SPM Effect in Glacial Till

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SUMMARY

The SPM effect is not traditionally associated with glacial tills. However, effects of viscous magnetization, i.e. superparamagnetism, are observed in many places in Northern Finland in high sensitivity and low frequency time domain ground EM surveys. These effects are typically observed on late time channels and they have a very good correspondence with magnetic anomalies. Usually there is also a clear reverse frequency domain RE component anomaly observed simultaneously with the SPM effect. In Ni ore prospecting it is essential to be able to recognize SPM effect because it has a response similar to a deep seated massive nickel ore body i.e. a deep seated very high conductivity conductor. Characteristic feature for SPM effect in time domain dB/dt data is its 1/t decay which can be used as a means to recognize this phenomenon. We also discuss alternative methods to recognize SPM effect.

Key words: SPM effect, glacial till, electromagnetics, magnetics, Ni ore prospecting.

INTRODUCTION

There are two natural phenomena affecting time domain EM measurements (Barrocu and Ranieri, 2000):

- Superparamagnetic effect (SPM effect)
- Induced polarization effect (IP effect)

In this work we are studying the SPM effect in glacial till areas in Northern Finland. SPM effect is caused by nano scale magnetic particles which are typically located in the overburden (Barsukov and Fainberg, 2001; Dabas et al., 1992; Nabighian, 1991). This kind of very small grain sized magnetic particles can carry viscous magnetization which means that the magnetization they acquire does not collapse instantaneously after the applied field is removed (Nabighian, 1991). This phenomenon is also called frequency dependent susceptibility.

SPM effect is typically observed on late time channels as a low amplitude anomaly which seems to have a very high time constant so that the anomaly does not seem to “turn off”. This kind of response is noticeably similar to a deep seated very high conductivity conductor. SPM response is also typically corresponding well with a magnetic anomaly as well as with a reverse frequency domain RE component anomaly, see figure 1. IM component of frequency domain data is not affected by magnetic properties.

Based on our experience, SPM effect is a common phenomenon when ground EM surveys are carried out over magnetic highs, i.e. areas where there are high amounts of magnetite in the rocks. I assume that on these areas nano scale magnetic particles are created through weathering processes and because there have not been any great movements in the overburden after the last ice age the correlation between the SPM effect and the magnetic anomaly stays clear. The reverse frequency domain RE component anomaly is caused by the permeability of the rock and is amplified by the SPM effect, when no conductors are present.

When using TEM method in Ni ore prospecting it is essential to be able to recognize SPM effect because it has a response similar to a deep seated massive nickel ore body i.e. a deep seated very high conductivity conductor. Good correspondence between a TEM late time channels anomaly and a magnetic anomaly can be used a first means to recognize SPM effect. Also, if frequency domain EM data is available, reverse RE component anomaly can be used as an indicator that magnetic properties are dominating the response, i.e. the TEM late time channels anomaly is likely caused by SPM effect. Finally, SPM effect can be recognized using its characteristic 1/t decay in dB/dt data, i.e. the decay is following a linear curve when log-log scale is used. This arises from the fact that SPM effect decays logarithmically (Nabighian, 1991). In figure 2 there is a comparison between a real conductors decay curve and a decay curve caused by the SPM effect. Both of these anomalies have been observed on the same area and the presence or lack of conductors is based on drilling and borehole EM results.

METHOD AND RESULTS

The time domain ground EM data used in this work has been gathered with moving loop method using a 100x100m transmitter loop and a high temperature SQUID B-field sensor. The B-field data has been converted to dB/dt data by calculating the time derivative of the B-field. The dB/dt data has been used to find out if the characteristic 1/t decay of SPM effect can be fitted to the TEM anomaly, see figure 2. The airborne magnetic and frequency domain EM data used in this work has been bought from Finish Geological Institute and it has been flown on 30-40m altitude with mainly 200m line spacing.

As a result we can say that also on glacial till areas the SPM effect has to be taken into account when doing high sensitivity TEM surveys. Combined use of geophysical data as presented here and the decay curve of the TEM anomaly can be used as efficient tools in identifying SPM effect and therefore reducing unnecessary drilling costs.

CONCLUSIONS AND DISCUSSION

The SPM effect is a considerable natural source of noise in TEM measurements also in glacial till. Modelling SPM effect with a conductor plate yields typically a deep seated conductor which has a conductance in the range similar to a massive nickel orebody. This is the reason why it is necessary to recognize the SPM effect before unnecessary drilling.

Kevitsa and Sakatti, the known Ni mineralizations in Finish Lapland, show up as conductors in frequency domain RE component data even though they are both located in ultramafic intrusions, i.e. on magnetic highs. Because RE component also contains information about magnetic properties, it can be used in categorizing TEM anomalies to those likely dominated by magnetic properties and to those likely caused by true conductors.

