UNIVERSITÀ DEGLI STUDI DI TRIESTE

A.A. 2020-2021

Laboratorio di Acquisizione ed Elaborazione dati Geofisici

UNITA' DIDATTICA 1 - UD1

INTRODUZIONE ai METODI GEOFISICI

SENSIBILITA' - RISOLUZIONE - APPLICABILITA'

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SCHEMA UNITA' DIDATTICA

- Che cos'e' la "GEOFISICA"
- CONCETTI DI BASE: parametri geofisici
  - ➔ Sensibilità
  - ➔ Risoluzione
  - ➔ Applicabilità
- Metodi attivi e passivi (+ & -)
- Metodi di potenziale e "wave field" (+ & -)
- Criteri generali di pianificazione di un rilievo
- Conclusioni/Domande

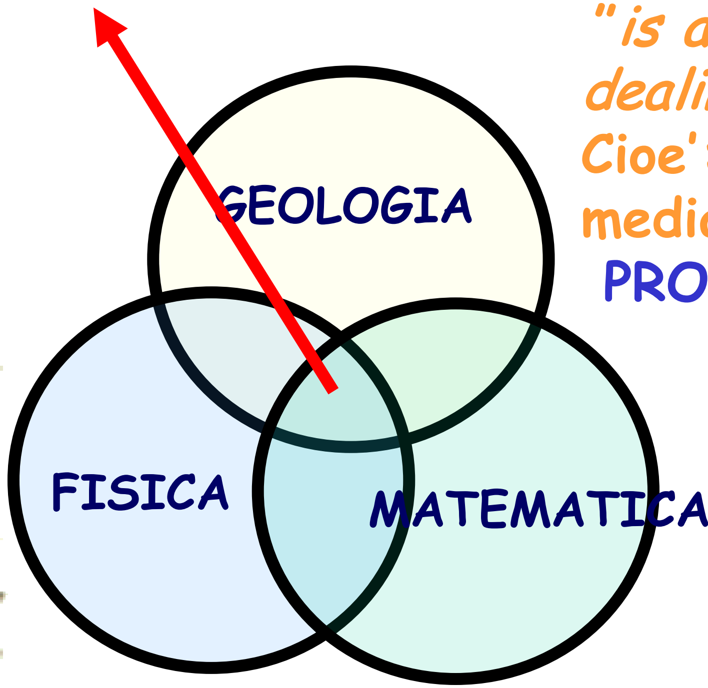
CHE COS' E' la GEOFISICA?

Geofisica:

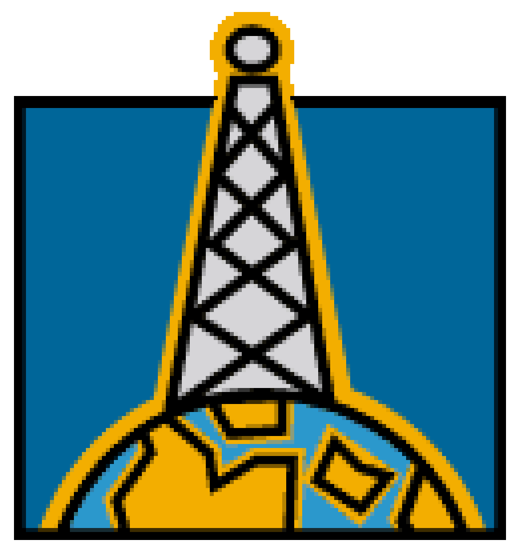
GEO (γεο) – FISICA (φυσικα)

"is a branch of experimental physics dealing with the earth" (SEG)

Cioe': metodi di esplorazione della terra mediante la misura e l'analisi di **PROPRIETA' FISICHE** dei materiali →



PARAMETRI FISICI



CONCETTI DI BASE

SENSIBILITA' / SENSITIVITA'

"Two different materials can be discriminate only if the applied geophysical method is SENSITIVE to a physical parameter DIFFERENT for the two materials" *SEG dictionary*

➔ **Contrasto (Geo)Fisico** ➔ **"Anomalia"**

➔ **APPLICABILITA' dei metodi**

E' FUNZIONE DEGLI OBIETTIVI DI INDAGINE!

Ad esempio: **resisitività**

	Resistivity range Ωm
Surface waters (sediments)	10 – 100
Soil waters	
Natural waters (ign. rocks)	0.5 – 150
Natural waters (sediments)	1 – 100
Sea water	0.2
Saline waters, 3%	0.15
Saline waters, 20%	0.05

	First medium		Second medium				
Interface	Velocity	Density	Velocity	Density	Z_1/Z_2	R	E_R
Sandstone on limestone	2.0	2.4	3.0	2.4	0.67	0.2	0.040
Limestone on sandstone	3.0	2.4	2.0	2.4	1.5	−0.2	0.040
Shallow interface	2.1	2.4	2.3	2.4	0.93	0.045	0.0021
Deep interface	4.3	2.4	4.5	2.4	0.97	0.022	0.0005
"Soft" ocean bottom	1.5	1.0	1.5	2.0	0.50	0.33	0.11
"Hard" ocean botom	1.5	1.0	3.0	2.5	0.20	0.67	0.44
Surface of ocean (from below)	1.5	1.0	0.36	0.0012	3800	−0.9994	0.9988
Base of weathering	0.5	1.5	2.0	2.0	0.19	0.68	0.47
Shale over water sand	2.4	2.3	2.5	2.3	0.96	0.02	0.0004
Shale over gas sand	2.4	2.3	2.2	1.8	1.39	−0.16	0.027
Gas sand over water sand	2.2	1.8	2.5	2.3	0.69	0.18	0.034

All velocities in km/s, densities in g/cm³; the minus signs indicate 180° phase reversal.

Metodi sismici

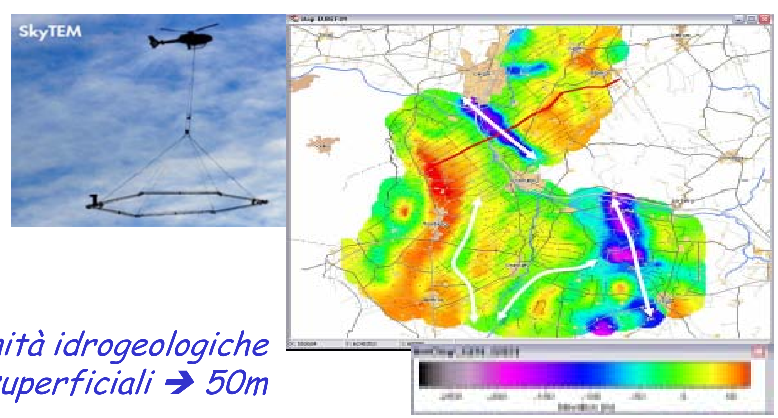
CONCETTI DI BASE

Risoluzione

Massimo livello di dettaglio raggiungibile

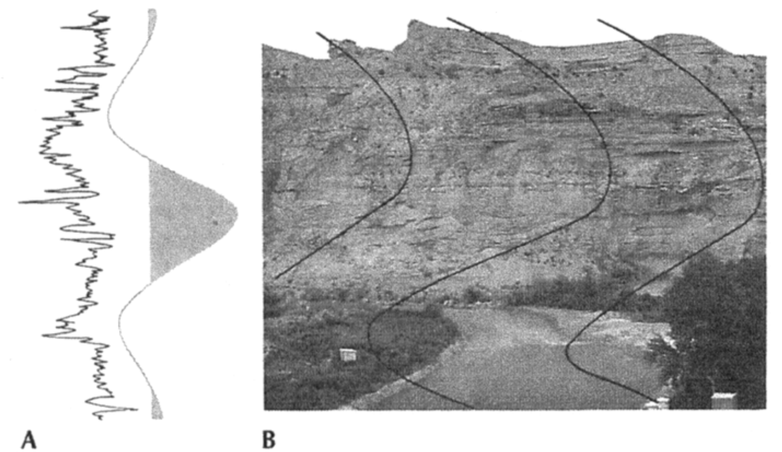
o, meglio, la minima distanza che consente di descrivere come "separati" due oggetti distinti

