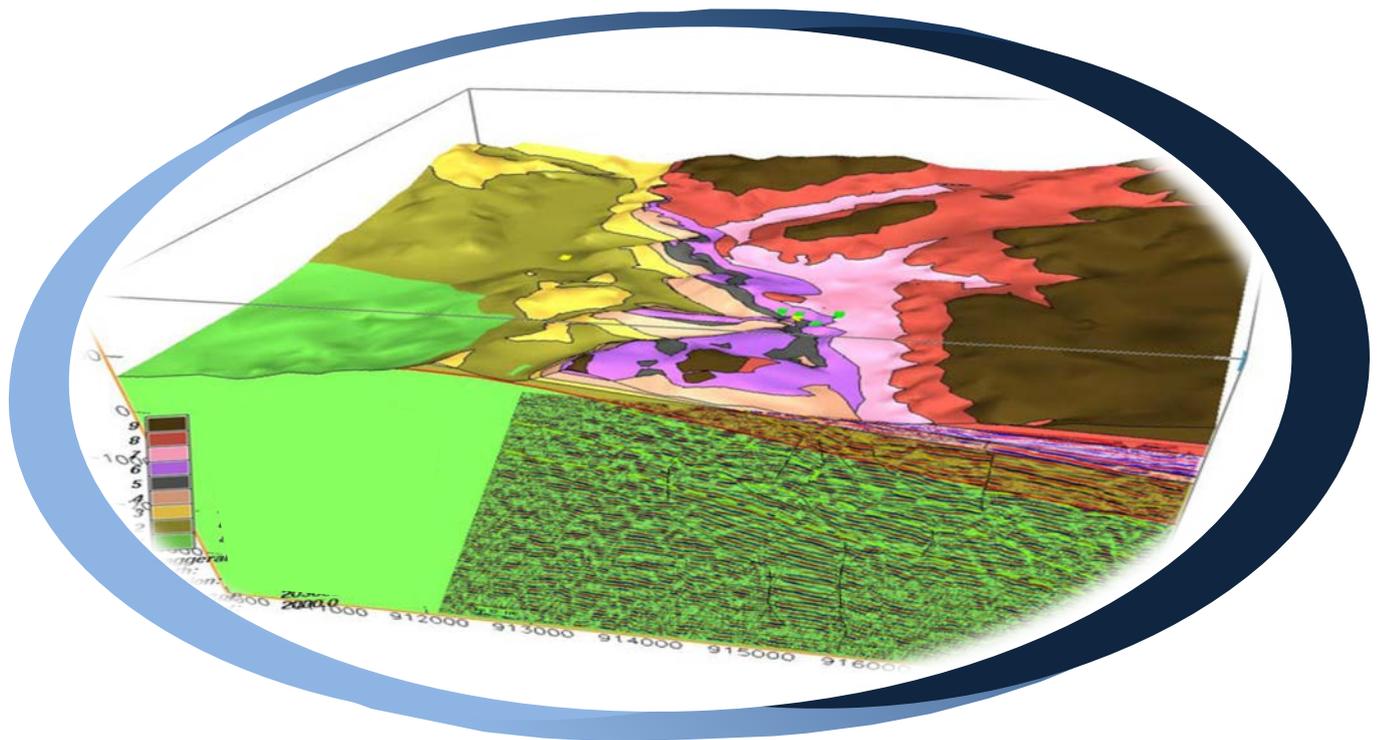




Seismic Acquisition, Processing and Interpretation



PRESENTATION

MISSION

EOSYS is a private company, incorporated in 1993, with offices in Paris and Aix-en-Provence and Guadalajara, Mexico.

Its core activity is numerical geology applied to all types of engineering projects: using 3D geological modeling tools, current geological data and interpretations are geometrically checked and if required integrated in 3D before being supplied in a numerical way to engineering departments. Uncertainties of all types (geological, geographical, geometrical, numerical ...) are assessed. Attention is drawn to related risks.

Its key guideline is **to preserve the integrity of common geological sense**. EOSYS so far has been working on about 80 sites in Europe, Africa, Central and South America for oil and gas development, underground storage, mining exploration, tunneling, hydrogeological, geological risk assessment and land use projects.

One of its main strength is that its engineers can monitor or do most of the key steps in the process of geophysical/geological data acquisition, processing and interpretation.

