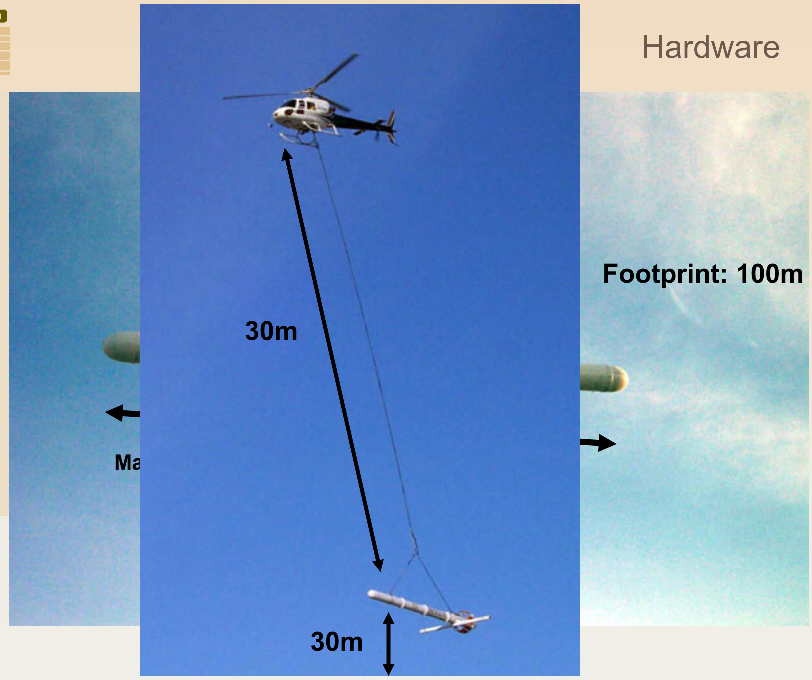
Fundamentals of Frequency Domain EM

Greg Hodges, Chief Geophysicist

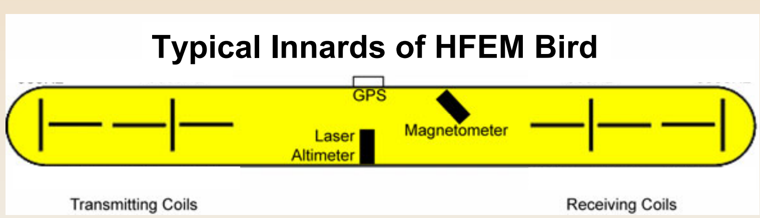
	Moving Tx Centre Rx	Moving Tx Offset Rx	Fixed Tx Moving Rx
Small Tx ↓ Large Tx	DIGHEM GEM2A IMPULSE RESOLVE HUMMINGBIRD *AEROTEM* *SIROTEM* *HELIGEOTEM* *SKYTEM* *VTEM*	MAX-MIN PROMIS-10 GENIE, *PEM,* GTK HAWK *THEM* *TEMPEST* *GEOTEM* *MEGATEM*	VLEM *UTEM* *CSAMT* *PROTEM* *PEM* *SIROTEM* FLAIRTEM
Distant Tx			VLF VLF
Natural Tx			MT MT

Airborne *Ground* Freq Domain, *Time Domain* SIZE, SIZE = Importance

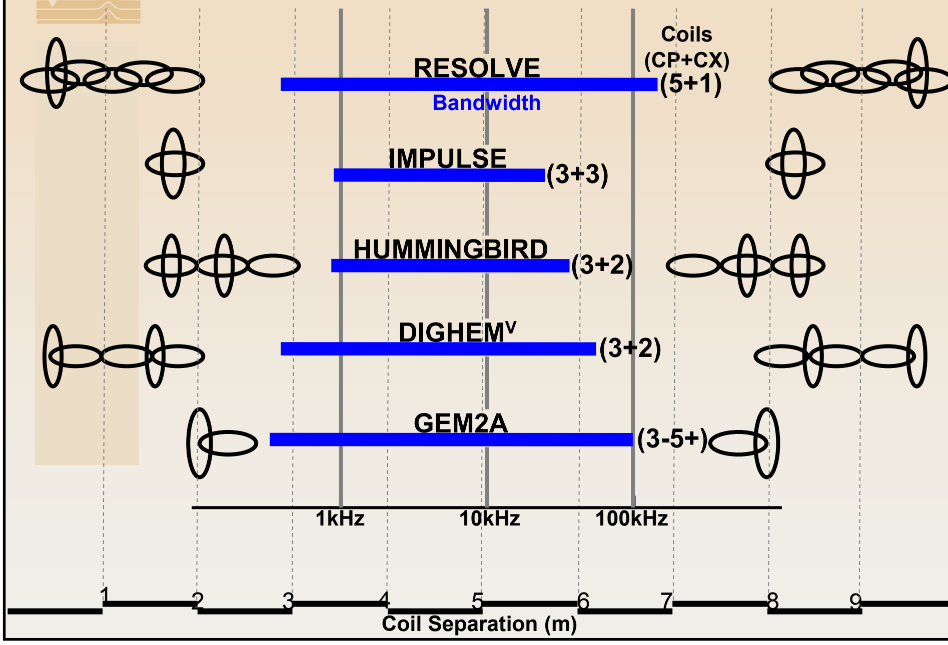
Hardware



Hardware Developments:HEM



HFEM Systems, 2007



HFEM Coil Configurations

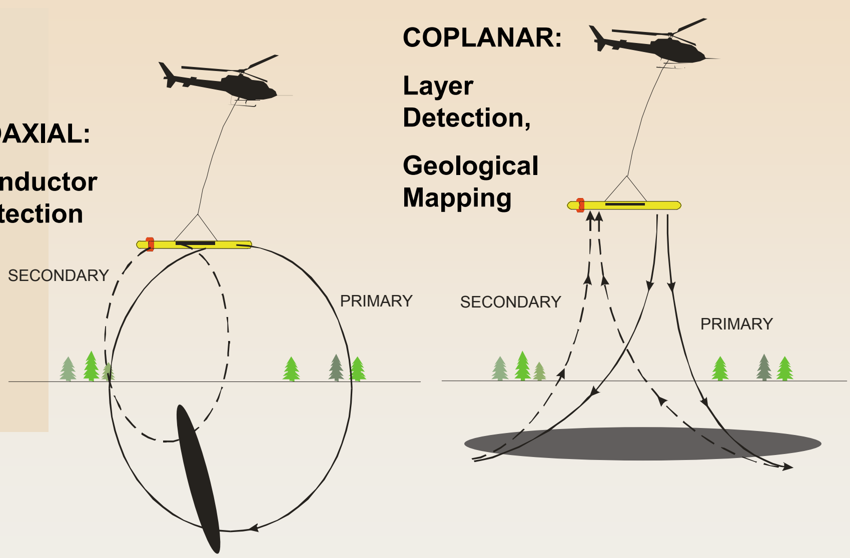
COAXIAL:

