

Recent Advances in the Application of Geophysics for Gold Exploration in the North-central Great Basin



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Overview



- Petrophysics of Great Basin rocks
- Recent applications of geophysics in the Great Basin
- Future developments in geophysics and their impact in the Great Basin
- Conclusions

Petrophysics – Great Basin



- **Petrophysics** is a measure of the physical properties of rocks
- Petrophysical **generalizations** for Great Basin rocks are:

Rock type \ Physical Property	Magnetization	Density	Conductivity	Chargeability
Lower Plate	L	M-H	M	L
Upper Plate	L	M	M	L
Pen-Perm overlap	L	M	M	L
Intrusive stocks	M - H	M	M	L
Dykes related to stocks	L-M	M	H (clays)	H (clays)
Cover: Alluvial/Colluvial	L	L	H	L
Cover: Volcanic	H	L	M	L

H = High, M = Moderate, L = Low

- Real world petrophysics are **highly variable** due to overprinting structural, hydrothermal alteration and metamorphic events
- Cannot rely on petrophysical **generalizations**
 - Requires specific **petrophysical studies** for project area

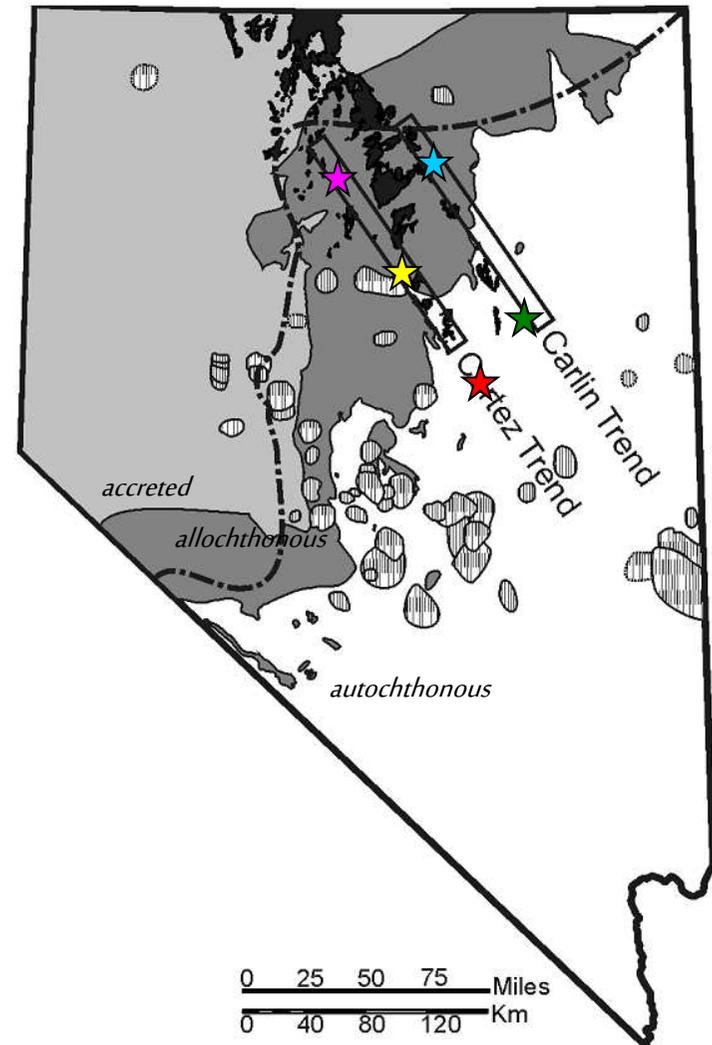
Petrophysics – Great Basin



- Effective application of geophysics requires:
 - specific **petrophysical studies** for project area
 - understanding of **geologic controls on mineralization**

- Recent examples:

- Magnetism, Goldstrike[★] and Cortez[★]
- Gravity, Stonehouse[★]
- Hardrock Seismic, Cortez[★]
- MT/CSAMT, Ruby Hill[★]
- IP/Resistivity, Bald Mountain[★]



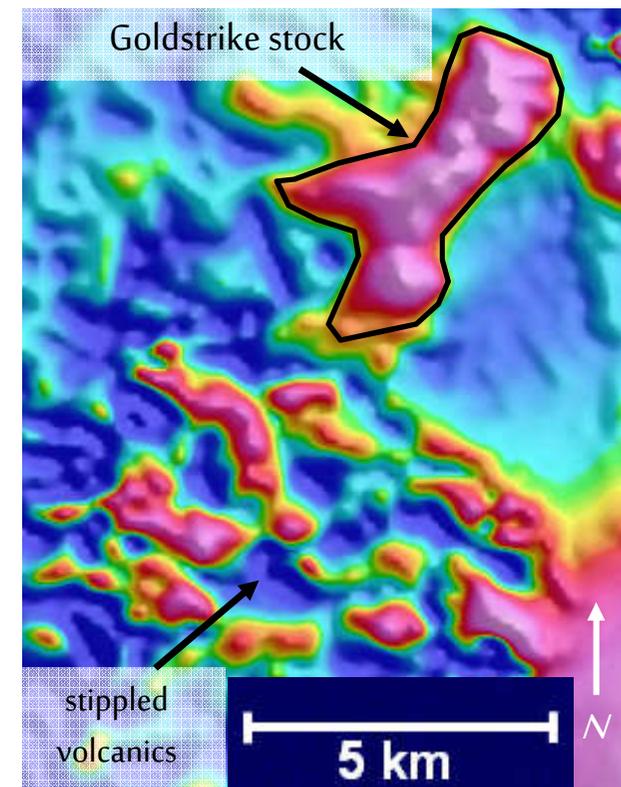
Airborne Magnetics - Goldstrike

BARRICK

- Remains the most effective reconnaissance mapping tool
 - Despite **limited developments** in acquisition technology
 - Lower cost, better processing tools, better geologic integration
- Stippled **high-low** volcanic signature
 - **Magnetite** in primary composition
 - Variable **remnant** and **normally** magnetized Basalt flows
- Intrusive stock **high**
 - **Magnetite** in primary composition
 - **Remnant** and **normally** magnetized

