Airborne induced polarization

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Airborne IP (AIP) effects have been detected in many airborne electromagnetic (AEM) surveys to date (Smith and Klein 1996; Boyko et al. 2001; Smith et al. 2008; Kratzer and Macnae 2012). The IP effect on an AEM system is generally opposite in sign to an EM decay, and appears as negative data in the late off-time during measurements. Figure 1 is an example of a map of late-delay off-time amplitude from a VTEM survey in Quebec.

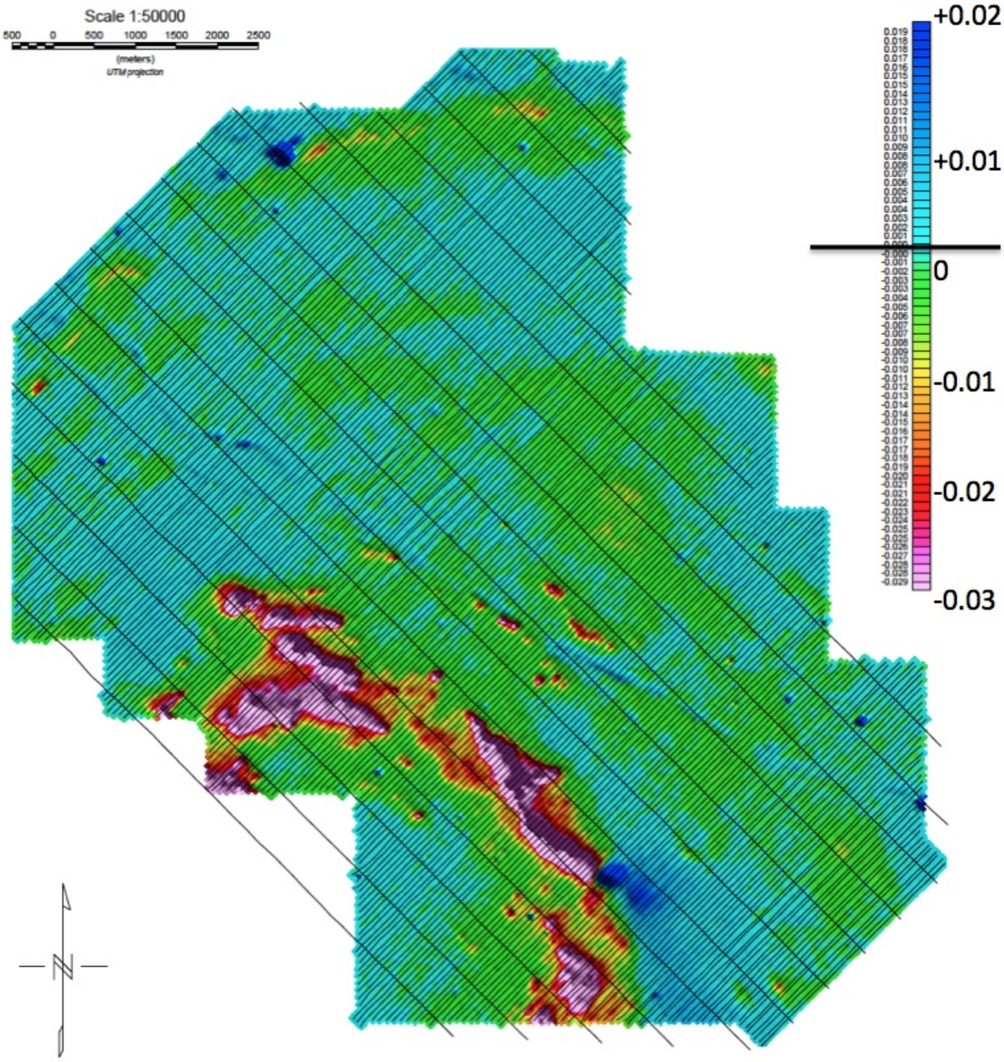

Fig. 1: Roughly 10 km by 12 km airborne VTEM survey in Quebec where large negative IP responses at late delay times were spatially coincident with Titanium mineralization. Data were collected at 3 m intervals along 170 flight lines spaced 100 m apart, with 16 tie lines.

All published AIP examples have the polarisable sources in the near surface. Recently, Kratzer and Macnae (2012) provided some quantitative fitting of AEM data with Cole-Cole models, taking into account the fact that the excitation current in the earth is of course conductivity- and geometry- dependent. This is because the transient current induced in the ground after the transmitter switches off expands downward and outward as it decays. Figure 2 shows the difference between Warburg decays from current injection, and those predicted for an AEM system flying over an area with a conductive overburden with a polarisable target within it and excited by the induced currents.

