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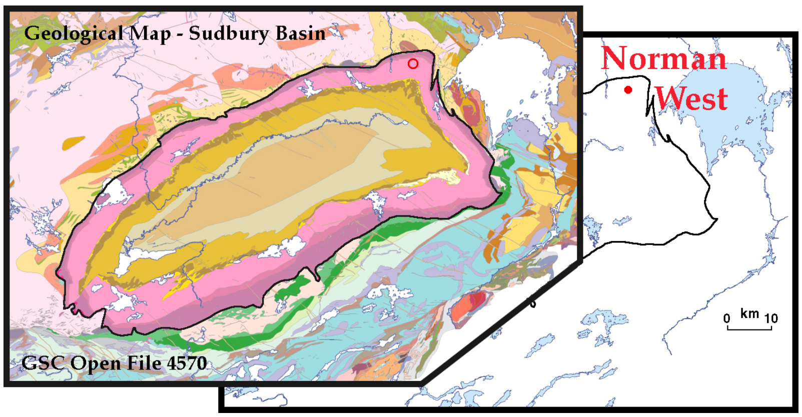
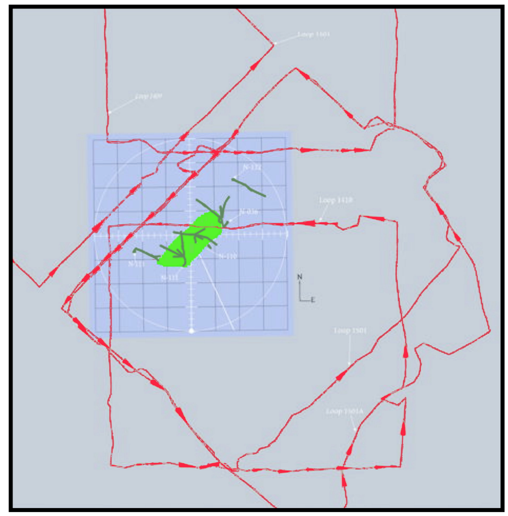
3D Modelling of a deep massive sulphide body at Norman West, Sudbury ON Canada

does the ore zone model explain all of the geophysical response?





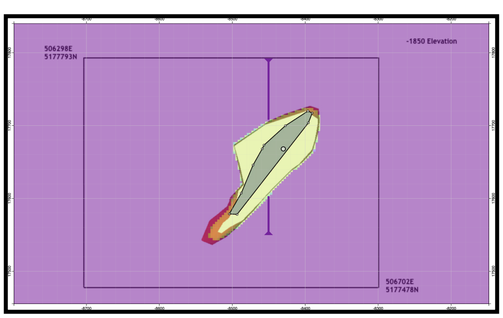
Plan view of the study area showing surface Transmitter loops (in red), drillholes, model and reference grid.

Introduction

During the process of drilling off and defining a deep Cu-Ni footwall deposit at Norman West in the Sudbury Basin the question arose: did the shape and size of the defined ore model explain the borehole EM data available (BHUTEM surveys in 17 holes) or were significant changes to the model needed? In short, did the defined ore model explain all of the geophysical response or is something more there?

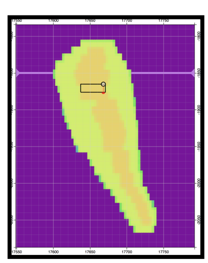
To answer this question Glencore geologists needed a 3D ore model to define the deep Cu-Ni footwall deposit beyond what could be achieved using traditional thin-ribbon/plate modelling. A detailed geological ore model of the Norman West deposit was developed from drill core information in combination with the EM interpretation of multiple survey (BHUTEM) passes of 17 separate boreholes. The **model** of the body generated represents the ore zone as 32 horizontal slices of 10m thickness starting at a depth below 2200m. Each slice consists of an inner zone of massive sulphides surrounded by an outer zone of less conductive (semi-massive or stockwork) sulphides. The **model** is shown in green in the above plan view and below right in a A3D perspective view as viewed from the WNW (blue reference plane at 2075m below surface).

