49 ppt with a range of about -20.4 to 20.5 PPT. However, one-half of the susceptibility measurements collected at this site was between about -1.8 and -1.33 ppt. The wide ranges of EC_a and magnetic susceptibility values reflect the presence of metallic cultural features

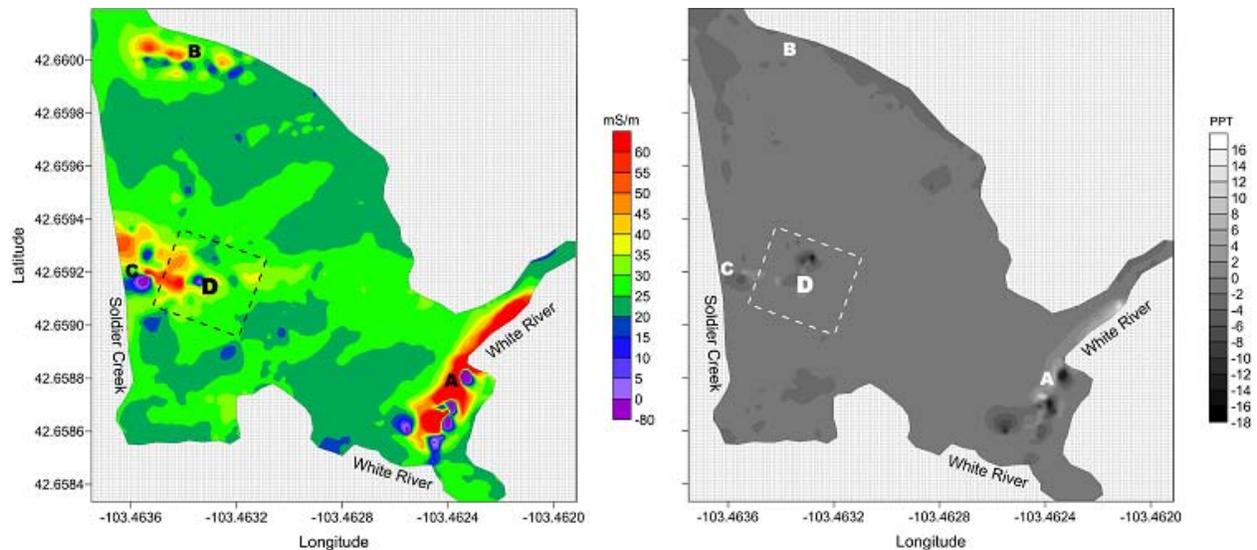


Figure 1. These plots from the suspected “Saw Mill” site depict quadrature (left plot; apparent conductivity) and inphase (right plot; apparent susceptibility) data collected with the EM31 meter operated in the deeper-sensing VDO.

Figure 1 contains plots of EC_a (left-hand plot) and magnetic susceptibility (right-hand plot) data collected at the *Saw Mill* site. Different colors and scales have been used in each plot. Similar labels are used in both plots. Near the embankment to the White River, segments of a partially buried, abandoned fence line were repeatedly crossed by the EM31 meter producing the anomalous, high conductivity and susceptibility, linear pattern (see A) in each plot. Recently deposited and identifiable cultural debris covers the surface near B. While this debris is detectable in the plot of EC_a data, it provides no measurable apparent magnetic susceptibility response (right-hand plot), which suggests a dearth of metallic objects. A mound of debris and earthen materials, and the metal bridge over the former location

of Soldier Creek produce anomalous spatial patterns near *C*. The most probable location of the saw mill has been enclosed in a rectangle with anomalies identified near *D* in both plots. The EMI survey reveals anomalies in this area (Fig. 1), but definition is rather poor. It is unknown whether any remnants of the burnt-down saw mill remain or have been either washed away or buried beneath deeper deposits of recent alluvial materials. If buried deeply in alluvial materials, the resolution of remnants would decrease rapidly with increasing depth of burial. The general area specified in these plots, however, was accepted as the most probable location of the former saw mill. After the results of the survey were shown to the participants, a Shaman from the Northern Cheyenne tribe provided a blessing or prayer over this site.