VERTICALE/ORIZZONTALE



Unità idrogeologiche superficiali → 50m

Sørensen, 2004



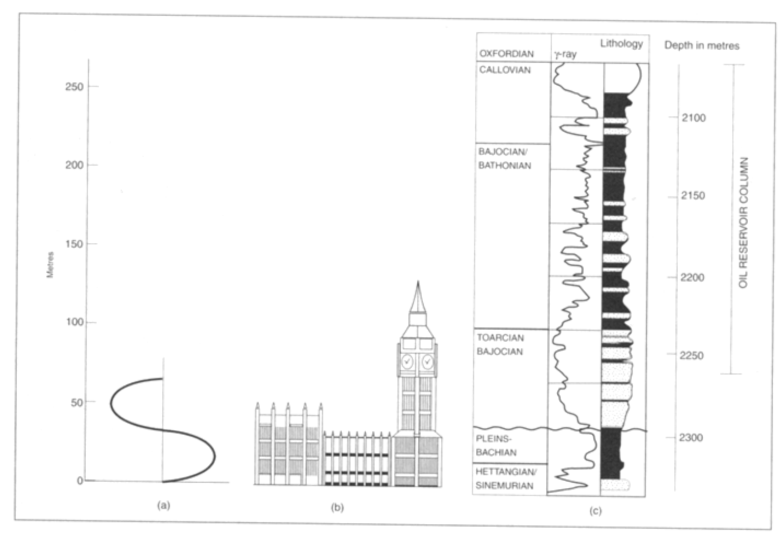


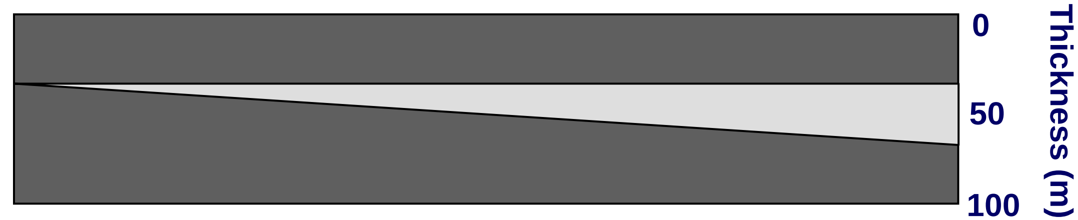
Fig. 3.2 A comparison of resolution of interpretation tools for the Beatrice Field, North Sea. (a) A single cycle sine wave of 30 Hz in medium of velocity 2000 ms^{-1} (or 60 Hz; 4000 ms^{-1}); (b) Big Ben, London, c. 380 ft; (c) A γ-ray log through the Beatrice Oil Field

Telford, 1989

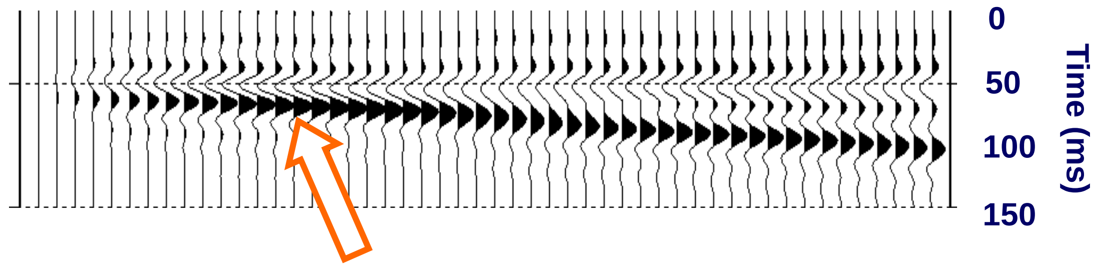
CONCETTI DI BASE

Risoluzione

Reale geologia



Sezione sismica A riflessione (sintetica)



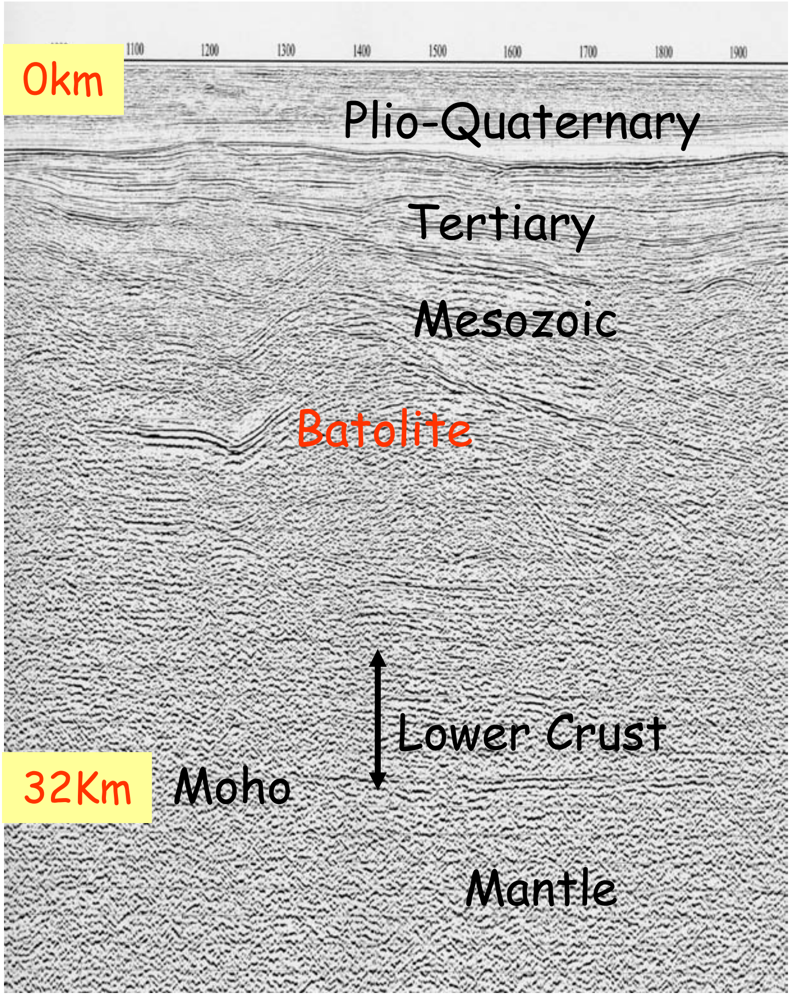
Normalmente (ma non sempre) i metodi geofisici altamente risolutivi sono i piu' costosi
Quindi è indispensabile un compromesso tra
COSTI GLOBALI e RISULTATI ATTESI

Un problema cruciale è che ogni metodo inappropriato (anche se a basso costo) non fornisce informazioni utili e rappresenta quindi un costo inutile e senza senso.

