AEM useful for Hydrogeologists

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The Airborne EM method has nowadays reached a great degree of progress, so that it can be considered a reliable tool for the hydrogeological modeling. It is indeed able to provide a detailed distribution of resistivity, so that it is possible to draw information of stratigraphic and, sometimes, of hydrochemical type. But, in order to achieve this outcome, it is demanded a high performance of the instrumentations, as such as an accurate data processing. We show some examples of application of the AEM method, for the solution of problems connected to the groundwater mapping, to the seawater intrusion and to the improvement of the hydrogeological models.
The role of a-priori information in inversion of airborne EM data are strategic, as it can provide better resolution of those parameters having low sensitivity (e.g. thin resistors), production of more credible results, better match with ancillary information, easier data integration for derived products and possibility to recalibrate the AEM dataset (in the case of incorrect definition of the Tx waveform or wrong timing of the gates).
As an example of application of this approach, we present the results of a SkyTEM prospection from Canada. Thanks to stratigraphic and hydrogeological information provided by some boreholes, we decide to use only point sources, i.e. the elevations of the hydrogeological units as such as defined by the hydrogeologists. We focused mainly on the aquifers and the bedrock. The first ones are represented by glacial formations, made up by sands and gravels layers, separated by several aquitards and aquicludes (clayey and silty tills). The aquifers are shown by yellow (from light to dark) layers in the hydrogeological section on Figure 1, while clayey tills are in green. The bedrock is formed by shales (Pierre Formation) and it is imaged by the light blue layer, at the bottom of the cross-section. Our approach was to fix layers' thickness (the apriori info), so to resolve better resistivity values, in order to evaluate if geophysical data can improve the hydrogeological knowledges.

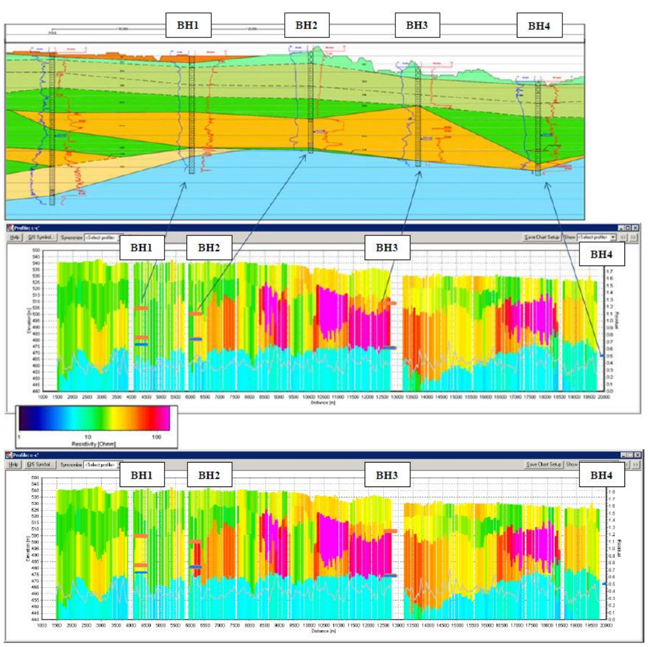

Figure 1

Figure 1 shows a comparison between the hydrogeological information and the results of SCI of a 5 layers model, without and with a-priori info. We were obliged to use a blocky model to facilitate the assignement of an electric layer to a specific hydrogeological unit. The hydrogeological cross-section shows the presence of one of the glacial aquifers (Upper Dundurn Aquifer, UDA), imaged by the orange colours, having variable thickness. Along the EM vertical profile we have imaged the top and the bottom of UDA (orange lines) and the top of the Pierre formation (SP). The middle panel of Figure 1 shows the results obtained without any apriori from boreholes. There is a good agreement of the depth of the bedrock, characterized by low resistivity (lower than 10 ohm-m), but some differences arise on the left part (BH1 and BH2), where the top of the conductor is about 5 m deeper than the effective depth of shales. Regarding the aquifer resolution there is a good match, above all where it has higher resistivity (BH3), while some problems arise for BH1. Of course, the AEM prospect is not able to resolve thin aquifers, like that one captured by BH4, but this is a well-known limit of the method. Notice however how the AEM hints at a much higher spatial hydrogeological variability than the hydrogeological sections.

The Lower panel in figure 2 shows the outcome of adding apriori stratigraphic information to the inversion input.). We used the as aprior only the elevation of the top and bottom of UDA formation, and of the top of the SP. The information were applied within a radius of 100 m from boreholes, with a standard deviation of 20 % assigned to it.

As expected, the results display a better agreement with BH1 and BH2, in the elevation of UDA and of SP. Moreover, the resistivity of the UDA aquifers increases, showing an enhanced vertical contrast with the above aquitards which is in better agreement with the borehole resistivity logs. Notice how the data residual (misfit between modeled and observed data, shown as grey line below the sections) remains low with the apriori, proving that the latter is not in conflict with the measured AEM data.

In a preliminary attempt to estimate a correlation between geophysical and hydrogeological parameters, we analyzed the possible link between resistivity and permeability or, more specifically, hydrogeologic productivity, by means of the so-called Dar-Zarrouk parameters, in the proximity of two boreholes within the cross-section of Figure 1. We estimated also Transverse Resistance (Resistivity-Thickness product), that can be compared more easily with hydraulic transmissivity, being this latter the permeability-thickness product. Furthermore the use of TR would bypass the problem of geophysical equivalence. The Recommended Pump Rates (RPR) have been suggested by the hydrogeologists, following pump tests. This parameter can provide a rough estimate of the hydrogeological productivity, even if it may be influenced strongly also by the technical features of the boreholes. Of course, a more rigorous statistical analysis would demand much more data.
A first consideration can be made about the RPR value of BH3, that is greater (12 IGPM) than that one of BH2 (8 IGPM); this is in agreement with an increase of resistivity (100 ohm-m vs 65 ohm-m). Of course this is due also to the greater thickness of the aquifer in BH3, but probably also resistivity has an influence. The good direct correlation between Transverse Resistance and RPR would confirm this feature of the aquifer. Thus, higher resistivity values seem to coincide with higher RPR and TR.