# Chałupki Dębniańskie Field: Improving Drilling Success in Shallow Gas Reservoirs with VectorSeis®

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## ABSTRACT

### Summary

In the spring of 2002, a field experiment was conducted over a gas field in Southeast Poland. The primary objective was to characterize the response of the I/O VectorSeis sensor in a direct comparison with conventional analogue geophone systems. Both dynamite and VIBROSEIS® sources were tested during the course of the experiment.

Analysis of the acquired datasets demonstrated clearly that, in this relatively shallow (160m – 800m depth range) clastic depositional environment, VectorSeis sensors not only matched the results of the analogue geophones but also produced datasets with superior vertical resolution.

In addition to the conventional compressional datasets, converted wave data were also acquired. These demonstrated that high quality converted wave data could be acquired in a cost-effective manner and that they could solve a number of imaging problems directly related to the presence of multiple stacked gar reservoirs. Mapping of the PS data into PP time also demonstrated that the PS data had similar apparent frequency response when compared to analogue geophone compressional data.

### Geological Overview

The Carpathian Foredeep, located in southeast Poland, covers about 18,000 km2 (*Fig. 1*) and is the second most important gas region in the country. Filled with molasse sediments of Miocene age whose total thickness may be more than 3000 meters, the region consists mainly of sandstone and shale sequences but can also include anhydrites such as those in the Middle Badenian section. Gas reserves are found primarily in Miocene sandstones, Jurassic carbonates and upper Cretaceous sandstones. This high methane gas (over 98% CH4) is free of toxic components except for small amounts in Jurassic deposits. Total reserves of gas of the Carpathian Foreland are estimated at about 190 x 109 m3 (W. Weil, 1998). More than 100 gas reservoirs have been discovered.

Total areal extent of the discovered deposits is about 700 km2 and the average area of a single deposit is about 10 km2. Average gas reserves for individual pools is 203.3 x 106 Nm3 per km2 (P. Karnkowski, 1999).

## Challenge

In the 1980s several wells were drilled to test the potential of these structures, especially in the northeastern part of the Carpathian Foredeep. Although they did not achieve commercial success, all of these dry wells were located using good quality P-wave seismic data. Yet numerous water-saturated horizons with gas shows were found, and fundamental geological, geochemical and reservoir studies made it clear that undiscovered commercial gas accumulations existed.

Many of these newly discovered gas fields contain multiple pay zones in unconsolidated or slightly cemented porous sandstones. A good example of this type of gas trap is Chałupki Dębniańskie Field located approximately 100 km northeast of Rzeszów Multiple gas horizons are located, but probably not limited to, the 160-800m interval. Sandstones sealed by shale, have porosities up to 35% and permeabilities up to 2500 mD. The field is delineated by two wells and more are planned.

Despite progress in exploration techniques, the main risks for new discoveries are associated with identifying true structural anomalies, either four-way closures or structures with sufficient relief to trap gas above the gas/water contact. Structural relief is often masked on compressional seismic data by the “gas effect,” a time delay created as compressional waves propagate through gas filled porous sediments. Given that multiple, stacked, gas-charged reservoirs are present in the field, the gas effect can often be significantly greater than the structural component. This leads to a significantly increased risk of drilling wells below the gas/water contact. Another geophysical challenge is the severe attenuation of compressional waves as they are transmitted through gas-charged reservoirs. This not only distorts the image of the shallow reservoirs but also completely masks deeper reservoirs. Finally, recognition of lithological and facies changes is becoming a critical factor for new discoveries.

## Seismic Acquisition

On behalf of the Polish Oil & Gas Company (POGC), Geofizyka Krakow designed and conducted a series of field tests in 2002 to determine performance characteristics of I/O’s VectorSeis 3C sensor. These tests had three specific objectives:

1. Understand “bright spots” observed on conventional P-wave data by comparing them to converted wave results obtained using VectorSeis sensors.
2. Compare VectorSeis P-wave data to conventional geophone P-wave data obtained during simultaneous and co-located acquisition.
3. Raise the multi-component experience levels of the Polish geoscience and reservoir engineering community.

Three parallel receiver lines were laid out, two lines of 10 Hz geophones and one VectorSeis line, each 5m apart. The first geophone line consisted of 16 geophones per station in a 6 x 6m areal patch and the second line consisted of 8 geophones per station bunched at the flag location. The VectorSeis units were deployed as point receivers (*Fig.2*). In all cases, the group interval was 10m. Nominal source interval was 15m, but the requirement for numerous detours due to urbanization created a series of offsets and gaps (*Fig. 4*). Maximum offset recorded was 1405m. Line length was 6km. This geometry yielded a nominal fold of 70 for the P-wave data.