CONCETTI DI BASE

Sensibilità, Risoluzione, applicabilità

GPR (electromagnetic waves)
Ultra High Resolution Section (150-350MHz)
MAX Penetration Depth 2-20m
Resolution 0.1-0.5m



Deep reflection Seismic (elastic waves)
Low Resolution Section (5-50Hz)
MAX Penetration Depth 40Km
Resolution 10-100m

PER TUTTI I METODI GEOFISICI LA RISOLUZIONE DIMINUISCE CON LA PROFONDITA'

➔ Non è possibile ottenere un alto grado di dettaglio per profondità crescenti ➔ Definizione dei TARGET/OBIETTIVI ➔ APPLICABILITA'

CONCETTI DI BASE

Applicabilità

L'APPLICABILITA' dipende quindi dalle POTENZIALITA' di una metodologia geofisica di INDIVIDUARE E CARATTERIZZARE uno o piu' OBITTIVI DI INDAGINE (Target)
➔ quindi f(parametri fisici) dei materiali

MA NON SOLO!

Dipende anche da:

1. DIMENSIONI E PROFONDITA' DEI TARGET
2. PARAMETRI DI ACQUISIZIONE UTILIZZATI (geometrici, campionamento, frequenze, energia,...)
3. RUMORI (coerenti e casuali) ➔ Rapporto S/N
4. CONDIZIONI LOGISTICHE (accessibilità, tipo di copertura, presenza di vincoli,...)
5. Tipologia di rilievo (geometria, copertura, 2D, 2.5D, 3D, 4D,...)
6. COSTI/RISULTATI ATTESI
7. Tipo e modalità di ELABORAZIONE APPLICATE
8. DISPONIBILITA' di dati pregressi

CONCETTI DI BASE

Applicabilità

Puo' quindi essere molto difficile STIMARE l'applicabilità ed i risultati attesi con l'utilizzo di una particolare metodologia:

➔MODELLAZIONE Preliminare (se sono noti almeno approssimativamente alcuni dei parametri fisici in gioco)

➔FIELD TEST preliminari per la valutazione dei risultati e la scelta dei parametri e delle tecniche ottimali di acquisizione

E' pericoloso procedere utilizzando solo schemi STANDARD
➔ Risultati altamente SITE-DEPENDENT

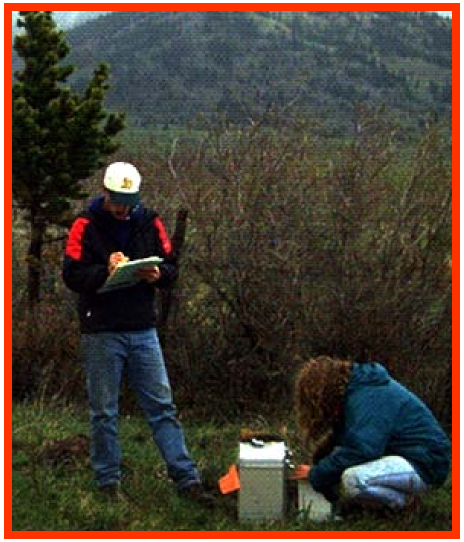
Ad es. il NUMERO DI MISURE NECESSARIE puo' condizionare pesantemente i risultati e dipende da molti fattori, quali:

- Rumori ambientali/di fondo ➔ affidabilità delle misure
- Grado di dettaglio necessario funzione della "complessità" del sito ➔ approssimazioni 1D, 2D, 3D, omogeneità, isotropia, …) e degli obiettivi di indagine (dimensioni, profondità, contrasto, forma, distribuzione geometrica, sovrapposizione,…)
- Metodologia di indagine prescelta

METODI ATTIVI e PASSIVI

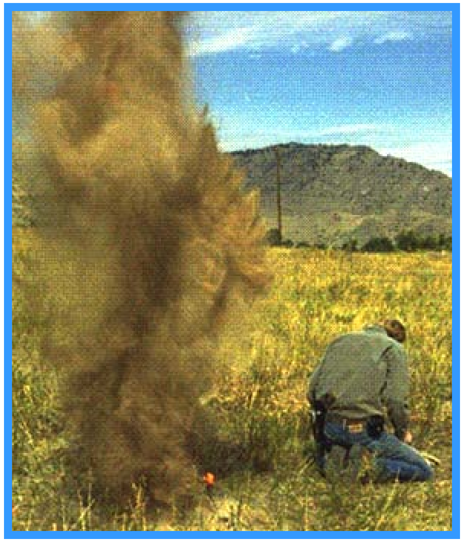
Geophysical methods can be classified into one of two types: *Passive* and *Active*

Passive geophysical methods ➔ Measurements of naturally occurring fields or properties of the earth ➔ Spatial variations of these fields or properties and attempt to infer something about the subsurface material distibution (geology).
Gravitational field, Magnetic field, Electric field (Self Potential), Electromagnetic field (Magneto Telluric), Earthquakes/natural ground movement,Temperature/Heat flow, Pressure, Radiometric decay products, ...



Gravity Survey

Seismic Survey with explosive



Active geophysical methods ➔ a "perturbation/signal" is injected into the earth to measure how the subsurface responds to this signal ➔ Extract subsurface physical parameter/imaging.
Electrical current ➔ Many electrical methods (ERT, VES, IP, ...);Electromagnetic currents/waves ➔ Ground Penetrating Radar, Several Inductive methods (FDEM, TDEM,...); Groung displacement ➔ Seismic methods (reflection, Refraction, MASW,...); Active radiometric sources, ...

METODI ATTIVI e PASSIVI: vantaggi e svantaggi

Active		Passive	
+	–	+	–
Better control of noise sources through control of injected signal	Complex Field equipment Both "Sources" and "Receivers" must be supplied	Surveyor need only record a naturally occurring field ➔ no source need	Less control of noise because source of the signal is out of the hands of the surveyor.
Active experiments usually provide better depth control over source of anomalous signal	Field operations and logistics are generally more complex ➔ time consuming ➔ more expensive than passive experiments	Field operations are generally very time efficient ➔ wide areas ➔ cost-efficiency	Results in term of "anomalous geological contributions" ➔ difficult (impossible) identification of the source
Survey design flexibility in customizing surveys for particular problems. Many possible Source/receivers geometries	Greater survey design costs and potentially leads to increased probability of field mishaps	Only few (standard) field procedures are generally used. Relatively easy survey design	Only few (standard) field procedures are generally used. This limits the amount of customisation that can be done for specific problems.
Large quantities of data can be acquired to interpret subtle details of the earth's subsurface	The large quantity of data obtained in many active experiments can become overwhelming to process and interpret	Limited datasets (not always) can be accomplished with modest computational requirements	The data sets collected are (usually) smaller than those collected in active experiments and do not allow for as detailed an interpretation.