SERVICES

Since 1993 EOSYS has been called to provide the following services:

- Mining or hydrocarbon exploration/production permit analyses
- Reserve estimates
- Development / appraisal of new hydrocarbon wells
- Design and supervision of geological surveys (terrain, seismic, drillings,..)
- Detailed geological mapping
- Satellite imagery, photogrammetry and numerical terrain model analyses
- Onshore and offshore seismic acquisition, processing and interpretation
- Three-dimensional geological model construction, including
 - 3D integration of surface data, seismic interpretations and well data
 - structural and stratigraphic interpretation
 - mapping and 2D/3D geostatistics
 - petrophysical and well log interpretation
 - reservel /geological engineering risk assessment

Geological surveys

EOSYS performs the following services:

- photo-geological interpretation from aerial or satellite pictures
- computation and analysis of digital terrain models
- field mapping and geological mapping missions
- 3D geological synthesis

Seismic surveys

EOSYS carries out conventional or very high resolution land and marine reflexion seismic data acquisition campaigns, using sources of all types (dynamite, weight drop, vibratory or marine sources). EOSYS has also developed a portable vibro-acoustic seismic source, used in the upper 300 m below ground.



Seismic acquisition in a mountainous area



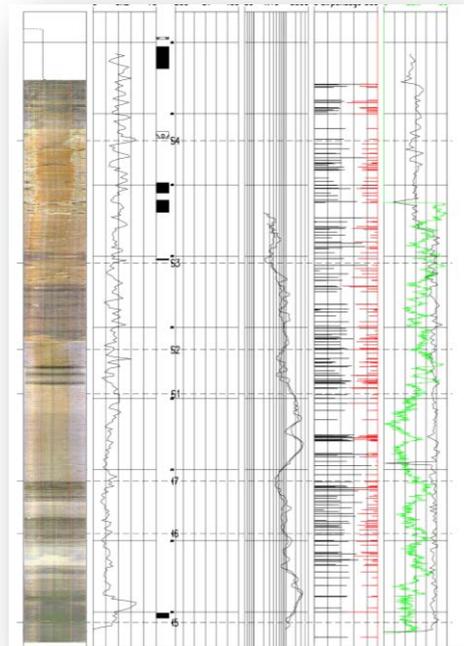
Drilling for dynamite acquisition

Exploratory drilling

For simple acquisition needs, or for geological exploration, EOSYS carries out the drilling operations itself or subcontracts them to specialised companies. EOSYS also coordinates the work of logging companies and has in-house resources for seismic logging. It can also supervise drilling operations.



Seismic drilling in the Landes region of France



Log analysis

RESOURCES IN SEISMICS

STAFF

Four full time engineers, specialised in geophysics, geology and modelling work at EOSYS. Around ten experts are regularly called upon to perform special studies. During seismic surveys or drilling operations, interim personnel are recruited and the company may then count up to fifteen or more people on its payroll.

EQUIPMENT

Seismic acquisition equipment

EOSYS has its own seismic equipment and uses sources suitable for seismic reflexion and refraction acquisition campaigns. The company has or use the following seismic resources:

■ **Source**

- Dynamite: Charges are set in drilled holes from 1 to 3m. Investigation depth is from 100m to over 5000m, depending on the purpose of the study.
- Other sources: Depending on the exploratory requirements and the context of the mission, accelerated weight droppers or vibrators may be used. Investigation depth is from 100m to 3000m. In marine acquisition, sparkers and boomers are used
- A vibro-acoustic source has been developed in-house since 1998. It is specially designed for very high resolution seismic reflexion and shallow well velocity surveys. This source emits a sweep of 16Hz to 200Hz. It has been geologically validated for depths of between 10m and 500m.



Field operations: acquisition with 2 vibro-acoustic sources



Acquisition truck

■ **Acquisition system**

POLYSEIS 24-bit digital acquisition system developed by the Institut Français du Pétrole (IFPEN) with up to 180 channels. It can be used with very short (100m long for Very High Resolution Seismics), intermediate or very long (up to 20km long for deep seismics) spreads in wireline, mixed and/or radio mode depending on site characteristics and seismic survey objectives. According to the type of survey, an alternative acquisition system SERCEL 428XL 24 bits with 240 channels can be used.

■ **Field equipment**

- Single geophones with a frequency range of 10 Hz – 350 Hz.
- Strings of 3 geophones with a frequency range of 10 Hz - 350 Hz.
- Strings of 9 geophones with a frequency range of 10 Hz - -350 Hz.
- Single low-frequency geophones starting at 4.5 Hz.
- Tri-axial geophones for measuring SV and SH waves.
- Gimbal-mounted geophones for transition zone surveys.
- A tri-axial well sonic probe.
- A laboratory truck with real-time shot control on screen and recording in SEG-D format on an IBM 3480 tape drive and a PC based system.

■ **Topography**

- A WILD T1000 theodolite with Distomat DI1000
- Depending on missions, GPS can be used, or topographic surveys can be subcontracted out to specialised companies.

