

What Lies Beneath? A Reflection on the Porphyry Copper Exploration Model

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SUMMARY

Electrical methods have been applied to the search for porphyry copper and IOCG deposits since the early 1950s. While there is a generally accepted model of disseminated sulfides giving rise to a chargeability response, no clear association has been attached to what EM surveys may be responding to. Work in the early 1990s (Nickson 1993) showed the well-developed supergene blankets over a porphyry copper could be conductive; this observation was however, never applied formally to generally accepted porphyry targeting models. The presence of other conductive zones associated with porphyry copper deposits is even less well studied. On the geological side, while there is a vast body of literature describing porphyry copper deposits and how to discover them, in very few cases do these studies even speculate if anomalous concentrations of sulfides could be conductive. On the geophysical side, observations of unexpected conductivity associated with porphyry systems is sometimes noted but these observations typically stop short of suggesting that there could be a more general observation made that a new class of geophysical feature should be defined. The present study is felt to have gathered a sufficient number of case studies which show that a significant number of porphyry copper deposits posse a mineralogical character which can be identified with EM techniques. This thesis can have significant implications as to how porphyry copper are explored for, especially those at depths >500 m, a generally accepted cut-off for IP techniques.

Key words: Porphyry Copper, conductivity, targeting model

INTRODUCTION

Porphyry Copper-Gold-Molybdenum deposits (PCDs) and Iron Oxide Copper Gold deposits (IOCG) are the primary source for copper resources in the industrialized world. For PCDs, the most likely location for these deposits has long been known and is commonly termed the 'Ring of Fire'. IOCGs are fewer in number and as well, more diverse geographically and geologically. Figure 1 (Sillitoe 2012) shows a global distribution of both deposit styles.

The author has examined numerous type-section of the geology and alteration for the PCDs and IOCGs. What is typically missing is any reference to physical properties, which if included, would allow a broader conversation to ensue as to how such deposits could be located with geophysical techniques. Fortunately, there is considerable 'trade knowledge' available for typical geophysical responses which allows sections as show Figure 2 (Hübert et al. 2016) to be produced.

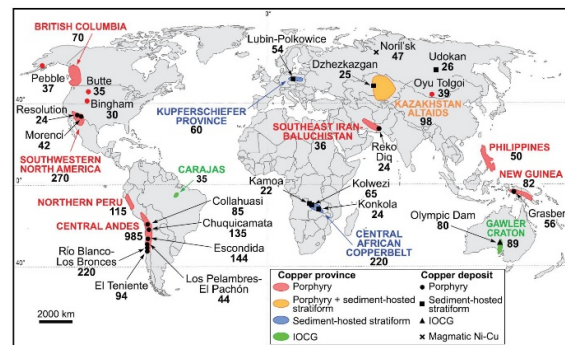


Figure 1: 'Ring of Fire' Global distribution of porphyry copper-au and IOCG deposits. (Sillitoe 2012).

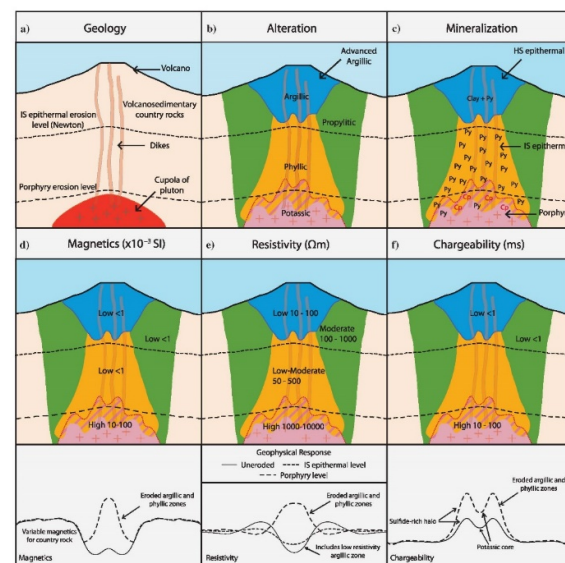


Figure 2: Stylized geophysical response of porphyry deposit. (Hübert et al. 2016).

While this type of characterization of physical properties is very useful, it is inherently an average response based

on measurements taken over many systems. Although geophysical outliers can be assumed to exist, these are hard to capture in a credible way unless there is associated geological evidence available to support a different model. Otherwise, geophysical variances will most likely be considered an issue with how the data was acquired, the processed was carried out or how the results were interpreted. Basically the [aphorism](#) attributed to Carl Sagan applies; this states that "extraordinary claims require extraordinary evidence". The geological evolution of the PCD model (Figure 3) was largely incremental but after 40 years, significant enhancements have been made. There has been no such corresponding change in the PCD geophysical model during this time until possibly now.