Conductor Detection

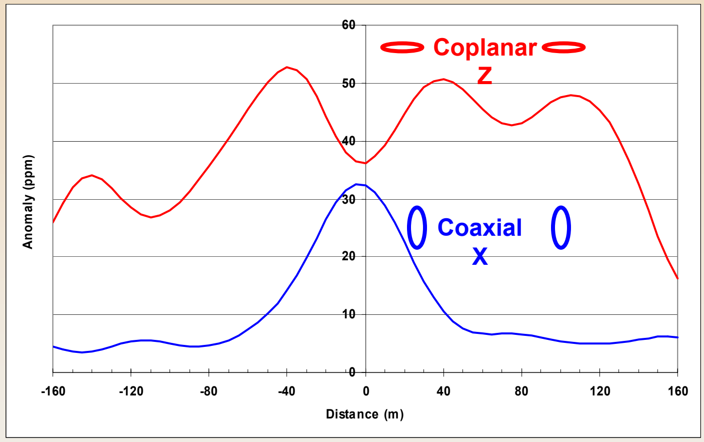
COPLANAR:

Layer Detection,

Geological Mapping

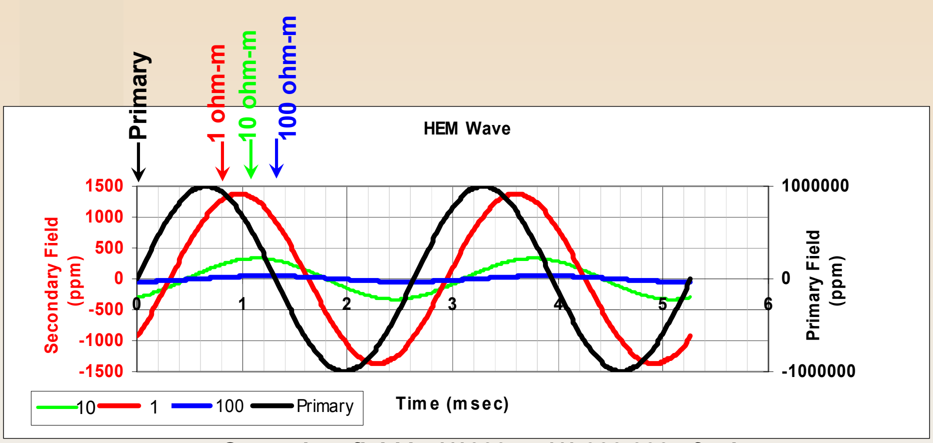


Making the Most of HEM Data



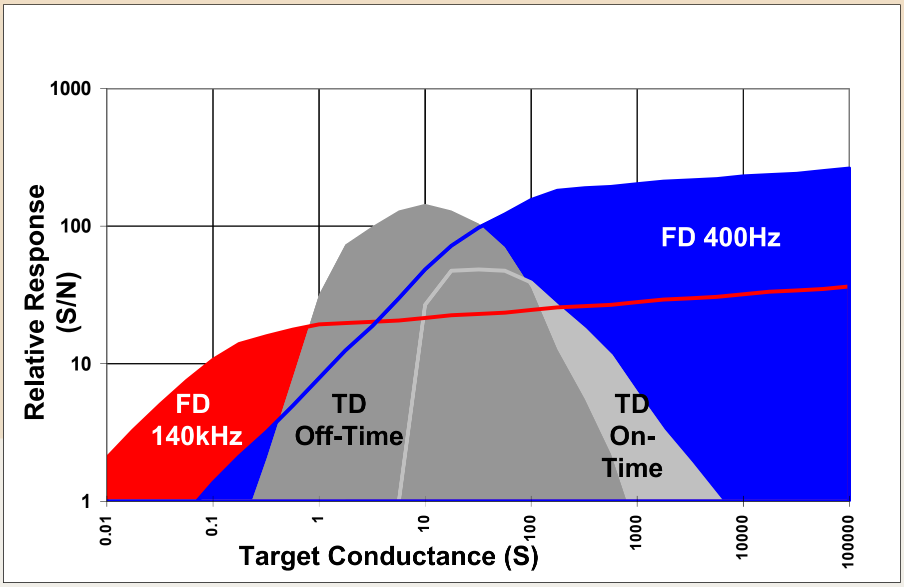
- 1 Vertical Conductor under conductive Overburden

Frequency Domain EM



Secondary field is 1/1000 to 1/1,000,000 of primary

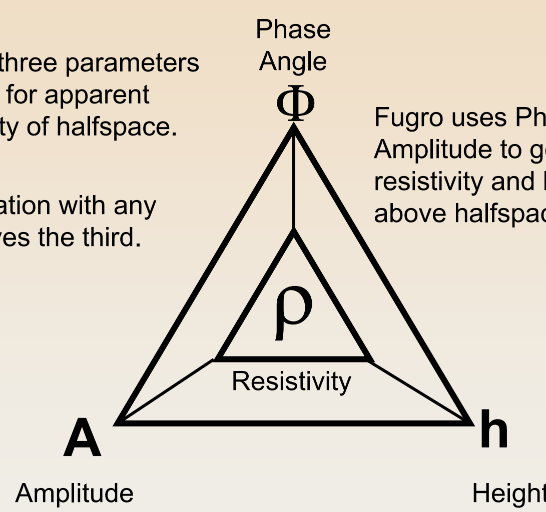
FD TD Range of Sensitivity



Pseudo-Layer Apparent Resistivity

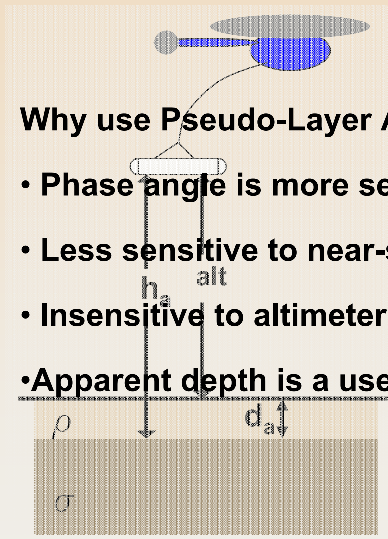
Two of three parameters needed for apparent resistivity of halfspace.

Calculation with any two gives the third.



Fugro uses Phase and Amplitude to get resistivity and height above halfspace.