METODI ATTIVI e PASSIVI: vantaggi e svantaggi

Active		Passive	
+	–	+	–
	Sometimes invasive methods: sources are required (explosives, high voltages)	Not invasive systems: only sensors are required	
Source type/energy can be tailored on the survey objectives. It can be perfectly repetitive with precise time and position knowledge			No source control → time drifting, changes, obstacles.

Un altro importante criterio di classificazione si basa sulla distinzione tra

METODI "di potenziale" e "wave field"

"Potential field" and "wave field" methods

Potential methods measure *potential fields*

NOTE: A force fields can be described as a *potential field* if the field is conservative (work path independent). Conservative forces can be represented mathematically by simple scalar expressions known as POTENTIALS

The Potential fields used for geophysical exploration are:
1) Gravitational 2) Magnetic 3) Electric

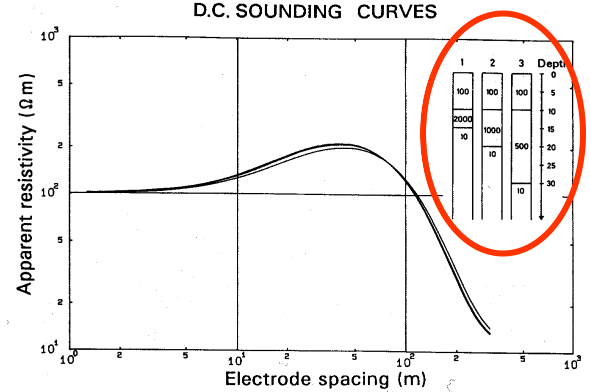
To recover the PHYSICAL PARAMETER DISTRIBUTION the dataset must be INVERTED

NON-LINEAR PROBLEM i.e. no by univocal correspondence between: MEASURED FIELD PROPERTIES and PHYSICAL PARAMETERS (MODELS)

➔ IN THEORY INFINITE MODELS COULD MATCH A MEASURED FIELD DISTIBUTION

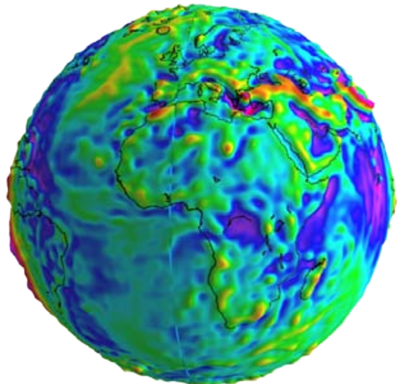
➔ TYPICAL UNDERCONSTRAINED PROBLEM

D.C. SOUNDING CURVES

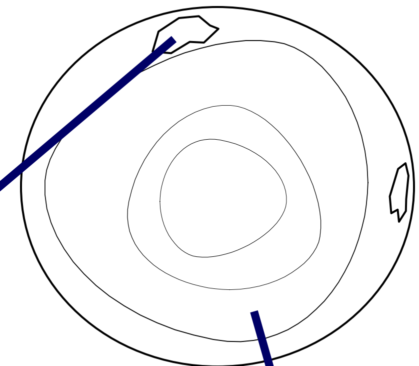


Additional information are required (direct data, other geophysical data, ...)

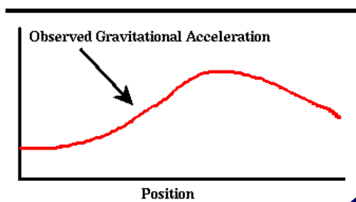
"Potential field" method: conceptual EXAMPLES



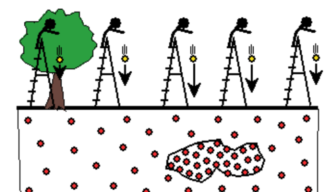
Measured gravity field



Mass/density distribution

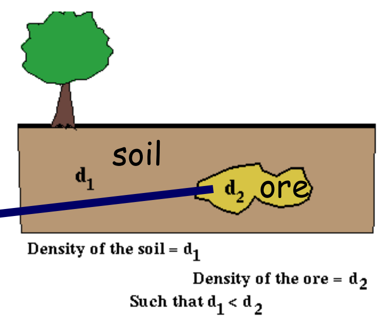


Measured gravity field



Mass/density MODEL

Local effects → local anomalies



Regional/global effects → large scale anomalies

Data INTERPRETATION

The direct problem is to compute gravity potential and force when the density is known.

The inverse problem is to determine the density using the force (the potential) on a given surface.

FORWARD modelling

INVERSE modelling

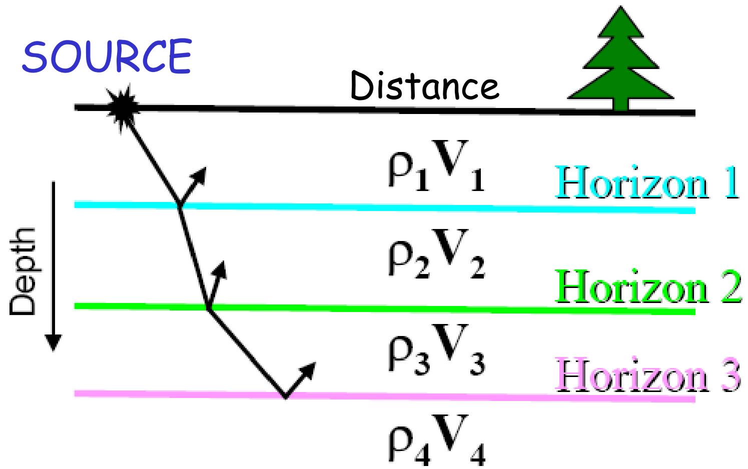
"Potential field" and "wave field" methods

Wave field methods based on the propagation of a perturbation (wave) within the earth

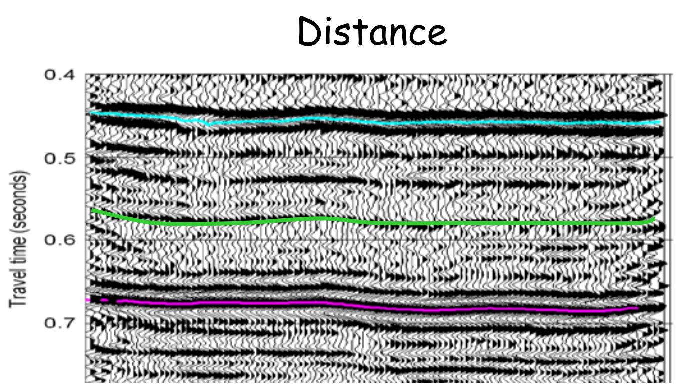
The most common are Seismic (elastic waves) and Electromagnetic waves

The perturbation (or signal) travels into the subsurface, is REFLECTED/REFRACTED/SCATTERED/BACKSCATTERED/CONVERTED and therefore can be recorded at the surface (or into a borehole) by one or more sensors as a function of the time (typically the time zero is the energizing instant)

No data inversion is required (but it is possible) ➔ direct IMAGING of the subsurface