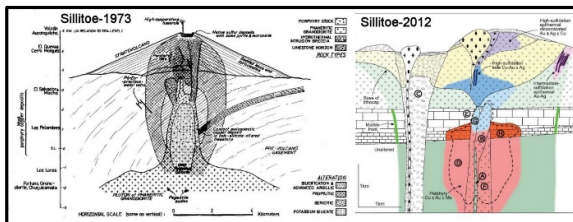


Figure 3: Sillitoe's PCD models; 40 years of evolutionary thinking. (Sillitoe 1973, Sillitoe 2012)

RESULTS

The line of investigation started with the examination of a legacy (2009) IP-DC resistivity and MT data over a PCD in the Yukon called Casino being selected for re-evaluation. The current owners of Casino were approached, Western Copper and Gold, who gave their permission for this assessment to be undertaken and provided access to relevant geophysical and geological data. Additional geophysical and geological data were accessed from government and public sources. Both the IP-DC resistivity and MT data were re-processed using 3D modeling whereas only 2D processing was carried out in 2009.

Due to the lack of glaciation over the study area, there was a thick layer of oxidized rock overtop a supergene zone that in turn overlaid the hypogene (fresh) rock. This geological and geophysical heterogeneity complicated the data processing for the IP-DC resistivity and once addressed, a result which far better matched the known geology was obtained. For the re-processed MT however, a very distinct and discrete conductive body appeared on the southern flank of the deposit with a depth to top of about 650 m. This feature was not defined in the earlier MT processing nor in the initial or subsequent IP-DC resistivity results. A 3D view of the IP chargeability and MT outcomes are shown in Figure 4. (Wetherly et al., 2018).

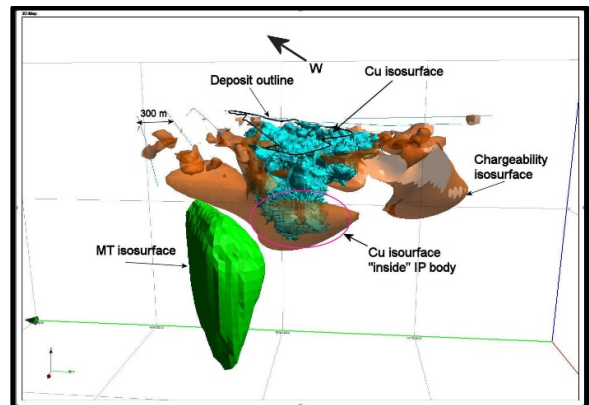


Figure 4: 3D view of Casino Chargeability, MT and Cu isosurface bodies. (Wetherly et al., 2018)

The source of this MT feature is not currently known but a geological body with a higher level of sulfide content is deemed the most likely candidate. Whether or not economic mineralization could be present is also unknown. If it were, then a potential underground mining operation could be envisioned which might be a more attractive development target than a large tonnage PCD in a remote part of the Yukon.

With one such example defined, the search was started for other such instances where strongly conductive features are found associated with PCDs. MT data was preferred as the depth of penetration for conductive sources is typically superior to that achieved with DC resistivity. Six other examples have been recognized and these are listed in Table 1.

Each one is someone different than the others in the size, relative location and strength of the response. Figures 4-9 show images from each of these other systems. This suggests differences in timing of such events in the history of the formation of the intrusive system as well as possibly the mechanism which creates these features. However, the fact that six porphyry deposits in a range of settings and ages all have some sort conductive feature closely associated with the deposit suggests this type of occurrence is not rare. Also, in four of six examples (and possibly a fifth, Morrison), the conductive feature is directly associated with known economic mineralization.

There is insufficient evidence gathered so far to state that the conductive zones are always associated with zones of higher grades but this conclusion appears to be supported by the samples examined. If this is the case in a more general sense, the identification of a conductive zone and the implied anomalous grades could have important economic implications. In the case of the Casino deposit, the defined resource while significant is likely too low a value to support the deposit's development. If the defined EM feature were a massive sulfide deposit with 2-3 times the grade and 15-25 Mt in size, it could be a viable target for development.

