



# Applied Geophysics for the Aggregate Industry

Northwest Geophysical Associates, Inc., (NGA) provides geophysical services to assist quarry operators in defining resources and planning operations prior to excavation. Surface geophysical techniques are non-invasive, cost effective, and can be conducted prior to, or as part of the permitting process.

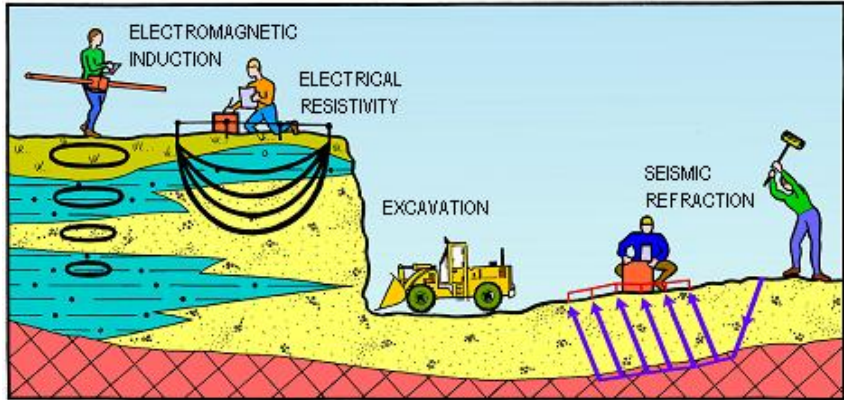


FIGURE 1: EXPLORATION TOOLS

## EXPLORATION OBJECTIVES

- Map and Delineate Sand & Gravel Deposits
- Optimize Drilling Locations
- Volume Estimates
- Rock Rippability
- Depth-to-Bedrock

## GEOPHYSICAL METHODS

- Seismic Refraction
- Electromagnetic (EM) Induction
  - EM Profiling
  - Time-domain electromagnetic (TDEM) Soundings
- Electrical Resistivity
  - Vertical Electric Soundings
  - Dipole-dipole Resistivity Profiling

## SEISMIC REFRACTION

### *Depth-to-Bedrock*

Because seismic velocities are significantly greater in competent bedrock than in alluvial sand and gravel deposits, the seismic refraction method is very effective in mapping the bedrock surface. Seismic velocities also provide an indication of the competence or “rippability” of the bedrock. A weathered bedrock layer is often mapped above the unaltered bedrock “surface.”

For a seismic refraction field program, a string of 12 to 24 geophones are placed on the ground surface, a series of 5-7 “shots” are initiated, and the impulsive arrival of the resulting seismic waves are recorded for each geophone. Shots can be sledgehammer blows (for exploration to depths up to 10-20 feet) or small explosives (for exploration up to several hundred feet).

The interpreted seismic refraction profile in Figure 2 shows a section of poorly consolidated sand and gravel over basaltic bedrock.

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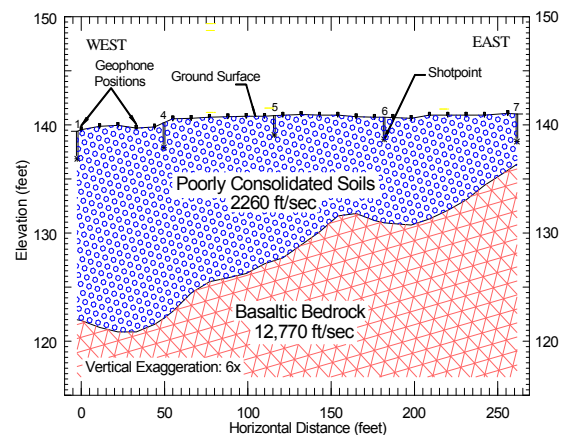


FIGURE 2: SEISMIC REFRACTION PROFILE

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## ELECTROMAGNETIC INDUCTION *Mapping Alluvial Channel Deposits*

Because the electrical conductivity of silt and clay is significantly greater than that of sand and gravel, electromagnetic (EM) and electrical methods can be very useful in mapping those deposits, delineating former river channels deposits, identifying clay interbeds, and mapping sedimentary deposits with a lower percentage of clay.

