

Magnetics and EM: The Dynamic Duo of Oil Field Subsurface Characterization

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COLLIER
GEOPHYSICS

A Brief Summary Bio

years in the geoscience industry: 40+

formal education: B.S. Applied Physics, Michigan Technological University, course work in geology

experience:

acquired, processed, visualized and interpreted a large volume of ground, airborne, and borehole geophysical data for resource exploration (ground water, minerals, hydrocarbons, and geothermal) as well as environmental & engineering site subsurface characterization.



geoDRONEology: 5 years of applying drones for geoscientific mapping

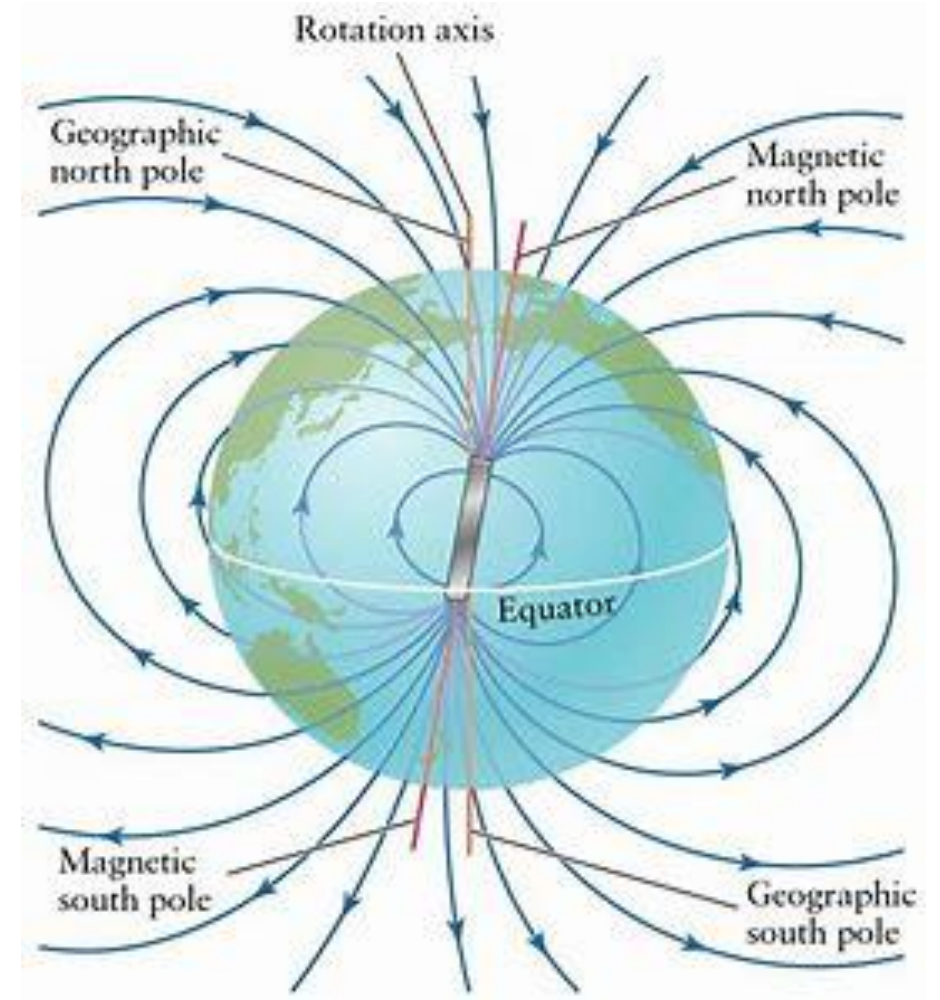
Magnetic and EM Subsurface Site Characterization

objectives

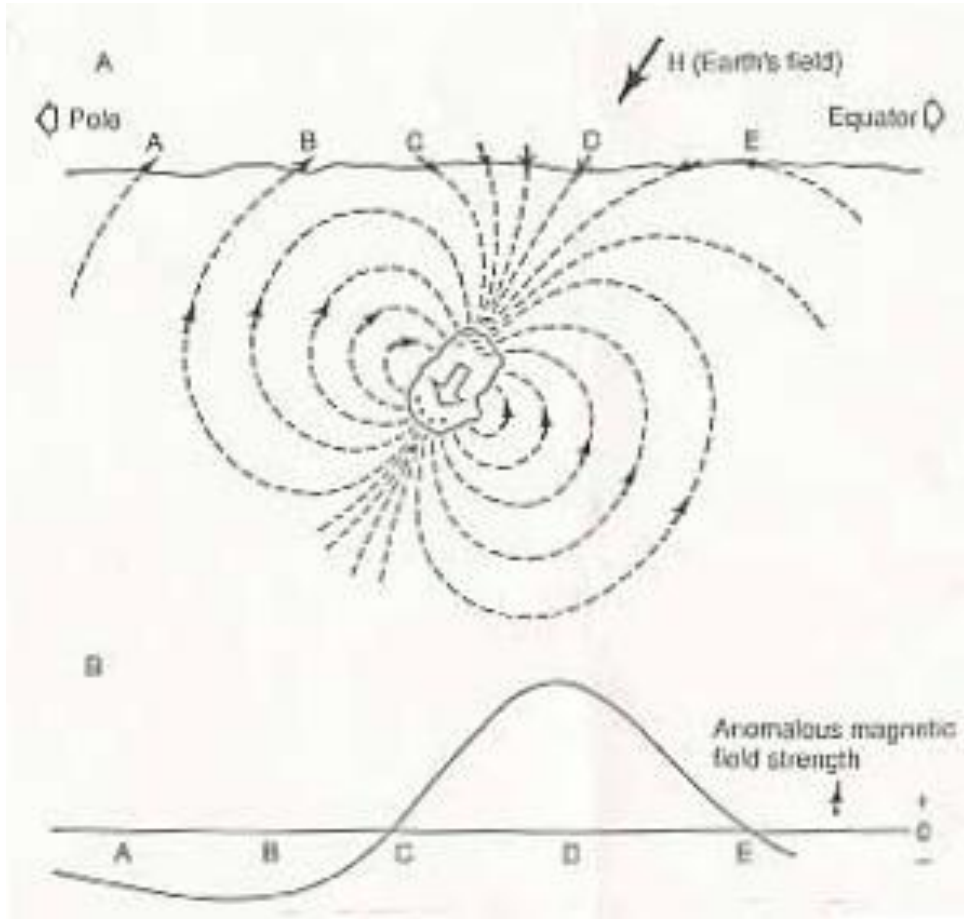
- locate and map wells
- map buried pipelines
- delineate areas of buried debris
- detect possible leaks
- detect and delineate contamination
- identify possible voids
- detect and delineate fractures

Advantages of Magnetic Geophysics

- measures spatial and temporal variation in Earth's magnetic field
- does not require direct contact with earth
- high sensitivity
- sensors mountable on moving platform
- applicable to mapping variations in rock type and geologic structure
- applicable to infrastructure detection & delineation (i.e. steel and iron)
- depth of exploration from a few inches to several miles



The Magnetic Method



- The earth's magnetic field induces magnetization in the rock and buried objects.
- Magnetic signature due to the induced magnetization, I , is a function of the direction and intensity of the geomagnetic field.
- The intrinsic magnetic susceptibility, k , of the rock or object material controls the degree to which it will be magnetized: $I = kT$ $T = \text{inducing field}$
- The size, shape, and orientation of the buried object or rock formation within the inducing magnetic field determines the characteristic anomaly shape.
- Buried objects made of a high magnetic susceptibility material, i.e. steel or iron, will result in significant magnetic anomalies.

Ground Magnetic Survey

Objective: map the spatial and temporal variations in the earth's magnetic field.