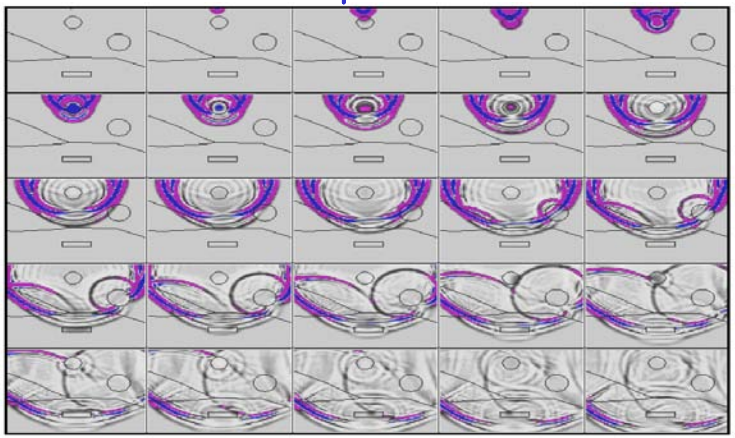


Record: reflection seismic section

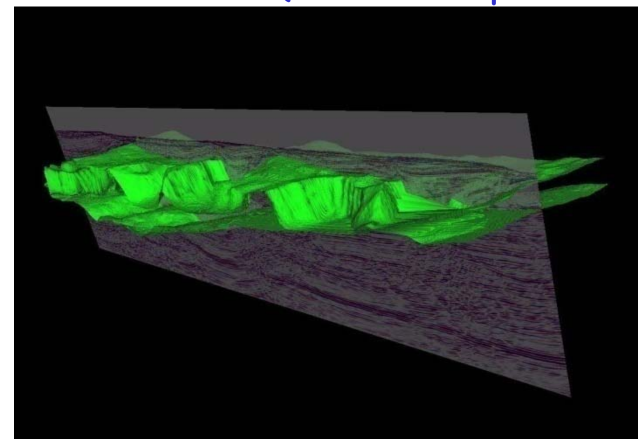


"Potential field" and "wave field" methods

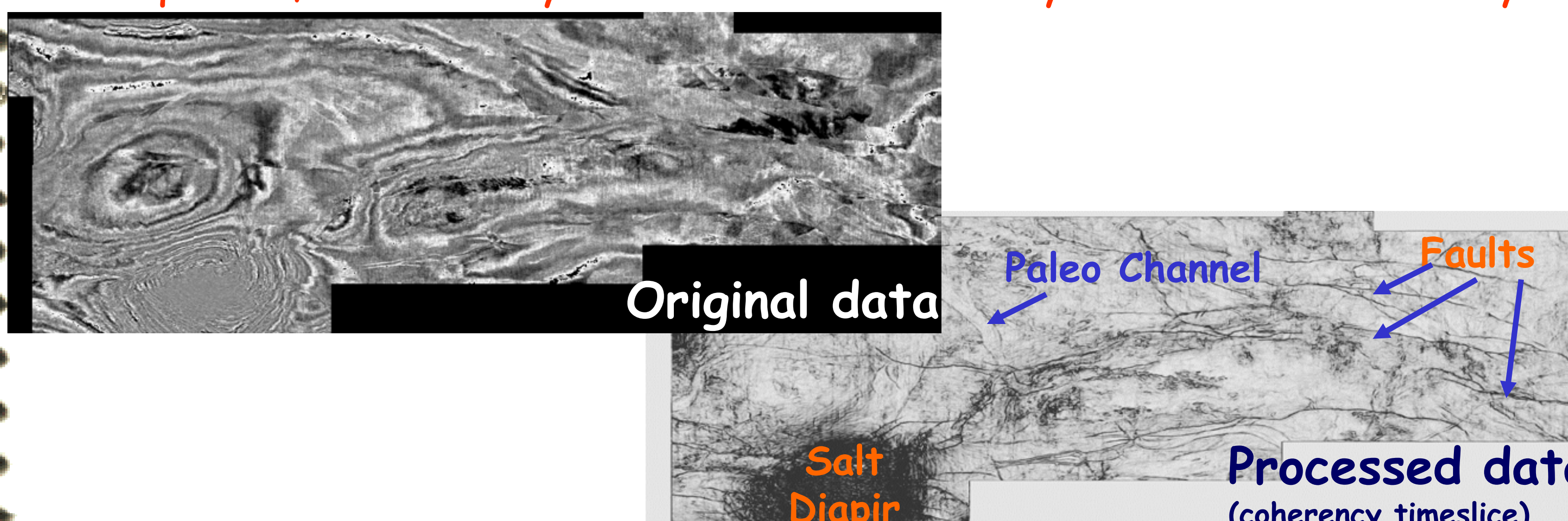
Field experiment



recorded data (with interpretation)



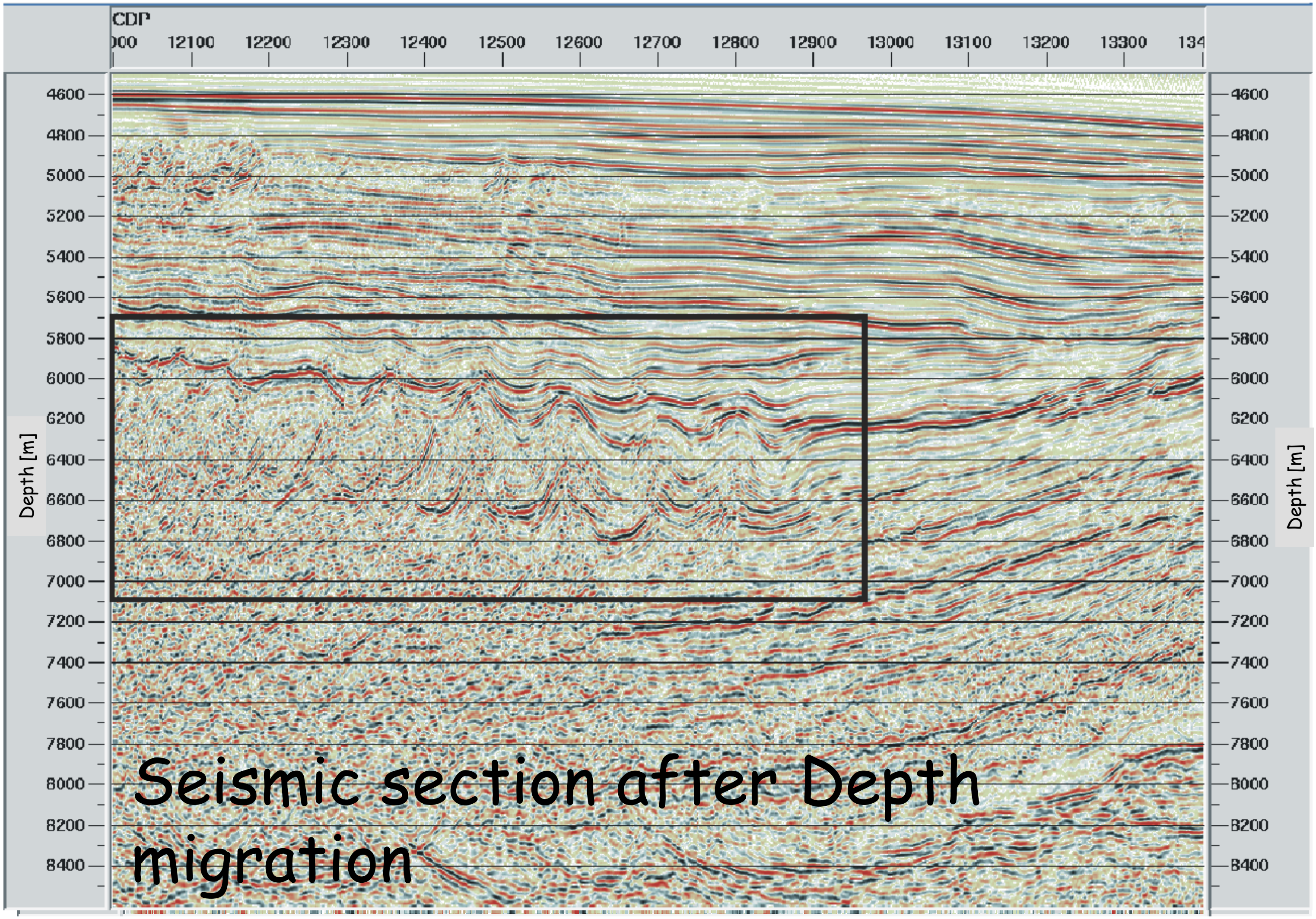
To obtain a real subsurface IMAGING a complex processing is required, but usually final results are very close to the reality