Also consider

 - **high** from **Monoclinic Pyrrhotite** in magnetic skarn surrounding intrusion



Airborne Magnetics - Cortez

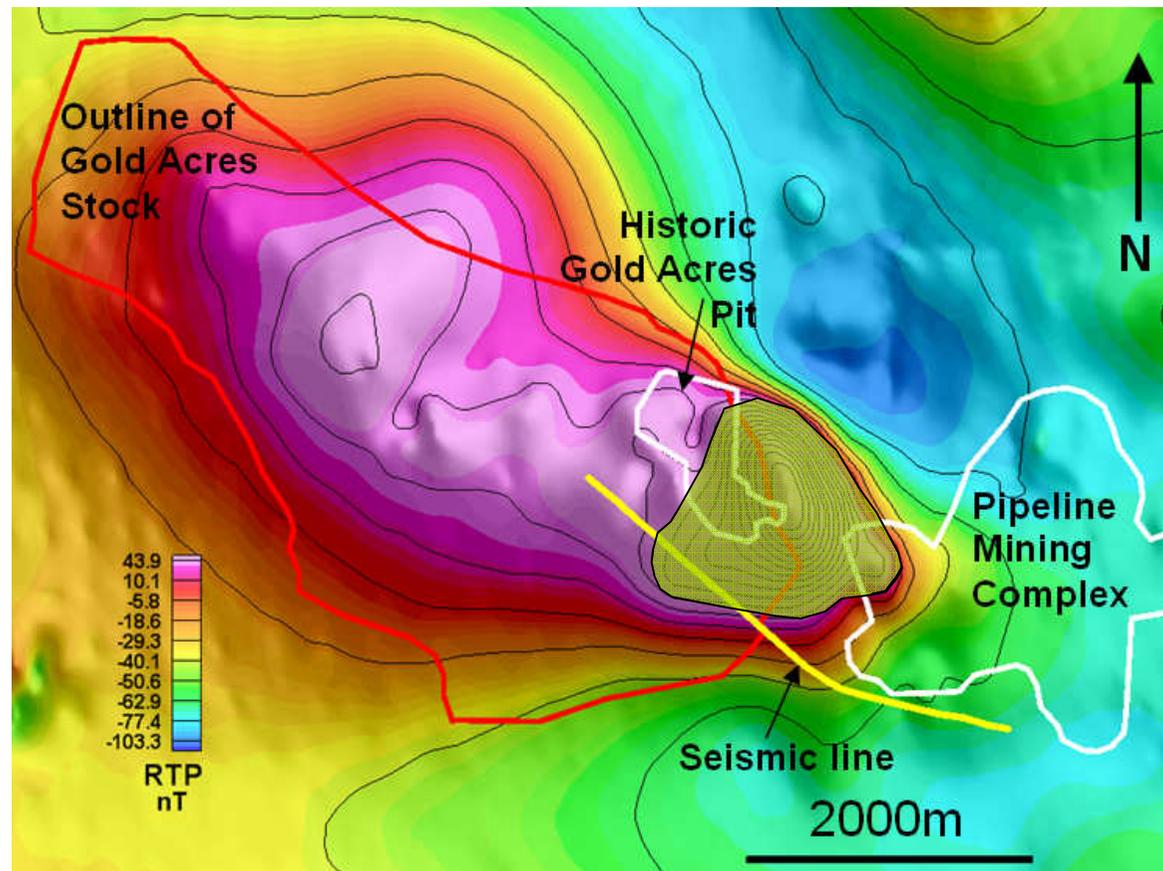


- Gold Acres Stock: buried intrusion exposed only in Gold Acres Pit
- Quartz Monzonite is **weakly magnetic** (below 2.0×10^{-3} SI)

- Skarn surrounding stock is **moderate to highly magnetic** ($<46.1 \times 10^{-3}$ SI)

- Peak magnetic response is outside bounds of intrusion

- Consider skarn in interpretations!



Reduced to Pole magnetic data over Gold Acres stock

Detailed Gravity



- Extensively applied in the Great Basin
 - Map **dense** Lower Plate vs. Upper Plate
 - Map **alteration and metamorphism** in uniform sediments
 - Map bedrock structure **beneath cover**
- Stonehouse example
 - Immediately north of Lone Tree mine
 - Wayne Zone is structurally controlled on high-angle (75° W) fault
 - Use gravity to map extension of Wayne Zone structure beneath I-80 highway
- Significant cover thickness (>500ft)
 - 1000ft gravity station spacing is sufficient resolution

