Structure mapping under cover and under deposits with FTG

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Summary

The search for metals requires exploring geological structures that are often under deep cover, difficult to reach or occur as subtle extensions to known deposits. FTG maps these structures allowing evaluation of their connectivity to known geological trends and prospectivity. Two examples are presented, potential for pegmatite veining on a felsic granite in NE Iowa and mapping mineralisation bearing structures in the Bathurst Mining Camp.

Introduction

Exploring the energy transition means exploring for key smart metals that allows the generation, capture & storage and distribution of energy be it from hydrocarbons, wind & solar, geothermal, or nuclear. The key metals needed are often found in those difficult to find structures or occur in structures forming subtle extensions to geology hosting the primary metals of choice in well established mining camps. Lithium, REE, cobalt and other deposits are prime examples.

Traditional usage of airborne geophysics is to detect and delineate the more ‘easy-to-find’ metal deposits in their near surface setting. Magnetics and EM target mafic rocks and sulphides and are technologies of choice. However, their usefulness in mapping geology is limited if target geology hosting smart metals is deeper, along geological trends that are non-magnetic or where associated sulphides are poorly established. Explorers often resort to regional scaled surveying to image deeper geology, but result with resolution less than that desired. Such technologies include ground gravity and airborne magnetics.

The desired solution is to deploy high resolution technologies on surveys planned with tight line / station spacings over large areas that capture sufficient signal bandwidth that maps the deeper extensions and connectivity with known shallow structures. However, such practices are not always feasible due to challenging terrain, be it water bodies, vegetation, swamp, or the shear time needed to acquire such data over large areas.

FTG overcomes many of these limitations where signal bandwidth is important for not only resolving shallow complexity but allow confident mapping of deeper complexity, thus fulfilling a need to map connectivity on key structures. In this paper, we describe how FTG data is worked to reveal geology in two data examples.

FTG and mapping geology

FTG, measuring the rate of change in gravity in all directions of the field, captures the requisite signal bandwidth that not only translates to a full depth scan but also facilitates direct mapping of key structure from basin channels to faulted ridge-like structures or fold axes, from intrusive body shapes to salt and carbonate mounds. FTG maps density contrasts, a useful discriminator when targeting geology showing variable conductivity and / or susceptibility.

Depth information from FTG is mapped using a migration workflow that models a starting density field for depth. Brewster and Murphy (2020) describe source body migration as an alternative method to traditional means of depth separation using frequency filtering. Migrated output clearly maps the change in signal at different depth intervals overcoming the delimiting FFT approach that often removes more signal than is desired.

Structures are mapped by combining the horizontal components Txx, Txy and Tyy to an invariant representation, the Total Horizontal Curvature or THC. THC anomalies show direct correlation with known struture and when compared with Tzz, are easily interpreted as low/high density structures. Further analysis, by first identifying the minimum and maximum curvature (Li, 2015) and then taking their ratio, maps the shape and form of subsurface structural complexity.

Contacts are mapped directly when Txz and Tyz are combined to produce the Total Horizontal Gradient, or THG. Maximum responses, or peak anomalies, delineate the contact structure, be it faulted, a fault zone or edge of granites etc.

This three stage approach to working FTG data not only identifies the targeted depth interval hosting geology of interest but also confidently maps structural complexity and their faulted contacts. The benefit is a clear advantage when targeting subtle geological structures beneath cover or beneath known deposits where the geophysical signature often dominates the signal.

Delineating geology under cover and deposits

We describe two examples of how geology is directly mapped from the tensor component data using examples from an area in NE Iowa, that is considered frontier, having potential for Lithium bearing pegmatites and from the Bathurst Mining Camp in New Brunswick. The examples are described in detail by Murphy et al (2023) and Yang et al (2023), and sumamrised here.

Structure mapping and Pegmatite potential in NE Iowa

FTG data were acquired on 400m line spaced survey on the Midcontinent Rift System for the USGS in 2013 and recently reprocessed (Murphy et al, 2023).

