



# Chap I: Généralités Geophysics & Hydro-geophysics

**Problematic:** Many agencies and institutes are describing the pressing need to more fully develop tools and approaches that can be used to characterize, monitor, and investigate hydrogeological parameters to improve groundwater recovery and ensure water resource sustainability.

**Limitation:** Conventional techniques for characterizing hydrogeological properties (such as pumping, and slug tests) typically rely on borehole access to the subsurface. Because their spatial extent is commonly limited to the vicinity near the wellbores, these methods often can not provide sufficient information to describe key controls on subsurface flow and transport. The natural heterogeneity and the large spatial variability of hydraulic parameters that control infiltration and transport of groundwater is widely recognized.

**Alternative:** The geophysical methods are a very good alternative that commonly used for shallow subsurface characterization; by applying geophysical principles/methods to link the petrophysical properties to hydrological properties. Hydrogeophysics builds on previous experience and developments associated with the hydrocarbon and mining industries.



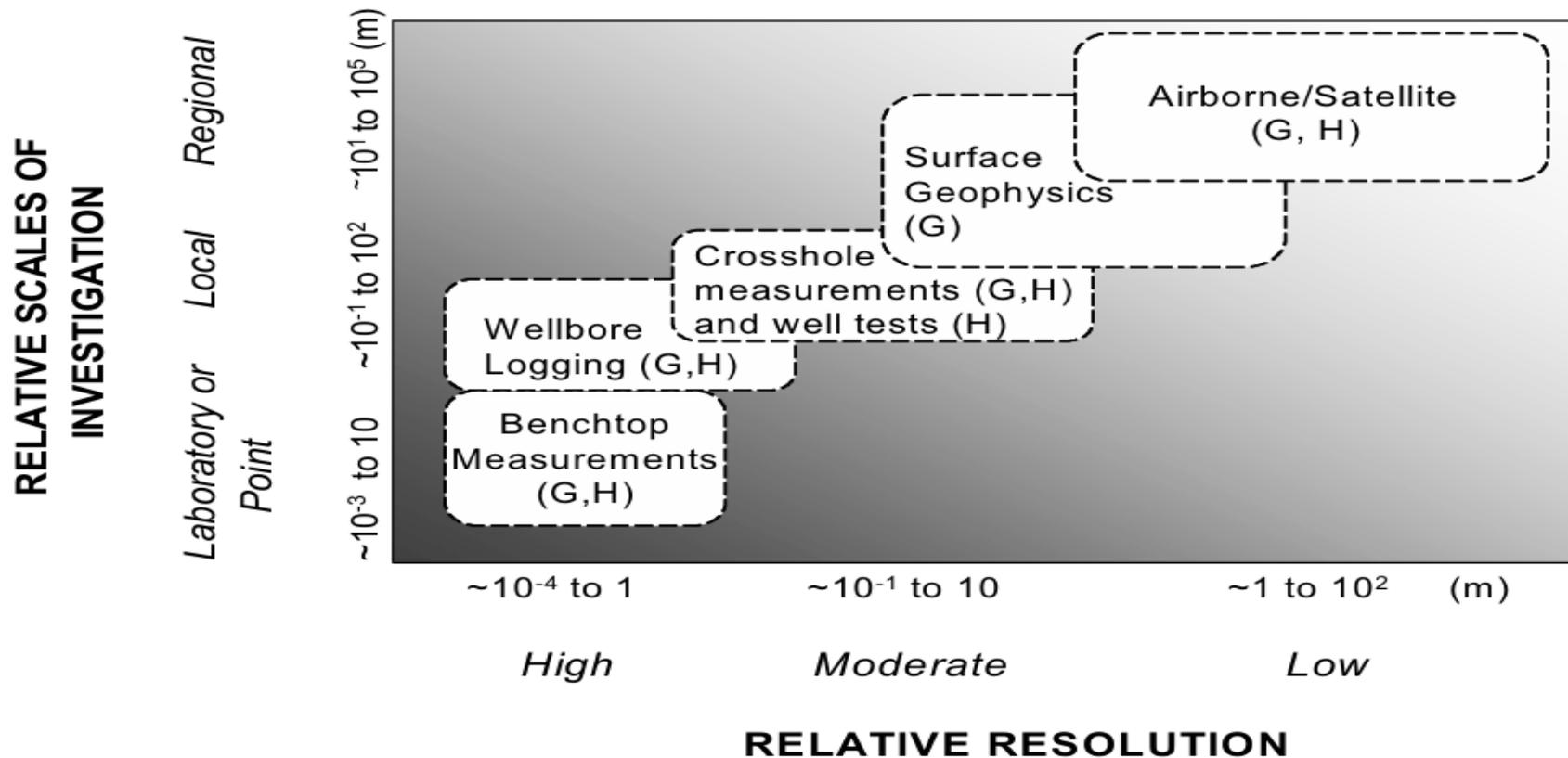
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- **Geophysics** has been used as a tool for petroleum and mining industries for so long to define lithological boundaries and other subsurface structures. It is an application of physical methods, such as seismic, gravitational, magnetic, electrical and electromagnetic at the surface and/or the subsurface of the Earth to measure the physical properties of the subsurface which give a relatively good understanding of petrophysical properties and associated fluids that reach a consolidated, high pressure, high temperature and deep subsurface environment.
- However, the subsurface conditions for **hydro-geophysics** studies are quite different. The shallow, low temperature, low pressure, and less consolidated environments characterize most hydrogeological investigation sites. Hydro-geophysical research has been also performed as near-surface where shallow geophysics methods applied ( <250 m) with a minimum exceptions for deep confined water ( ex: Continental intercalaire in Algeria Desert).