Dear's Trading Post:

Intrinsic spatial variations and patterns of apparent conductivity and susceptibility measured with an EM38-MK2 meter were used to identify areas with “cultural loading” (Dalan and Bevan, 2002) at this site. Differences in magnetic susceptibility and apparent conductivity have been used as indicators of human occupation and soil disturbance (Simpson et al., 2009). Magnetic susceptibility has been effective in mapping burned structures and areas with dispersed cultural debris.

The measurement of magnetic susceptibility with EMI meters is not common. Though principally associated with soil mineralogy (Magiera et al., 2006) and the presence of ferromagnetic minerals (Mullens, 1977), magnetic susceptibility has also been associated with soil particle size distributions, organic matter and moisture contents (Maier et al., 2006; Mullin, 1977). Magnetic susceptibility has been observed to vary with slope positions (de Jong et al., 2000), soil drainage (Maier et al., 2006), vegetation (Dearing et al., 1996). In addition, local variations in magnetic susceptibility have been associated with anthropogenic disturbances (Clark, 1990; Dalan and Banerjee, 1996). In a study of a 17th century castle in Belgium, Simpson et al. (2009) observed that most of the magnetic anomalies were related with the presence of bricks, ceramics, charcoal, and phosphates. Investigations conducted by Dalan (2006) in North Dakota and Minnesota associated magnetic responses to nodules of burnt clay found in the prehistoric archaeological sites. Magnetic studies conducted by Kvamme and Ahler (2007) on an earth lodge village in North Dakota, revealed pits, hearths, midden deposits, trails, refilled fortification ditches, bastions, houses, and burrow pits. Dalan (2007) noted that walls are often identified by linear magnetic differences (usually highs). As a caveat, it must be emphasized that excavations of some magnetic anomalies have provided no indication of the sources of these anomalies as these footprints only indicated differences in susceptibility, which may not be observable in the field.

At the *Dear's Trading Post* site, for the shallower-sensing, 50-cm intercoil spacing (nominal depth of 0 to 75 cm) soil materials had an average EC_a of about 10.6 mS/m with a range of about -294 to 558 mS/m. However, one-half of the measurements collected in the shallower-sensing, 50-cm intercoil spacing, however, were between about 8.5 and 13.9 mS/m. For the deeper sensing, 100-cm intercoil spacing (nominal depth of 0 to 150 cm) soil materials had an average EC_a of about 10.4 mS/m with a range of about -121 to 52 mS/m. However, one-half of the measurements collected in the deeper sensing, 100-cm intercoil spacing were between about 9.9 and 13.2 mS/m. The extreme range of EC_a is associated with the presence of cultural features and debris.

Figure 2, contains two plots of EC_a data collected at the *Dear's Trading Post* site. The same color scale and scheme are used in each plot. The left- and right-hand plots represent spatial EC_a data recorded in the shallower-sensing, 50-cm and the deeper-sensing, 100-cm intercoil spacing, respectively. In each plot, anomalous values are believed to represent cultural features and debris remnant from the trading post. These anomalies are clustered in the central portion of the survey area. Although no clear outline of a structure is identifiable in these plots, based on broad spatial EC_a patterns, a rectangle has been used to approximate the likely location to the trading post. The enclosed area contains anomalous (both high and low) EC_a measurements. Bevan (1983) observed that high conductivity measurements frequently occur over middens, large earthen features, leveled mounds, refilled ditches and refuse pits.