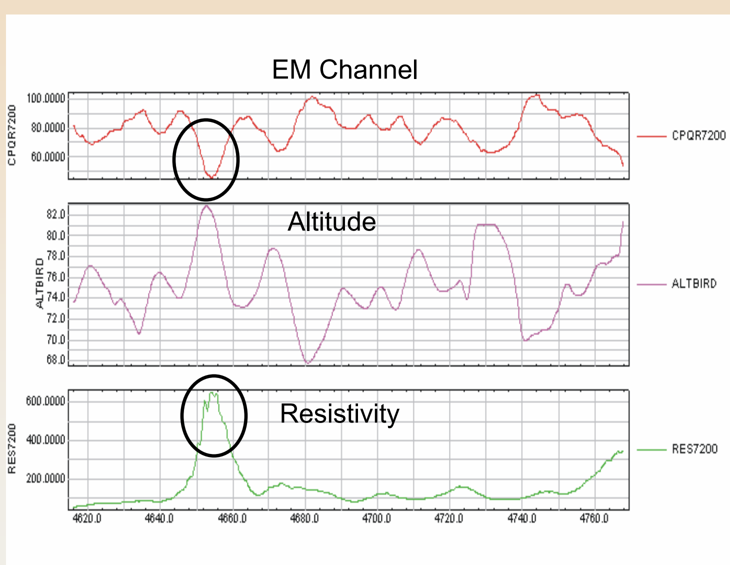
Why Pseudo Layer Apparent Resistivity



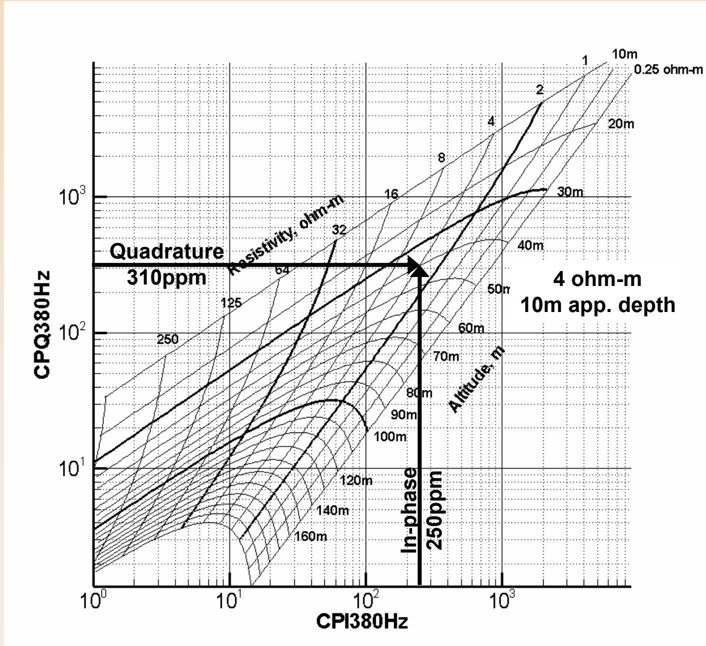
Why use Pseudo-Layer Apparent Resistivity?

- **Phase angle is more sensitive to deep conductors**
- **Less sensitive to near-surface layers.**
- **Insensitive to altimeter errors (e.g. tree cover).**
- **Apparent depth is a useful interpretive tool.**

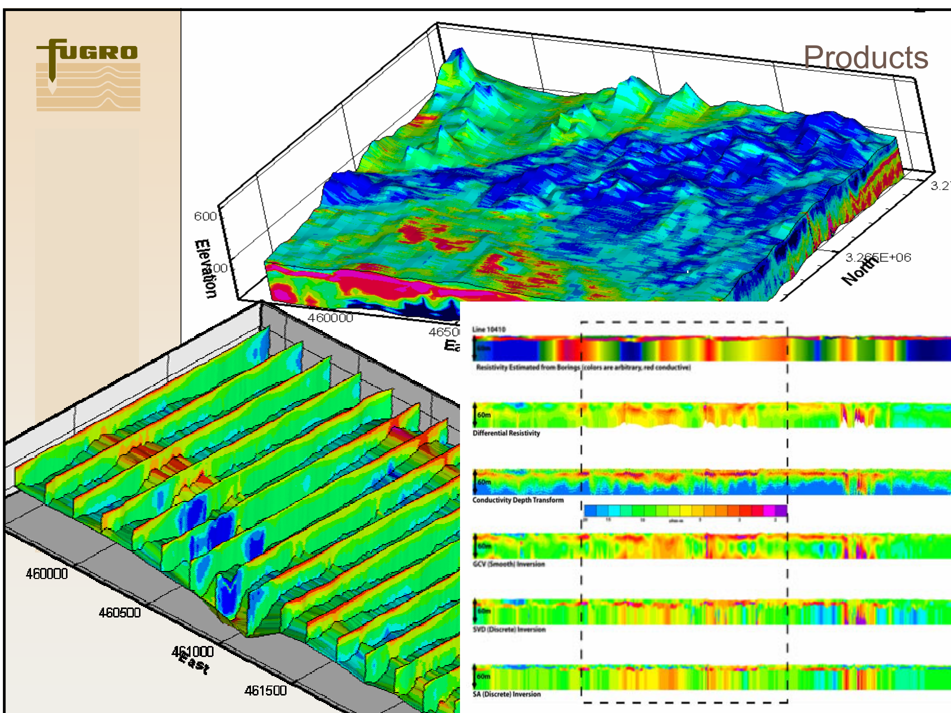
Resistivity Immune to Variations in Height