EM modelling was carried out with Lamontagne Geophysics' **MGEM** - **M**ulti**G**rid **EM** - a 3D EM modelling tool suitable for modelling geological settings common in mineral exploration. Powered by a full volume multi-grid finite-difference solver capable of handling conductivity contrasts of 1:10 000 000, MGEM generates finely meshed grids (for local geological features) encased in coarser larger grids (for regional electrical structures). This cross-platform software generates high-resolution EM data for timely interpretation and survey design.



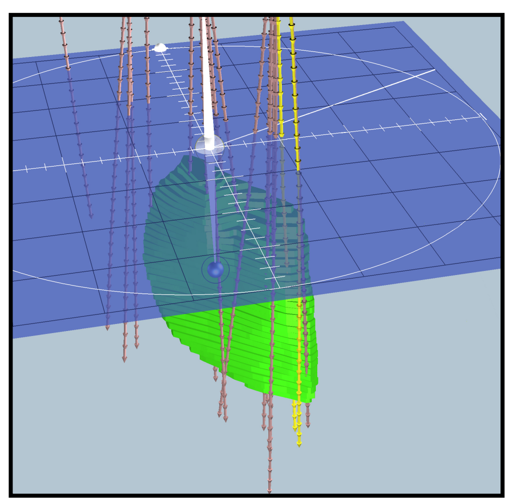
Model horizontal slice being drawn

model slices for both outer and inner zones were drawn using Gridplot which generates a conductivity mesh as the polygonal boundaries are drawn (*NS section*)



NS section view

NS section view of the multigrid conductivity mesh with one slice of the inner zone highlighted (scale matches horizontal slice)



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The MGEM modelling process

In the study MGEM calculated the step response everywhere in all volumes and at all eight mesh levels over 54 time steps ranging in delay times from 12.5µs to 22s. The multi-grid calculation consists for each time step of solving a system of linear equations using an iterative method (Full Multigrid, or FMG) by which solutions on coarse meshes are used to speed up the solutions of finer meshes.

In the first four models considered there were 17 million unknowns to solve for. The largest model was run on a mesh with 33 million unknowns. After each time step the 3-axis response was interpolated at 10 m intervals in all holes and saved to 3-axis output files.

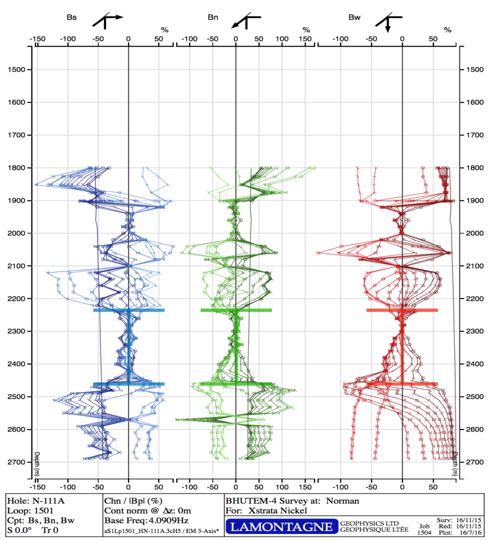
Modelling sequence

The plan for MBEM 3D modelling at Norman West was to proceed in two phases.