Data were recorded using two I/O systems in a Master/Slave configuration. An I/O System Two was used for the analogue geophone lines while an I/O VectorSeis System Four™ was used to acquire data from the VectorSeis sensor line. Both systems recorded 5 seconds of data at 2 millisecond sample rate. For more background information on the I/O VectorSeis sensor and its theory of operation, please refer to the references supplied at the end of this paper.

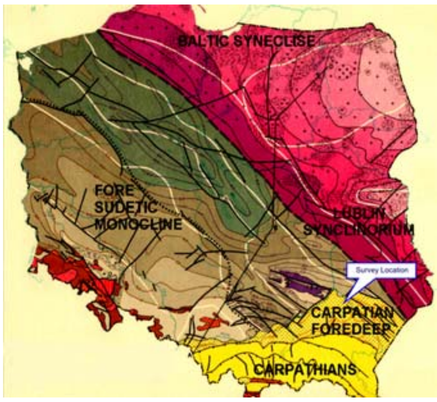


*Fig. 1 Geologic Setting*

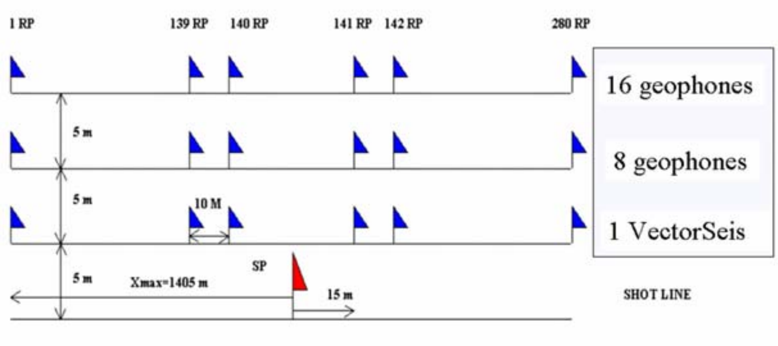


*Fig. 2 Line layout*

## Processing

OMEGA® seismic processing software was used for data processing. Shot gathers recorded by traditional vertical 10 Hz geophones and three-component VectorSeis phones were separated into five individual datasets. Shot records exhibit high data quality with some surface wave noise contamination. Processing of the vertical data was quite generic. *Fig. 4* shows a comparison of final migrated stacks along with the migrated converted wave stack mapped into PP time.

Initial PS stacks show significant coherent energy on both in-line and cross-line components before and after rotation to source-detector direction. This indicates the presence of azimuthal anisotropy effects which were previously unknown. Final stacks show very good imaging of the objectives. *Fig. 3* compares the converted wave data at various stages to the final migrated converted wave stack.

## Observations

### Compressional Data

Both geophone datasets were similar in both image quality and spectral content. When viewing the datasets with relative amplitude preserved processing, there was a slight (but noticeable) amplitude advantage to the 16 geophone array dataset over the 8 geophone array data. The data were recorded in a good data area and as such, the S/N is excellent for all three datasets (i.e. with and without spatial arrays).

The VectorSeis compressional dataset shows a marked improvement in bandwidth over the two geophone datasets. As shown in the amplitude spectra at 100Hz the VectorSeis data has approximately a 10 dB advantage over either geophone dataset. This translates into a significant advantage in vertical resolution. As with the geophone datasets, there is no appreciable shot generated noise visible in the final stack data.

### Converted Wave Data

The converted wave data acquired in this experiment are of exceptional quality. It is evident in that the apparent bandwidth of the PS data (after mapping into PP time) is equivalent to that of the geophone PP data. As expected, the “gas effect” (push down and absorption) is not apparent on the PS data. This solves a great number of reservoir development related issues because the true structure is visible for the first time, as are both shallow and deep reservoirs.

The PS data are not problem-free. Shear wave statics are still a significant issue in PS processing. Time-consuming laborious hand statics have brought the data to this stage. In addition to the statics issue, the PS velocity model is difficult to determine without prior information, specifically the Vp/Vs relationship as determined from multi-component VSP or dipole sonic logs.

## Conclusions

All objectives established at the beginning of these tests were achieved:
Recording of converted wave data over these gas-filled reservoirs solves a number of related imaging issues. In addition, the ability to determine rock properties directly from seismic data will greatly benefit explorationists by minimizing drilling risk and improving project economics through drilling only the best locations.

1. The acquired data showed that VectorSeis sensors recorded data comparable to conventional analogue geophones, and produced images with greater resolution. This is attributed to a combination of point receiver geometry (such as eliminating spatial arrays that act as low pass filters) and the inherent properties of the I/O micro-electromechanical systems based sensor.
2. The collected 10 datasets will significantly contribute to the multi-component experience in the Polish geoscience and reservoir engineering community. While initial results are significant, much work remains to be done before completely understanding the reservoir system.
3. Given the cost-effectiveness of acquiring converted wave data using the I/O VectorSeis System Four, this is the beginning of a new exploration cycle in Poland. An increasing number of converted wave surveys will be conducted to solve imaging problems that cannot be addressed using conventional seismic techniques.