IT equipment

EOSYS has the following hardware for use in its missions:

- A dozen UNIX and Windows network computers
- All necessary peripherals, such as:
 - 3490 tape drives
 - DAT drives
 - EXABYTE drives
 - 9-track reel tape drives
 - Plotters

SOFTWARE

Seismic processing software

The PROMAX 2D software, developed by Halliburton and installed on two Silicon Graphics workstation, is used by EOSYS for seismic processing, or for reprocessing old data. The Seismic-Unix software, in Unix and Windows versions is also used for in-house developments and quality control.

Other software used

EOSYS offices are equipped with UNIX and Windows workstations and network peripherals.

Specific softwares are used in the following areas:

- 3D geological and geostatistic modelling
- Scientific calculations
- Photogrammetry
- Remote sensing
- Geographical Information System
- Catchment area modelling
- Flow modelling

In-house developments, based on C programming language are used for special applications in:

- Geological modelling
- Flow modelling
- Seismic processing
- Image processing

OTHER GEOPHYSICAL METHODS

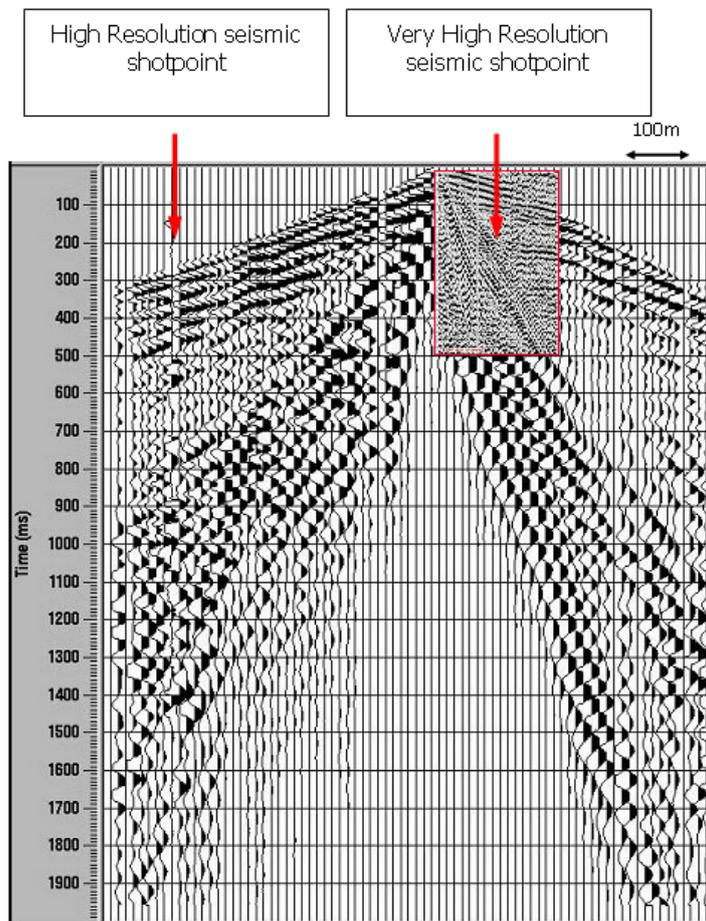
When required, the company can supervise the use of other geophysical investigation methods, i.e. electric, gravimetric, magnetic, ground-penetrating radar, etc.

VARIOUS SCALE SEISMIC SERVICES

The table below shows the different scales of seismic acquisition work.

Seismic type	Exploration depth	Distance between traces	Spread length
Very High Resolution	10m - 500m	0.50m - 5m	50m - 800m
High Resolution	100m - 1200m	5m - 20m	300 - 2 000m
Conventional	500m - 5000m	20m - 60m	800 - 5 000m
Deep	2000m - 35000m	60m - 120m	3 000m - 20 000m

The following figure shows a comparison between the High Resolution and Very High Resolution seismic surveys.



Comparison of shotpoints acquired in HR and VHR seismic surveys

DEEP CRUSTAL SEISMICS

Deep seismics provide an overall image of the earth's crust down to the mantle at 30 km deep. Acquisitions are made using explosives or several vibrator trucks. The distance between traces can be from several hundred meters to several kilometers and very low frequency seismic signals are generated.

This method is used to identify large-scale thrusts and deep faults, as well as large geological structures. During the nineties, deep seismics were routinely used in France for research purposes. EOSYS's specialists have worked on the ECORS and GEOFRANCE 3D programs and are able to perform, monitor and process such surveys.

CONVENTIONAL OIL AND GAS SEISMICS

The objective is to detect or better define oil and gas fields, typically located a hundred meters to a few kilometres deep. The inter-trace is several tens of metres and the signal frequencies are up to around 100 Hz. EOSYS engineers are active in providing specifications, supervising, performing or processing such surveys.