From: Bahorich et al., 1995

"Potential field" and "wave field" methods

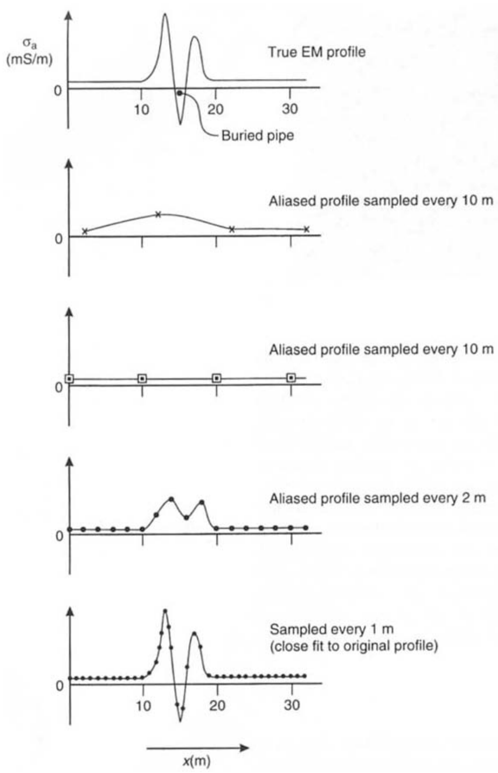
Processing 1D, 2D, 3D



Pianificazione di un rilievo

Bisogna tenere conto di molti fattori, spesso contrastanti:

- *Obiettivi dell'indagine*
- *Sensibilità, Risoluzione, Applicabilità*
- *Costi/risultati*
- *Tempi*
- *Vincoli logistici*
- *Disponibilità e tipologia delle informazioni pregresse*
- *Disponibilità della strumentazione*



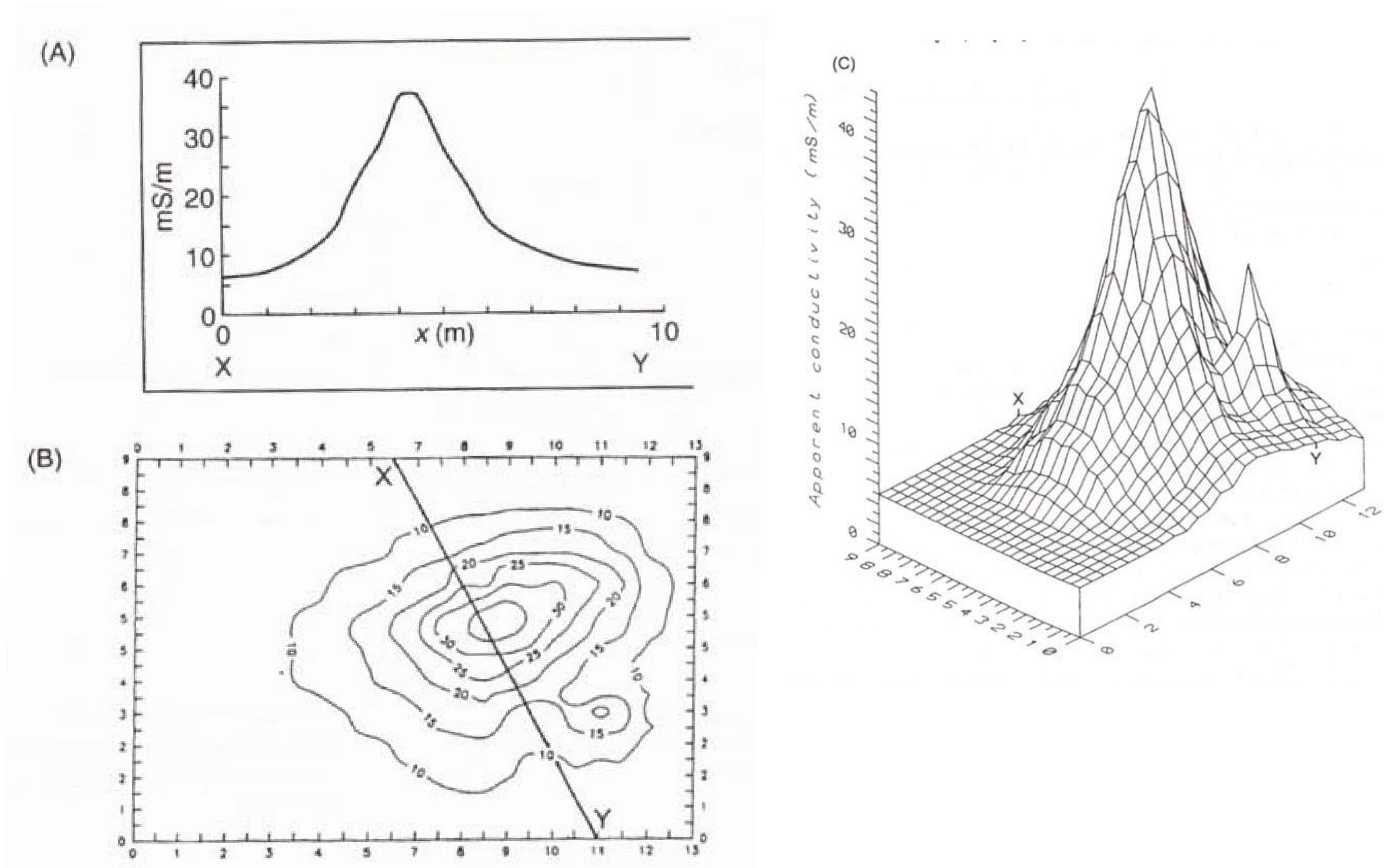
Quantità e modalità delle misure necessarie

🡐 *Campionamento spaziale*

Pianificazione di un rilievo

Quantità e modalità delle misure necessarie

1D, 2D, 3D, 4D,...