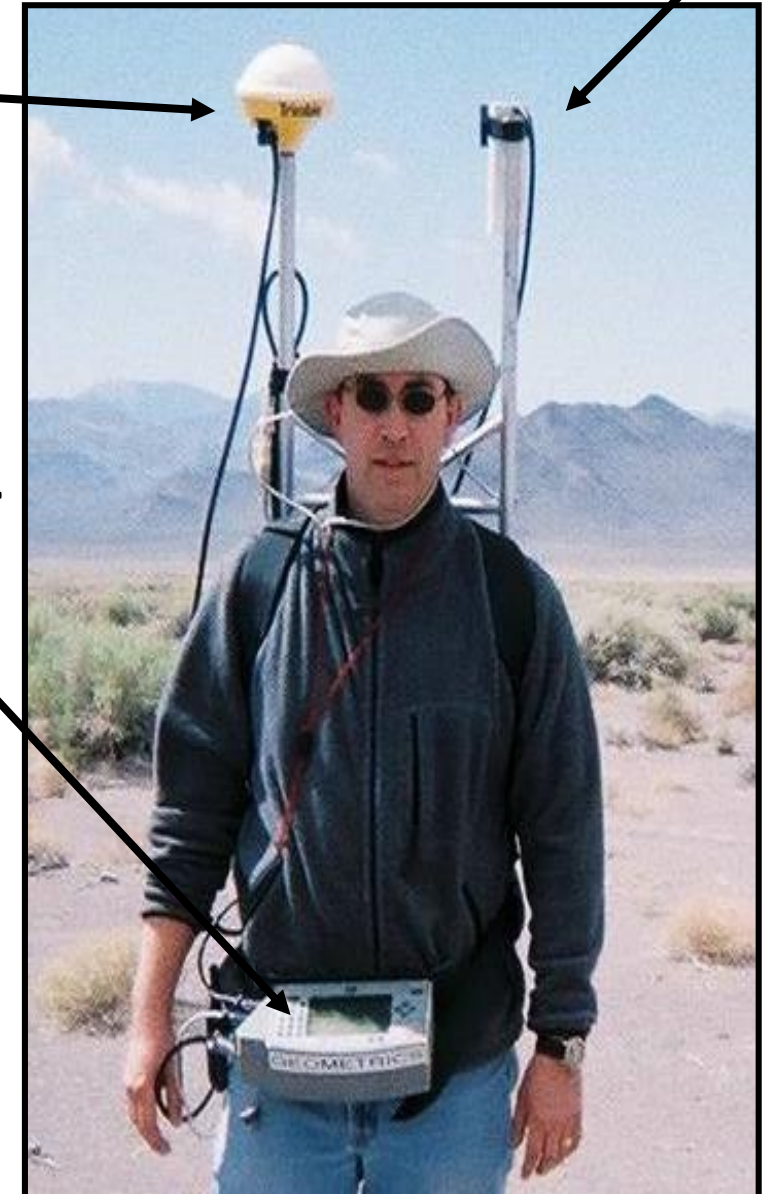
The resolution is a function of the proximity of the magnetic field sensor to the source of the magnetic field anomaly and the spatial density of the magnetic field measurements.

Modern magnetometers consist of a high sensitivity, magnetic field sensor paired with a digital recording data logger and global positioning system (GPS).

Autonomously operated unmanned aerial vehicles equipped with a geo-magnetometer effectively extend the range of a human being while simultaneously obtaining higher resolution data.

**GPS
Antenna**

**Control Unit
& Data Logger**

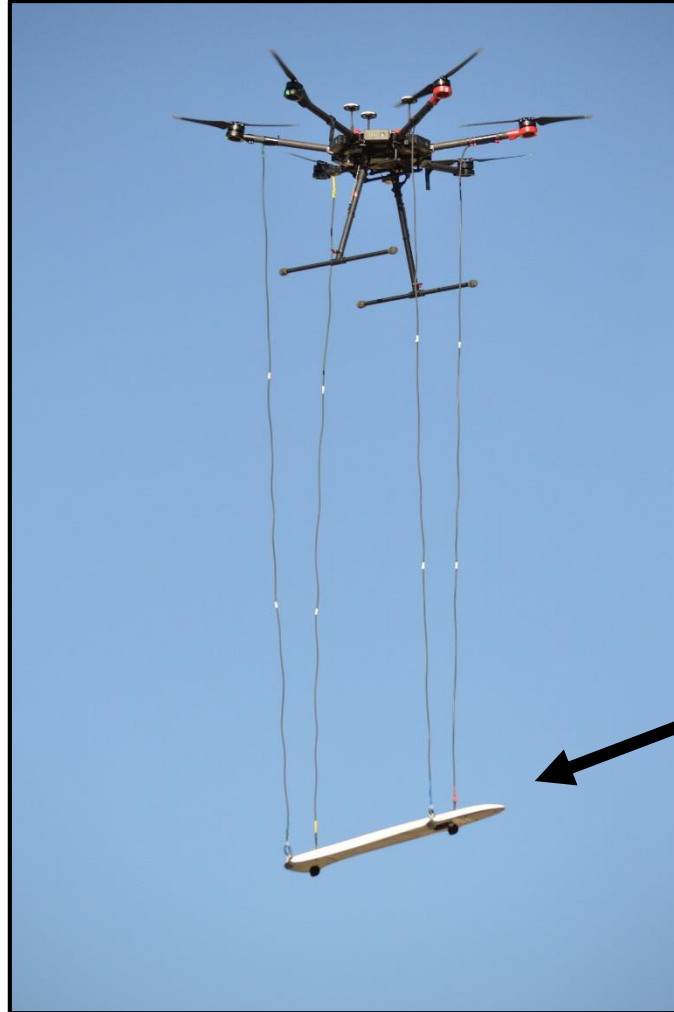


MagArrow Survey

Objective: map the spatial and temporal variations in the earth's magnetic field.