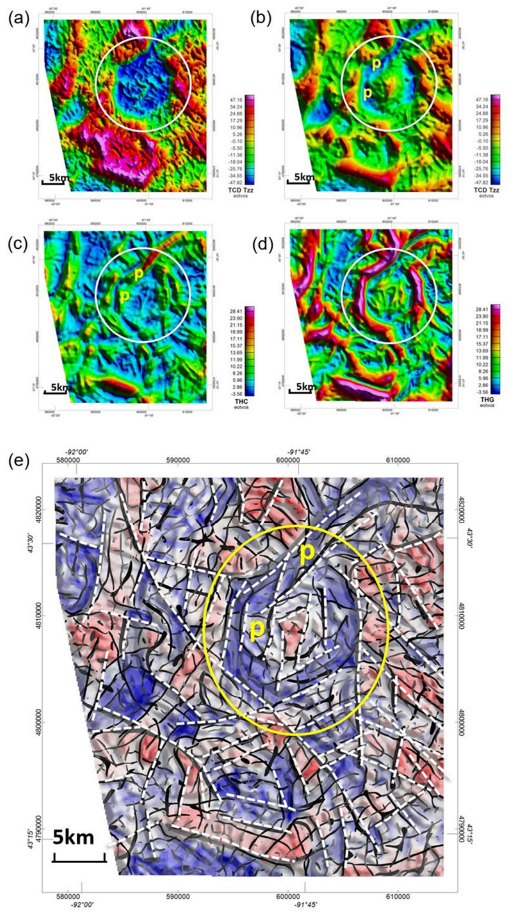

Figure 1. Source Body Migrated FTG for NE Iowa FTG survey. (a) shows the full spectrum Tzz, (b), (c) and (d) show the Tzz, THC and THG for depth interval 250m to 1000m below ground. (e) displays the interpretative map from the tensor (structures in shades of blue to red, lineaments in grey). See text for details.

Depth analysis on the migrated tensor identifies clear depth sensitivity for key structures from 250m to 1,000m below ground. Figure 1(a) to 1(d) show the migrated output. The encircled anomaly is due to a large felsic granitic pluton (Drenth et al, 2015) and is supported by this analysis.

Figure 1d maps the edge of the granite with the positive anomalous rim depicted by the THG. Analysis of the Tzz response identifies negative Tzz anomalies on the edge of the granite (Fig 1b) that are interpreted as localised structures (Fig 1c). The negative Tzz response (denoted by ‘p’ in Figure 1) is interpreted as low density structuring, possibly associated with lithium bearing pegmatite veins on the edge of the low density s-type or felsic granite.

Additional information is the mapped fault framework. The THG anomaly pattern lends itself ideally suited for mapping contact lineaments that are then geologically interpreted. Figure 1(e) displays the interpretation (dashed white overlay) of the contact lineaments mapped from THG. Locating these on the structures mapped from the analysis of the THC presents context. Displacement and clear characterisation of structures showing both locally high (shades of red) and low (blues) density steer the interpretation. The dominant trends mapped show a change in orientation from ENE & NE to NNW & NW reflecting the dominant trends on the Midcontinent Rift System in Iowa (Drenth et al, 2015).

Structure mapping Bathurst Mining Camp

The Bathurst Mining Camp (BMC) is one of Canada’s oldest mining camps for VMS deposits. Many of the numerous deposits are found at the surface or beneath a thin but discontinuous sediment layer. Figure 2(a) summarises the primary geological elements for the BMC which is essentially that of a back-arc rift basin that underwent closure resulting in an amalgamation of different blocks resulting from collision (Goodfellow et al. 2003). Mineralisation style is in the form of lens shaped pods or stringer form along veins with their deposition facilitated by motion along NNW and ENE trending lineaments.

The area was explored extensively and the many airborne geophysical surveys include both magnetics and EM (Ugalde et al, 2019). The surface and near surface geology are particularly well suited for magnetics and EM and much of the well understood and mapped geology is from their interpretation. However, what is less understood is the continuation and extent of these structures at depth. The magnetic and EM responses are dominated by the near surface.