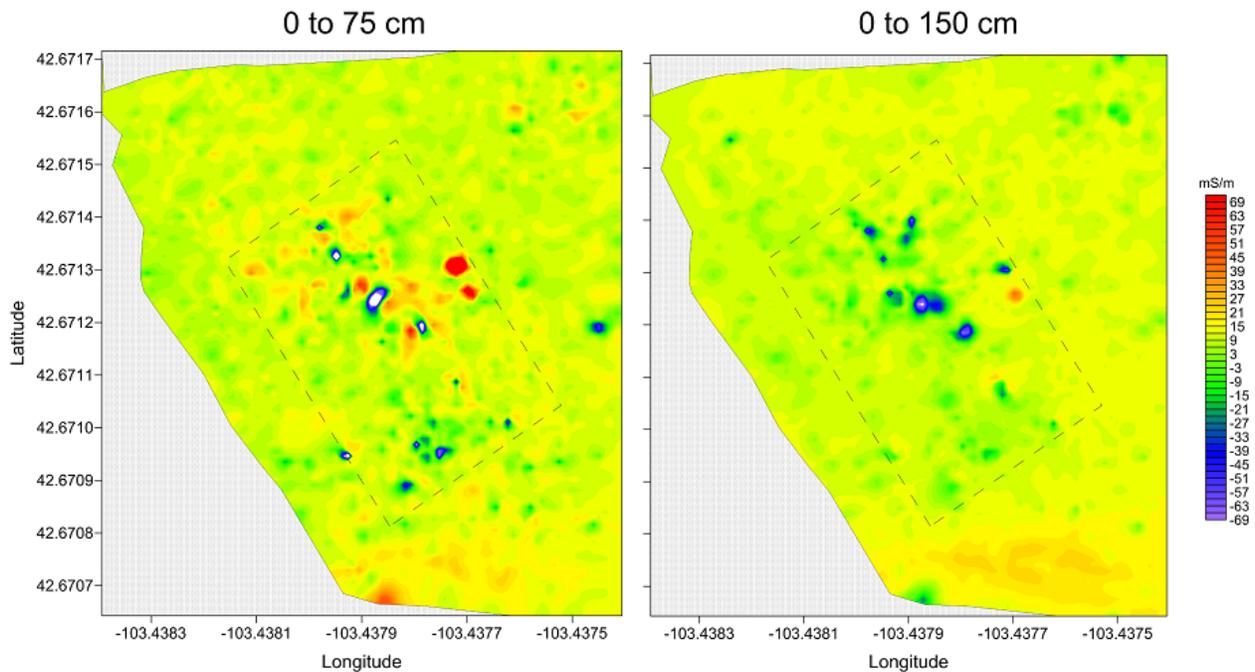


Figure 2. These plots of EC_a data from the Dear's Trading Post site were collected with an EM38-MK2 meter. Data were recorded in the shallower-sensing, 50-cm intercoil spacing (left-hand plot) and the deeper-sensing, 100-cm intercoil spacing (right-hand plot). In each plot, a rectangle has been used to approximate the suspected location to the trading post.

Typically, in most archaeological EMI investigations, only the quadrature phase response (apparent conductivity) is measured (Dalan, 2007). The newly-developed EM38-MK2 meter is capable of simultaneously recording both conductivity and susceptibility data for two penetration depths. Our philosophy is: if you measure it, use it. At this site, for the shallower-sensing, 50-cm intercoil spacing (nominal depth of 0 to 75 cm) susceptibility averaged -44.3 PPT with a range of about -206 to 703 PPT. One-half the susceptibility measurements collected in the shallower-sensing, 50-cm intercoil spacing were between about -76 and -20 PPT. For the deeper sensing, 100-cm intercoil spacing (nominal depth of 0 to 150 cm) susceptibility averaged -10.6 PPT with a range of about -162 to 155 PPT. One-half the susceptibility measurements collected in the deeper sensing, 100-cm intercoil spacing were between about -18 and -4 PPT. The extreme ranges of susceptibility measurements are presumed to reflect the presence of magnetic features, which are related to human occupation and deposition.