Walking Mode



UAV Mode

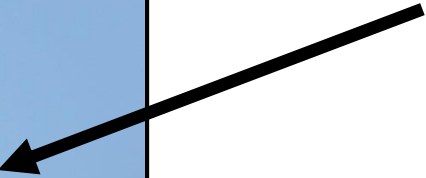
Magnetic Field Sensor

**Control Unit
& Data Logger**

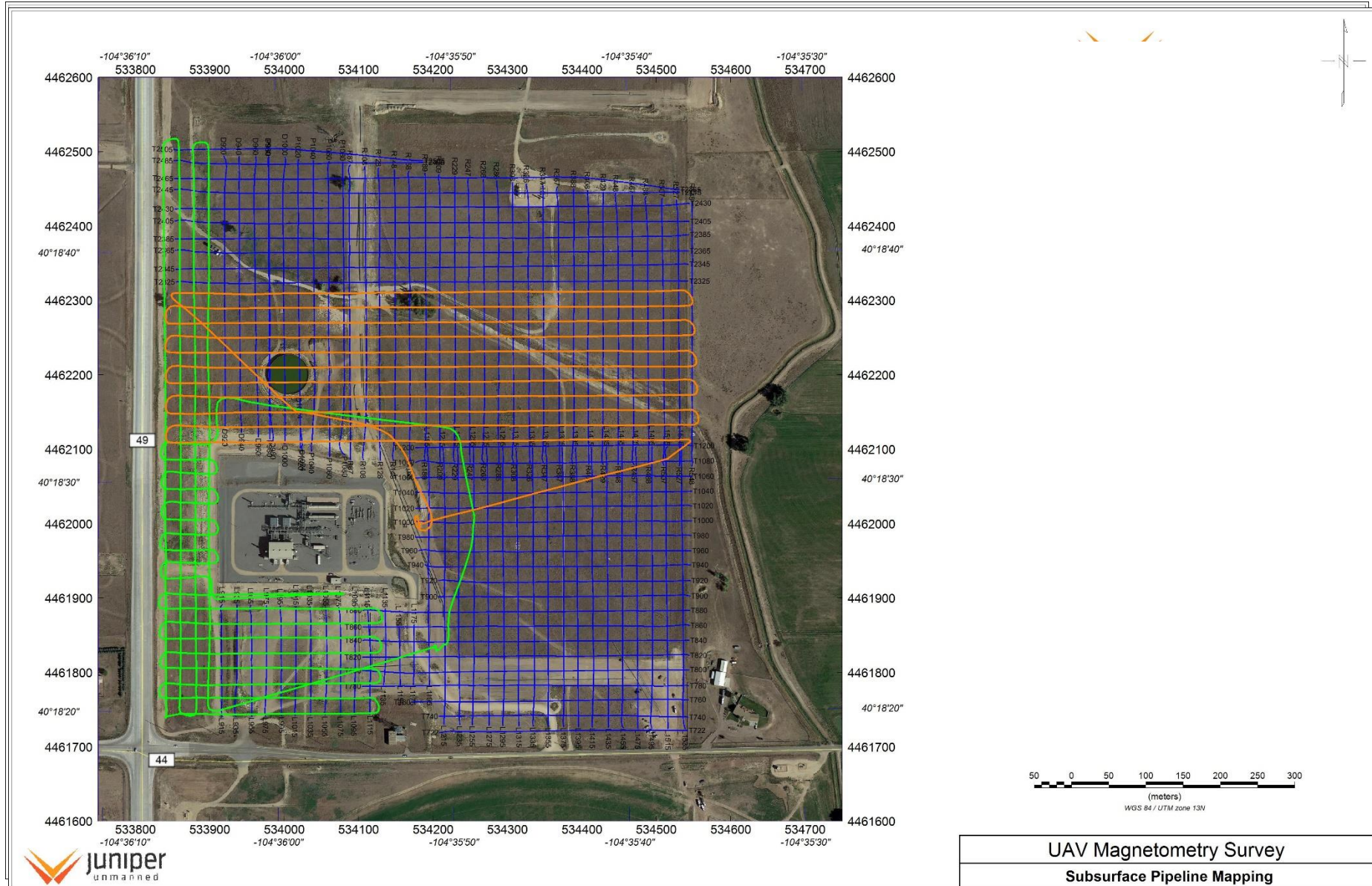
GPS Antenna

IMU
3D gyro
3D accelerometer
compass

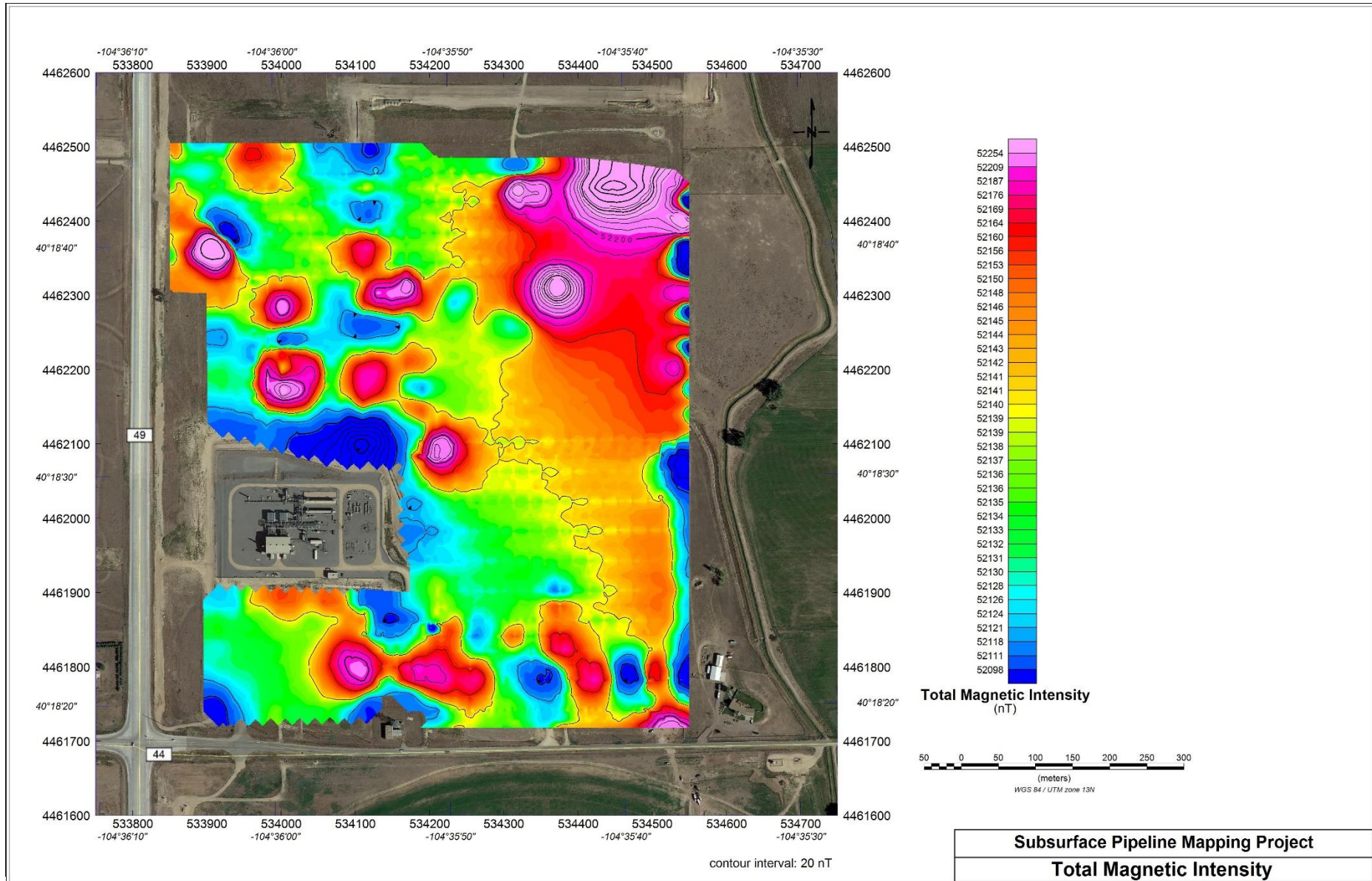
WiFi



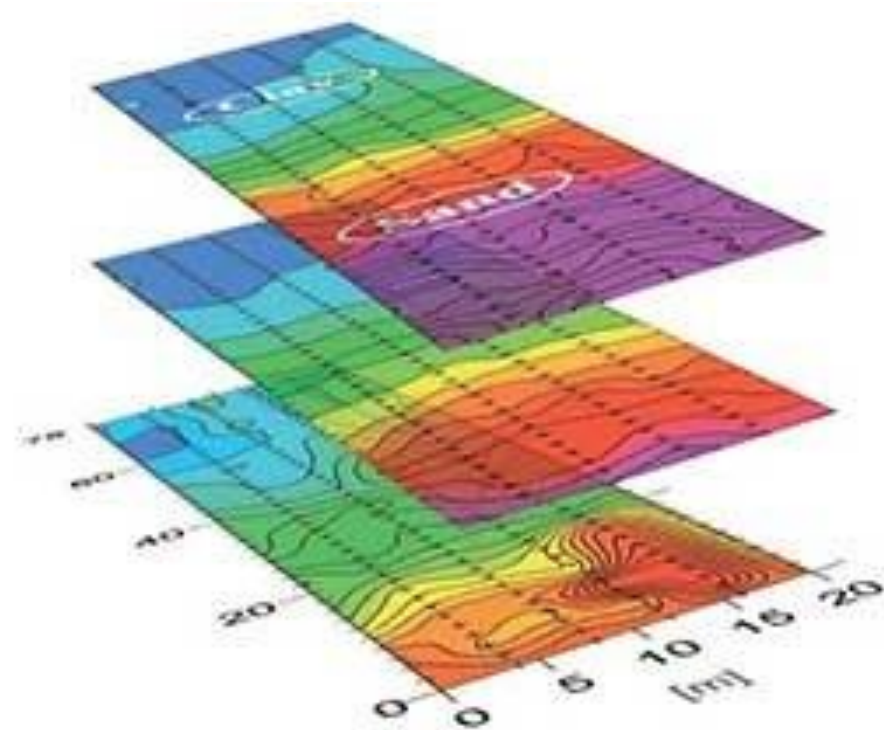
UAV MagArrow Survey in O&G Production Site – CO



UAV MagArrow Survey in O&G Production Site – CO



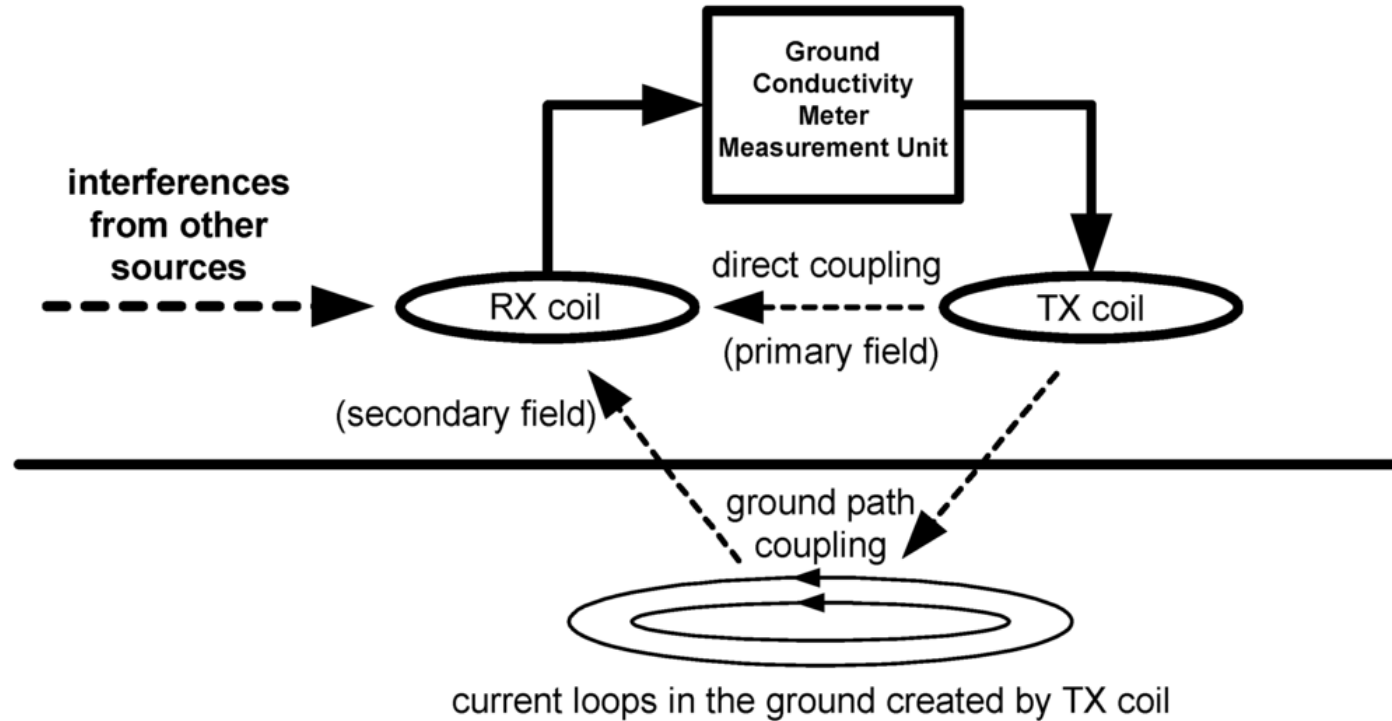
Advantages of EM Geophysics



MULTI-DEPTH PROBES

- measures spatial and temporal variation in electrical conductivity of subsurface
- does not require direct contact with earth
- different flavors for different problems
- sensors mountable on moving platform
- applicable to mapping spatial variations in rock type and geologic structure
- applicable to detection & delineation of any type electrical conductor (e.g. pipelines)
- depth of exploration up to 1000 ft+
- multiple depths of investigation