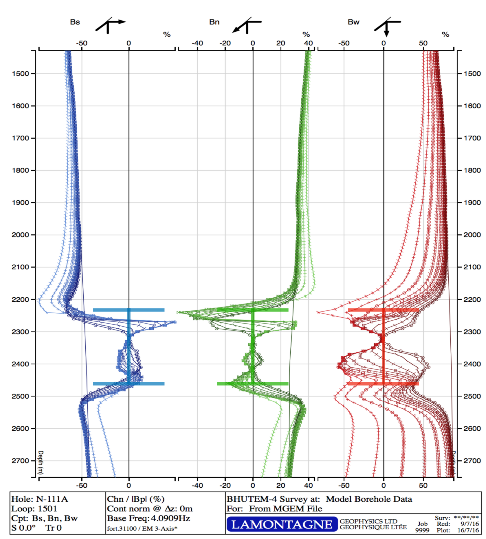
Phase 1: consisting of comparing the response of the objective model shapes to measured data while adjusting the conductivities to fit the general decay times of the observed response to those in the measured data. how well did the objective model explain the data? were there significant differences?

Phase 1 - Conclusions

Phase 1 MBEM modelling results confirmed the general correctness of the objective **model** but indicated a lower than expected outer zone conductivity (250 S/m) and a higher inner zone conductivity (~10000 S/m).



Observed response in Hole N-111A measured at 4Hz with Loop 1501



Phase 1 Modelled total field 4Hz data in N-111A with Loop 1501 using model E (250/6000 S/m)

At the conclusion of Phase 1 three main responses were unexplained:

1) The background response which appears to be due to the known contact zone intersected ~1800-2000m depth in almost every hole. In hole N-110D the response is mainly off-hole. In hole N-113, a poorly conductive extension of the zone is off-hole to the east at 1825m depth giving rise to a huge short decay-time anomaly.

2) The response of the "contact zone" around hole N-112 is indicative of a much higher conductivity than in (1).

3) The apparent late channel off-hole responses observed in hole branches N-113 and N-113A.

Phase 2: modelling involving the addition of more conductive bodies and/or revision of the original model. Note that preliminary work on model additions overlapped with Phase 1 - preliminary work started early to help guide ongoing drilling.

Interpretation of variance in the modelled/measured responses showed that the conceptual **model** was incomplete and that possibly two separate conductors located to the southwest were required. 2 Modelling Suites were completed and the results of one follow. These results served to guide exploration outwards from the Footwall Main Zone.

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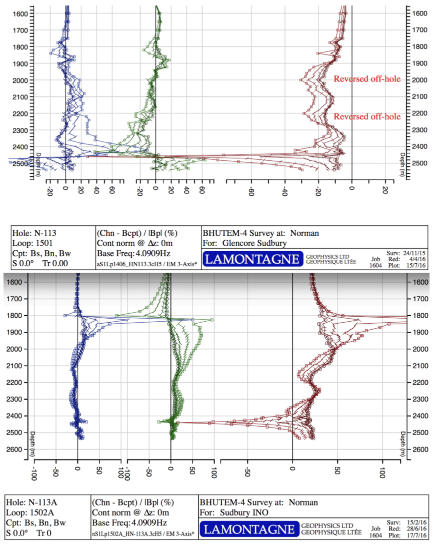
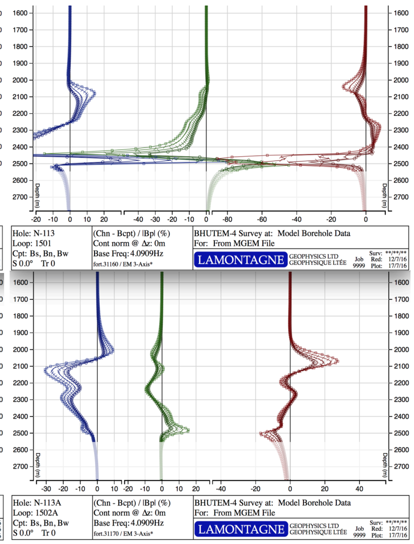


Two anomalies in Hole N-113 Lp1501 response that appear to be reversed coupled off-hole responses with Lp 1501/forward coupled with Lp 1502A.



