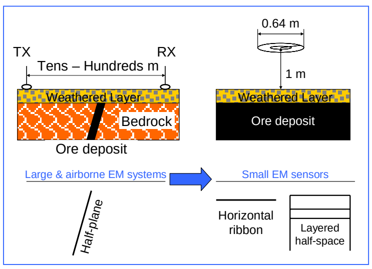
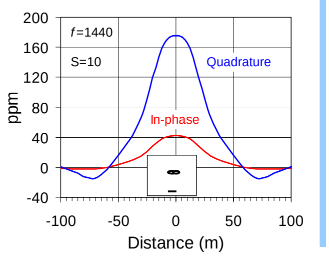
Mineral Exploration Using Small One-man-portable Broadband EM Sensors

Small EM sensors, such as **GEM-2** and **GEM-3** by Geophex, are extensively used for mapping shallow geological structures in environmental and engineering geophysics. However, the small EM sensors may also be used in mineral exploration to detect shallow conductive ore bodies or confirm airborne EM anomalies, particularly for those that are outcropping or buried under a thin overburden. The GEM sensors are ideal for such jobs because they produce the maximum ratio of target-to-host response, are designed for single operator, thus, no need for line-cutting, light, and very user-friendly.

The models for small EM sensors

A dike of sulfide ore or graphite body may be modeled as a conductive thin sheet with vanishing thickness, and therefore, conductive half-plane and finite plates become the most popular models for large EM sensors. However, for a small EM sensor with coincident coils or a small coil separation, a dike of massive sulfide body likely appear as a thick plate. When the sensor is close to the top of plate, the induced currents concentrate mainly on the flat top of dike. Thus, a horizontal ribbon can be a choice for modeling a steeply dipping dike. Even a half-pace can be used to model a dike when its thickness is greater than the distance from sensor to its top. The figure below illustrates the situation.

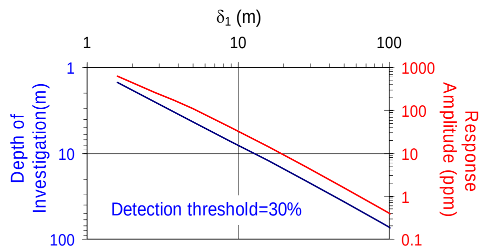




Small sensor EM response on a horizontal ribbon with width of 10 m.

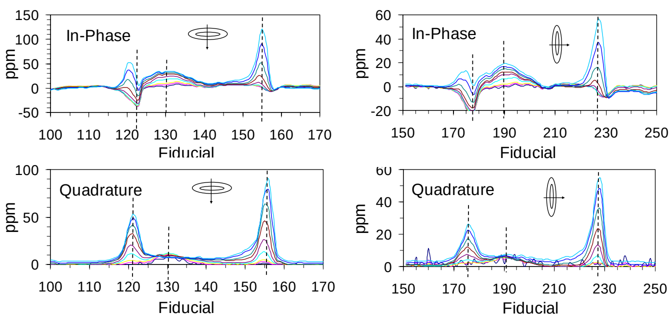
Depth of investigation for small EM sensors

The depth of investigation is estimated for a coincident coil sensor using a horizontal sheet under overburden. The sheet is 100 times more conductive than the overburden. Figure below shows the depth of investigation (in blue) and signal amplitude (in red) as a function of skin depth, δ_1, in the overburden. Theoretically, such a sensor can see several tens of meters in depth, depending on the noise level. When the transmitted frequency is up to several kHz, the noise level for the sensor is only a few ppm, where a 10-ppm anomaly is easily recognized. The depth of investigation for massive sulfide ore body could be 10 m or more.



GEM-3 Field Examples – Obtained by Prof. Ken Duckworth at Univ of Calgary, Canada

George Lake, Ontario

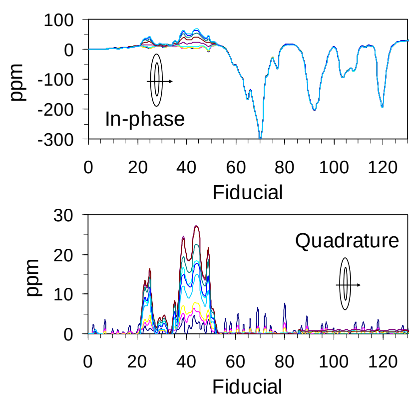


Figures above are the GEM-3 data at 9 frequencies ranged from 90 Hz to 20,010 Hz, that was acquired with both horizontal and vertical coil configurations at George Lake, Ontario. Three conductors are indicated in these figures, two of which were outcropping while the central conductor was clearly much deeper. The central conductor responds strongly positive for all frequencies, and the magnitudes are higher for the in-phase components than the quadrature components indicating the approach of the inductive limit. In contrast, the two outcropping conductors for which the in-phase starts out negative and then goes positive at high frequencies, indicating that these conductors are also magnetically permeable.

The horizontal coil responses are indistinguishable from the vertical coil results, indicating that the response is dominated by the flat top of each conductor and that they are not really responding as thin steeply dipping tabular conductors. These results confirm the outstanding spatial resolution that a coincident coil sensor can achieve.

Graphite Lake, Ontario

Figures below are 70-meter long profiles of the GEM-3 data at the 9 frequencies acquired over a pyrrhotite body at Graphite Lake, Ontario. This data was collected in a walking traverse with the coil held vertical and parallel to geological strike. There are 4 strong anomalies on the in-phase response which is frequency independent at each of the 4 anomalies, indicating that the geology is magnetic but not conductive. The latter can be also seen from no quadrature response at these anomalies.



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