Principals of EM Geophysics



- time variant controlled source magnetic field induces electrical currents to flow in the subsurface
- Time variant electrical current flow creates secondary magnetic field
- Geometry of receiver and transmitter coils determines depth of investigation
- Frequency of signal or time rate change determines depth of investigation

CMD Explorer System



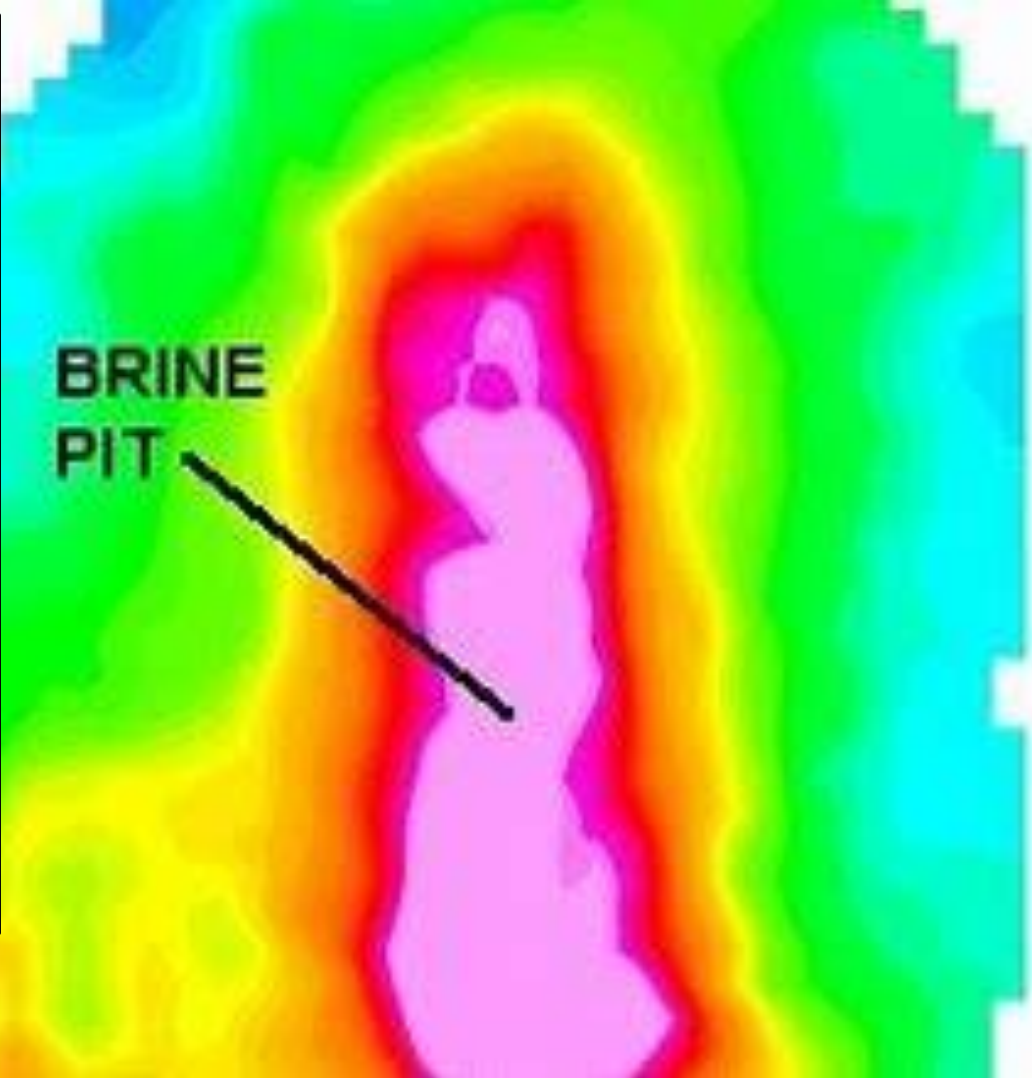
3 coil separations + 2 coil orientations (VMD & HMD)

GPS capable

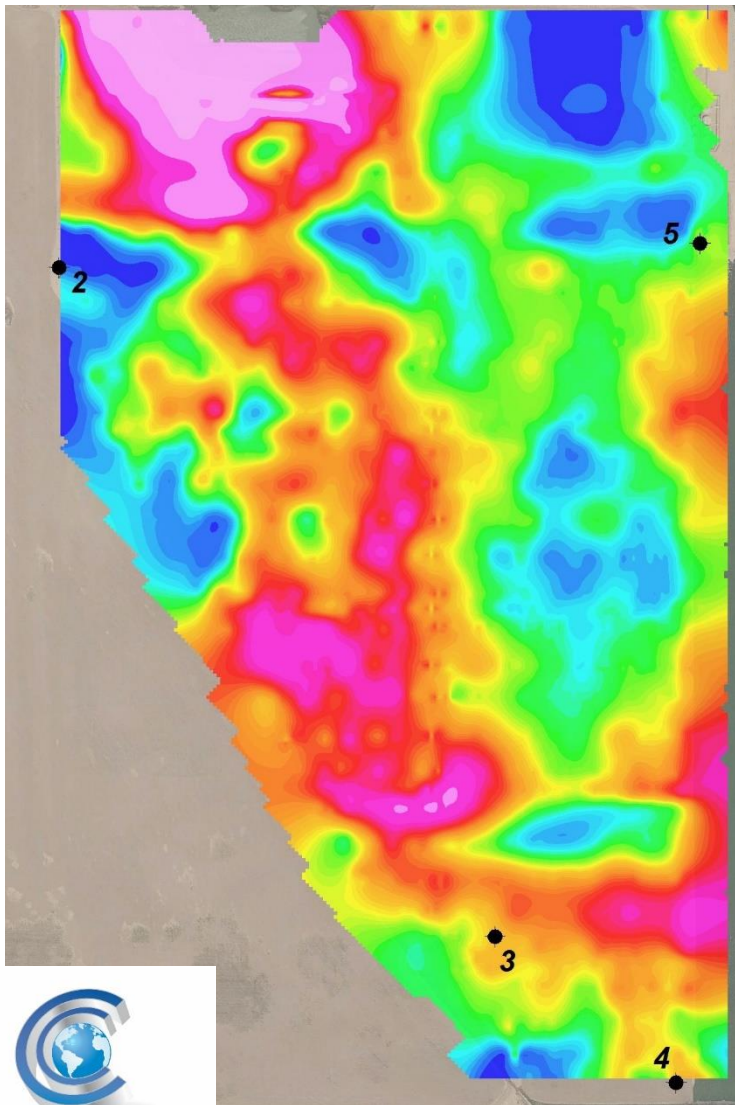
6 DEPTH RANGES 2.2 / 4.2 / 6.7 M - VMD
1.1 / 2.1 / 3.3 M - HMD



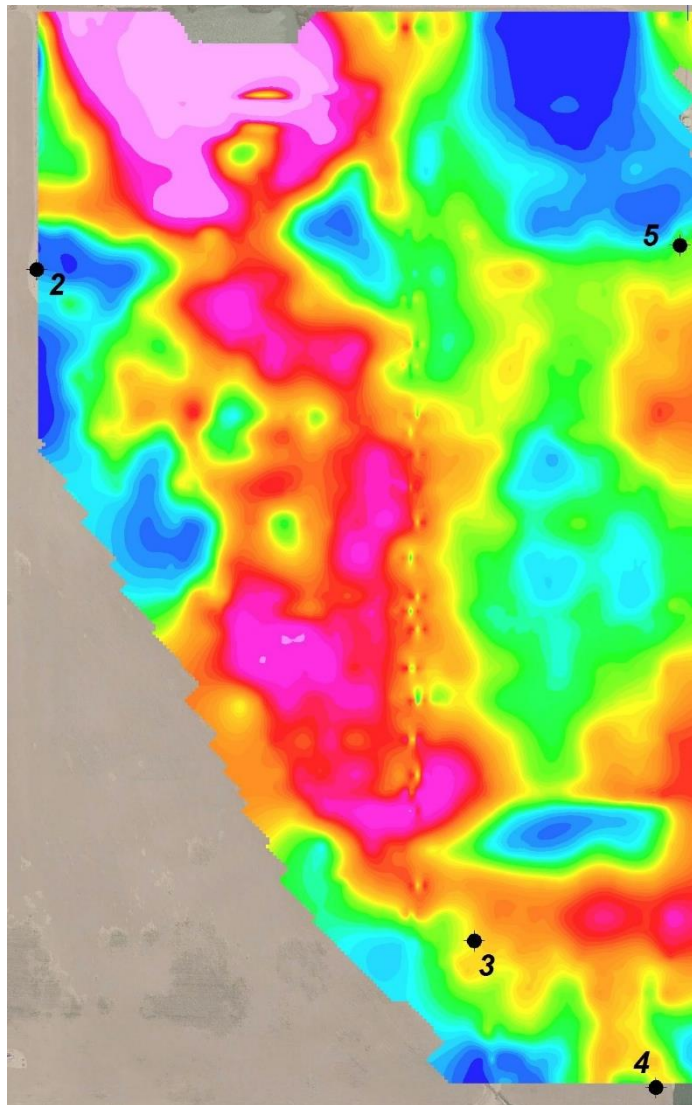
EM Conductivity Survey at O&G Production Site