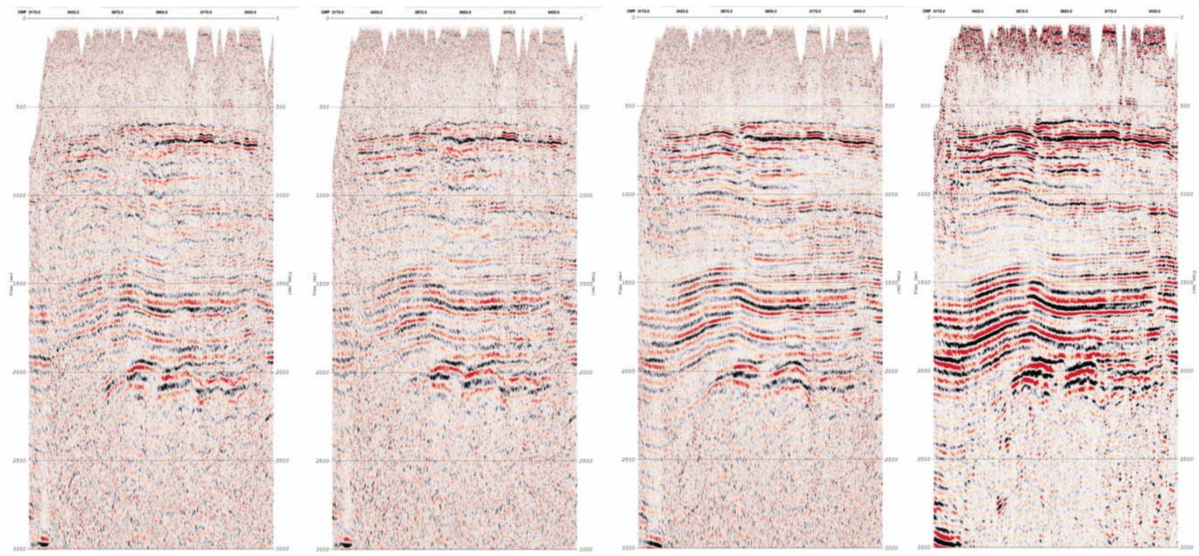

*Fig. 3 Comparison of converted wave data at various stages of processing; CDP stack of radial data, CDP stack of radial data with final statics, CCP stack, FX*

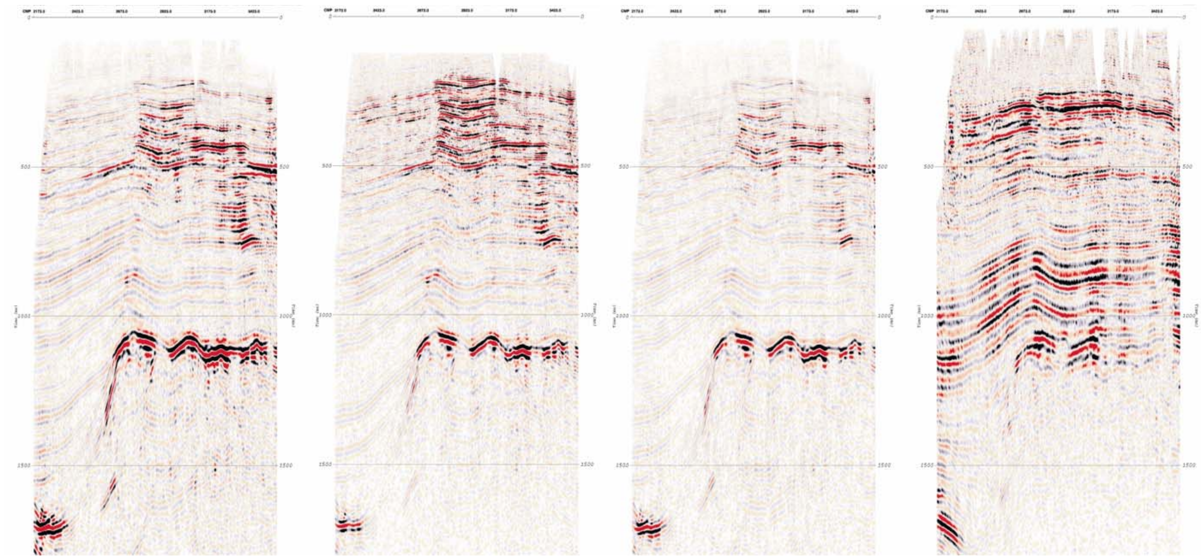

*Fig. 4 Comparison of final migrations of compressional data; 16 geophone RAP migration, VectorSeis RAP migration, 8 geophone RAP migration, and CCP RAP*

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