Geophysics
Applications for
Environmental &
Engineering Problems

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Service Offerings

Specializing in:

- Characterization and Monitoring for fluid
  - Mine Heaps, Tailings, Waste Rock
  - Plume Mapping

- Leak Detection & Monitoring (LDM)
  - Secondary Recovery of Metal in Heaps
  - Underground Tanks

- Environmental Site Characterization
  - Fracture Mapping

- Engineering Site Characterization
  - Panama Canal
  - Sago Mine

- Exploration
  - Copper and Gold
  - Uranium
  - Groundwater
Our Philosophy

- Every project involves some scientific research
  - Requires some investigation on our part
  - May require non-conventional use of geophysics
  - Our work will pass peer review
- We will be honest on the effectiveness of geophysics
  - Not applicable to track dissolved-phase DNAPL (but may be used to understand geology)
  - Not applicable to map preferential flow paths in saturated zone
  - Not applicable to find 10’ target, 300’ bgs from surface measurements alone
Partial List of Pubs

Partial List of Clients

Apollo Gold / Jipangu
Alamos Gold
Anglo Gold
Barrick
Freeport McMoRan
Coeur Rochester
Cotter Corporation
Inland Explorations
Kinross Gold
Kennecott Mining
Newmont Mining
Sago Mine

BLM
Fremont County SWDD (WY)
Panama Canal Authority
Tucson International Airport
U.S. Dept of Energy
U.S. EPA

ARCADIS
Brown & Caldwell
Clear Creek Consulting
CH2M Hill
Montgomery & Assoc.
Flour Hanford
SRK Consulting
TEC
Tetra Tech
URS Corporation
What is Geophysics

- **1st Order: Target recognition tool**
  - Requires contrasts in physical properties
  - Collect sufficient “background”

- Higher order analyses
  - Topics of current research
  - Relative degree of target size, intensity
  - Correlation to hydro/geo/bio/chemical measurements

Uranium Targets on the Plateau
- Planet / Continent Scale ($10^5 - 10^7$ m)
  - Earthquake analysis
  - Satellite-based instrumentation
- Regional Scale ($10^4 - 10^5$ m)
  - Airborne methods
- Macro Site Scale ($10^1 - 10^4$ m)
  - Surface methods
- Micro Site Scale ($10^{-2} - 10^1$ m)
  - Borehole methods
Innovations in Resistivity

- Acquisition
  - For specialized projects, we have our own equipment
  - Upscaled 3D (700+ stations)
  - Rapid Monitoring
  - Quality Assurance, NRC (NQA-1)
- Processing
  - Expanded hardware & software
- Interpretation
  - Integration of hydrology and geophysics
  - Contextual interpretation
Specialized System for Nuclear Waste Tank Monitoring

LDM Automated System

LDM AutoPro and AutoView Software:
- Near Real Time Data Processing
- Automated Data Assessment
- Web Based for Remote Access

Operations:
- 24/7 System Status Monitoring
- Daily Expert Visual Assessment
Specialized Methodology for Hanford LUSTs

- 54 Mgal waste stored in 177 tanks
- Grouped into 12 tank farms
- Single Shell Tanks supposed to have a 25 year life expectancy
- 2010 minus 1943 = 67 years and counting
Typical Tank Farm
New Technique: Well-to-well

Well-to-Well Summary:
- Acquired data from 110 Wells
- 17 Ground water wells
- 93 Vadose zone wells
- 11,322 Data points
- Data acquisition: 4 days
- New algorithms developed
Advantage of using wells
Geophysical Methods for Mining

**Methods**
- Gravity
- Seismics
- Electromagnetics
- Electrical
  - IP
- Magnetics
- Radar
- Radiometrics

**Properties**
- Density
- Strength
- Conductivity
- Resistivity
- Capacitance
- Susceptibility
- Dielectric
- Gamma

**Exploration - Operations - Environment - Closure**
Operations

APPLICATIONS
- Heaps
- Tailings
- Waste Rock
- Liners

PROBLEMS
- Is solution getting in
- Is solution getting out
- Is it stable
Issues Causing Poor Recovery from Heap Leach Pads

- Solution Management
- Side Slope Under-leaching
- Preferential Flow Pathways
  - Compaction
  - Migration of fines
- Heap settlement
- Clay zones
- Inadequate Ripping
- Chemical precipitation
Understanding Saturation