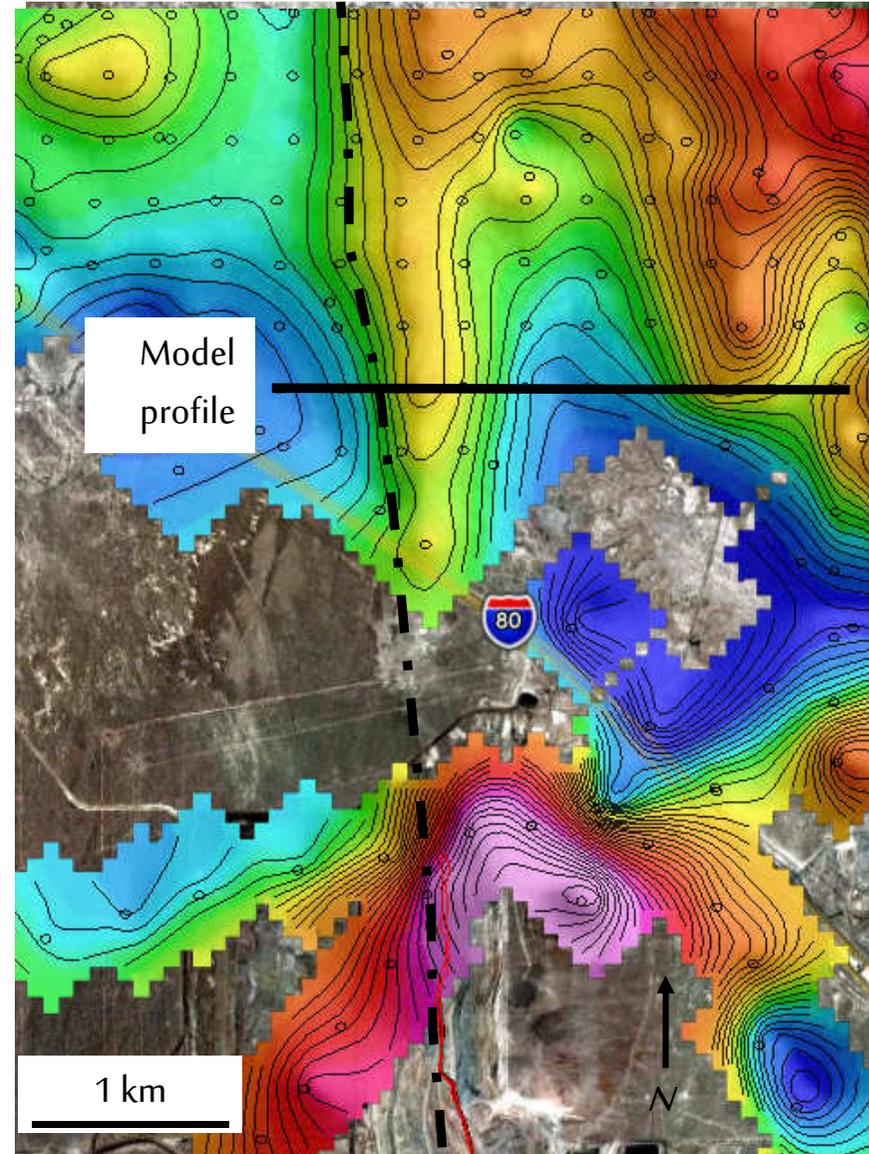


Google Earth image over Stonehouse

Detailed Gravity - Stonehouse



- Residual gravity maps density contrasts in upper 2000ft
- Mapping bedrock horst beneath pediment
 - 1500ft wide, 3 miles long
- Gravity modeling to define geometry and quantify offset
 - Simple 2-layer earth model
 - Bedrock vs. cover