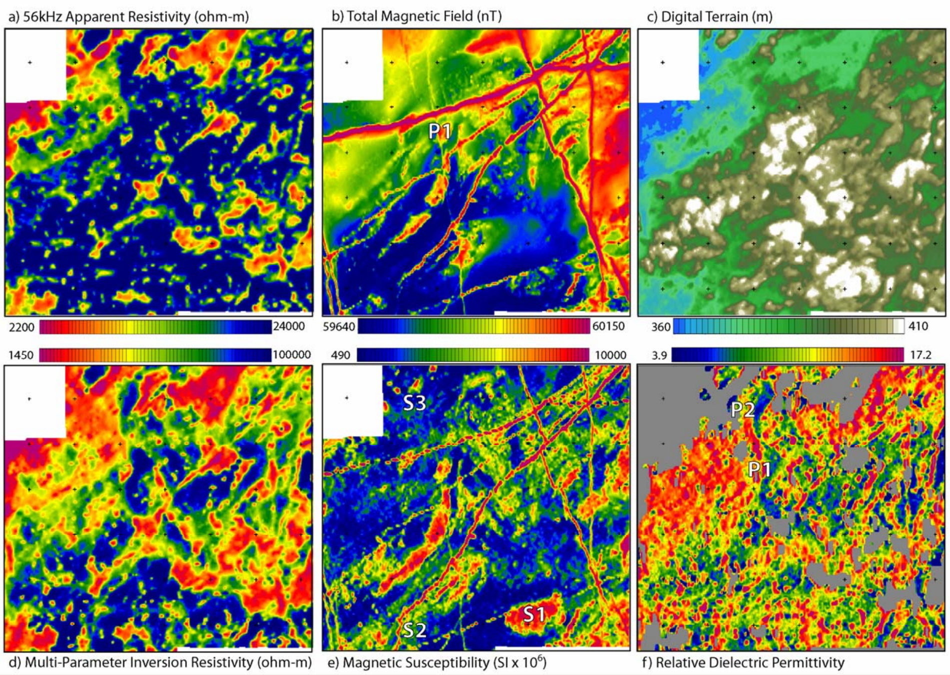


Resistivity Nomogram



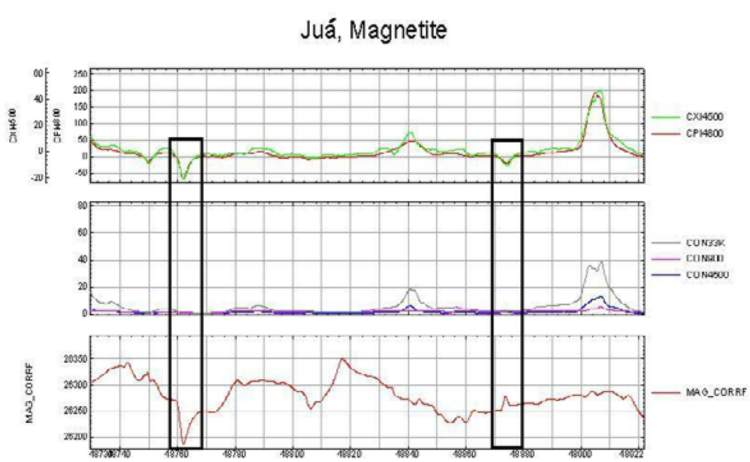
Products



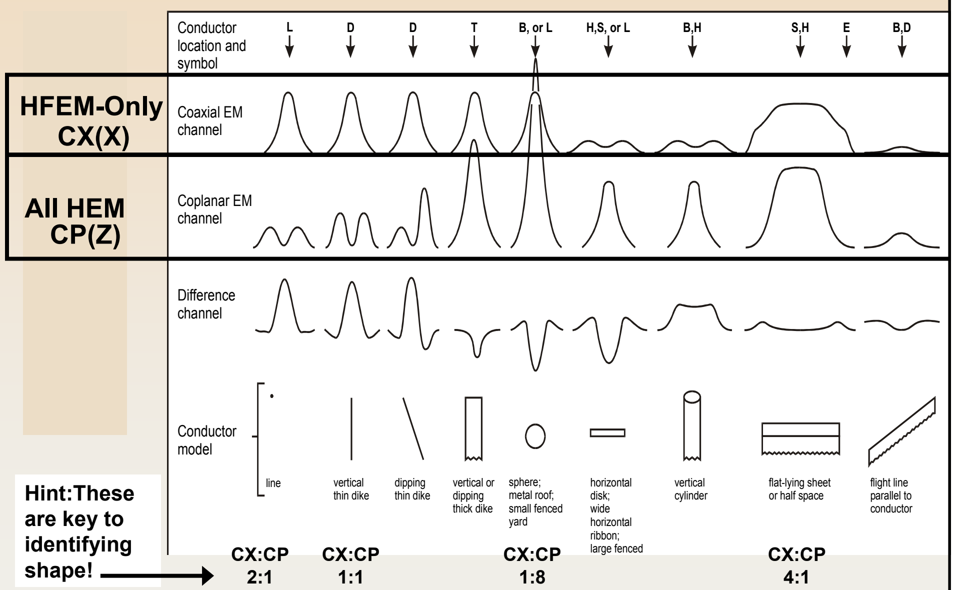


More than just Resistivity

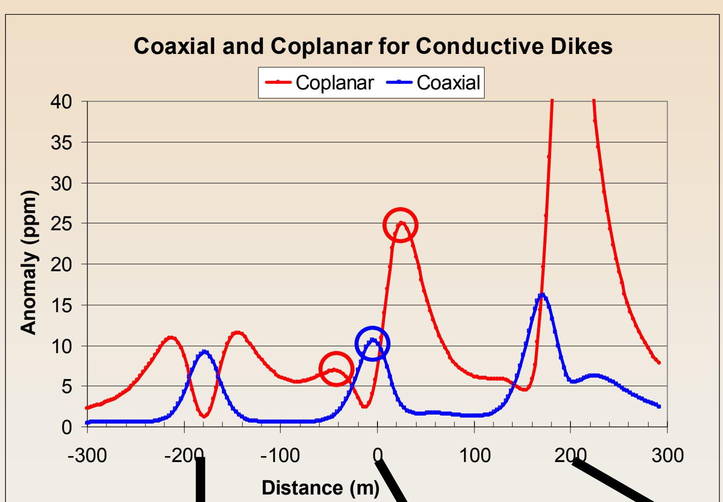
Magnetite Anomaly: Example



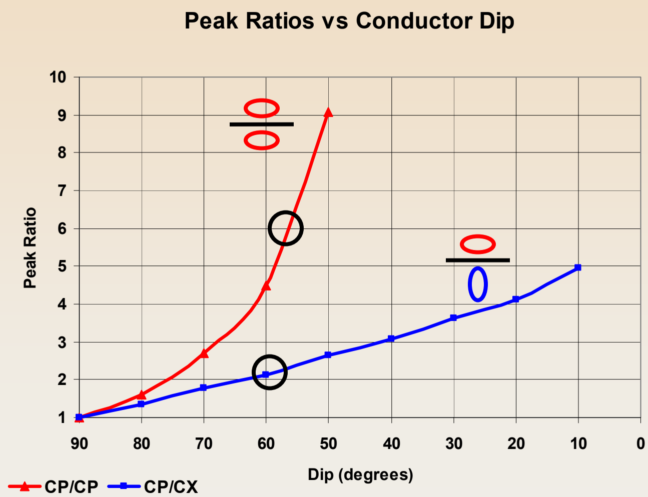
Typical HEM Anomaly Shapes



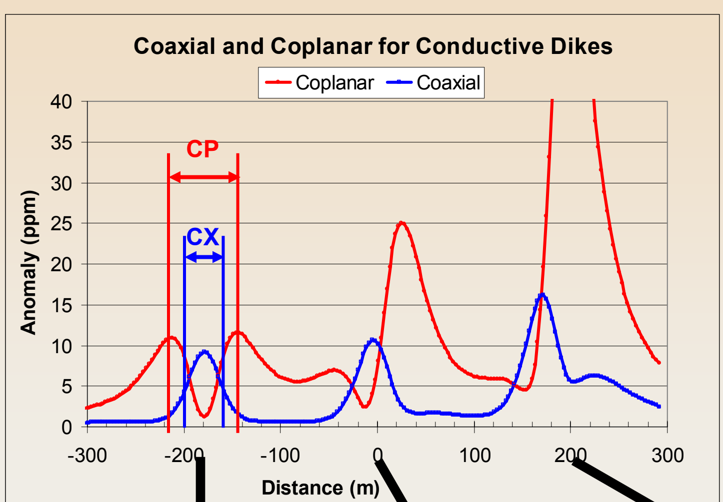
HEM Anomaly Shape: Dipping Thin Dike



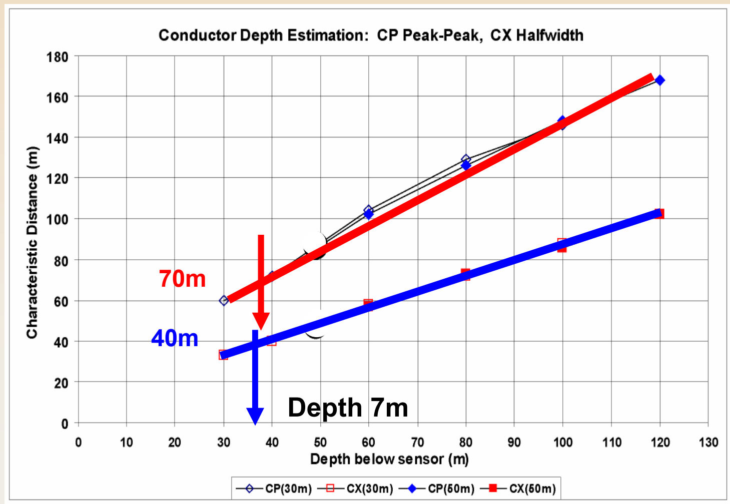
Dipping Thin Dike: Peak Ratios