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- As a result Hydro-geophysics is the process of making geophysics methods in service of hydrogeology or groundwater exploration and saline water intrusion at different scales from core sample to satellite and airborne (plane) images. See in figure-1 below how can data characterization scale spread and the right technique to be used.



• **Figure 1: Data characterization scales**



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- The selection of which technique or acquisition approach to use for a particular investigation is made by considering many factors, such as:
  1. The objective of the investigation relative to the sensitivity of different geophysical methods to that objective ( Shallow or deep.....).
  2. The dimension of the project and allocated funds; cost monitoring is compulsory.
  3. The desired level of resolution; conditions at the site; time, and computational resources available for the investigation ( Software and computers) .
  4. Experience of the investigator; and availability of other data. Data are often collected in a sequential manner , where lower-resolution acquisition approaches are used for reconnaissance investigation, followed by higher-resolution approaches to provide more detailed information as required.
  5. Not all geophysical methods suits to hydrogeological investigation see table-1.



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## GEOPHYSICAL METHODS OF EXPLORATION

**CORE DRILLING**

Core drilling can be considered both a geological and geophysical exploration method and forms the foundation for the positive confirmation of targets, the delineation and pricing of ore bodies, and the expansion of reserves. Core drilling also provides the backbone of detailed mine planning activities. Core drills are used frequently in mineral exploration where the coring may be several hundred to several thousand feet in length. The core samples are recovered and examined by geologists and geophysicists for mineral percentages, lithology, petrology, and stratigraphic contact points. Drilling represents one of the most significant and costly methods employed throughout exploration programs for virtually every mineral.

**OTHER METHODS**  
**GRAVITY METHOD** - Gravity measurements define anomalous density within the earth.  
**GAMMA-RAY METHODS** - Gamma-ray methods use scintillometry to identify the presence of the natural radioisotopes potassium, uranium, and thorium.  
**THERMAL METHODS** - Thermal methods can be used to determine the Earth's surface temperature and thermal inertia of surficial materials or of subsurface materials exposed in a borehole.

**SEISMIC**

Seismic techniques have recently had relatively limited utilization, due primarily to their relatively high cost and the difficulty of acquiring and interpreting seismic data in strongly faulted and altered igneous terrain. However, shallow seismic surveys employ less expensive sources and smaller surveys than are typical of regional surveys, and the cost of studying mineral deposits hosted in the near subsurface may not be prohibitive. Reflection seismic methods provide fine structural detail and refraction methods provide precise estimates of depth to lithologies of differing acoustic impedance. The refraction method has been used in mineral investigations to map low-velocity alluvial deposits such as those that may contain gold, tin, or sand and gravel.

**MAGNETIC TECHNIQUES**

The magnetic method of mineral exploration exploits small variations in magnetic mineralogy (magnetic iron and iron-titanium-oxide minerals, including magnetite, titanomagnetite, and titanohematite, and some iron sulfide minerals, including pyrrhotite and greigite) among rocks. Measurements are made using fluxgate, proton-precession, Overhauser, and optical absorption magnetometers. In most cases, total magnetic field data are acquired; vector measurements are made in some instances. Magnetic rocks contain various combinations of induced and remanent magnetization that perturb the Earth's primary field. The magnitude of both induced and remanent magnetization depend on the mineral composition and size of magnetic mineral domains.