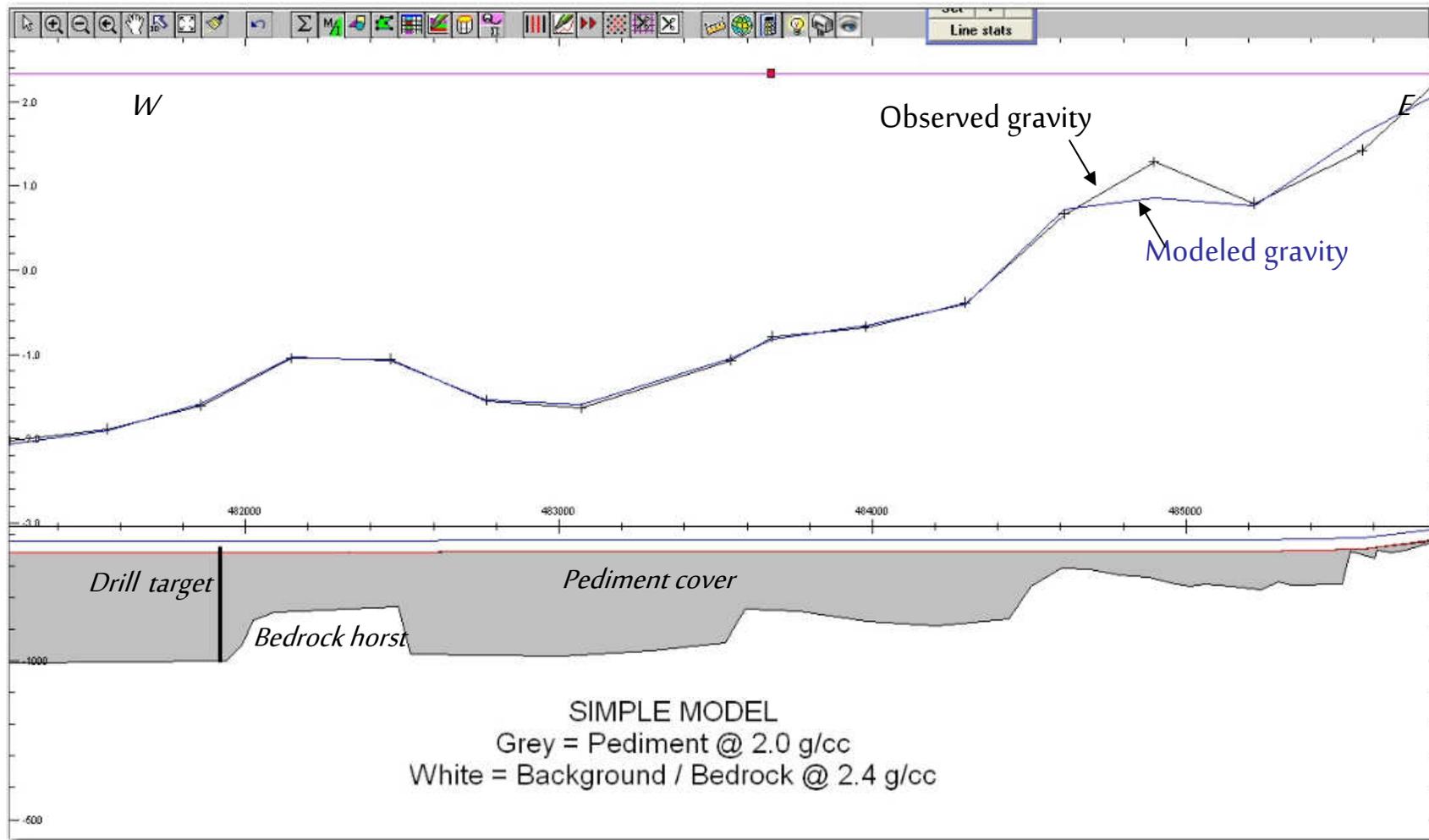


Residual gravity data over Stonehouse

Detailed Gravity - Stonehouse



- Simple two-layer* 2D gravity model (Encom ModelVision)



**Tertiary Basalt layers of unknown thickness are not accounted for in modeling*

Hardrock Seismic



- Softrock seismic - unlithified, sedimentary basin (Hydrocarbons)
- **Hardrock** seismic - lithified, crystalline rock (Ore deposits)
- **Hardrock Challenges**
 - Complex 3D geology (scattering)
 - Higher intrinsic velocities
 - Non-homogeneous near-surface
- **Variations for Hardrock**
 - High resolution: spatial and temporal
 - High fold (**spatial stacking**) >120
 - Specific processing considerations
 - Statics corrections for topography
 - Accurate velocity models for depth
- **Interpretation**
 - Integrate with drilling
 - 2D structural interpretation
 - Update geologic model
 - Direct drill targets