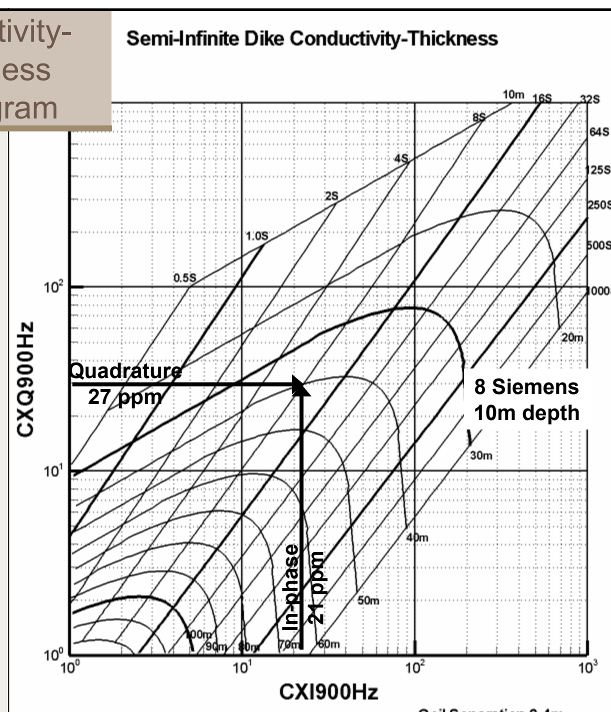
HEM Depth: Dipping Thin Dike

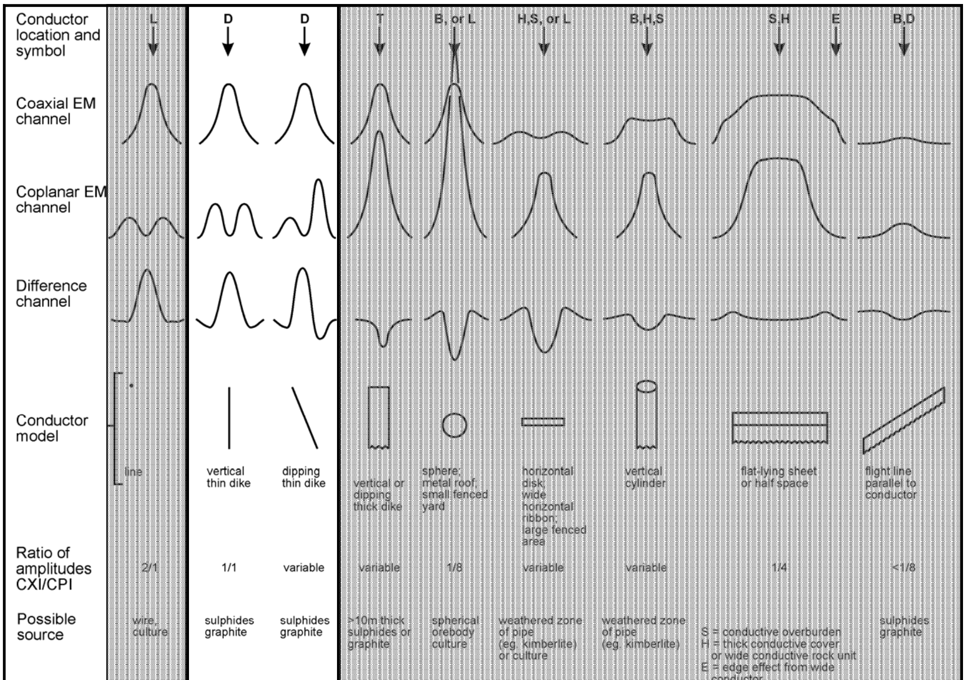


Thin Dike: Depth Measurement



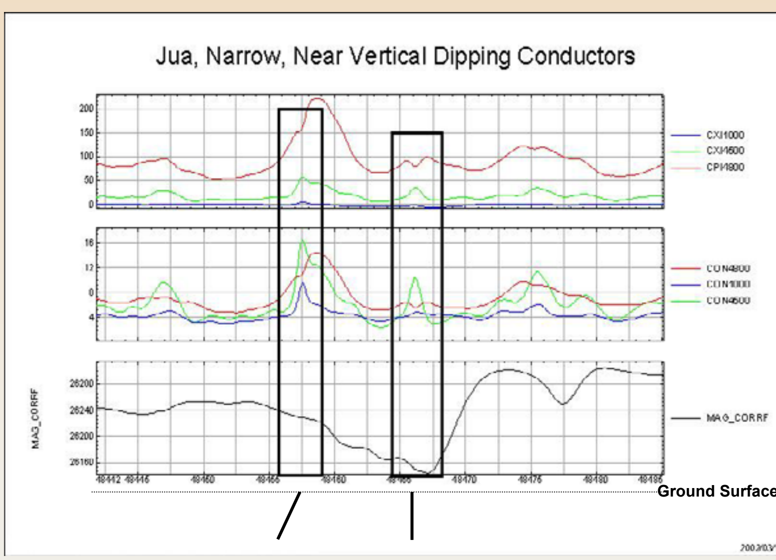
Conductivity-Thickness Nomogram

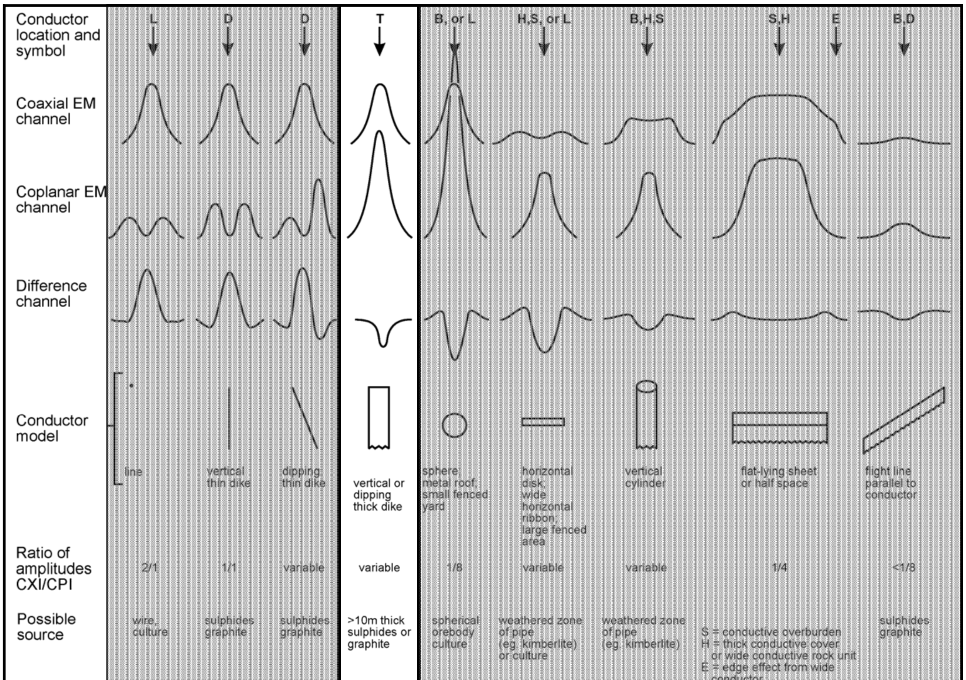




Typical HEM Anomaly Shapes:**Thin Dike**

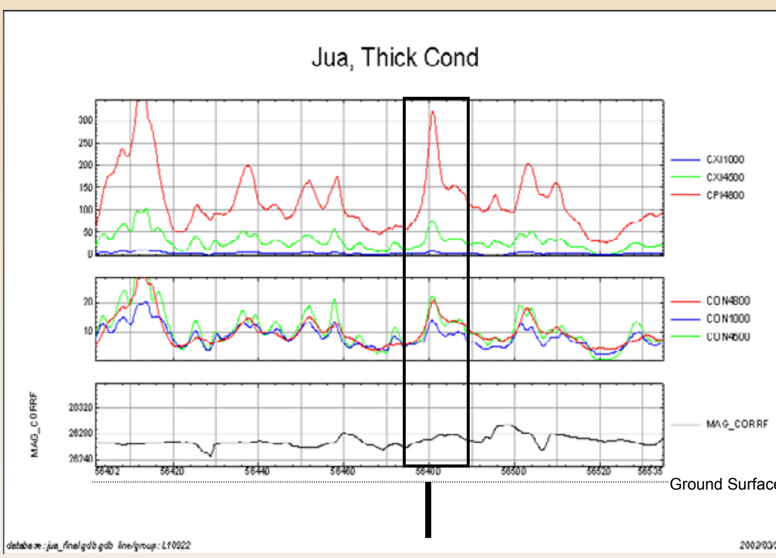
Thin Dike: Example

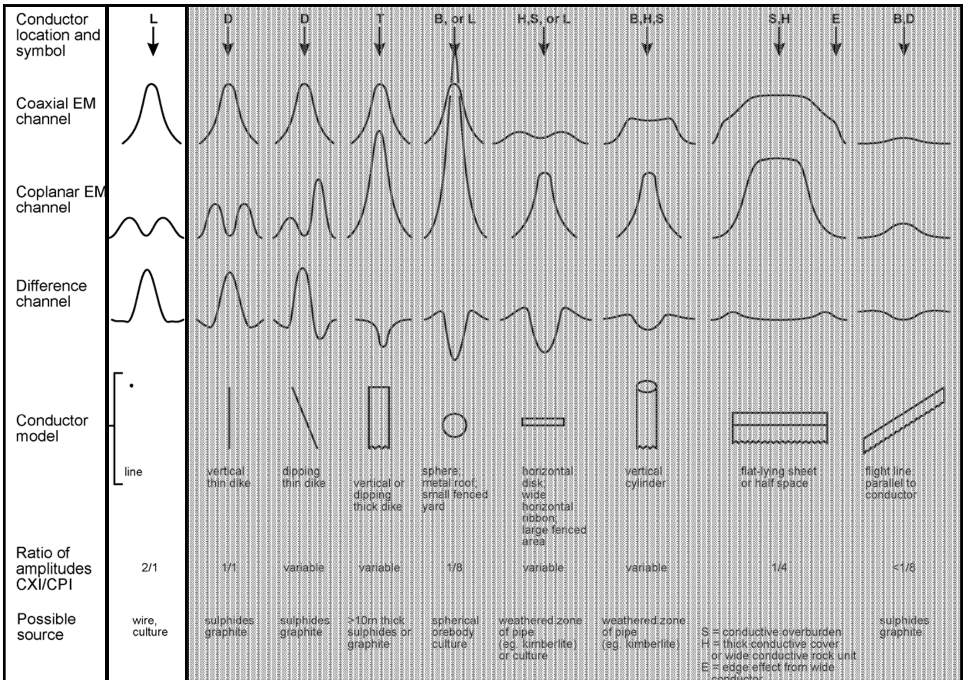




Typical HEM Anomaly Shapes: Thick Dike

Dipping Thick Dike: Example