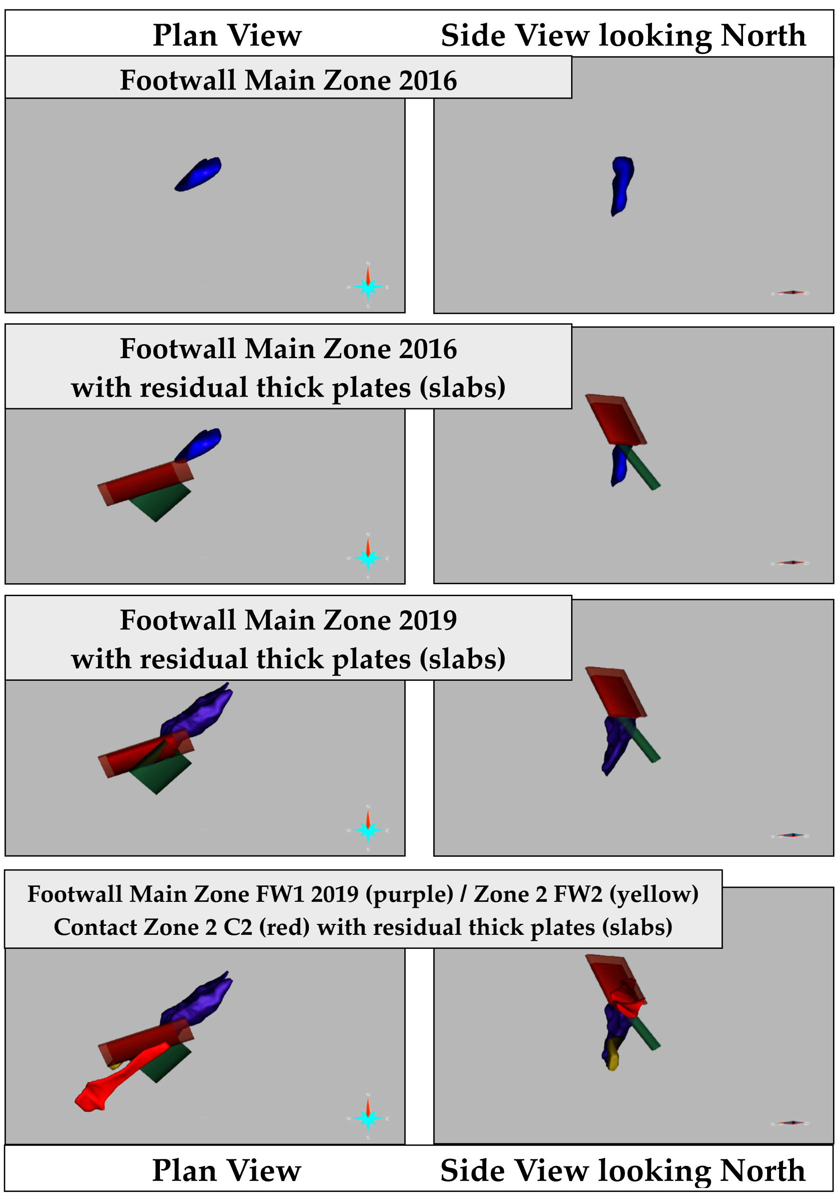
Phase 2 model response in N-113/ N-113A for Loops 1501 and 1502A.

Phase 2 - Results

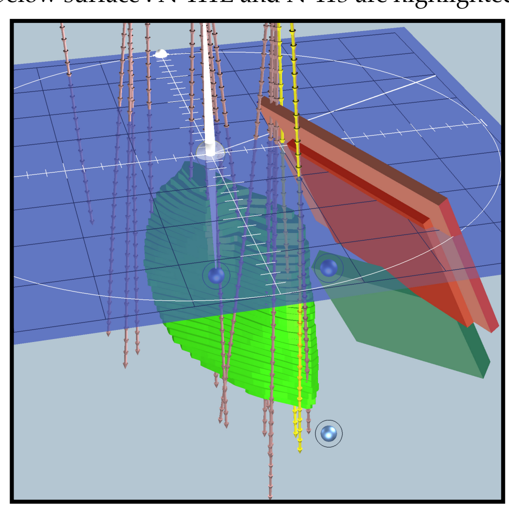
The Phase 2 modelling results are shown below along with a comparison of the model response and field data. Two conductive zones - a shallower zone (**reddish**) and a deeper zone with a higher conductivity (**dark green**) - are modelled and these new zones needed to be electrically isolated from the known ore zones. The two zones also appear in the figures to the lower left - the term “residual plates” is attached to the plates due to their being responsible for the “residual response” after the response of the objective **model** is accounted for.