FTG data were acquired over the BMC for Noranda Exploration in 2004 on a 200m line spaced survey. The data was recently reprocessed (Yang et al, 2023) and subject to a migration workflow to extract signature patterns from the deeper levels across the BMC. Figure 2(b) shows the migrated Tzz component sensitive to geological structuring at depths of 400m below ground. The anomaly patterns show clear delineation of both NNW and ENE oriented trends as evident in the Brunswick and Heath Steele areas where mineralisation is known.

This is investigated further through an analysis of the corresponding tensor components as shown in Figure 2(c). The tensor interpretation maps structuring from a THC (varying shades of blue to red) and contact lineaments (grey) from the THG for the migrated BMC FTG data. The white overlay is the geological interpretation from magnetic and EM data and the green dots locate areas of known mineralisation. We see clearly how the ENE trending structures are faulted (NNW oriented dashed yellow lines) in the areas away from known mineralisation. The modelled depth is 400m.

Discussion

The migration workflow applied to FTG data confidently maps the tensor field for targeted depth intervals. The implications are a clear targeting exericse identifying potential for lithium bearing pegmatites at depths of 250m in NE Iowa and structuring known for mineralisation trends at 400m below ground in the Bathurst Mining Camp.

Delineating key structures hosting mineralisation in both established mining camps and in new areas beneath cover is important as the industry extends its remit to explore for metals not previously sought and in particular, where such metals are in geology that is difficult to reach or has poor magnetic and EM responses. Mapping the density change has a clear advantage and employing FTG technology helps reduce the uncertainty when faced with increasing challenges for continued exploration.

The implications from this analysis helps position FTG as a primary technology for consideration when exploring the energy transition. This is ever more important when identifying the right technology for the right geology, especially at a time when budgets are being formulated.

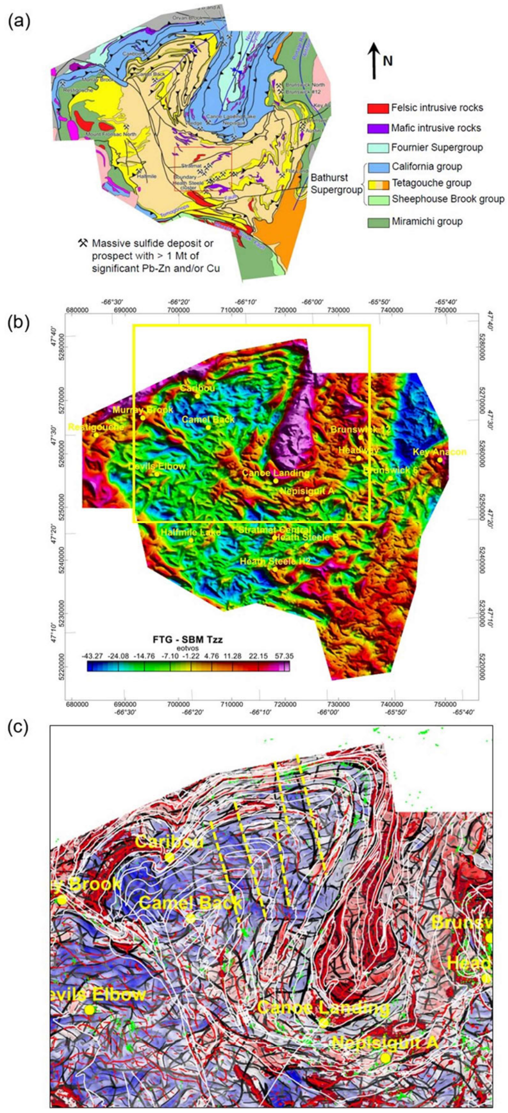

Figure 2. Bathurst Mining Camp. (a) primary geological elements for the BMC, (b) source body migrated Tzz at 400m below ground and (c) interpretative map from the Tensor for the inset area. See text for details.

Conclusions

FTG tensor components map structures and contact lineaments for targeted depth intervals in the subsurface. Two examples are described, identifying lithium bearing pegmatite potential at 250m depth in NE Iowa and mapping structures known for mineralisation at 400m below ground in the Bathurst Mining Camp. FTG has a clear role for identifying and delineating geological structure often not detected with magnetics or EM alone, but where density change is important for understanding complex geology.

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