Assay Data

- Water is an easy parameter to measure
  - Direct
  - Indirect
- Direct drilling shows:
  - Variability at small scale
Calibration

\[ y = 0.0744x + 0.0112 \]

\[ R^2 = 0.73 \]
Specialized System for Mining

Data from high pressure injections

- Day 2 - 15:08 after injection at -27.4m
- Day 3 - 05:06 before injections
- Day 3 - 08:07 after injection at -21.3m
- Day 3 - 10:43 after injection at -15.2m
- Day 3 - 13:07 after injection at -9.1m
Liner Leak Location

Fluid Filled Lined Ponds
Heap Leach Pads

LOCALIZED LEAK AREAS (confirmed)

High Wall

electrical location of leaks
Liner Leak Location

Single Liner

Double Liner

Tx
- Acid rock drainage
  - Acidic waters leaving site
    - From pit
    - From piles
  - Low pH water will mobilize heavy metals
  - Usually ends up in sensitive water areas
  - Good target for resistivity
- Abandoned mine lands
  - Subsidence
  - Contamination
  - Good targets for gravity, seismic
Reclaimed Gold Mine

- It is suspected that ARD is migrating from Suprise and Queen Rose Pit Area to Swift Gulch.
- Migration of ARD is likely structurally controlled
Results
Results

Distance (m)

1350
1400
1450
1500
1550
1600

Elevation (m)

Suprise Shear
Suprise Pit
GCL in Suprise
GCL in Queen Rose
Water Table

log Resistivity (ohm-m)

3.9
3.7
3.5
3.3
3.1
2.9
2.7
2.5
2.3
2.1
1.9
1.7
1.5

Fracture (low certainty)
Fracture (high certainty)
Pre-mine Topo
Mine Topo
Reclamation Topo
Looking Overhead from Southwest

Results – 3D
Results – 3D

\[ EC = 4.796 \times 10^{-7} \times TDS + 0.0013 \]

\[ R^2 = 0.8541 \]
Panama Canal

- Canal is expanding
  - Current = 4000 containers
  - Expanded = 10,000 cont.
- Expansion will include
  - Widening
  - Dredging
- Dredging efficiency
  - Type of rock
  - Strength of rock
  - Volume of rock
Gamboa Reach
Results

- Qa: Fill, Chagres River gravels
- Tcr: Caraba Fm.
- Tbo: Bohio Fm.
- Tgo: Gatuncillo Fm.
- Tba: Bas Obispo Fm.
- Tcm: pre-Tertiary (altered volcanic rocks)

- Former Chagres River Route
- Boreholes with rock
- Boreholes with Quaternary fill

Logarithm of Resistivity (ohm-m)

Scale (km)
Geotechnical Mapping
Geotechnical Mapping

Stratigraphic Sequences
- Tb: Intrus./Extrus. Basalt
- Tpa: Pedro Miguel Fm.
- Tca: Cucaracha Fm.
- Tcb: Culebra Fm.

Oligocene
- Tlc: Las Cascadas Fm. (agglomer.)
- Tlca: Las Cascadas Fm. (andesite)

Map Features
- Major Fault
- Projected Line of Fault

Rock Hardness Attributes
- Moderately Soft Rock
- Moderately Hard Rock
- Hard Rock

Scale (m)
0 500
- First Phase: Site Clearance
- Second Phase: Fault and fracture mapping
Resistivity Results

2D Resistivity Inversion Results, Line 1
Nemo, SD

Log Resistivity

Line Intersection
Interpreted Fracture
Resistivity

2D Resistivity Inversion Results, Line 6 and Line 8 with Lithology Logs, Nemo, SD.
EOR Monitoring

- Surfactant Injection at RMOTC – Teapot Dome (WY)
- Unattended monitoring for 4 month period
- Obtained formation hydraulic conductivity
- Identified possible barriers to flow
Buried Object Detection

GEM-2 In Phase response

Buried Water Well Casing
Sometimes unique solutions are needed for characterizing and monitoring sites

HGI has a good background in geology, hydrogeology, engineering, and resource evaluation to provide solutions

We have worked on some very unique problems

But have the ability, interest, and pricing model to work on more routine problems