Exploration in NW Greece With Application of Passive Seismic Tomography

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Abstract

Tomographic Passive Seismic Inversion utilising P and S-wave travel times from 455 local micro-earthquakes has been applied in Epirus (NW Greece). The objective of the project was to image the sub-surface volume in the region, an area which is currently being explored for hydrocarbons by a consortium operated by Enterprise Oil.

Introduction

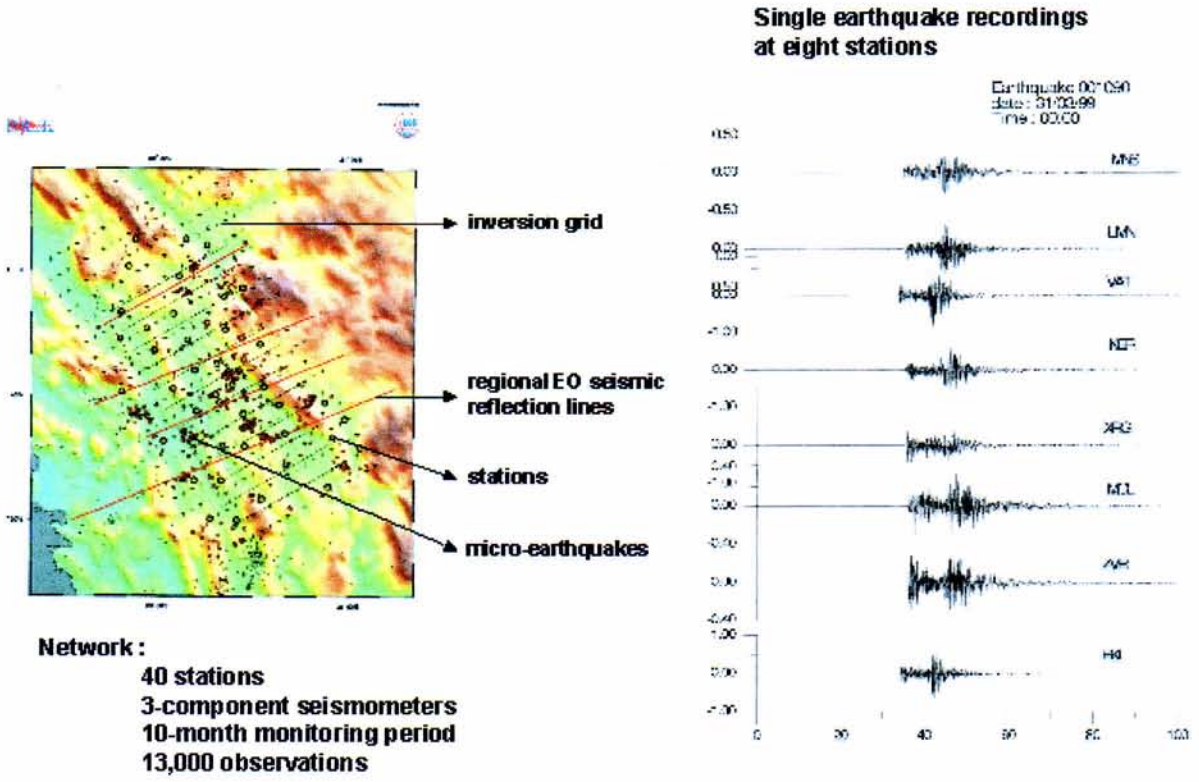
In recent years, there has been an increase in exploration activities in geologically complex areas, such as fold and thrust belts. Exploration in these areas is challenging, as well as expensive and is driving the oil exploration industry towards the application of state of the art techniques. The Passive Seismic Tomography Programme falls into the aforementioned category. The rationale for the application of tomography as a complimentary imaging tool is twofold.

Firstly, it is a cost effective manner to image a large area, where the terrain is difficult (mountainous) and as a consequence, conventional seismic is expensive and can be of poor quality.

Secondly, the technique has the added advantage of being environmentally friendly, which is an important consideration in all of Enterprise Oils operational activities.