Figure 3, contains two plots of the apparent magnetic susceptibility data collected at the *Dear's Trading Post* site. The same color scale and scheme are used in each plot. The left- and right-hand plots represent the apparent magnetic susceptibility recorded in the shallower-sensing, 50-cm and the deeper-sensing, 100-cm intercoil spacings, respectively. In each plot, anomalous values are believed to represent cultural features and debris, which are remnant from the trading post and associated features. Background soil levels of magnetic susceptibility are believed to be in the 0 to -20 ppt range (colored green). A large area with "*culturally disturbed or modified*" soils, which display generally more negative susceptibility values (colored blue and dark green), is evident in the plots shown in Figure 3 and extends over a larger area than was outlined from the EC_a data presented in Figure 2. In Figure 3, linear spatial patterns, which are more prominent in the shallower-sensing, 50-cm intercoil spacing measurements, suggest the possible

presence of walls, refilled-trenches, and/or trails. It is evident in these plots and from the recorded data that levels of magnetic susceptibility decrease and become less variable with increasing depth. This trend is believed to represent *cultural loading* of surface layers and/or firing (Dalan and Bevan, 2002; Bevan, 1994). Compared with the conductivity data (Fig. 2), the collected apparent magnetic susceptibility data (Fig.3) provide more impressive and informative results.

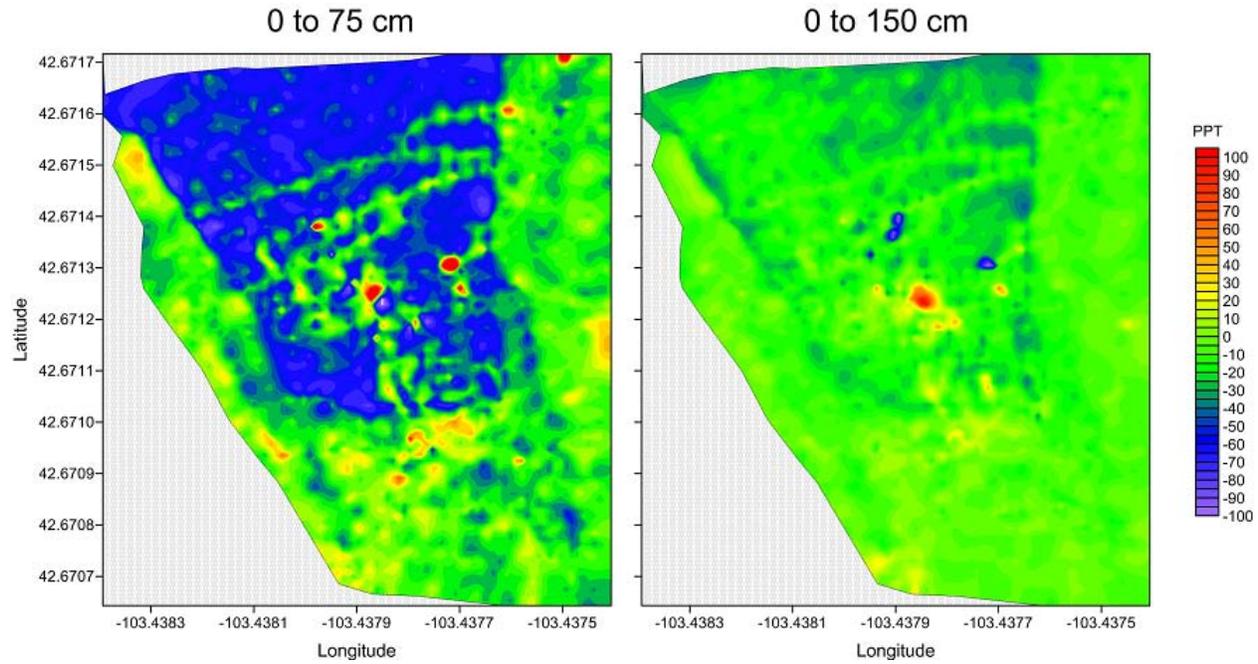


Figure 3. These plots of susceptibility data from the Dear's Trading Post site were collected with an EM38-MK2 meter. Data were recorded in the shallower-sensing, 50-cm intercoil spacing (left-hand plot) and the deeper-sensing, 100-cm intercoil spacing (right-hand plot).

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