

3D SEISMIC FOR THE DEEP EXPLORATION OF THE TRAVALE GEOTHERMAL FIELD (ITALY): I-GET PROJECT RESULTS

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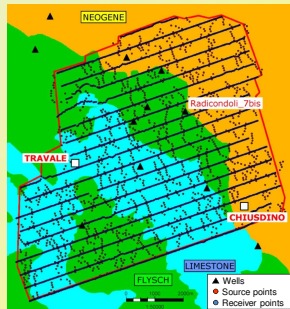
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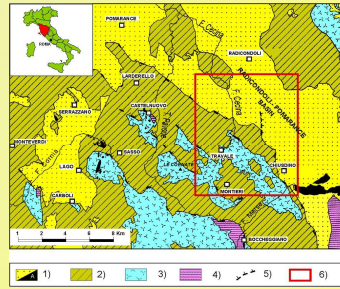
In the framework of the European project "Integrated Geophysical Exploration Technologies for deep fractured geothermal system" (I-GET), Travale area (Tuscany) has been chosen as Italian test site.

Exploration and exploitation of a deep superheated steam reservoir at depth of 3000-4000m started in the wide Larderello-Travale geothermal system more than 20 years ago. The deep reservoir is mainly hosted in the metamorphic basement and shows a rather inhomogeneous permeability due to confined fracture systems that are the potential productive drilling targets.

The 3D seismic survey in the Travale area was acquired in 2003 by using explosive as energy source (1484 shot points) and a bin dimension of 25 x 40 m. The actual acquisition layout guaranteed the required 1600% full fold on an area of about 33 km².

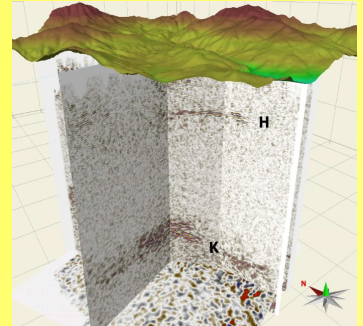


Actual acquisition layout and schematic surface geology in the 3D surveyed area.



Schematic geological map of the Larderello-Travale area. 1) Neogenic Sediments (A=Hydrothermal deposits); 2) Ligurian Flysch Unit; 3) Tuscan Nappe; 4) Metamorphic Basement; 5) Normal fault; 6) Area of the Travale test site.

The processing was aimed at the reconstruction of the geological/structural setting and at the seismic reflections true amplitude recovery. It allowed the detection of two main deep reflectors already known in the Larderello-Travale area: the deep K horizon and the H marker that represents the most interesting seismic target.

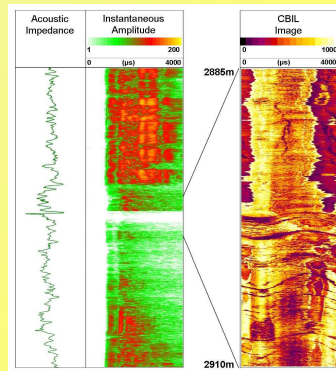


Seismic volume and main deep reflectors H and K.

A full set of geophysical logs was acquired in the Radicondoli_7BIS deep well in order to perform the petrophysical characterization of the main geological units, to calibrate the 3D seismic survey and to identify the seismic response due to fractured/permeable zones.

Significant variations of acoustic impedance, due to density and velocity decrease, usually characterize the fractures as well as the strong attenuations of the Instantaneous Amplitude (IA).

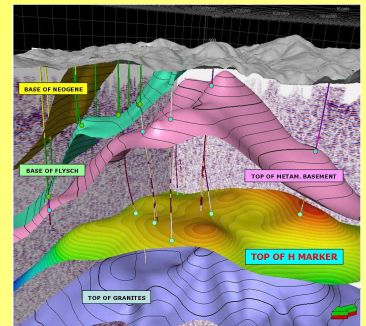
Borehole image log (CBIL), acquired in correspondence of evident seismic energy attenuations, allowed the fracture geometrical reconstruction that resulted to be consistent with high angle fractures (70-85°) mainly oriented in NW-SE direction and dipping toward NE.



Fractured level evidenced by CBIL and characterized by strong absorption of acoustic energy and AI decrease.