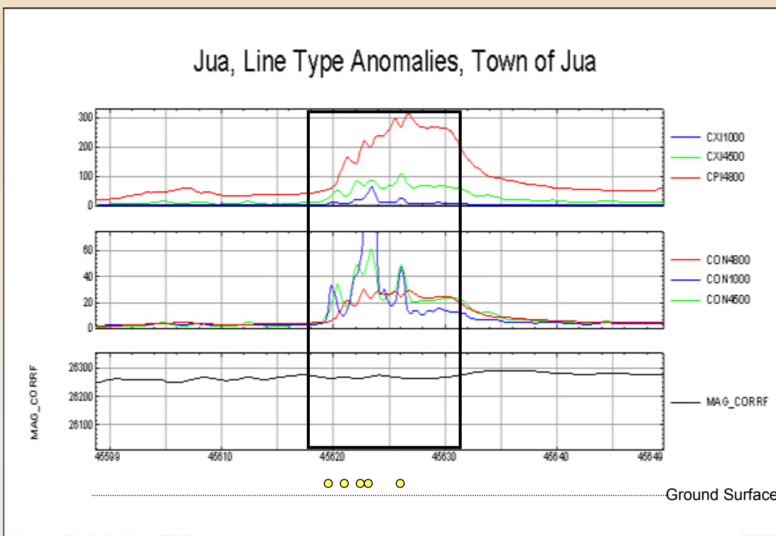


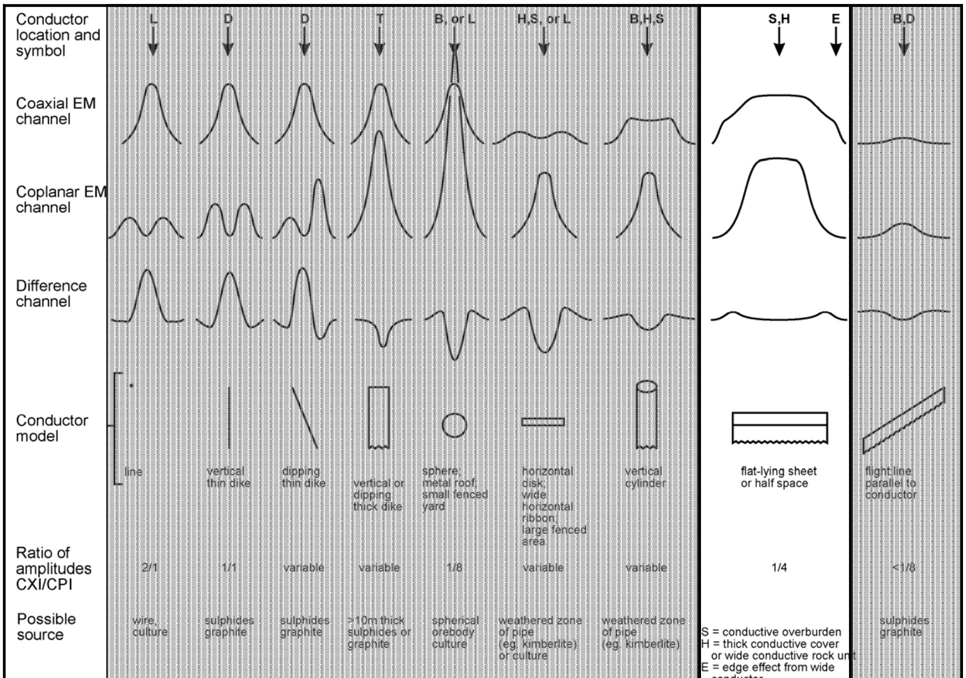


Typical HEM Anomaly Shapes: Line Source

FUGRO

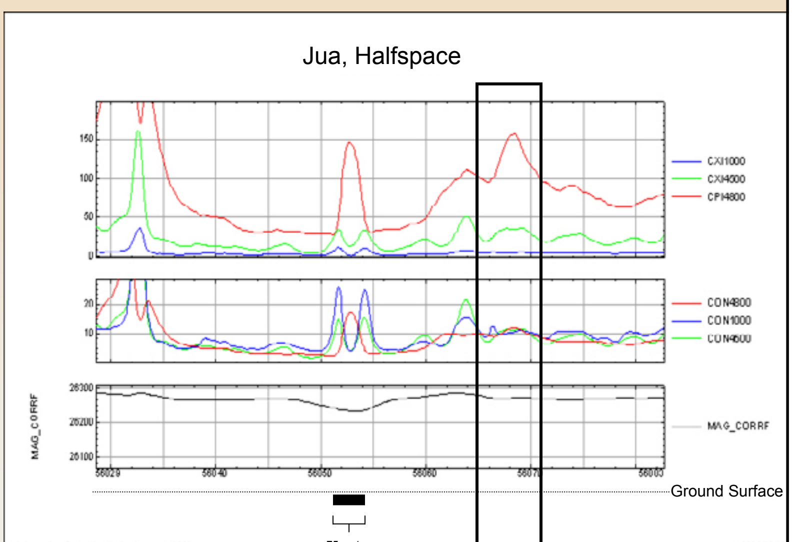
Line Source: Example

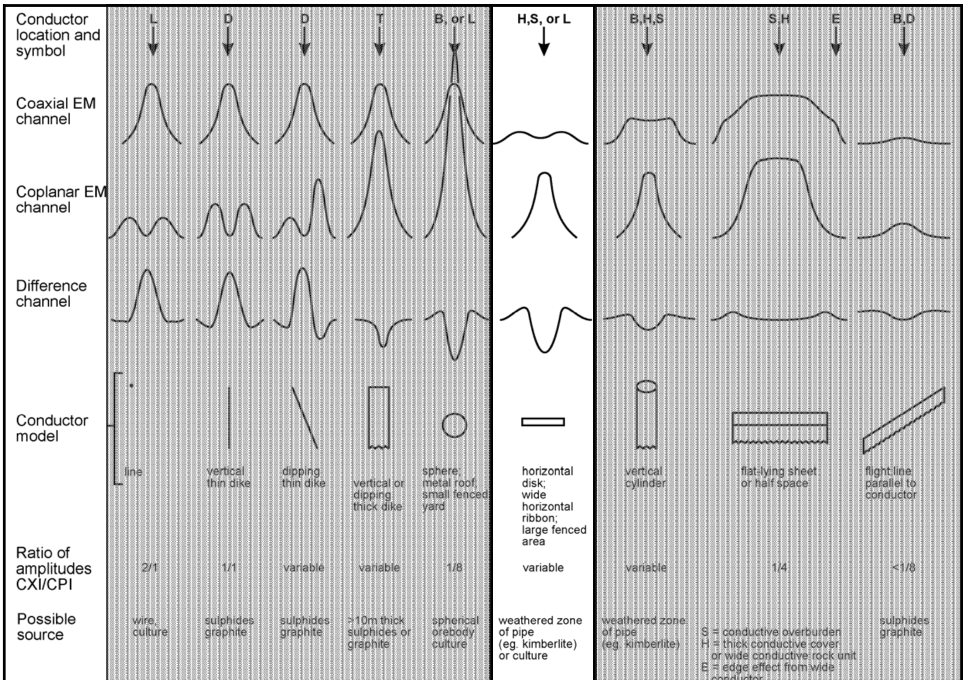




Typical HEM Anomaly Shapes: Large Sheet or Halfspace

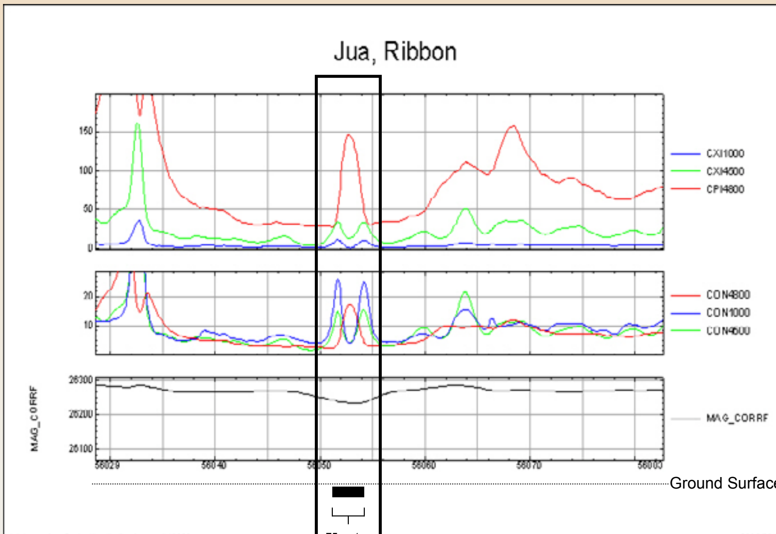
Halfspace Source: Example

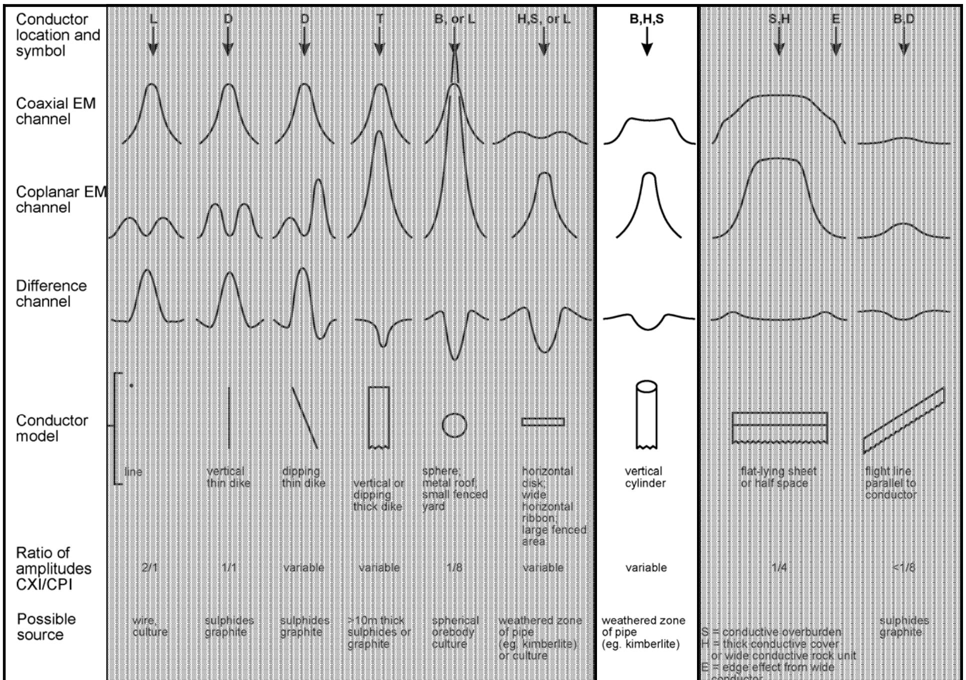




Typical HEM Anomaly Shapes: Small Sheet or Ribbon

Ribbon Source: Example