Pianificazione di un rilievo

Quantità e modalità delle misure necessarie

1D, 2D, 3D, 4D,… ➔ La scelta è funzione degli OBIETTIVI DELL'INDAGINE

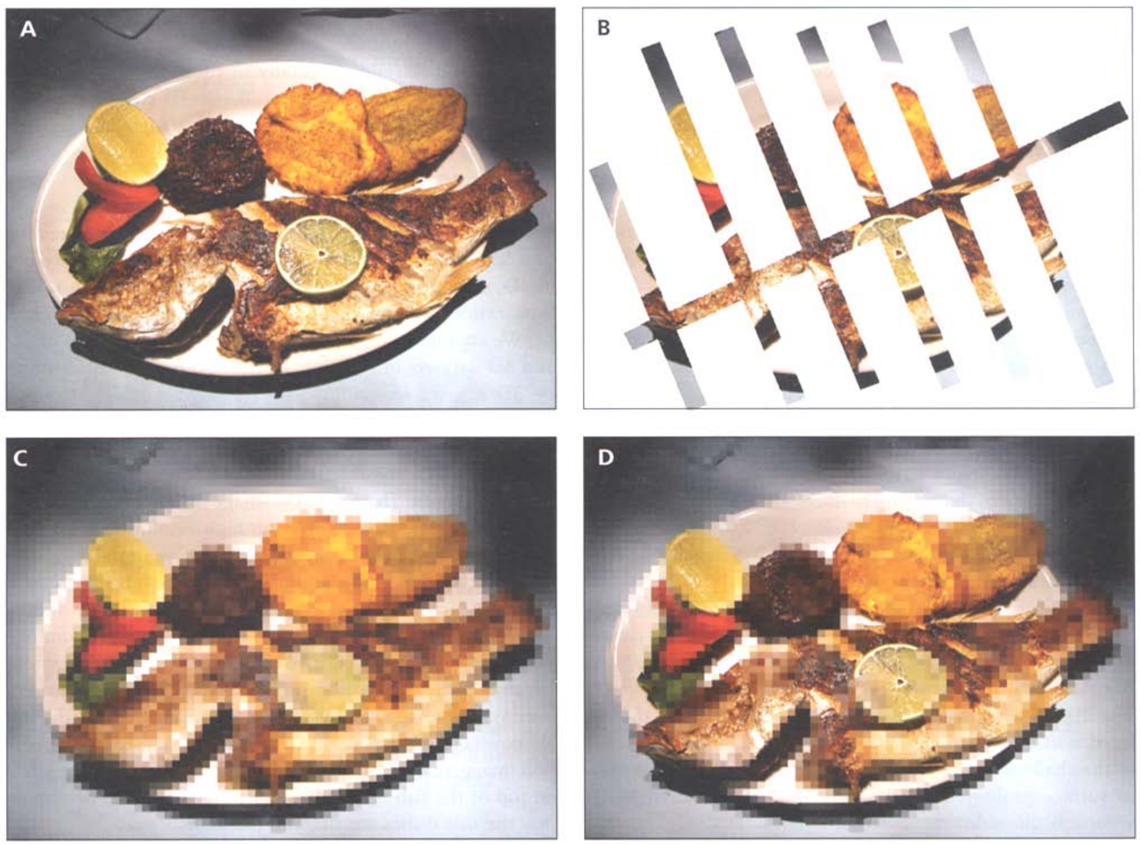
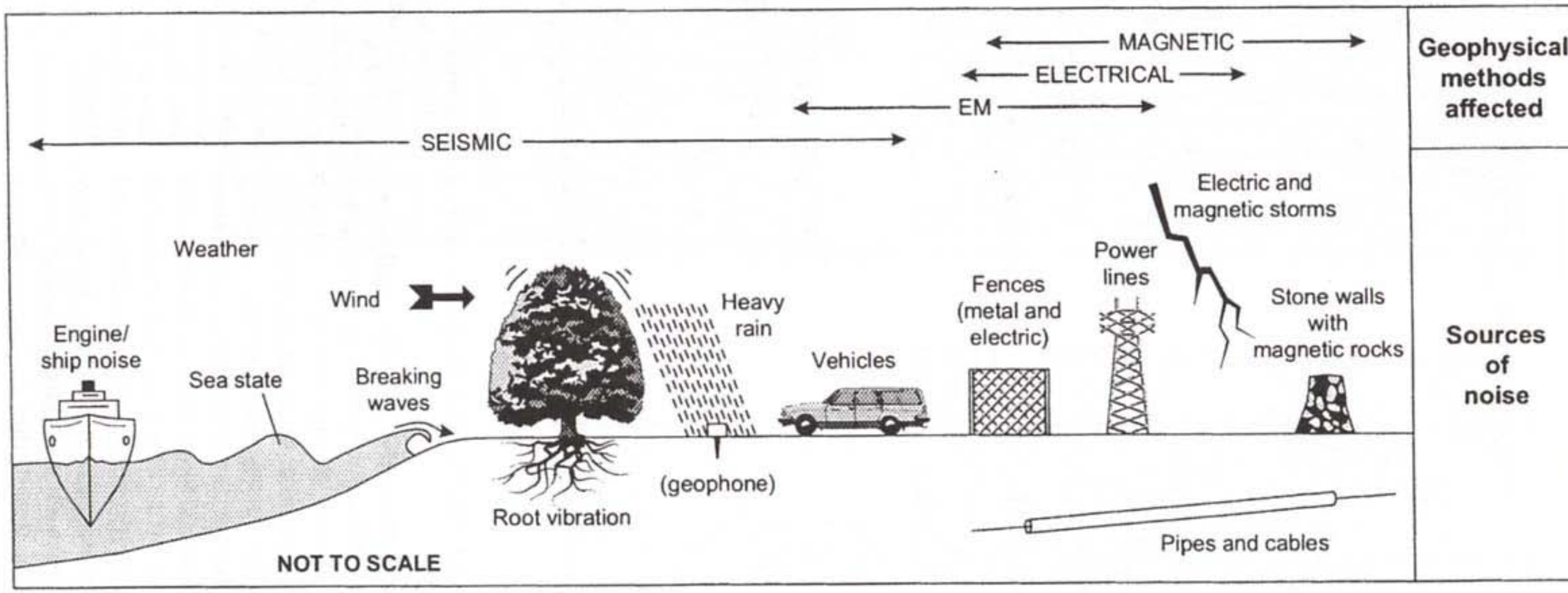


Figure 1 Complementary nature of 2D (linear) and 3D (areal) coverage. (a) Full-resolution image of fish dinner. (b) 2D coverage has high resolution but with significant gaps. (c) 3D coverage complete but at lower resolution. (d) Combining 2D and 3D coverage gives full picture plus more detail where 2D coverage exists, increasing probability of identifying the side dishes.