The company's available seismic equipment can today be used for 2D oil and gas seismic surveys with about 250 active traces.

HIGH RESOLUTION (HR) SEISMICS

The aim is to display an underground imagery from a few hundred meters down to 1500 meters. This kind of investigation enables the following areas to be studied:

- Underground gas storage: top reservoir mapping, fault detection and storage volume assessment
- Hydrogeology: locating deep heat sources
- Geothermal energy
- Special drilling, with good awareness of surrounding structures

HR seismics is a complementary field to that of VHR seismics because of its relatively fine resolution and its precious help on VHR seismics interpretation.

EOSYS is perfectly equipped to conduct acquisition, processing and geological interpretation of such surveys.

VERY HIGH RESOLUTION (VHR) SEISMICS

VHR seismics is a technique which first appeared in the years 1980's in order to characterize the geology at shallow depth. This type of acquisition uses sources that can emit very high frequencies and a dense acquisition spreads in which the interval between geophones is of the order of a few metres or less.

Since 2000, EOSYS chose to use and develop this technique to meet with the demand for improved underground characterisation. This method can be applied to shallow depths (down to a few hundred meters deep) and to reach very specific objectives:

- Detecting faults and fractures of all sizes and evaluation of fracture orientation and intensity
- Feasibility studies of underground infrastructures
- Studying shallow reservoirs, outcrop analogues, estimation of static corrections for seismic processing
- Hydrogeological studies, water resource exploration and monitoring
- Exploration of cavities, former mine workings
- Exploration and evolution of geological strata and facies
- Monitoring of underground storage

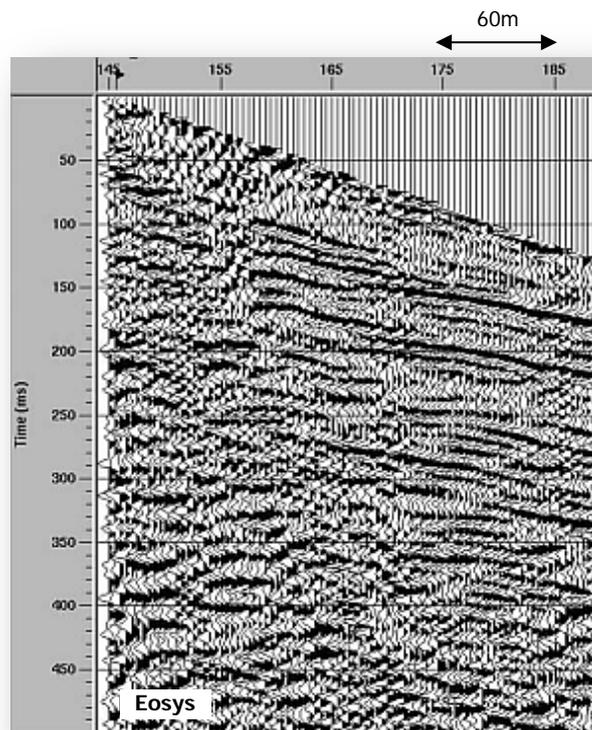
VHR SEISMIC SOURCE DEVELOPED BY EOSYS

EOSYS has developed a vibro-acoustic source for very high resolution surveys. This source is compact, light and easy to handle by one or two field operators. It does not pollute (battery powered), is safe and can therefore be used on all types of sites: mountainous, forest, urban, industrial, inside buildings, etc.

The source control system interfaces with POLYSEIS acquisition system and allow the source to operate by wireline or by radio link.

As a vibrating source, it emits a sweep of variable frequency range and length. Another advantage is that the emitted sweep can be simultaneously recorded using a pressure sensor inside the source.

This means that, during data processing, shotpoints can be correlated much more accurately. The combination of system dynamics, wide frequency range and the recording of the emitted sweep gives a bandwidth of 30 to 200Hz on shotpoints and on stacks. Developments are under way to enlarge this bandwidth.



Example of vibro-acoustic shotpoint

TIME-DEPTH CURVES, VELOCITY SURVEYS, MINI VSP

EOSYS also conducts seismic measurements of wells using 2 methods:

- Seismic source at the surface, geophones inside the wellbore and possibly also at the surface
- Seismic source inside the wellbore and geophones at the surface in a predetermined pattern

These techniques are used for:

- Measuring stack velocities as a function of depth
- Measuring near surface velocities
- Dip analysis
- Improving resolution (the signal crosses the Wz layer only once)
- Obtaining the corridor stack
- Checking the result of the stack