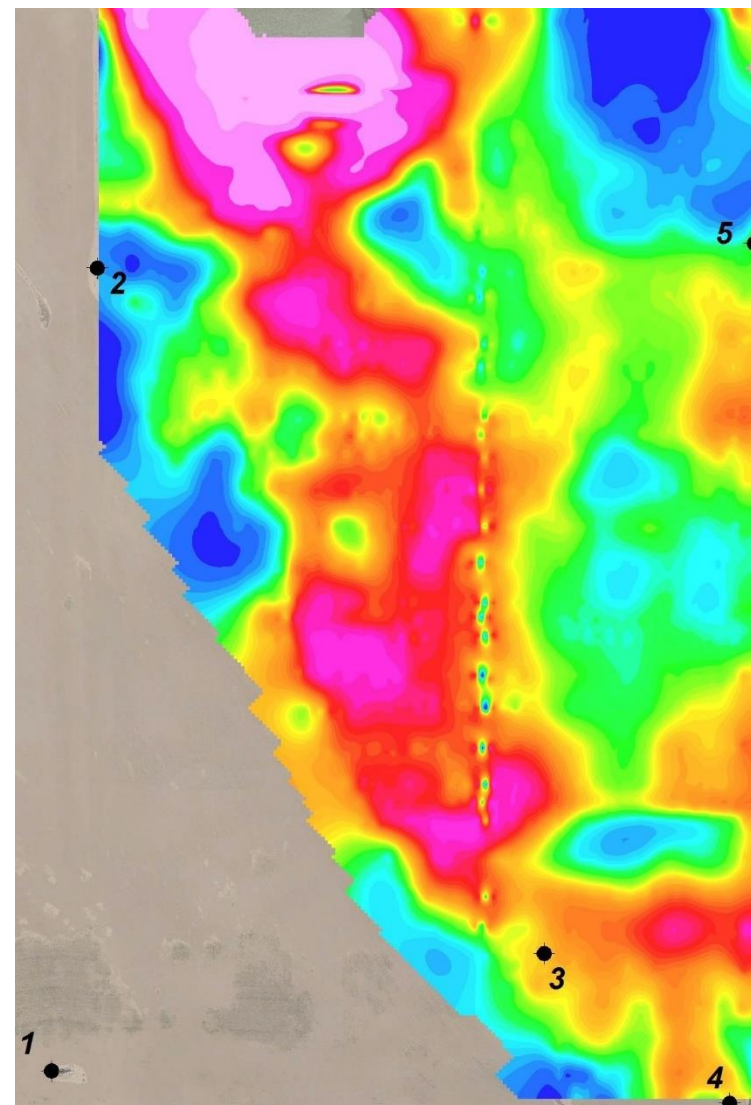
EM Conductivity Survey at O&G Production Site – CO



2.2 m



4.2 m



6.7 m

EM Conductivity & In Phase

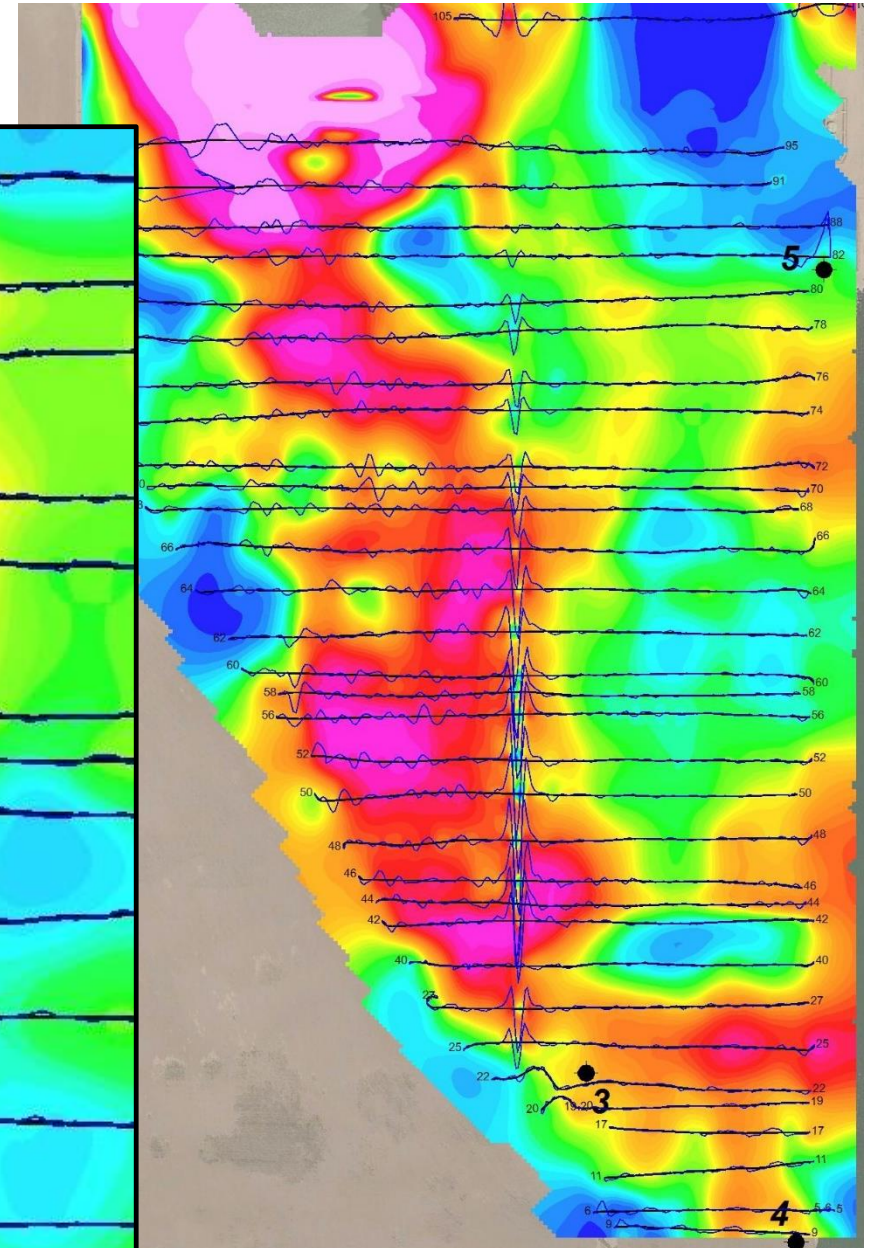
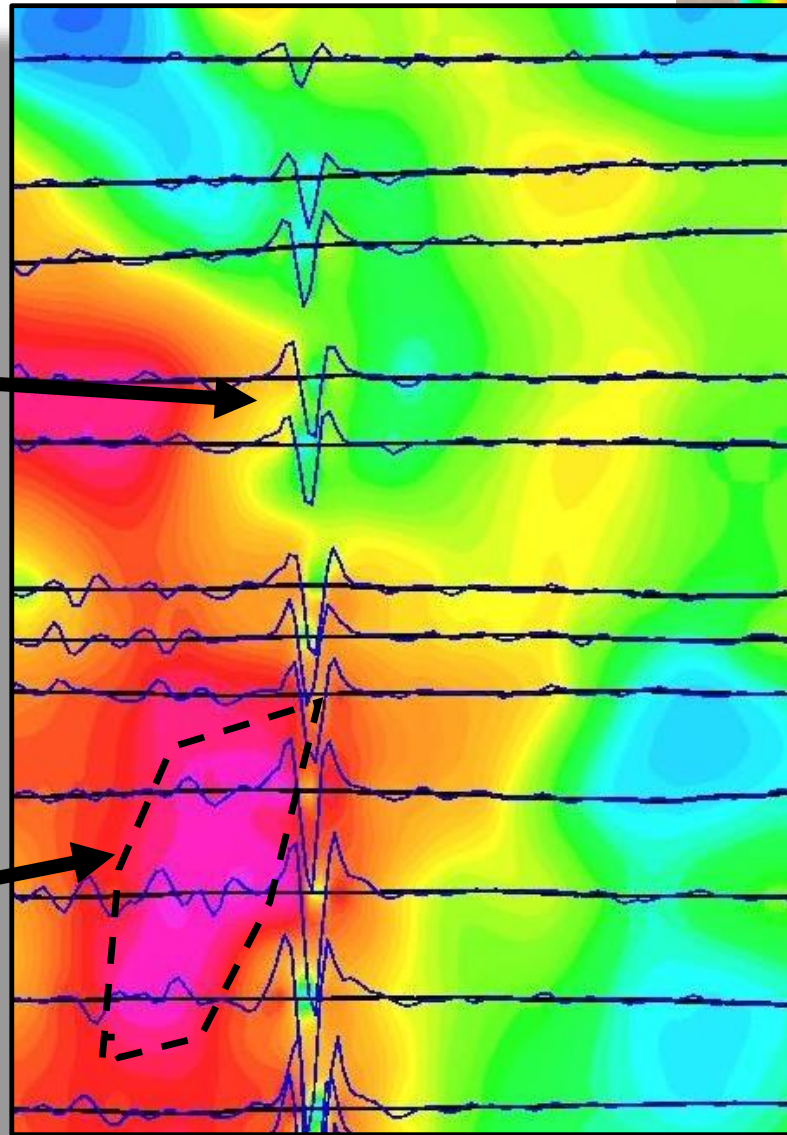
DOI - 6.7 m