Source

15,000 IB Envirovibe



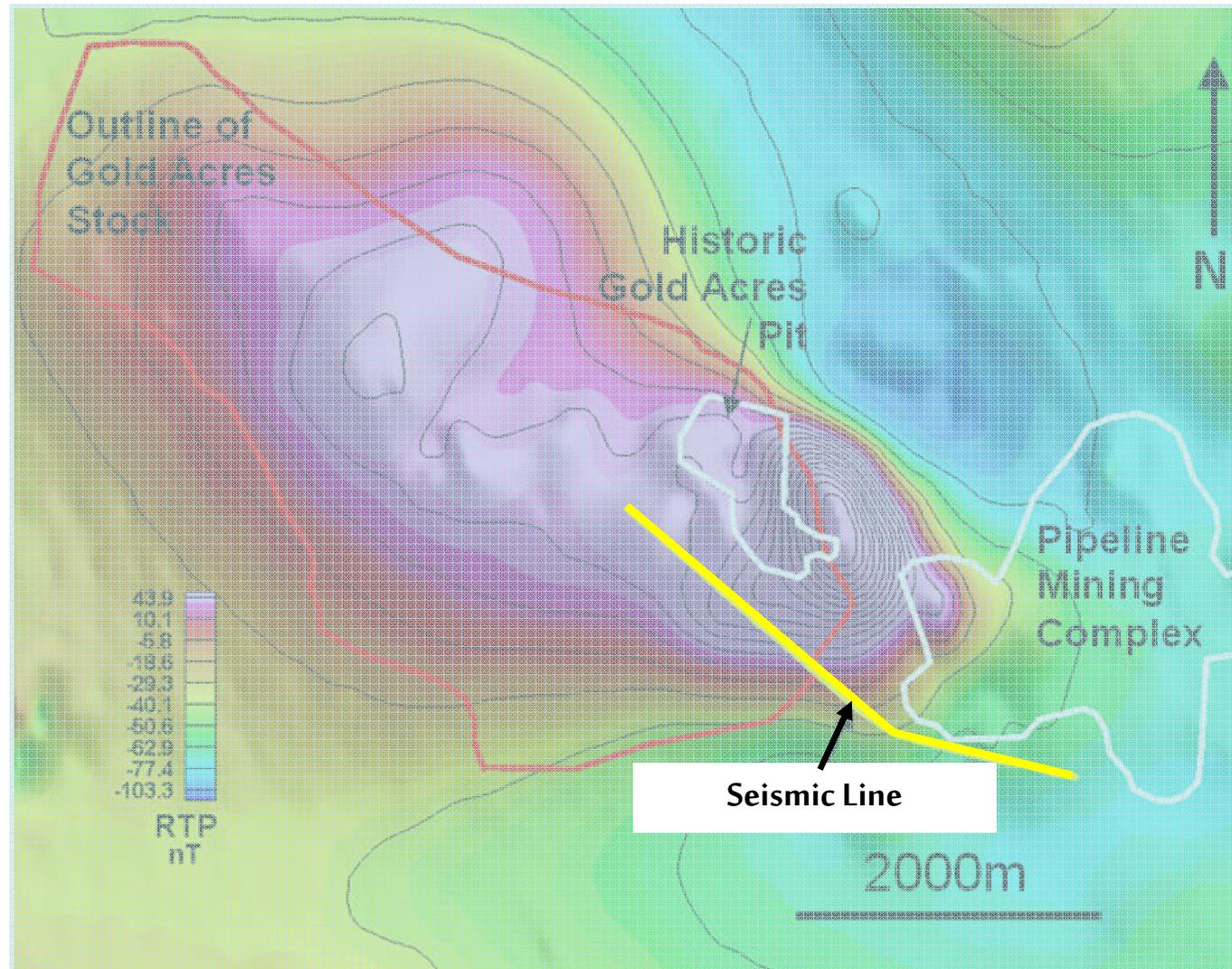
Receivers



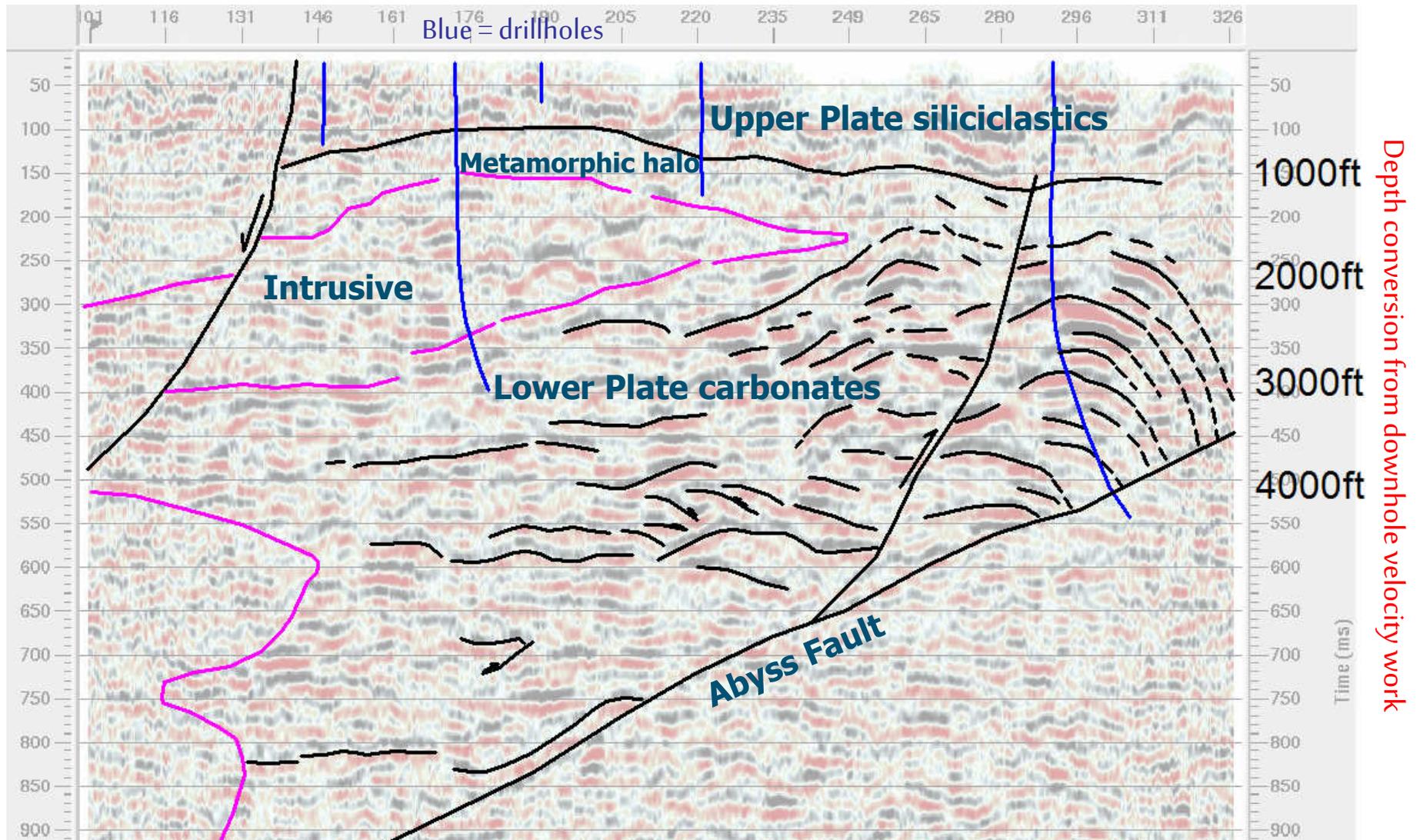
Hardrock Seismic - Cortez



- Location of Gold Acres seismic line



Hardrock Seismic - Cortez



MT/CSAMT Resistivity

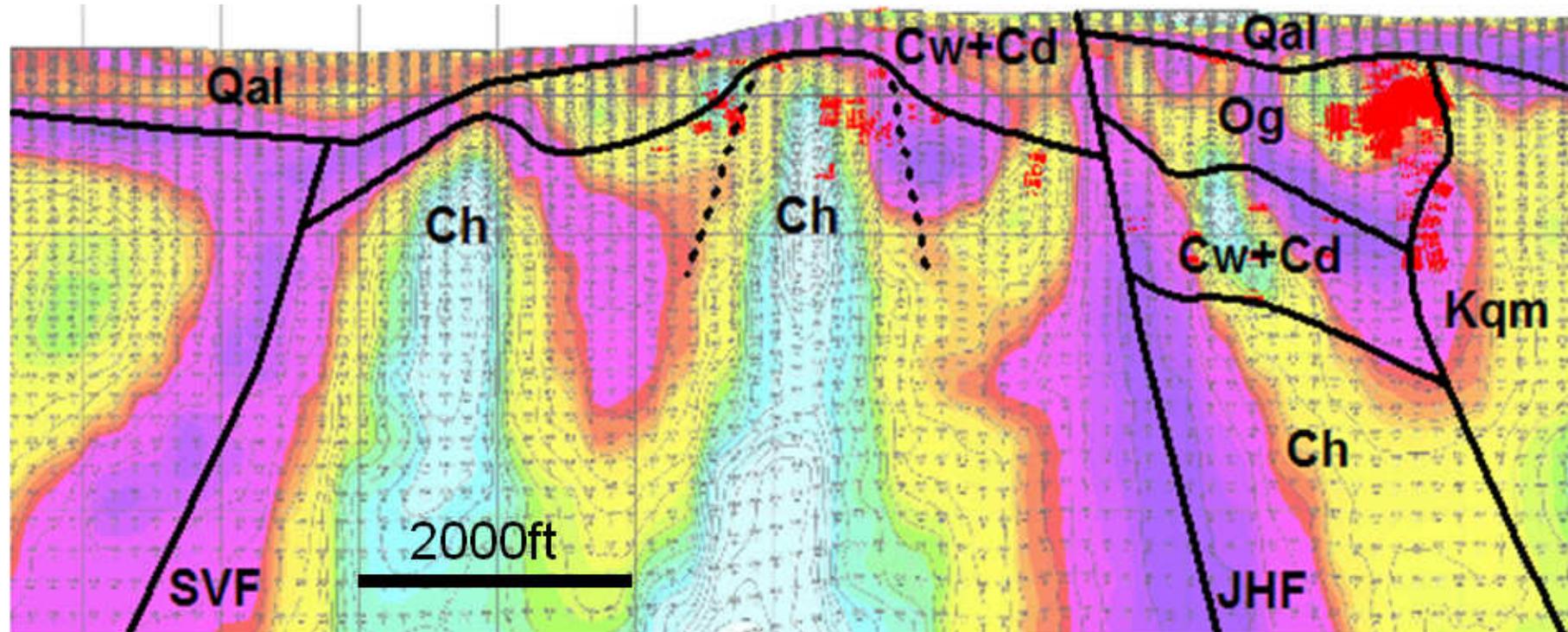


- Resistivity and Electromagnetic applications increased through advancements in distributed array systems
 - e.g. Titan 24, MIMDAS
- Controlled source for improved resolution in upper 1000ft
 - Supplements data in the “dead band” of natural energy fields
 - Inherent technical issues with CSAMT surveying over cover
 - No bedrock information
- Petrophysics studies and base level geology **imperative**
 - Large resistivity variations between lithologies, metamorphism and alteration