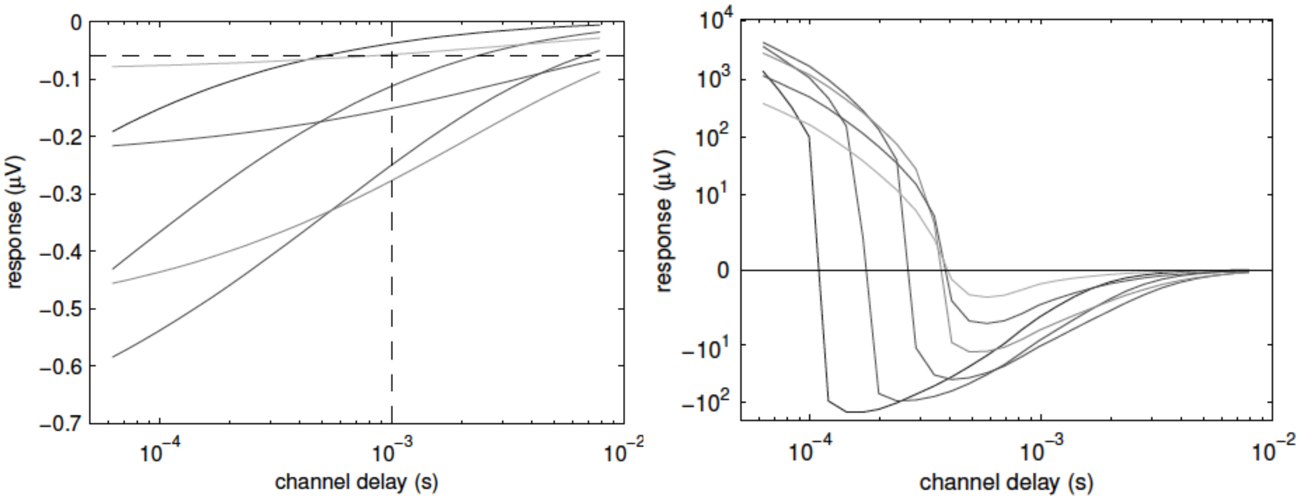

Fig. 2: Warburg IP decays with time constants of 1, 0.1, 0.01, 10^{-3}, 10^{-4}, 10^{-5} seconds from a 25 Hz injected square wave current (left) and Warburg IP decays with the same time constants as excited by induced currents from a 25 Hz square wave current in an airborne loop (right).

From Fig. 2, and a field data example (Fig. 3), we can generalise that AIP effects are seen as negatives of amplitude typically 4 to 5 orders of magnitude less than the peak amplitudes of the EM responses from induced currents. To see them at all has required 1) significant increases in the Signal/Noise ratio of AEM systems 2) significant improvements in the linearity and dynamic range of data acquisition systems and 3) poorly to moderately conductive cover of host rocks.

Even though the AIP effect is small, it can be useful in mapping tailings (Smith et al. 2008) and with technological advances could become more useful for contaminated site mapping.

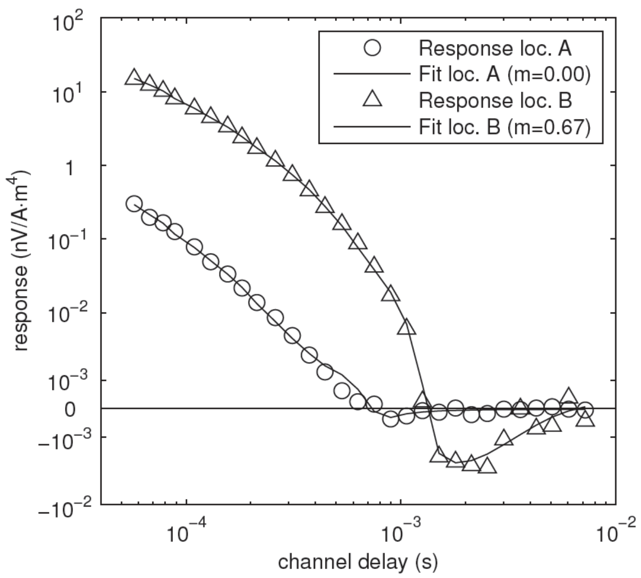

Fig. 3: Fit to AEM sample data at locations with (B) /without (A) polarisable material at surface.

The key questions for mineral exploration it the detection of AIP responses from targets at depth, as opposed to the surface examples from existing systems. Targets at depth will necessarily have smaller responses that those at surface. A large target at 100 m depth would have a response about $(140/40)^3$ or ~40 times smaller that the same target at surface (for an AEM system flying at 40 m above the ground). This is undetectable in existing systems with concentric transmitter-receiver geometry: assuming observed responses are a factor of 5 above noise level, it might be realistic to explore to a depth to top of target in the 50 to 60 m range. To achieve target detection at 100 m depth there are several options available from a conceptual framework. 1) Increase S/N by a factor of 4, possibly through use of a flock of UAV mounted receivers rather than a single receiver; there is little scope to increase transmitter signals at present; 2) locate the receiver closer to the smoke-ring currents, such as occurs in the fixed-wing AEM system geometry where the receiver is towed in a bird behind the aircraft and transmitter and 3) lower the base frequency of the AEM system so that there is more transmitted energy at low frequencies, giving clearer negatives at late delay times. This last option has significant technical challenges attached to it. In much of Australia for example, cover is sufficiently conductive that EM response is dominant to even the latest measured delays (Fig. 4).