The best way to recognize SPM effect is to take samples from the overburden and drill core and test which part behaves superparamagnetically if any, i.e. where the dB/dt response decays logarithmically following 1/t. Alternatively, a small scale TEM survey can be carried out so that effectively only the overburden becomes sampled, assuming the superparamagnetically behaving source is located in the overburden, and check if SPM effect can be recognized. The depth to the source of SPM effect can also be estimated by conducting a normal ground TEM survey so that one reading is taken on the surface and another reading so that the sensor is lifted a few meters above the surface. From the difference between these two amplitudes the depth to the source of the SPM effect can be estimated. If the SPM source is located in the overburden, i.e. near to the surface, there should be a clear drop in the amplitude of the corresponding TEM anomaly when the sensor is lifted compared to the amplitude of the anomaly when the reading is taken on the surface. Assuming again that the SPM source is located in the overburden, this latter method can also be used in recognizing the presence of the SPM effect. Based on the fact that if the observed TEM anomaly was caused by a deeper seated true very high conductance conductor, there should not be any significant drop in the corresponding amplitude of the TEM anomaly when the sensor is lifted.

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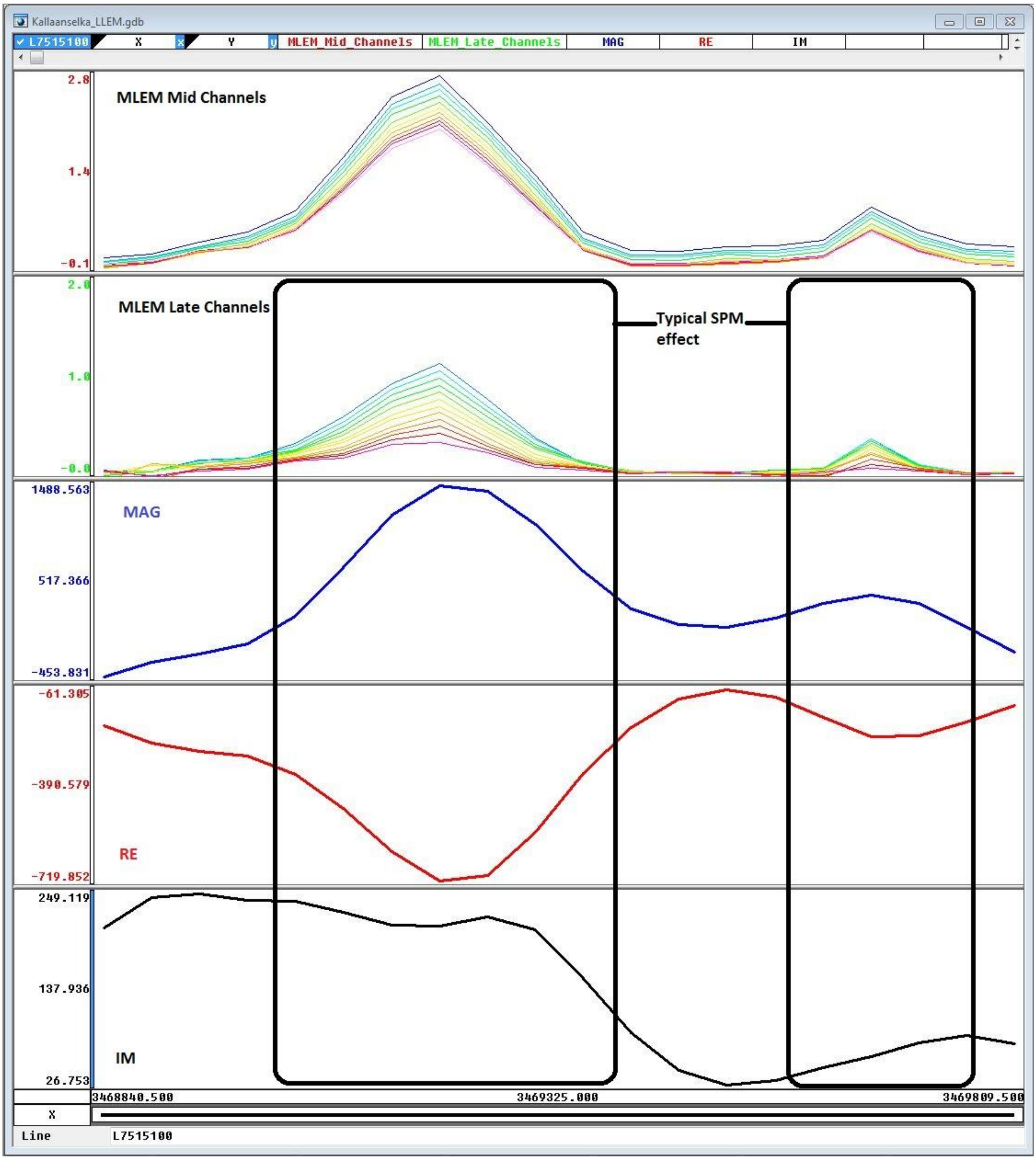

Figure 1. Typical SPM effect. Two topmost profiles are showing ground EM Z-component data measured with 3-component HT SQIUD sensor and 100x100m TX loop, middle profile is showing airborne MAG data and two undermost profiles are showing airborne FEM RE and IM component data.