Methodology and Application

The Passive Network (PATOS) was installed and operated by the Seismological Laboratory of the Patras University, Greece (PSL). The network design took into consideration a uniform spatial coverage of the area, high sampling resolution and frequency content. The PATOS network consisted of forty 3-component high-resolution seismometers, buried in 15m boreholes to improve the signal-to-noise ratio. It covered the Ioannina plateau in Epirus, an area of approximately 1800 km^2, where there is strong attenuation in conventional seismic reflection energy due to high velocity and/or karstified carbonate outcrop. PATOS recorded micro-earthquakes continuously for eleven months. In total, 1370 events were accurately located.



Manual P and S phase picking using PSL's "SEISMWIN" was performed, and the data were subsequently incorporated for hypocenter and earthquake parameter calculations.

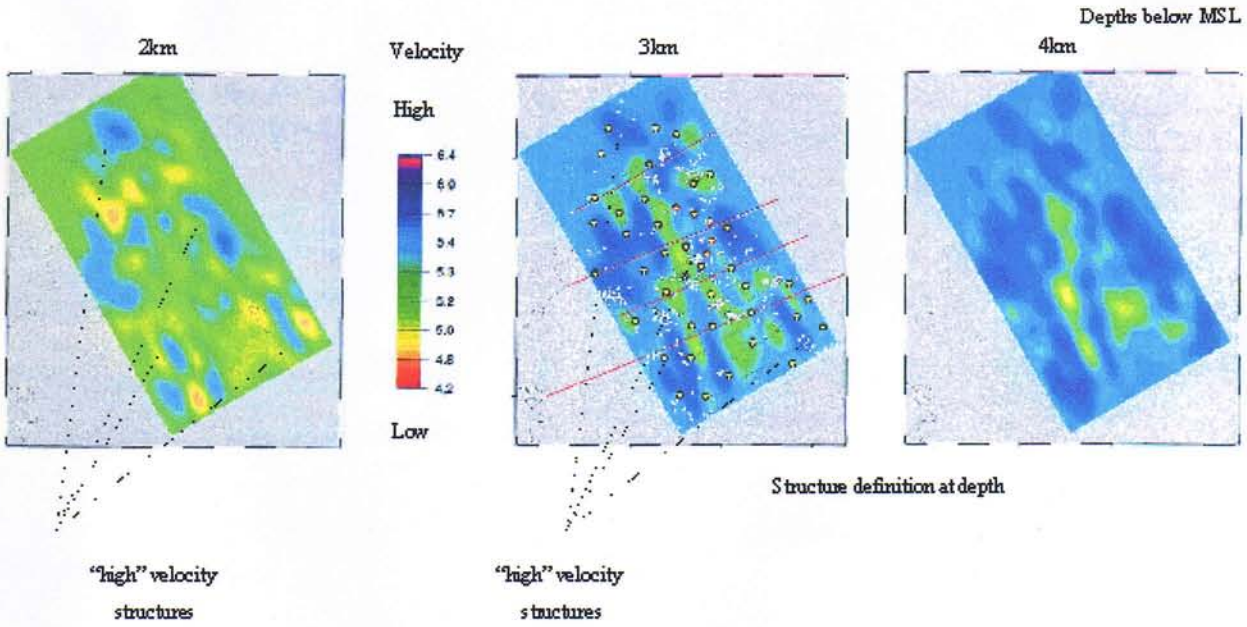
Data selection is one of the most critical and important steps to be undertaken before an inversion, where we solve simultaneously for earthquake location and velocity model adjustments. It is therefore, important to use earthquakes with locations well constrained by the data. 455 earthquakes, satisfying strict selection criteria (events must lie within the network and the inversion grid, have a minimum number of recorded phases and an upper limit in the RMS residual), resulted into a total of 13,091 phases that were included in the velocity inversion. The tomographic method used, has been developed by Michelini and introduces improved inversion algorithms. The procedure is iterative and inverts both P- and S-wave arrivals for velocity model perturbations.