**In Phase
Profile**

**due to
pipeline**



**High Conductivity zone
due to O&G production**

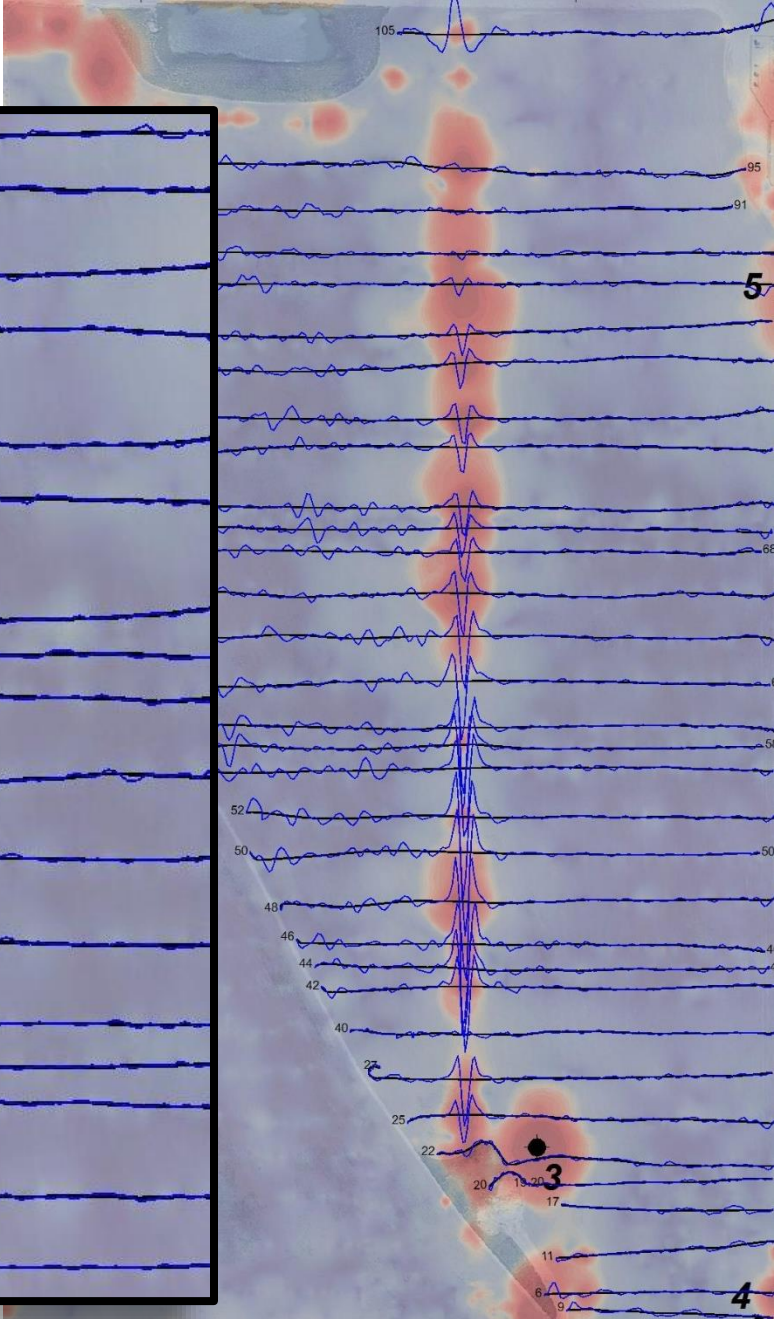
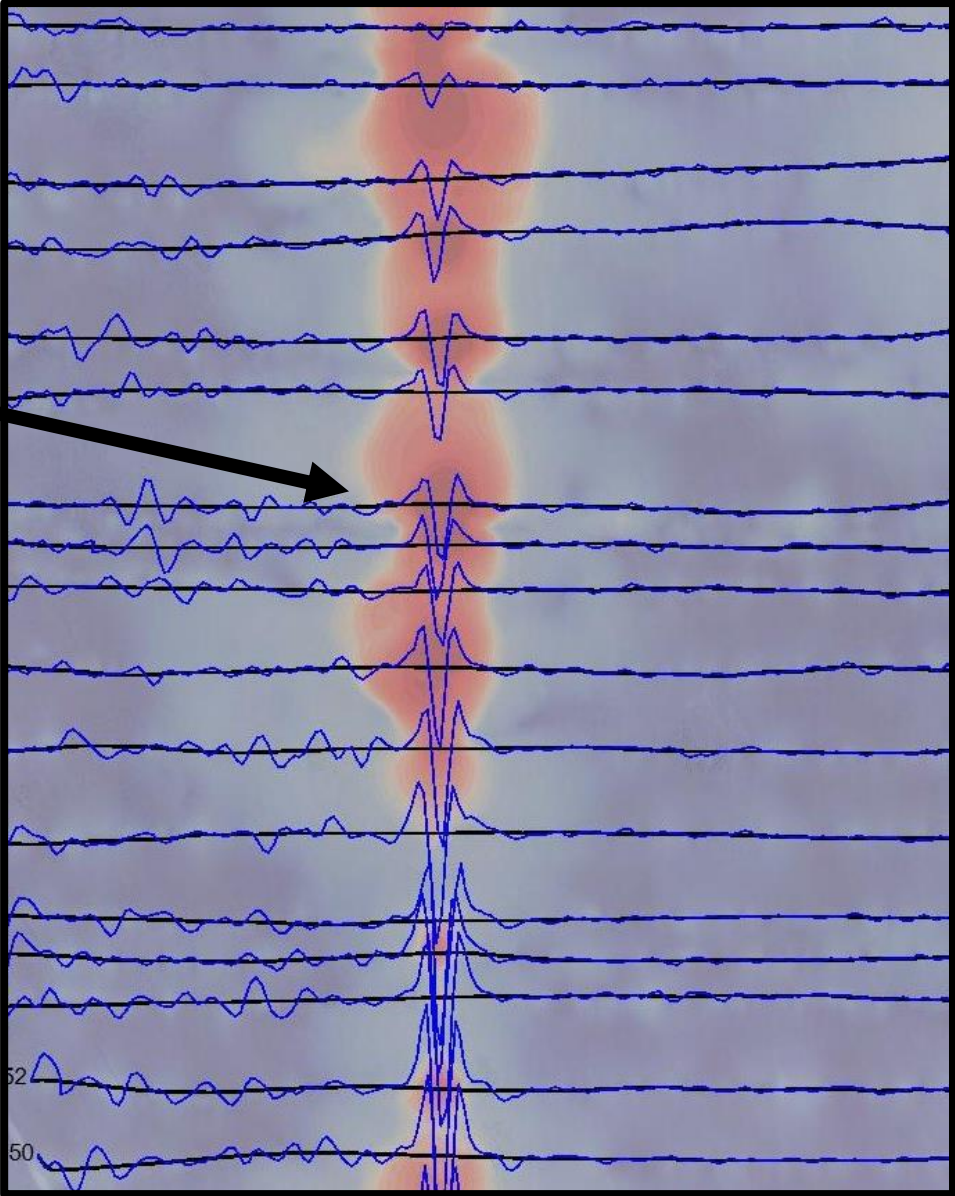
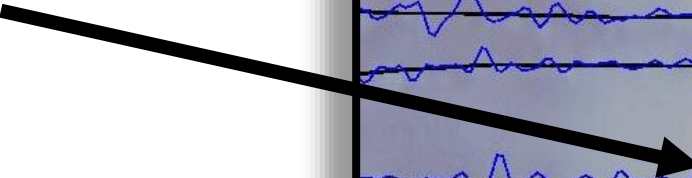