 - Easy to make inaccurate interpretations

MT - Ruby Hill



- Unconstrained 2D inversion of MT profile
- E-W section, S of East Archimedes Pit. Pink is conductive
- Black: Modeled geology – MT maps structure very well
- Red: Anomalous gold – MT maps mineralization on gradients



Induced Polarization



- Limited use in the Great Basin due to geological 'noise':
 - Chargeable graphitic shales
 - Remobilized carbon outbound of contact metamorphic aureole
 - Diagenetic pyrite not associated with mineralization

- Applied on case by case basis depending on geologic setting

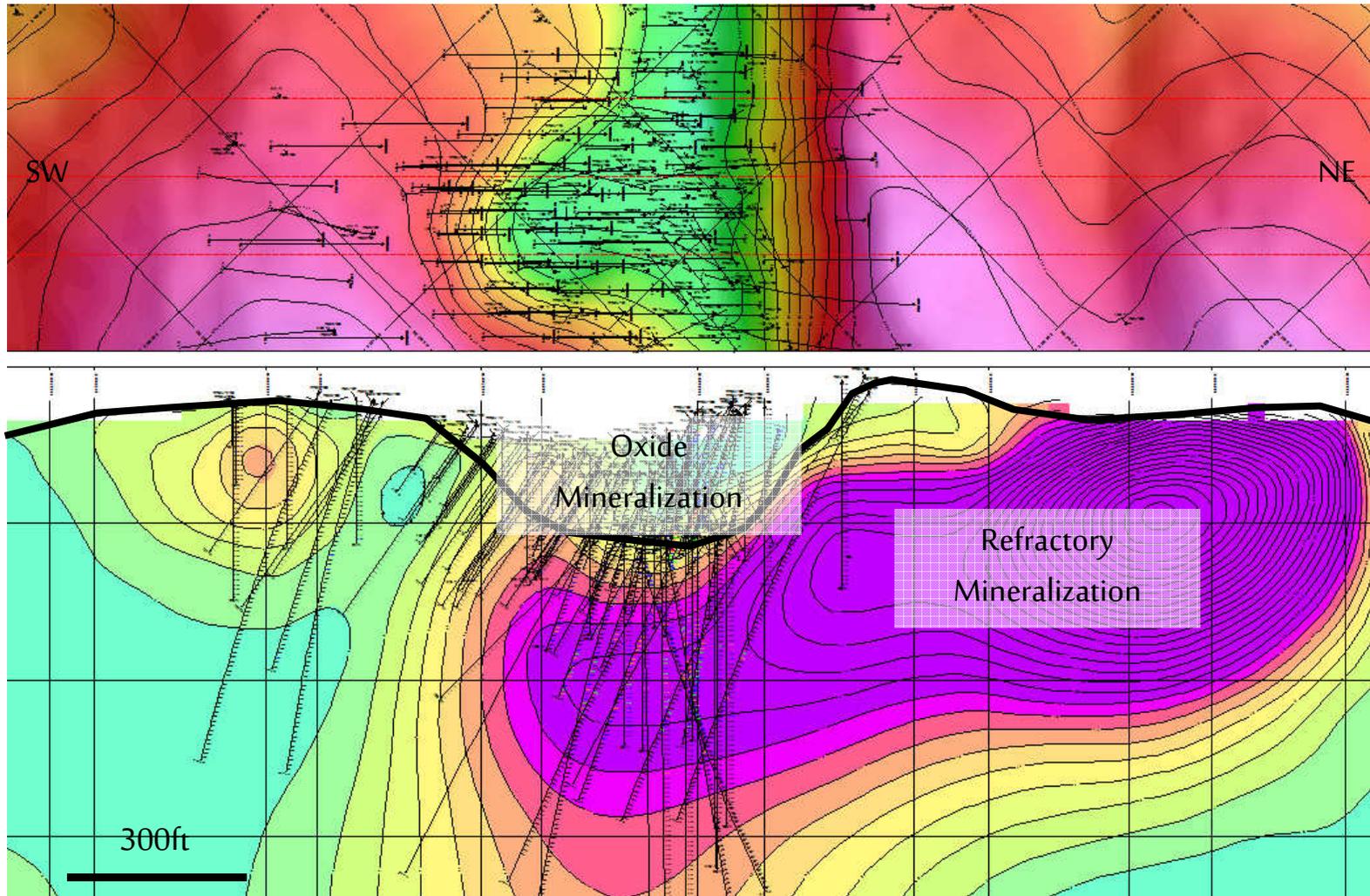
- Advanced applications of traditional IP techniques
 - Distributed array systems
 - 3D inversion
 - Downhole IP experiments