Subsequent **drilling** has located and verified these zones but with a more complex shape than in the MGEM models.

The figures to the left and on the following page document the development of the Norman West deposit from 2016 through 2019 - a program guided by the combination of BHUTEM and MGEM modelling.



Phase 2 model. Two conductive zones added to the objective **model**. Zone A1 (50 S/m) in rose / A2 (500 S/m) in darker red. Zone B (3333 S/m) dark green. The reference plane protractor is at a depth of 2275 m below surface . N-111E and N-113 are highlighted



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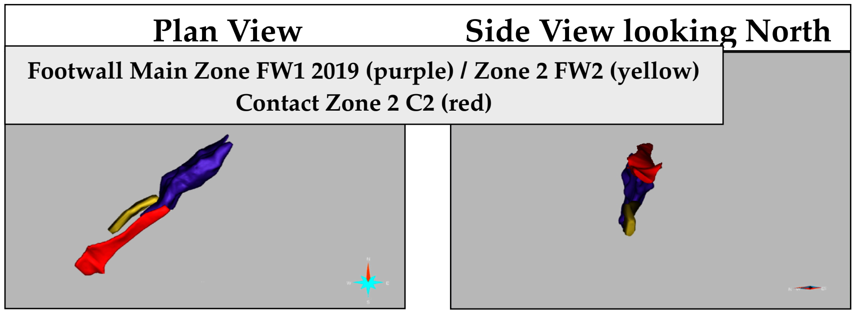
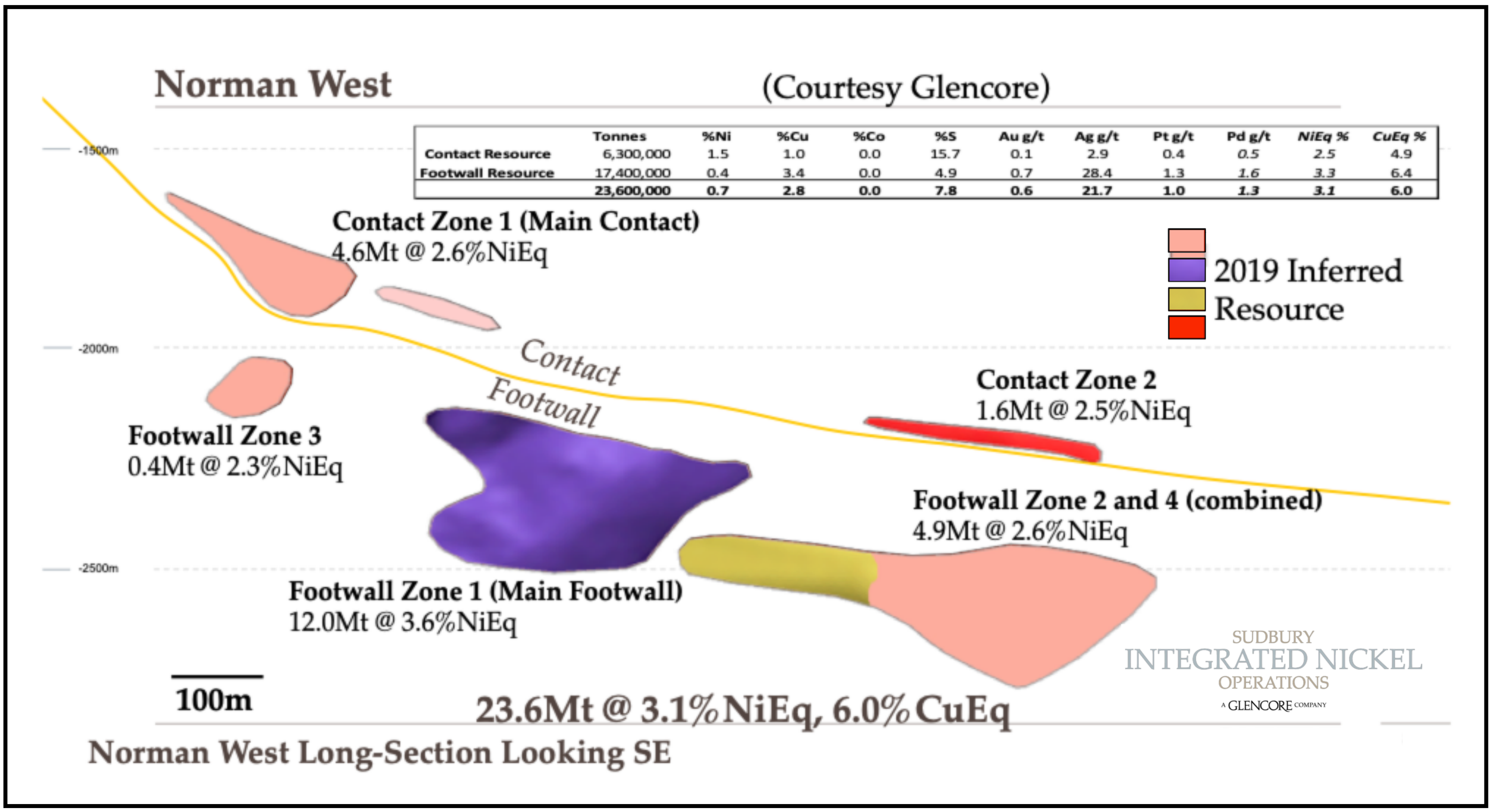


