ASEG 2015 IP Workshop: Gradient Array

HPX
HIGH POWER EXPLORATION

Barry de Wet

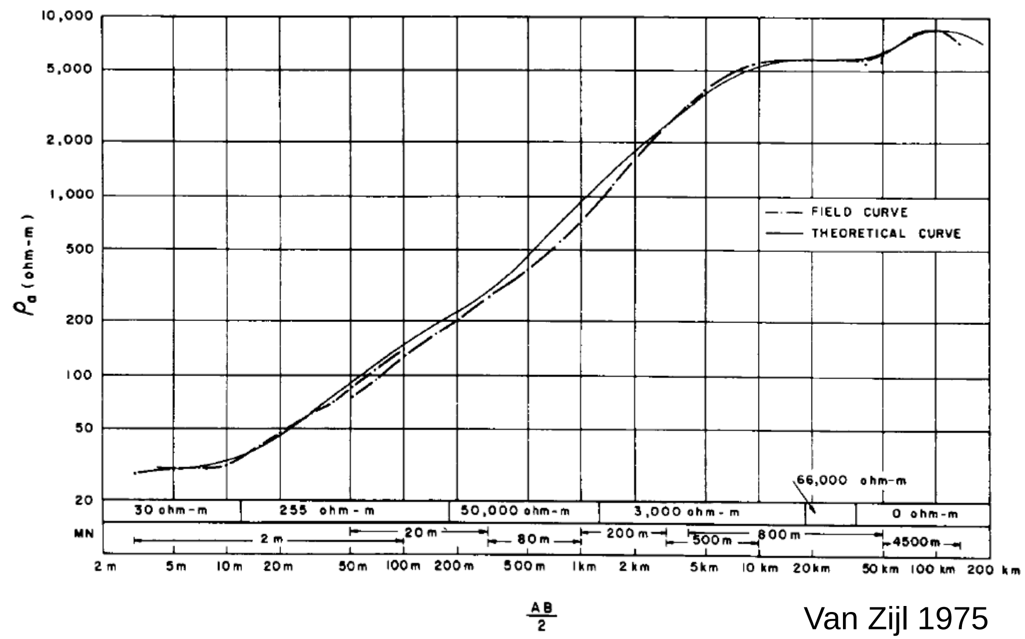
31/03/15

Introduction

- Challenge was to follow up an unexplored 30,000 km2 area of gravity and magnetics in Mongolia for undiscovered porphyry copper deposits.
- IP is the principle geophysical technique for detecting sulphides in a porphyry system, the question is how one could complete a reconnaissance IP survey of a reduced geologically favourable area of 710 km2
- To quote IP Contractor "*We currently deploy 14 receivers; production has been averaging around 150 km per day when doing the initial recon of an area. Productivity can easily be increased further by simply adding a few more receivers".* That's about 30km2 per day!
- The Zeus Transmitter enabled them to deploy large current electrode AB's which gave him the necessary S/N to deploy 14 receivers. It's true that the country and terrain were ideal for such a survey, but many lessons were learned that have now been built into the new Typhoon IP/EM transmitter series.