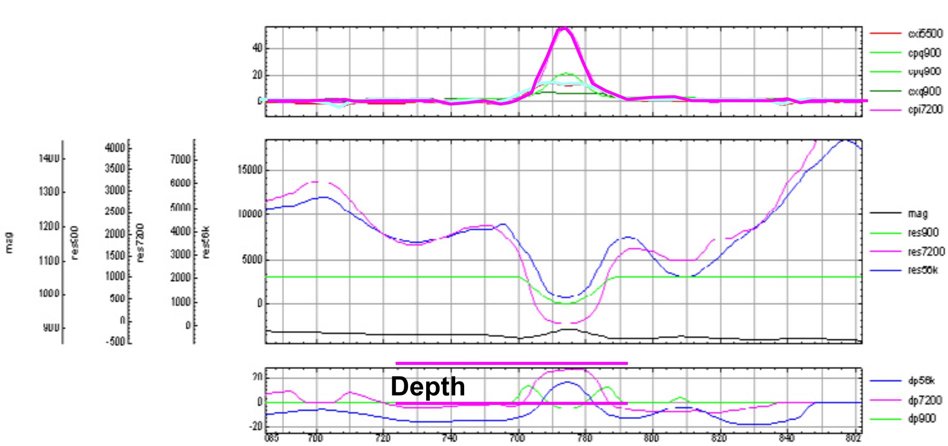




Typical HEM Anomaly Shapes: Vertical Cylinder

Diavik HEM/Mag Examples

A21



ANALYSIS OF HFEM ANOMALIES

- CP(Z) and CX(X) anomaly shapes for source type
- In-phase/quadrature ratio for conductivity or resistivity
- Amplitude of response for depth
- CP/CP or CP/CX ratio for dip
- CP and CX distances for depth
- Strike direction and length
- Variations of characteristics within zone
- Associated geophysical parameters
- Position with respect to structure
- Geological environment

Choosing the Best System

	Freq Domain Helicopter	Time Domain Helicopter	Fixed-wing Time Domain
Spatial resolution	Best	Good	Poor
Resistive targets	Best	Poor	Poor
Terrain following	Best	Best	Poor
Near-Surface	Best	OK	Poor
Depth of Exploration (conductive)	Least	Better	Best
Base of Operation	Camp	Camp	Airport
Strengths	Diamonds Gold Engineering Small areas Mountains	Base Metal (esp small, complex) Small areas Mountains	Deep BM Deep water Athabasca Big areas Conductive