Table 1

Deposit Name	Location	Survey/Data Types	Conductive zone associated with mineralization
Casino	Yukon	Titan IP/MT	Unknown
Morrison	BC	ZTEM/MT	Possibly
Resolution	Arizona	MT/ZTEM	Yes
Bingham	Utah	MT	Yes
Collahuasi	Chile	TEM	Yes
Santa Cecilia	Chile	CSAMT/Orion (IP-MT)	Yes

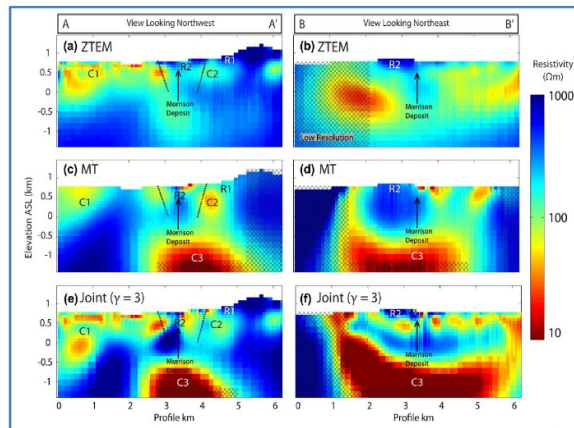


Figure 5: ZTEM and MT sections through the Morrison deposit (Hübert et al. 2016).

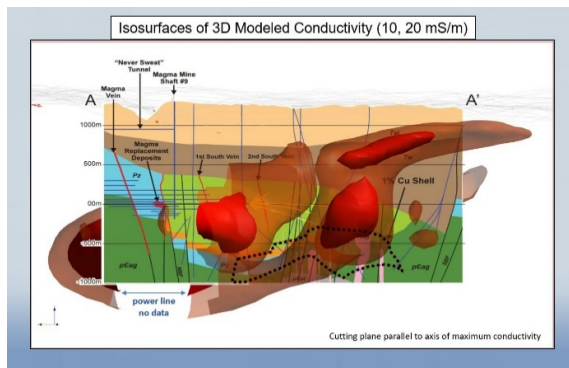


Figure 6: Section through Resolution deposit showing ZTEM and geology (Witherly et al., 2016).

CONCLUSIONS

EM techniques have been applied to porphyry copper exploration since the early 1950s. Unlike how EM is applied to the search for VHMS and magmatic nickel deposits, EM for porphyry coppers has never been established as a primary exploration approach, due in large part it is suggested to a lack of well defined petrophysical models that relates sulfide content with

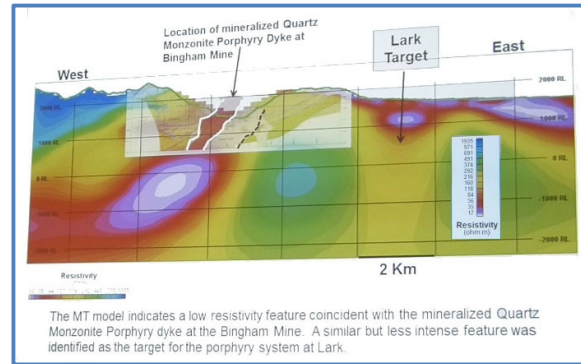


Figure 7: Section through Bingham deposit showing MT section and geology. (Hinks 2013).

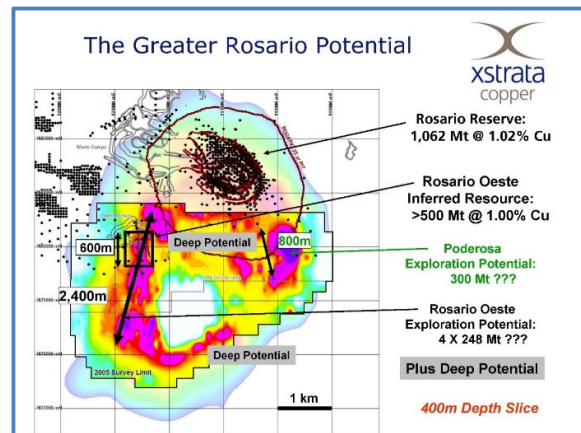


Figure 8: Depth section through Rosario deposit-Collahuasi mine. (Xstrata 2006).

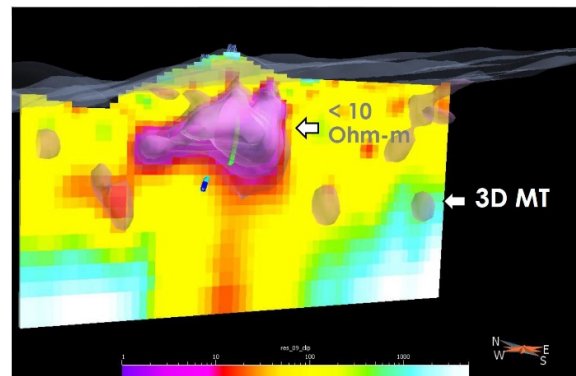


Figure 9: Cross-section of MT through Santa Cristina deposit. (Bournas and Thomson 2013)

grade. The current assessment is not considered rigorous in a geological deposit model or geophysical response model but given the number of examples which show observationally strong and economically important correlations between EM derived conductivity responses and porphyry copper deposits, a previously undefined targeting relationship is suggested. Further study of the defined systems and other deposits with suitable geophysical coverages is deemed warranted.

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