For the EM field program, electrical currents are induced in the ground with hand carried loop antennas. Soil conductivity measurements are made rapidly, and a large area can be covered quickly.

The conductivity contour plot shown in Figure 3 was taken from a Time-domain Electromagnetic (TDEM) survey over alluvial deposits in the Willamette Valley. It shows the interpreted conductivity of a sand and gravel unit overlying an extensive clay layer. The lower conductivity soils are expected to have a lower percentage of silt and clay.

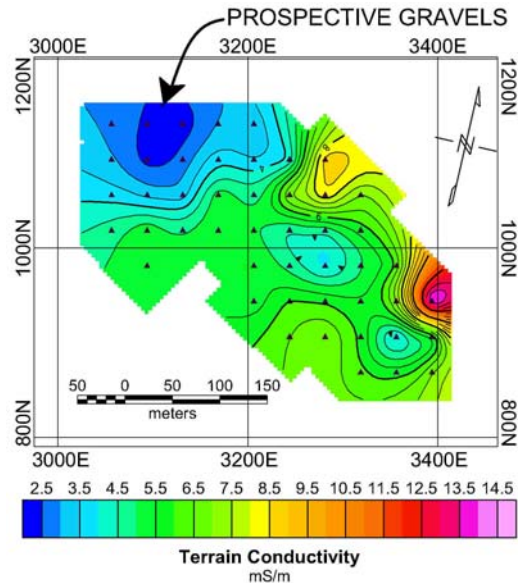


FIGURE 3: EM TERRAIN CONDUCTIVITY MAP

For electrical field measurements, a series of steel electrodes (stakes) are driven 6"-12" into the soil. Two of the electrodes are energized to drive a DC current through the ground. The resulting electrical potentials are measured at the other electrodes. As the distance between electrodes is increased, currents flow deeper in the earth, and hence the depth of investigation is increased.

## ELECTRICAL RESISTIVITY *Geoelectric Cross Sections*

Electrical methods, like electromagnetic (EM) methods, measure the electrical properties of earth materials. Schlumberger soundings and dipole-dipole profiling are two of the more common adaptations of the electrical method or the DC resistivity method.

Electrical methods are somewhat better suited for providing a 2-dimensional earth cross section than the common EM methods. The geoelectric cross section in Figure 4 shows a conductive fractured and weathered fault zone in the more competent bedrock. Similarly, a geoelectric section of an alluvial deposit would display resistive sand and gravel channel deposits surrounded by less resistive silt and clay.

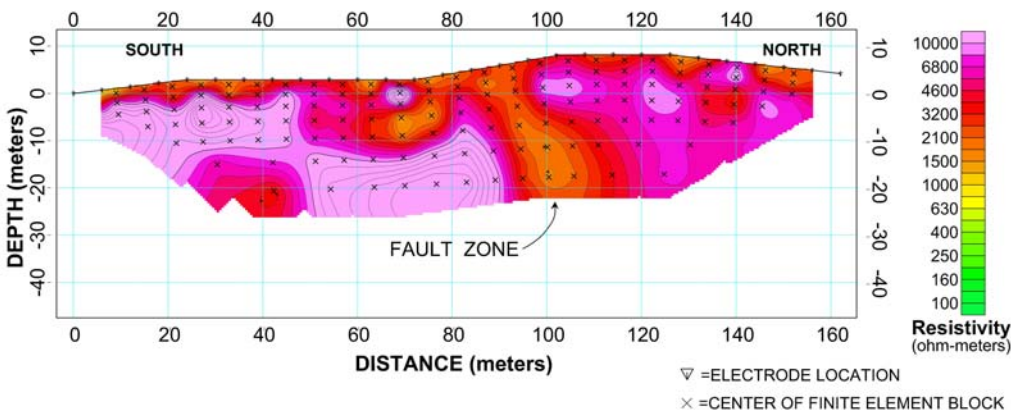


FIGURE 4: DIPOLE-DIPOLE GEOELECTRIC CROSS SECTION

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