Schlumberger soundings

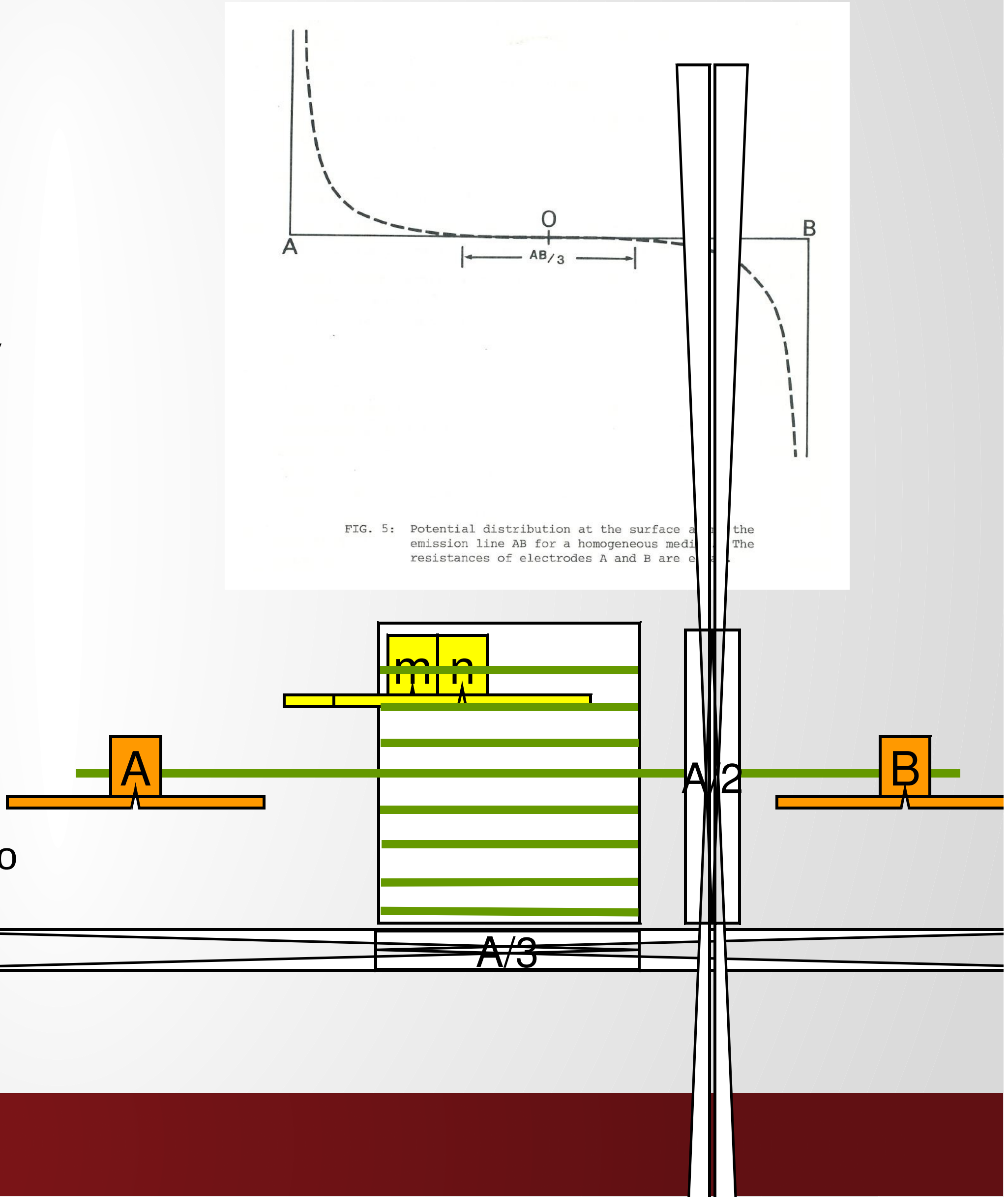
- Deep Schlumberger soundings have been used for crustal studies in the USA by Keller (1966), Brace (1971) and in South Africa by van Zijl (1975) confirming seismic survey low shear velocities at depths of up to 24km, Bloch et al (1969).
- Van Zijl used AB separations of up to 450km using telegraph lines during his study of the South African crustal structure.



Van Zijl 1975

Why Gradient Array?

- Advantages of Gradient array method are mainly in the rate of production. The design of the survey is critical
- Typical gradient array survey design requires that the electrical field is mostly uniform.
- This is roughly AB/3 parallel to the AB direction and AB/2 perpendicular to the AB direction, preferably in flat terrain.
- For an AB=20km, this covers an area of 67km2. Using a 200m dipole on 500m line spacing, one can do the 134km in one day if one uses a multiple receivers approach. Typically AB preparation and line preparation takes one to two days so that theoretically, one should achieve 45km per day production.
- But this is naturally very dependent on the terrain.