VARIOUS ENVIRONMENT SEISMIC SERVICES

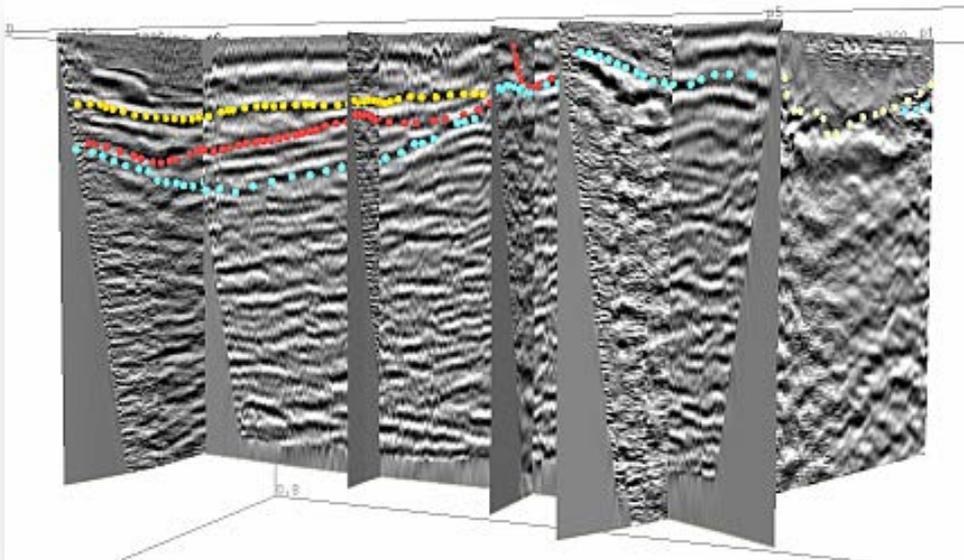
LAND AND INDUSTRIAL ZONE SEISMICS

EOSYS can perform onshore acquisition also in difficult access areas. Acquisitions were already carried out in industrial sites where specific acquisition systems were developed to avoid contamination for example.



MARINE AND TRANSITION ZONE SEISMICS

On client's request, EOSYS can book and setup marine vessels in order to realize marine seismic acquisition and processing in open or coastal marine areas as well as in transition zones between onshore and offshore domains.



Exemple of acquisition in transition zone (Thau lagoon, France)

ICE CAP SEISMICS

Since 2006, EOSYS has developed an original method to acquire and process (pre stack depth migrated) seismic data in 3D in order to assess bedrock depth with good accuracy for ice caps over rugged topography. This new methodology has been implemented and validated on the "Mer de Glace" glacier above Chamonix.



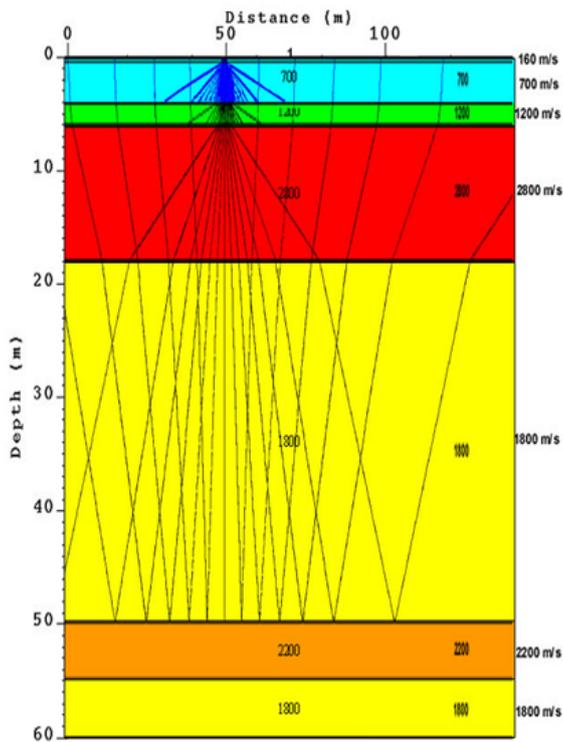
Field operations and 3D modelling based on seismic data (Mer de Glace area, France)