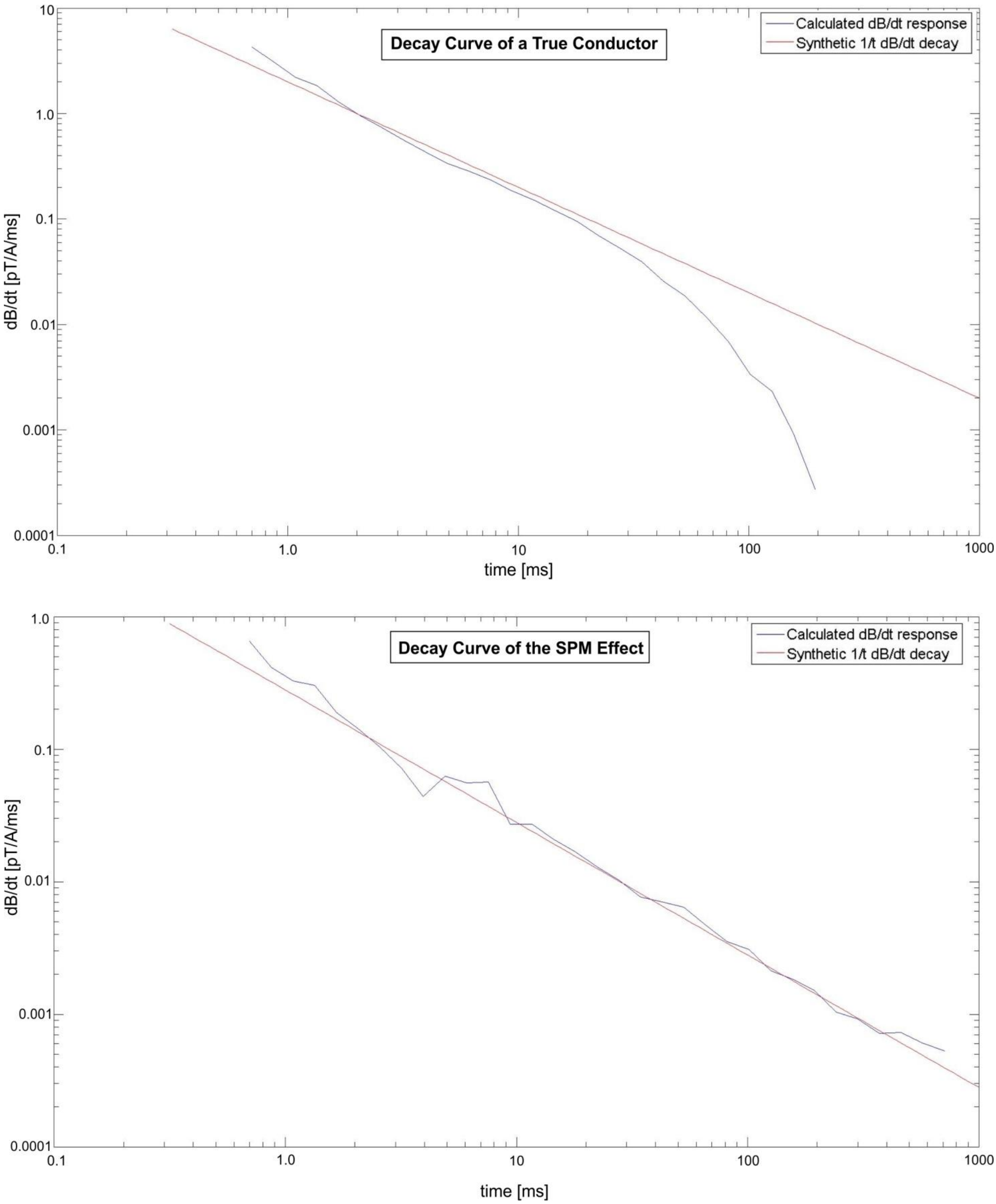

Figure 2. Decay curve of an ordinary conductor shown in the upper panel and decay curve of the SPM effect shown in the lower panel. The calculated dB/dt response shown with blue colour has been calculated from B-field data acquired with HT SQUID sensor using 100x100m transmitter loop and 0.25Hz base frequency. The SPM decay curve shown in the lower panel is from the left sided anomaly shown in figure 1. That decay curve is clearly following the logarithmic decay curve (shown with red colour) characteristic for the SPM effect.