Typhoon

HPX HIGH POWER EXPLORATION

- In Australia and particularly in NSW, the safety requirements also limit the production rate.
- AB wire resistance will limit power output for long AB’s.
- Agriculture, livestock and paddock fences slow down operations. Despite this, we have achieved production rates ranging from 4 line km to 27 line km per day in NSW and more in SA using 3 receivers.
- In Africa it’s the rural population, livestock, agriculture, rivers and vegetation that slow down operations. Typically we achieve 7 to 14km per day in the DRC using 3 receivers.
- Chile is more suited to high production and the main issue in Chile is contact resistance on AB electrodes. Typhoon has achieved between 6 and 30amps with minimal electrode preparation.

AB limits

- The Gradient Array configuration can be expanded to any size. Depth of investigation is a function of AB and we use the estimated transverse resistance Σ(ρi h i) to set AB
- Two of the most important limitations to overcome are Signal to Noise (S/N) and electromagnetic coupling (EMC).
  - S/N includes many sources but these are not the subject for this talk. The most important factor is the amplitude of Vp which is a function of the current injected into AB. We require at least Vp=10mV for reliable IP data (Fig 1&2).
  - EMC is a significant, if not the most important consideration when doing large Gradient Array surveys (Fig3).
  - The Survey objective can only be achieved if the correct survey design is applied so that prior knowledge of the conductivity structure of the area becomes a critical input.

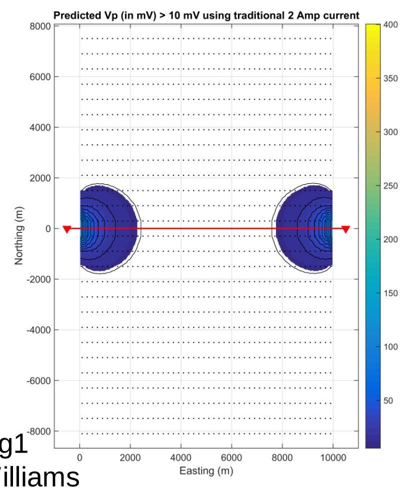


Fig1
Williams

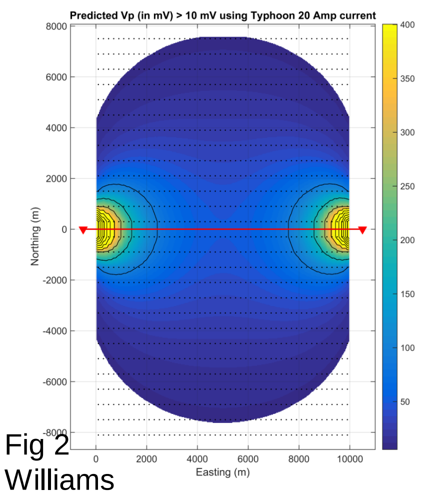


Fig 2
Williams

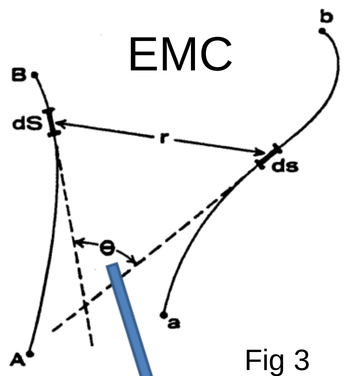


Fig 3

$$Z_{Ss} = \iint \left\{ P(r)\cos\theta + \frac{\partial^2 Q(r)}{\partial S \partial s} \right\} dSds$$

Coupling Term   Earth Term

Data processing and Inversions

- There are no shortcuts! Every transmitter position and every receiver position must be accurately known.
- The exact transmitter waveform is required to define the zero for each decay. The S/N on every recorded cycle can destroy late time decay so the statistics must be quantified for each receiver point. This process needs specialised QA/QC software and is not commercially available.
- Once the chargeabilities and the resistivities are calculated, a first pass map can be produced showing the conductivity and chargeability structure of the survey area.
- We use 3D inversions to improve our knowledge of the deeper structure using depth weighting and geological constraints

Generalised resistivity/depth formula;

$$V = \frac{I\rho}{2\pi}\left(\frac{1}{r_{Am}} - \frac{1}{r_{Bm}} - \frac{1}{r_{An}} + \frac{1}{r_{Bn}}\right)$$