REFERENCES & EXAMPLES OF WORK CARRIED OUT

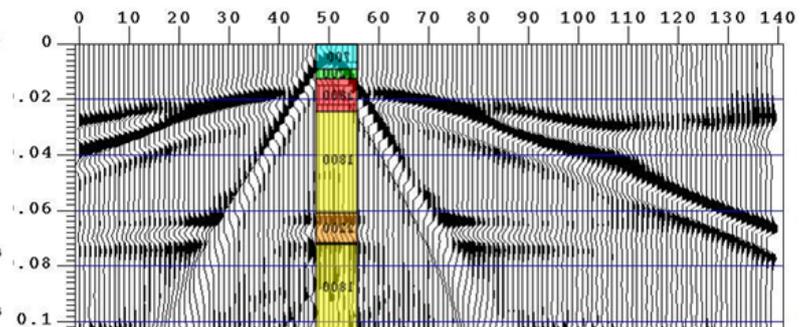
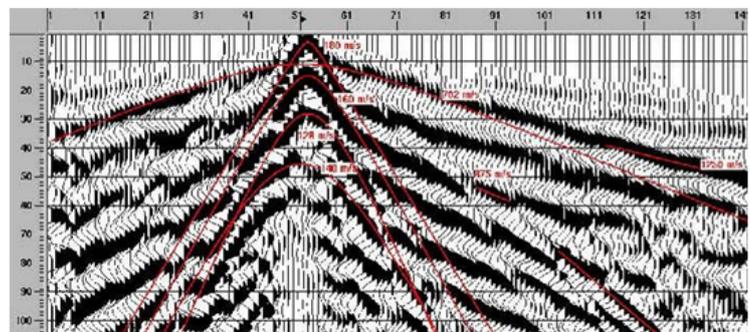
EOSYS operates in France and abroad for industrial and public clients and research organisations. These include the Ministère de l'Équipement (Laboratories, CETE, DDE), Local Authorities, SCETAURROUTE, ANTEA, IFP, Université de Provence, CEA, EDF, GDF, TOTAL, ENI/AGIP, RHODIA, NESTLE WATERS, individuals and investment companies.

SEISMIC SURVEY PLANNING

Before planning any new survey EOSYS analyzes the terrain conditions by a preliminary field survey, coupled with aerial and satellite image investigations. Seismic wave propagation modelling is commonly used to specify survey parameters and layout. All localization data is stored in a GIS used for mission planning, mission control and final interpretations.