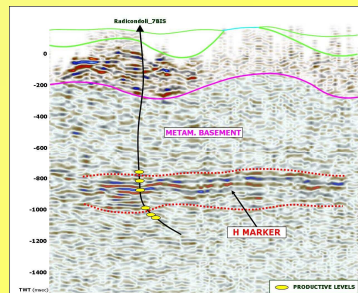
The 3D seismic survey allowed an update of the geological and structural model of the area with a better definition of the reflector geometries corresponding to the main geological horizons and of the H seismic marker.

Well data showed that in the Travale area this marker is above the top of Pliocene granites and can be the expression of a contact metamorphic aureole (skarn and hornfels). Hence, the interpretation of this marker allowed also a better structural reconstruction of the Pliocene intrusions that caused the aureole itself.



Main geological surfaces and seismic horizon (H) reconstructed from 3D seismic interpretation.

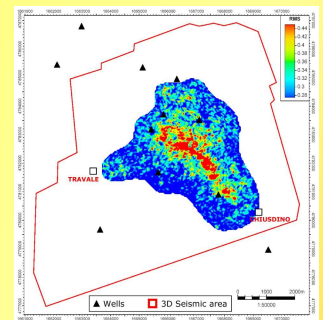
Among the seismic reflectors, special attention was given to the analysis of the H marker that constitutes the potential drilling target, being at attainable depths in the metamorphic basement. The deeper and stronger K marker, well known in literature, was never reached by drillings and cannot be considered a target.



H marker and fractured levels identified in the Radicondoli_7BIS deep well.

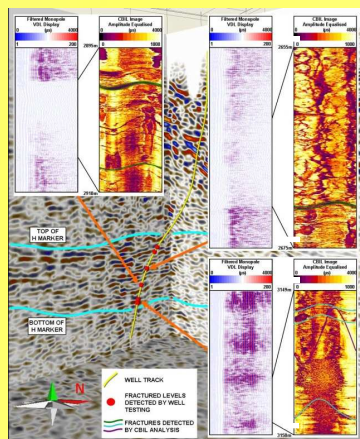
In order to identify the drilling targets, an amplitude analysis of the H horizon was performed since the areas characterized by the highest amplitude values can be correlated to fractured levels.

Nevertheless, the high amplitudes and strong reflections that characterize the H horizon can be generated by the combined effect of lithological variations (contact metamorphic aureole) and of higher fracture occurrence.



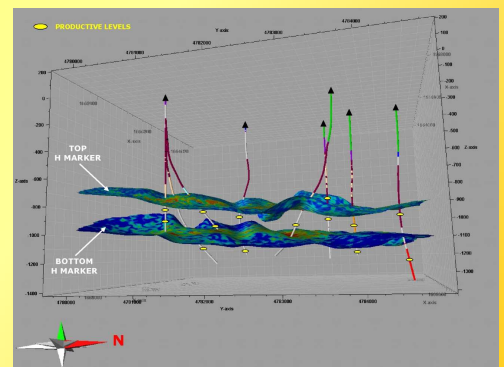
RMS amplitude map of the H horizon.

H marker was matched up to well testing data to estimate the contribution of each single fracture to the total production. Geophysical logs were also compared both with the fractured levels and 3D seismic images to improve the integrated interpretation and provide a better target characterization.



Correlation between fractured levels from well testing, 3D seismic and well log data.

A significant correlation between seismic reflections and productive levels was verified analyzing the average production inside and outside the H marker of 24 deep wells in the 3D surveyed area. Among these, 13 productive wells met the H horizon, while 8 of the 11 wells located outside this horizon resulted unproductive. Furthermore, the results of this analysis indicated that the production supplied by fractures occurring within the H marker is about 77% of the total.



Correlation between productive levels and the H seismic horizon

The interpretation of the 3D seismic survey allowed a detailed reconstruction of the geological/structural model of the Travale area and the identification/characterization of potential drilling targets that are associable to high amplitude anomalies of the H seismic marker in the metamorphic basement. The integrated interpretation with well data highlighted that the H marker corresponds to a contact metamorphic aureole, strictly connected to the emplacement of granitic bodies and characterized by a locally high fracture density. In the Travale test site, the reasonably good correspondence between productive levels and seismic targets showed the reliability of seismic method for the detection of fractured levels, defining the H marker as a potential drilling target.