EM In Phase on MagHeat Map

DOI - 6.7 m

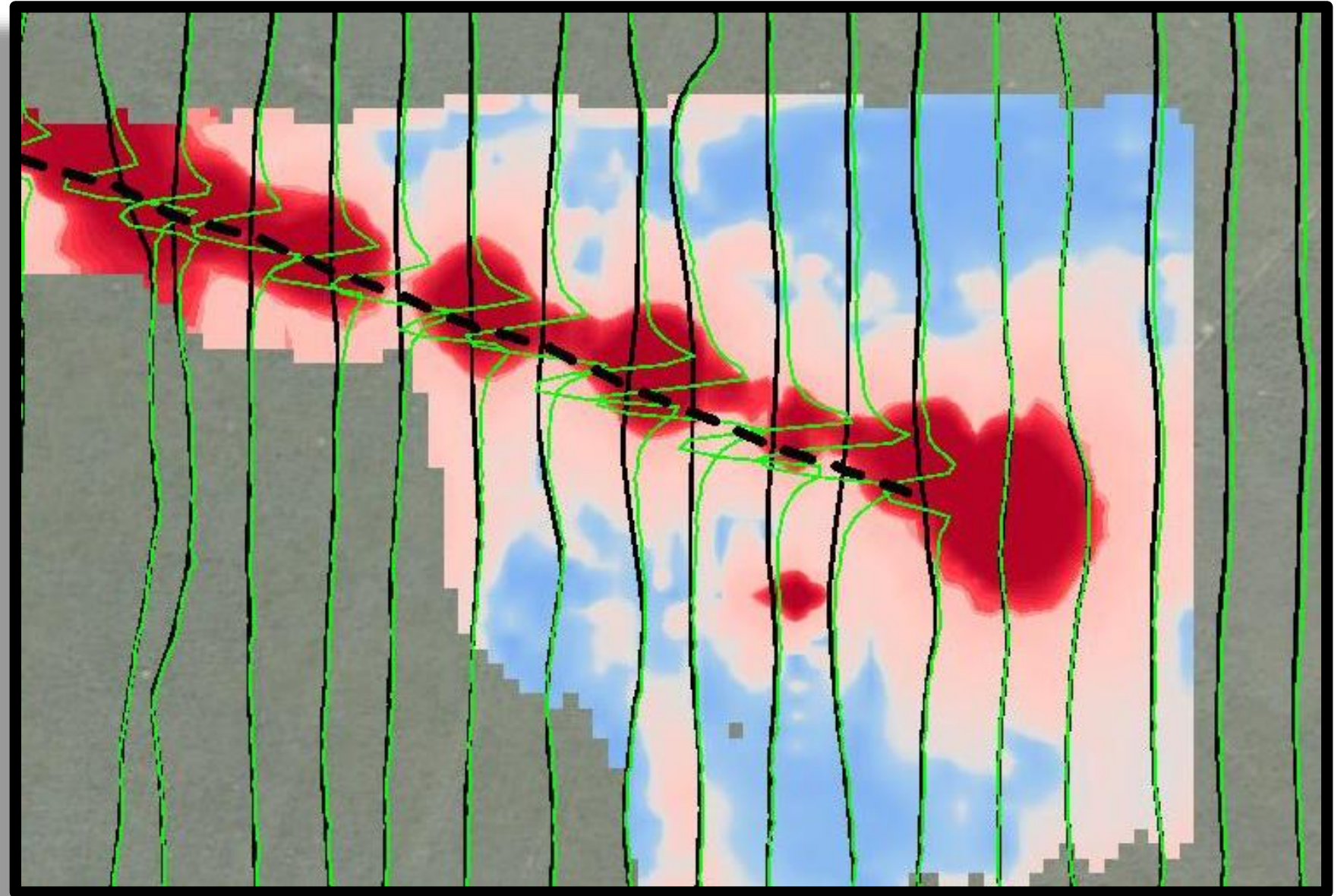
**In Phase
Profile**

**due to
pipeline**



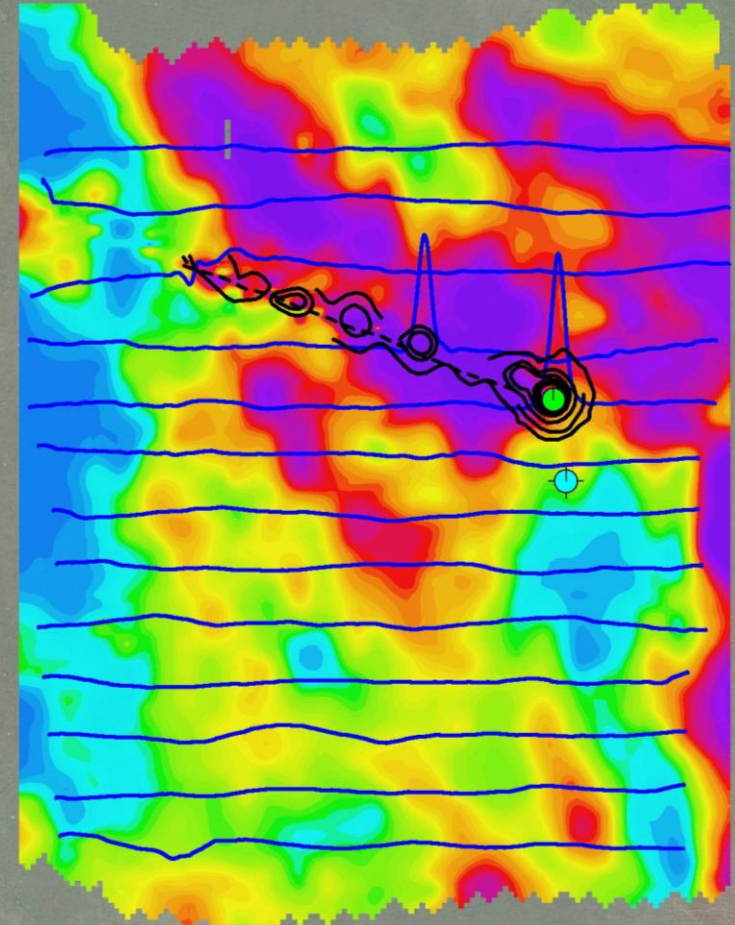
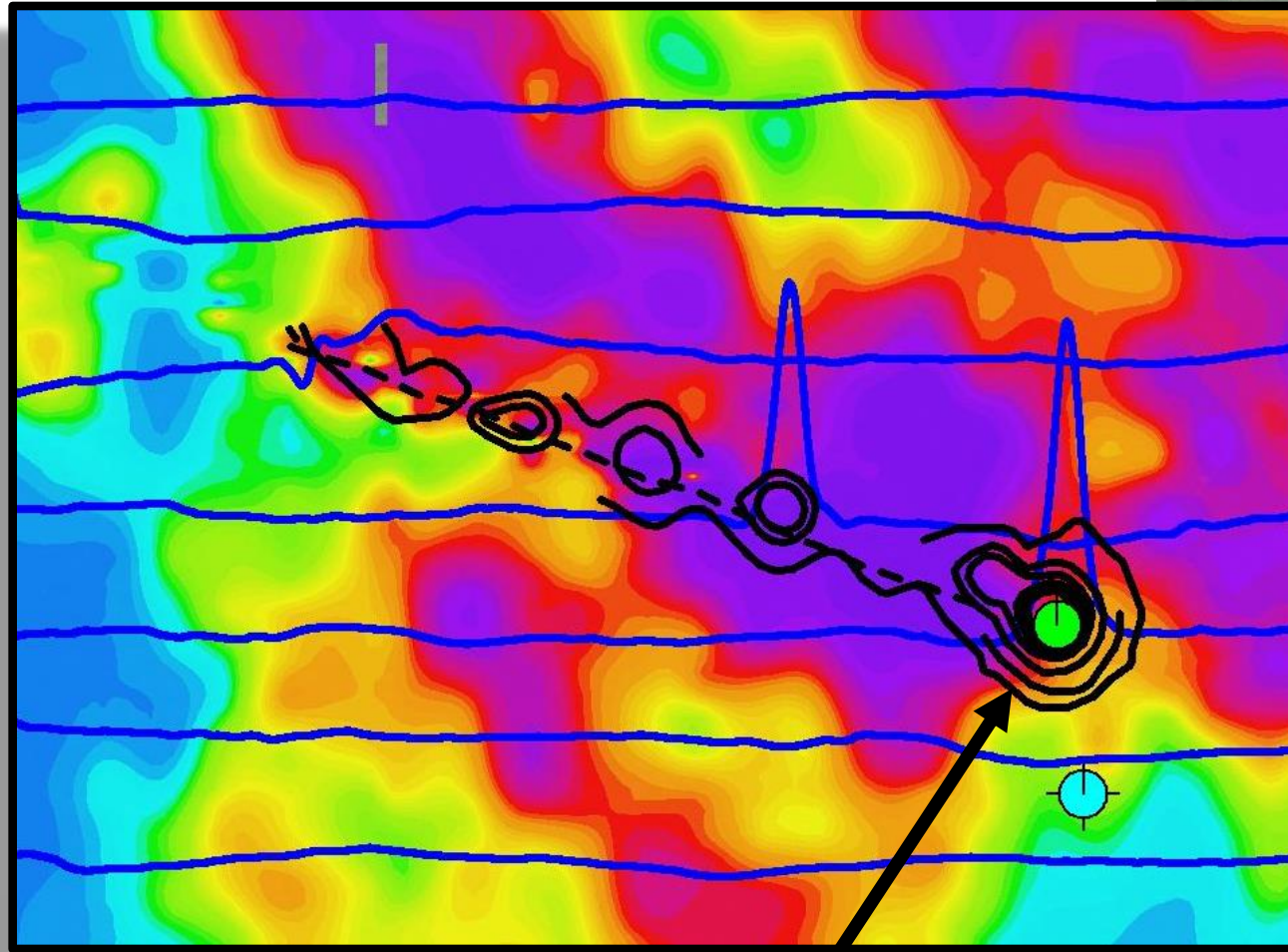
EM Conductivity & Mag – O&G Site – CO