Above: the Footwall Main Zone (2019) with 2 additional zones discovered out of the Phase 2 MBEM Modelling

Below: Long Section Looking SE through Norman West to date showing the above three zones and further zones discovered with BHUTEM and MBEM Modelling.



	Tonnes	%Ni	%Cu	%Co	%S	Au g/t	Ag g/t	Pt g/t	Pd g/t	NiEq %	CuEq %
Contact Resource	6,300,000	1.5	1.0	0.0	15.7	0.1	2.9	0.4	0.5	2.5	4.9
Footwall Resource	17,400,000	0.4	3.4	0.0	4.9	0.7	28.4	1.3	1.6	3.3	6.4
	23,600,000	**0.7**	**2.8**	**0.0**	**7.8**	**0.6**	**21.7**	**1.0**	**1.3**	**3.1**	**6.0**

Summary

Plate modelling of BHUTEM data has successfully led to the discovery of new deposits in the Sudbury area. At Norman West, direct integration with the geological ore model was becoming time consuming and more and more complicated. Drilling at depths greater than 2km is expensive especially with a such a complex footwall target. More ore was there to be found - but where to find it?

The innovation here is the use of MGEM to accurately model the main footwall zone in 3D. This allowed for a better agreement between the geological model and the geophysics to be arrived at - all in one environment. MGEM modelling was completed in 2016. Exploration confidence rose as the predicted model was verified. The addition of more targets to chase to the SW increased focus. Further drilling increased the size of FW-1 and confirmed success with new ore bodies found. Ore tonnes has increased from 9Mt to 23.6Mt (260%).

Recommendation

Further MGEM modelling should be undertaken with the current geological models as input.
Three years of drilling success will provide further exploration guidance and, hopefully, additional ore targets.

For more information, please visit us at PDAC booth 1103