Since the inversion is a non-linear problem and the solution is non-unique, the degree of confidence and reliability in the results are important factors and were taken into consideration before and during utilization of the results. The quality of the inversion, extensively assessed quantitatively and qualitatively, was considered very good. In the final inversion a 1-D initial velocity was used, RMS values decreased by nearly 30% and results converged after 5 iterations.

During integration and prior to interpretation, the inverted velocity results were assessed and evaluated by comparing and correlating features of the 3D-velocity structure to other geological and geophysical observations and datasets.

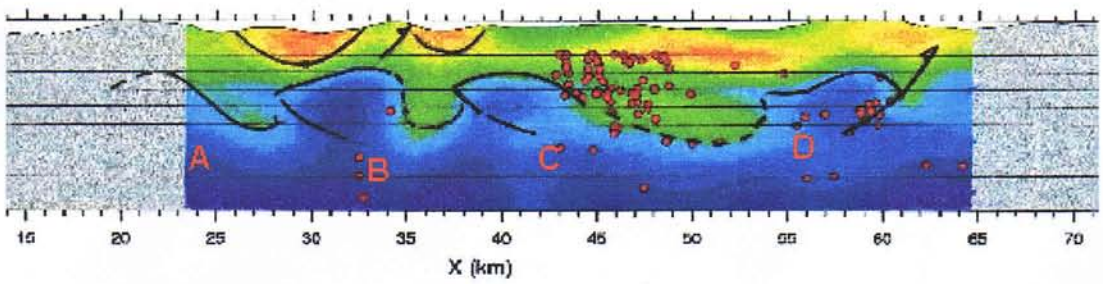
The range of the resulted velocity values appeared to be generally lower than expected, but, consistent with crustal values and within acceptable limits. Velocity structure images were taken at specified vertical cross-sections and at horizontal depth slices. Depth slices at 1 and 0 km elevations showed a very close correlation with surface geology and structure.

HORIZONTAL CROSS-SECTIONS

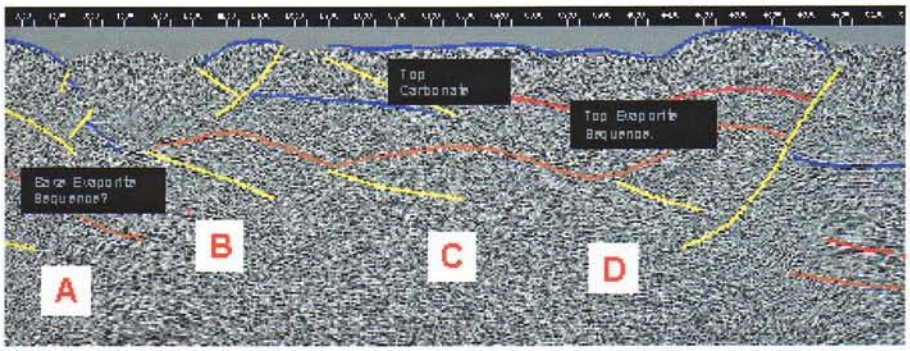


The results gave indications about carbonate and clastic velocities, which were converted into density information, incorporated into gravity and supported potential modeling.

VERTICAL CROSS-SECTION ALONG SEISMIC



Correlation of Seismic and Passive



Outlined velocity boundaries and contrasts define sub-surface geometries, and appear to match interpreted seismic lines. They also correspond to features identified in gravity and Magnetotelluric modeling. The calculated Vp/Vs ratio, directly related to lithology and rock properties will also be incorporated in the evaluation and interpretation of the results. Initial analysis indicated high Vp/Vs (saturation) coincident with fault zones. Moreover, velocity variations and lineation of hypocenters define fault geometries.

The integration and correlation of the inverted velocity structure is currently being utilized for the structural modeling of the area, assisting in prospect identification, and providing confidence in the overall interpretation.

Conclusions

The application of seismic tomography is part of an integrated approach required while exploring an area such as NW Greece. The passive methodology has provided a cost-effective and environmentally friendly imaging tool, supporting expensive and often poor-quality seismic data.

Results of this pioneering exploration tool have demonstrated that the technique could be useful for similar, tectonically active regions of Southern Europe and elsewhere.

Acknowledgments

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