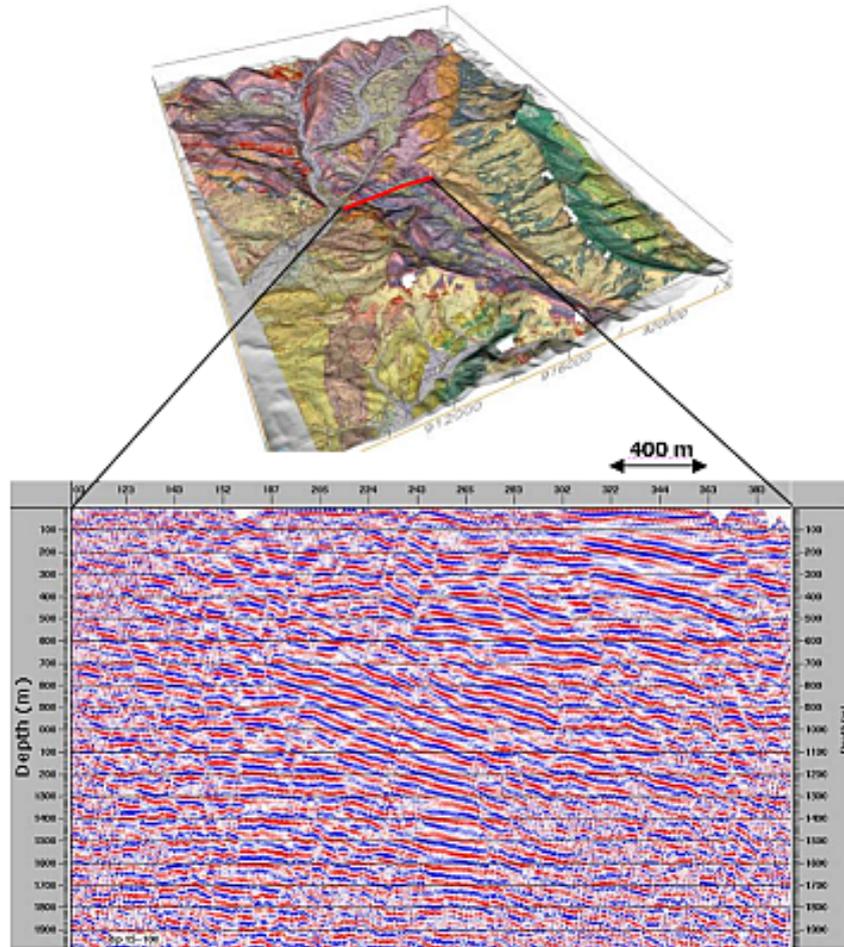
Interval velocity model and raypaths



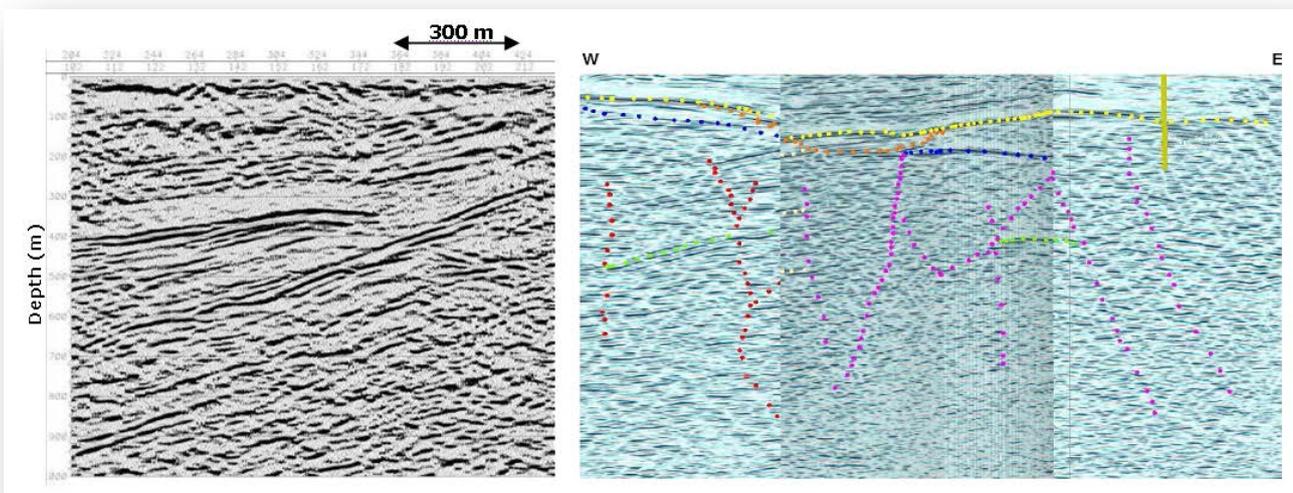
Comparison between acquired and synthetic seismograms

HIGH RESOLUTION SEISMICS SURVEYS IN UPPERMOST 4000m

EOSYS conducts deep 2D seismic reflection acquisition surveys for oil and gas or deep hydrogeological / geothermal / thermal waters exploration.



2D HR seismic acquisition for thermal water exploration (Digne-les-Bains area, France)



2D HR seismic acquisition for drinkable water exploration

2D GEOLOGICAL EXPLORATION AND MONITORING GAS STORAGE SITES

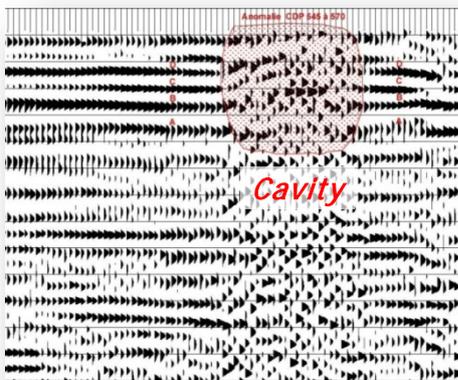
EOSYS conducts 2D seismic reflection acquisition surveys for hydrocarbon storage sites, waste storage or saline cavities. The aims of such missions may be:

- To explore the 0-1000m layer
- To make a fine analysis of the first 500 metres of depth
- To evaluate the depth of the reservoir top and extension
- To identify the presence of a fault or a fractured zone
- To identify possible communication zones with neighbouring aquifers or between different aquifers.

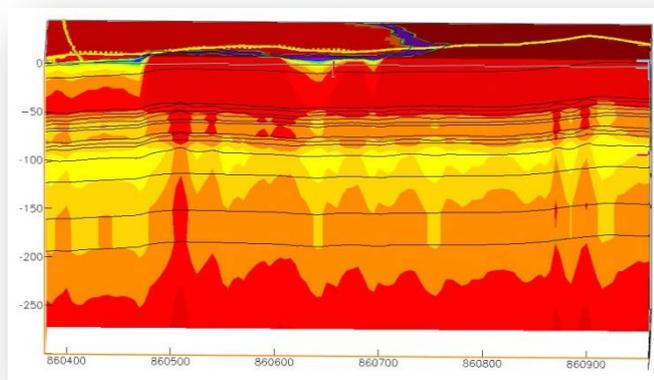
CAVITY DETECTION

EOSYS has developed an integrated methodology which is applied on several sites in France. This methodology, defined as a result of numerous projects, comprises the following phases and includes the study of archives and geological documents, and geological exploration in the field:

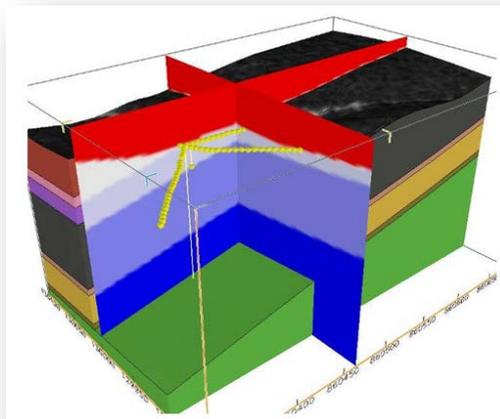
- Photo-geological analyses and satellite (Landsat, SPOT, IRS, ASTER, Quickbird, etc.) or aerial imagery, particularly using infrared thermography, cavity detection by structural and morphological analysis of the topography, and stereophotographic observation.
- Reflection and refraction seismics:
 - 2D acquisition and Vertical Seismic Profiles (VSP)
 - Processing of seismic sections
 - Identifying cavities and their filling status
 - Explorations for well positioning and operation follow-up
- Map synthesis, building of a GIS database, 3D modelling, if required



2D seismic reflexion profile



Velocity model

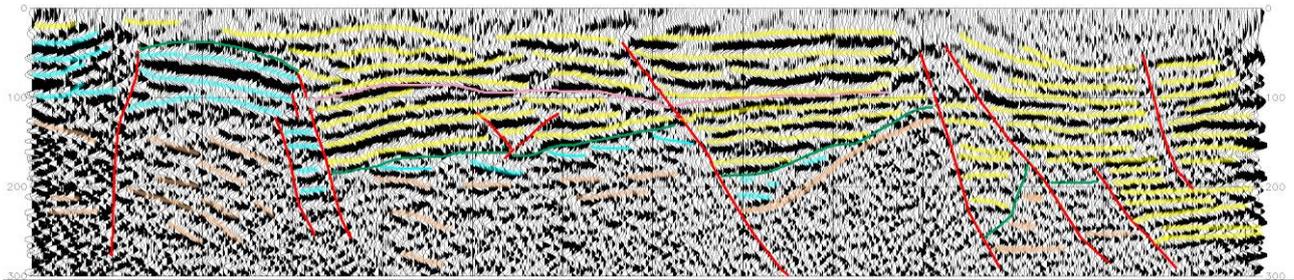


3D modelling of the speed field for detecting old mines

HYDROGEOLOGICAL STUDIES

Seismic reflection surveys are used to locate new water resources and assess the vulnerability of existing resources from saline intrusions or drainage water from contaminated or surface water aquifers.

60m



Assessment of the vulnerability to salt water intrusion of carbonate nappes (blue) covered with sandy and clay formations (yellow)

INFRASTRUCTURE FEASIBILITY STUDIES

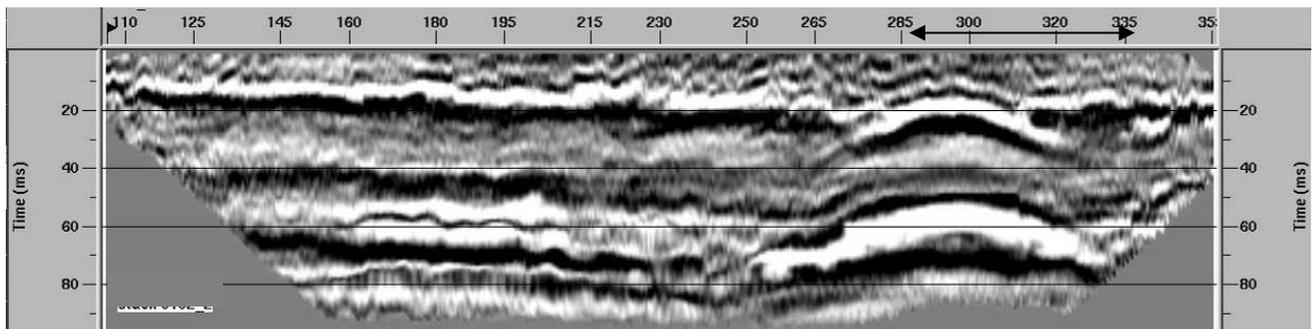
Reflection seismic surveys allow a better choice in underground road projects at preliminary study phase and contribute to specify the geological image at detailed study phase and during construction. In conjunction with drilling surveys, it provides the client with excellent visibility over any geological difficulties that the work may encounter.

ENVIRONMENTAL HAZARD ASSESSMENT

Very high resolution seismic surveys make it possible today to improve quantitative assessment of:

- Disorders due to clay dissolution, shrinking or swelling phenomena
- Risks of landslides: detection and quantification of unconsolidated zones
- Seismicity: identifying faults traversing recent terrains
- Vulnerability of underground water to pollution

50m



Detection of sub-outcrop faults in a marl-limestone series