Bald Mt example



- RBM dipole-dipole IP Survey

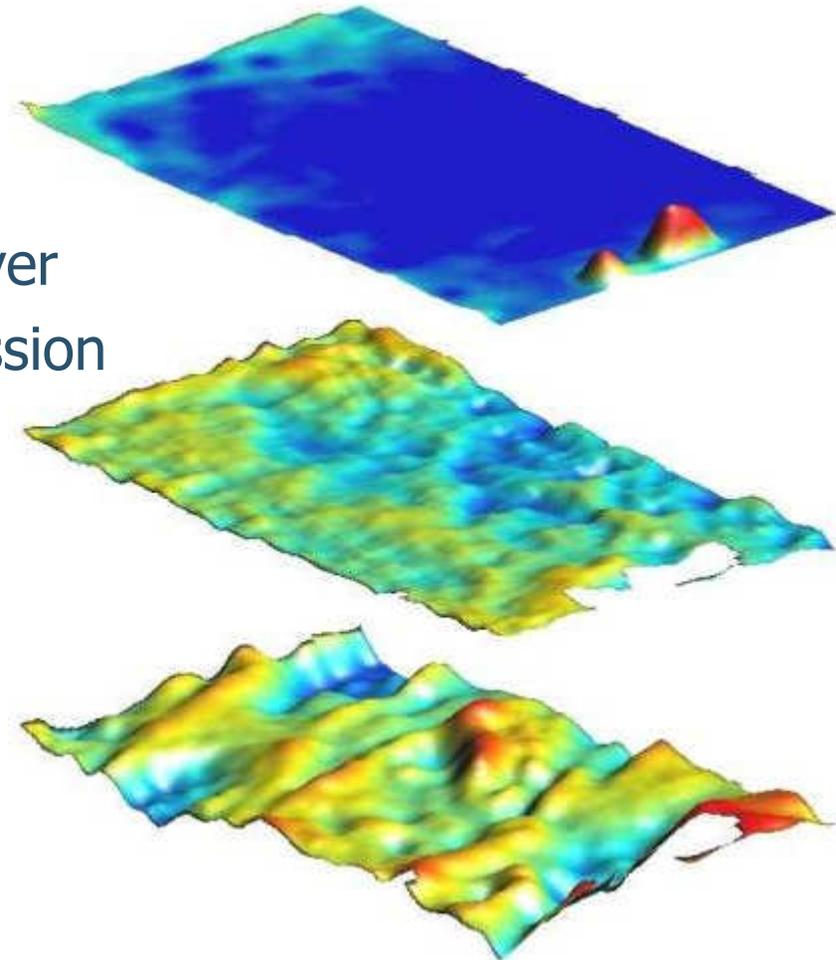
**Lee to resupply with elevation colour stretch for plan map – not hot/cold*



Future: Great Basin geophysics



- Geophysics will play an increasing role in Great Basin exploration in the future
- Blind deposits
 - beneath alluvial or volcanic cover
 - No surface geochemical expression
- Following section describes developments expected in the next 5 to 10 years in:
 - Acquisition
 - Processing and inversion
 - Geological integration



Future: Acquisition



- Distributed array electrical methods
 - Multiple source-receiver combinations
 - Reduce non-uniqueness in inversions
 - Higher interpretability, more accurate
- 3D Hardrock Seismic
 - Better images complex 3D geology
 - More affordable in past decade
 - Wireless receivers with built in GPS locators for formidable terrain
- Airborne gravity
 - Noise levels **down** roughly an order of magnitude in the past decade
 - **Drape** over mountains in the Great Basin will be an issue for the large aircraft required



Wireless seismic receivers
with inbuilt GPS www.Sercel.com



Aircraft for low-noise airborne gravity photo: M.Hope (Barrick)