**ELECTRICAL TECHNIQUES**

Electrical methods of exploration comprise a multiplicity of separate techniques that employ differing instruments and procedures, have variable exploration depth and lateral resolution, and are known by several names and acronyms describing techniques and their variants. Electrical methods can be described in five classes: (1) direct current resistivity, (2) electromagnetic, (3) noise-a-la-masse, (4) induced polarization, and (5) self-potential. In spite of all the variants, measurements fundamentally are of the Earth's electrical impedance or relate to changes in impedance. Electrical methods have broad application to mineral exploration. These techniques may be used to identify sulfide minerals, are directly applicable to hydrologic investigations, and can be used to identify structures and lithologies.

**REMOTE SENSING**

Remote sensing includes methods that utilize images obtained in the ultra-violet, visible, and near infrared bands of the electromagnetic spectrum. Remote sensing data are treated in digital image format so that they can be processed conveniently. By comparison with known spectral responses of minerals or mineral groups, iron hydroxide minerals, silica, clay alteration, etc., can be defined over broad areas. Remote sensing can also be used in geo-environmental studies to map surface alteration and to identify anomalous vegetation patterns in areas related to abnormal metal content in soil. With the rise in UAV (drone) use, remote sensing on a high-resolution regional or project specific scale has now become more accessible and affordable than ever before.

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Figure 2: Geophysical exploration methods



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**Table 1: Main Geophysical methods and their main applications**

Geophysical method	Chapter number	Dependent physical property	Applications (see key below)									
			1	2	3	4	5	6	7	8	9	10
Gravity	2	Density	<b>P</b>	<b>P</b>	s	s	s	s	!	!	s	!
Magnetic	3	Susceptibility	<b>P</b>	<b>P</b>	<b>P</b>	s	!	m	!	<b>P</b>	<b>P</b>	!
Seismic refraction	4,5	Elastic moduli; density	<b>P</b>	<b>P</b>	m	<b>P</b>	s	s	!	!	!	!
Seismic reflection	4,6	Elastic moduli; density	<b>P</b>	<b>P</b>	m	s	s	m	!	!	!	!
Resistivity	7	Resistivity	m	m	<b>P</b>	<b>P</b>	<b>P</b>	<b>P</b>	<b>P</b>	s	<b>P</b>	m
Spontaneous potential	8	Potential differences	!	!	<b>P</b>	m	<b>P</b>	m	m	m	!	!
Induced polarization	9	Resistivity; capacitance	m	m	<b>P</b>	m	s	m	m	m	m	m
Electromagnetic (EM)	10	Conductance; inductance	s	<b>P</b>	m							
EM-VLF	11	Conductance; inductance	m	m	<b>P</b>	m	s	s	s	m	m	!
EM – ground penetrating radar	12	Permittivity; conductivity	!	!	m	<b>P</b>	<b>P</b>	<b>P</b>	s	<b>P</b>	<b>P</b>	<b>P</b>
Magneto-telluric	11	Resistivity	s	<b>P</b>	<b>P</b>	m	m	!	!	!	!	!

**P** = primary method; **s** = secondary method; **m** = may be used but not necessarily the best approach, or has not been developed for this application; **(!)** = unsuitable

**Applications**

- 1 Hydrocarbon exploration (coal, gas, oil)
- 2 Regional geological studies (over areas of 100s of km<sup>2</sup>)
- 3 Exploration/development of mineral deposits
- 4 Engineering site investigations

- 5 Hydrogeological investigations
- 6 Detection of sub-surface cavities
- 7 Mapping of leachate and contaminant plumes
- 8 Location and definition of buried metallic objects
- 9 Archaeogeophysics
- 10 Forensic geophysics



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The methods can be classified as primary or secondary use because of:

- The geophysical/ hydrogeological properties and parameters they can give.
- The implementation procedure and the dimension of the project.
- The cost/benefit related to the use of specific methods.
- The nature of hydrogeological study; groundwater exploration and subsurface contaminant use different methods in their studies.

Note there are other new methods confirming their efficiency such as GPR ( Ground Penetration Radar) , VSP ( Vertical Seismic Profil) that are in common use recently.

We will go through each method from the less used to the most and the best in use.