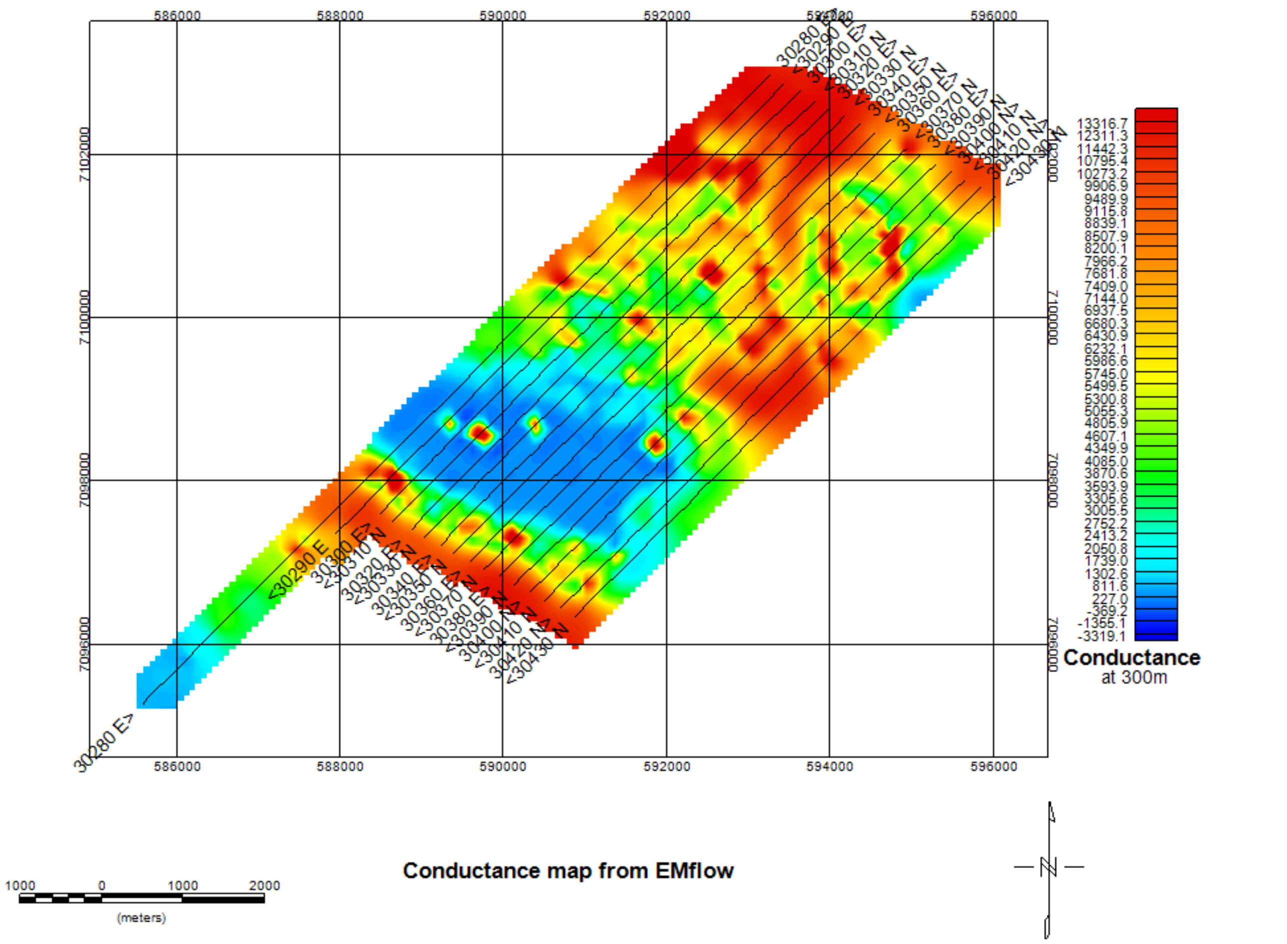

Fig. 4: Example of an airborne survey where AIP negatives (in dark blue, from clays) are only detectable where the cover is least conductive.

Conclusions

Airborne IP effects are seen as negatives of amplitude typically 4 to 5 orders of magnitude smaller than peak AEM responses. As a result, existing systems only "see" responses from targets in the top few 10s of metres. Significant challenges are the focus of current research to increase the reliable target depth detection range to 100 m and beyond.

References

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