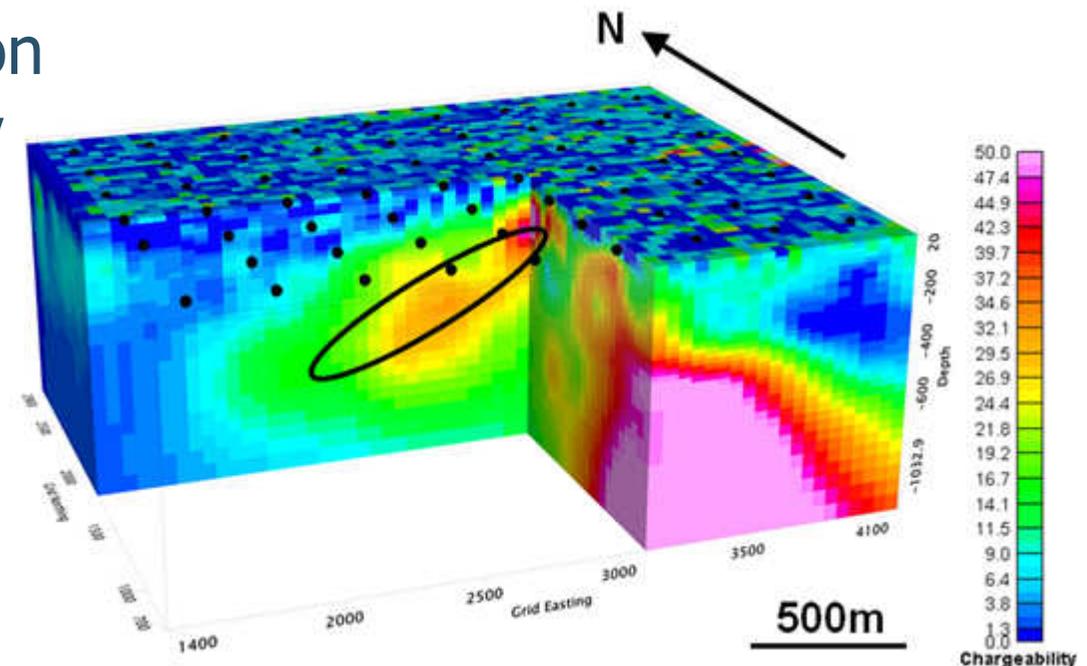
Future: Processing and Inversion



- 3D survey planning
 - 3D seismic / 3D MT station planning to best 'illuminate' target
- 3D inversion
 - Faster algorithms e.g. UBC MUMPS algorithm
 - More complex geophysical methods e.g. 3D EM inversion

- Example: 3D IP inversion

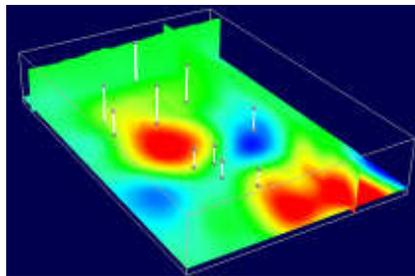
- Gold Hill, Round Mt, NV
- Quantec trial
- Replicated 2D results



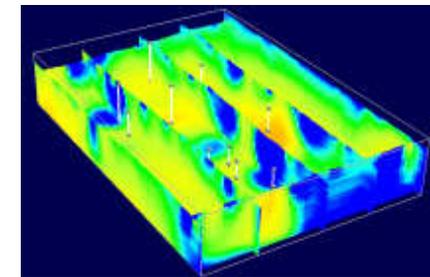
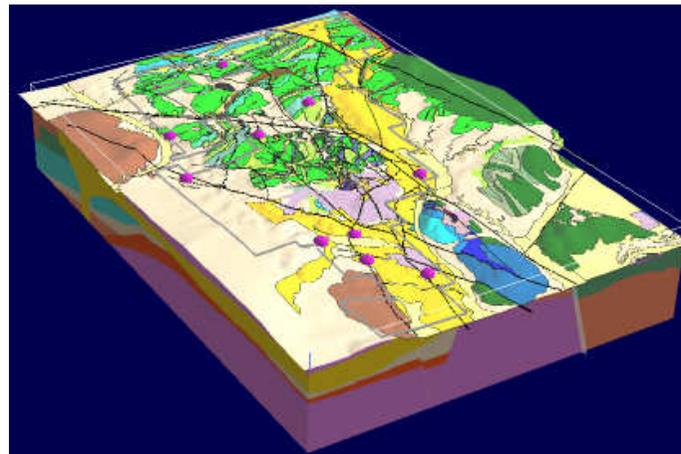
Future: Geological Integration



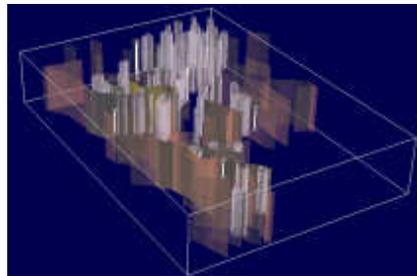
- Integration of geophysical, geochemical and geologic data
- Common earth models populated with multidisciplinary data



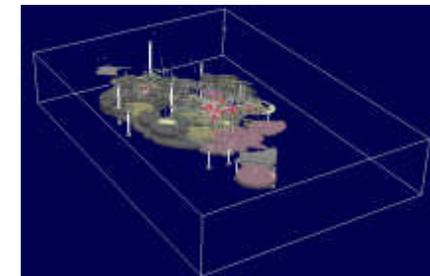
3-D INVERTED GRAVITY



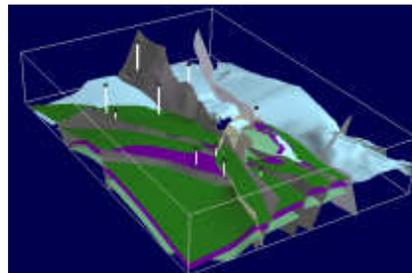
3-D INVERTED MAGNETICS



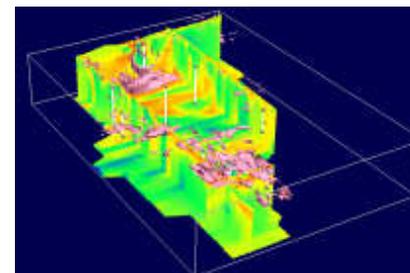
PROJECTED SURFACE ANOMALIES



DRILLHOLE ALTERATION AND GEOCHEMISTRY



GEOLOGY



MT INVERSIONS

Conclusions



- Variability in physical properties of Great Basin rocks warrants petrophysical studies in individual survey areas
- Recent advances in geophysics have played major role in more accurately identifying host rock lithologies, alteration and structure associated with gold mineralization
- Presented examples where geophysics has assisted the exploration program
- Future is in distributed array, 3D seismic and tools for better processing, inversion and geologic integration