**EM Profiles
on
MagHeat Map**



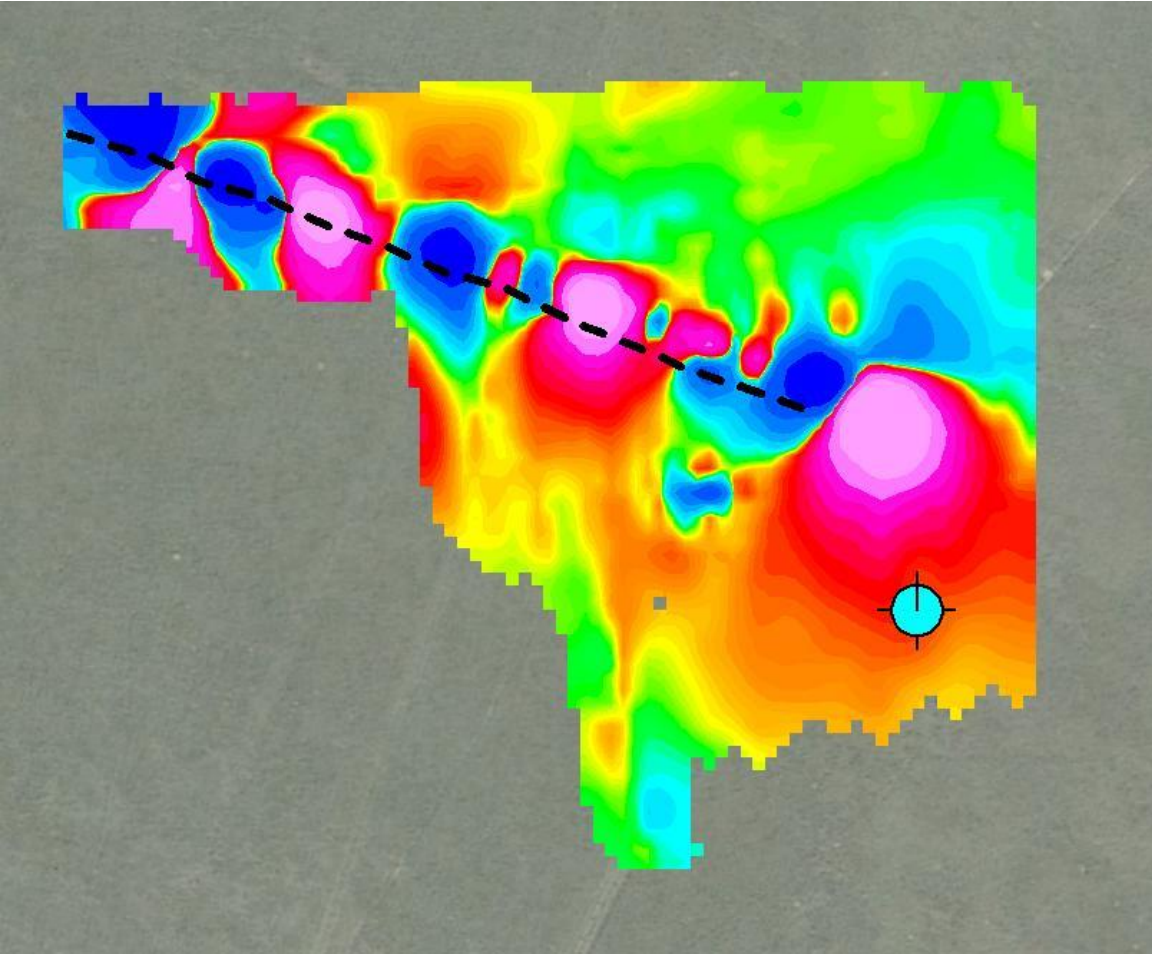
EM Conductivity & Mag – O&G Site – CO

Magnetic Profiles & contours on EM Conductivity

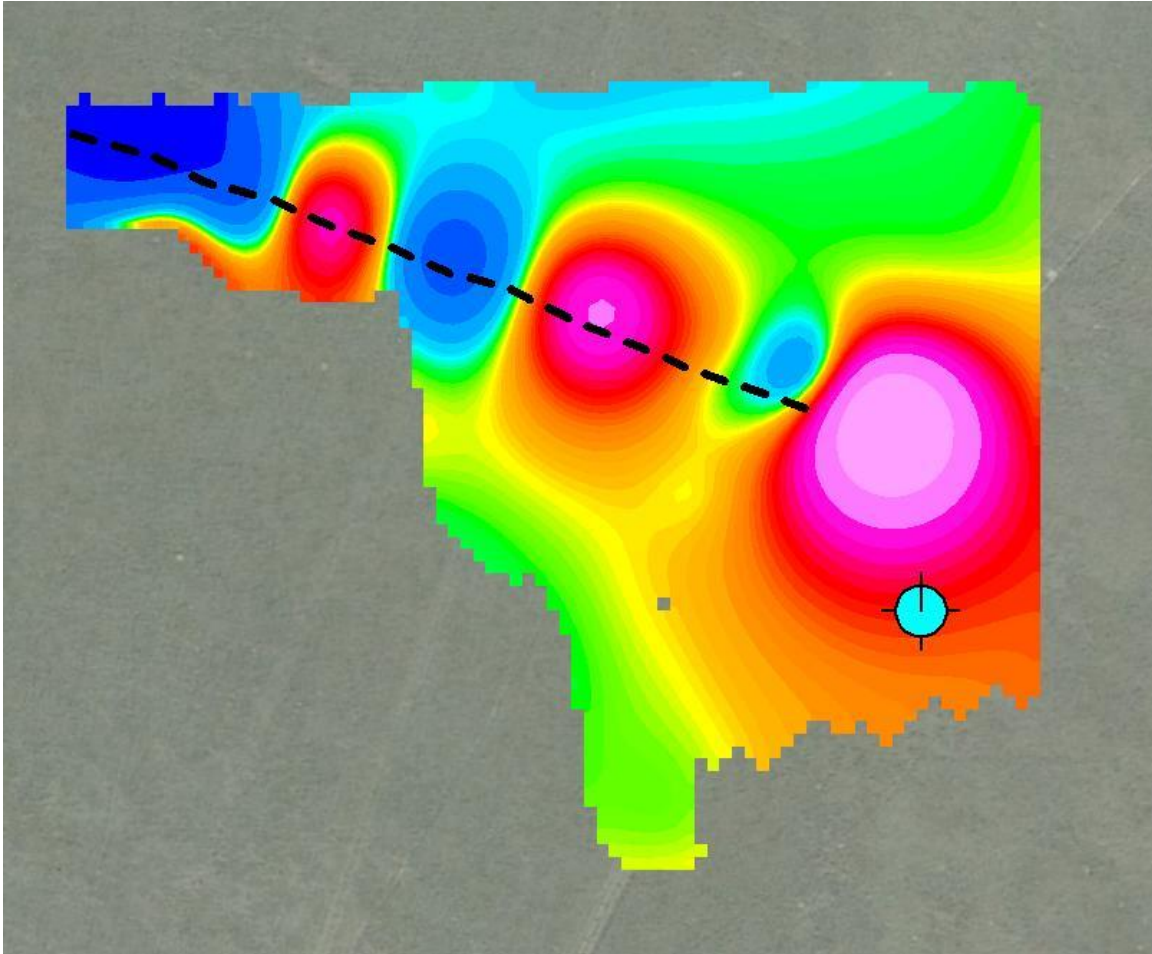


Abandoned Well

TMI data from different heights



2.5 m AGL



10 m AGL

Summary Conclusions

Magnetometry & EM Conductivity
- when used in tandem –
provide a more complete
characterization of the O&G site.

They are the Dynamic Duo of
geophysical subsurface
characterization.



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