Vestrum & Gittins 2008

Pianificazione di un rilievo

Quantità e modalità delle misure necessarie

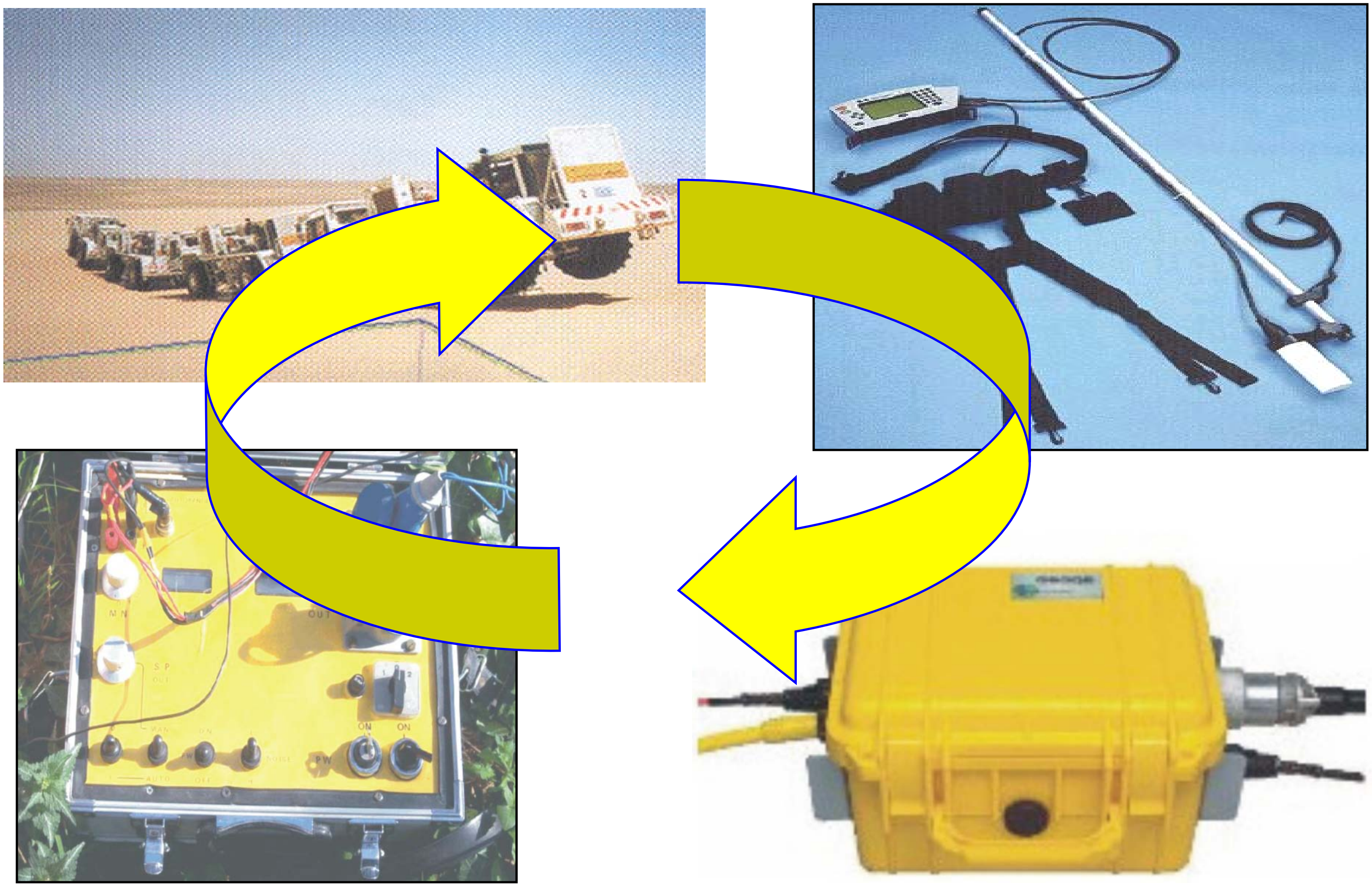


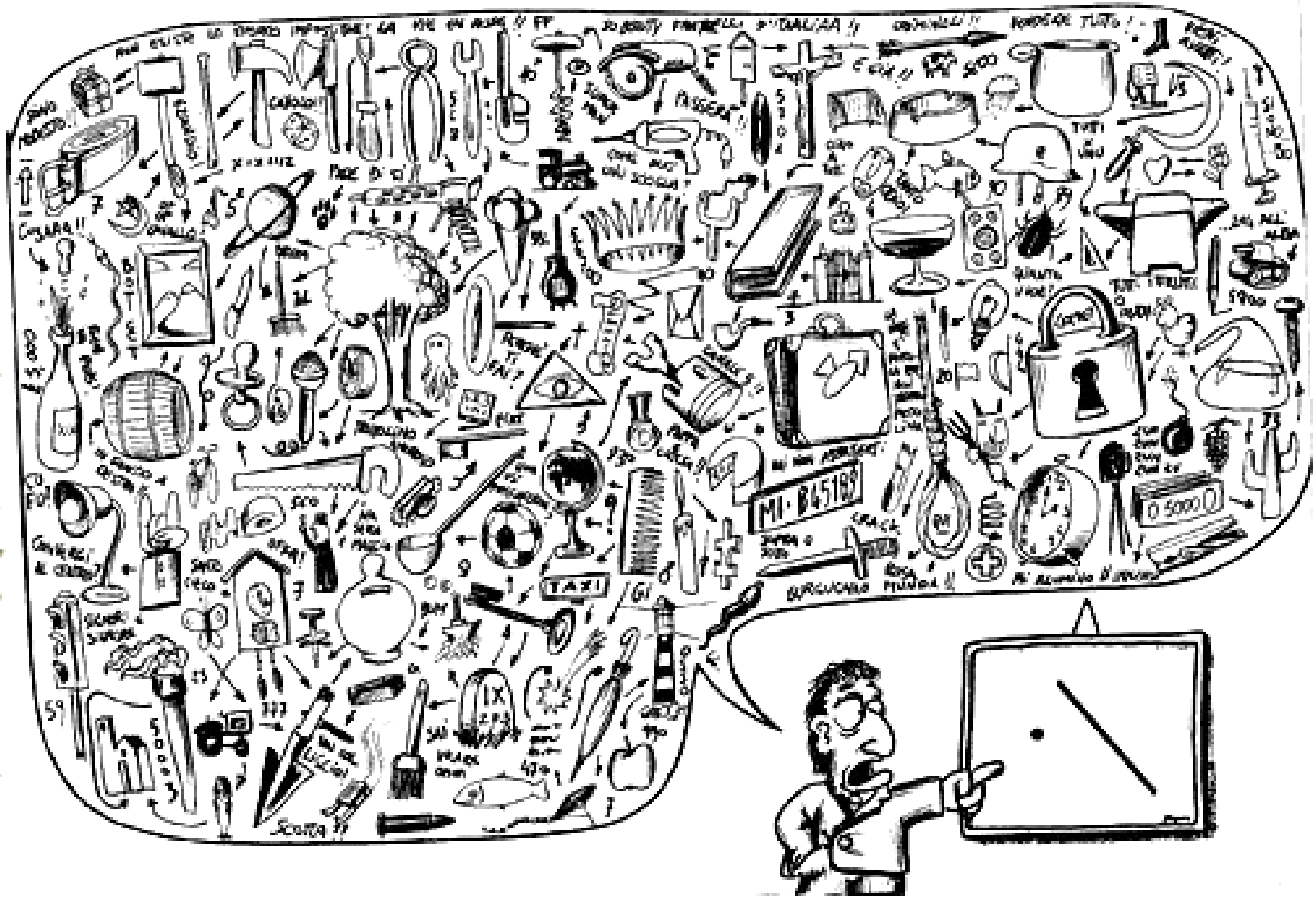
Reynolds, 1997

Figure 1.10 Schematic illustrating some common sources of geophysical noise

Livelli di rumori → S/N ratio

E' molto importante INTEGRARE metodi geofisici diversi che analizzano vari parametri fisici e VERIFICARE/TARARE i risultati anche con metodi diretti





TUTTO E' CHIARO?