

**AAPG International Conference  
Barcelona, Spain  
September 21-24, 2003**

Giovanni Benevelli<sup>1</sup>, S. Angella<sup>1</sup>, L. Fava<sup>1</sup>, P. Rocchini<sup>2</sup>, A. Valdisturlo<sup>2</sup> (1) University of Parma, Parma, Italy (2) ENI - E&P Division, San Donato Milanese, Italy

**From a Field Based Geological Model to a Seismic Image: The Middle Eocene Ainsa System (South-Central Pyrenees)**

**INTRODUCTION**

Most of the uncertainty on deep-water reservoir characterization concerns the possibility of recognizing detailed sandbodies geometric patterns, related depositional settings and processes. During the last years, the importance of better constraining reservoir geometries and properties led to a growing interest in the geophysical characterization of outcrop-based geological models (e.g., Valdisturlo *et al.*, 1996; Betzle and Gardner, 2000; Campion *et al.*, 2000; Sullivan *et al.*, 2000; Pacht, 2001). These types of studies aim to transfer the detailed reconstructions of the geometries and the sedimentologic characteristics of the outcrop analogues in the subsurface successions.

The Ainsa systems (late Middle Eocene) crop out in the south-central Pyrenean foreland basin and develop during a major phase of structural deformation characterized by basin narrowing and compartmentalization. In particular the systems were deposited along an uneven submarine ramp, constituting the southern margin of the deformed foredeep, within a small syncline (presently St. Maria de Buil syncline) delimited by the growing Boltaña and Mediano anticlines (e.g., Mutti *et al.*, 1988; Remacha *et al.*, 1998). The Ainsa systems are composed of sand-rich channel-lobe bodies encased in mudstone-dominated units. Stratigraphic and facies analysis indicate that the Ainsa systems can be considered a potential outcrop analogue for slope basins in divergent margins where salt tectonics play an important role in the deposition of small and confined channel-lobe turbidite systems (Benevelli *et al.*, this volume; Mutti *et al.*, in press).

The available data set, consisting of a 2D seismic line, three wells with continuous coring and logging, acquired by ENI- E&P Division, and a detailed field work provided by Parma University (measured sections, stratigraphic cross-sections, facies analysis and mapping), allows the geophysical characterization of the Ainsa systems. Cores and logs were used to convert a 2D stratigraphic cross-section of the Ainsa 2 channels and lobes into a petro-acoustic model that allowed the generation of a forward seismic model. The model was then compared with the recorded seismic lines in order to check the quality of the modeling and test the resolution of the seismic.

**FORWARD SEISMIC MODELING**

A stratigraphic cross-section of the exposed Ainsa 2 channels and lobes was firstly realized correlating field-measured sections and well data. A quantitative relational data base, associating sonic and density data recorded in wells with sedimentological facies classification of the cores, was then used to construct pseudo-sonic and pseudo-density logs of the field-measured sections. Then logs and pseudo-logs were used for a direct, reliable and continuous measurement of the values of velocity and density. These data were further corroborated with laboratory analysis on core plugs. Starting from the logs and pseudo-logs, the petrophysical values were extrapolated within the interpreted layers of the cross-section using the seismic-modeling software (GX Technology).

The obtained petro-acoustic model that describes the impedance acoustic distribution was used as input data to generate noise-free 2-D synthetic seismic lines. The first step of the forward seismic modeling is the ray-tracing that allows computing of the depth section of reflectivity. We use in particular zero-offset, vertical incidence ray-tracing and compressional synthetic seismic source. Then we convolve the reflectivity section with a source wavelet. In order

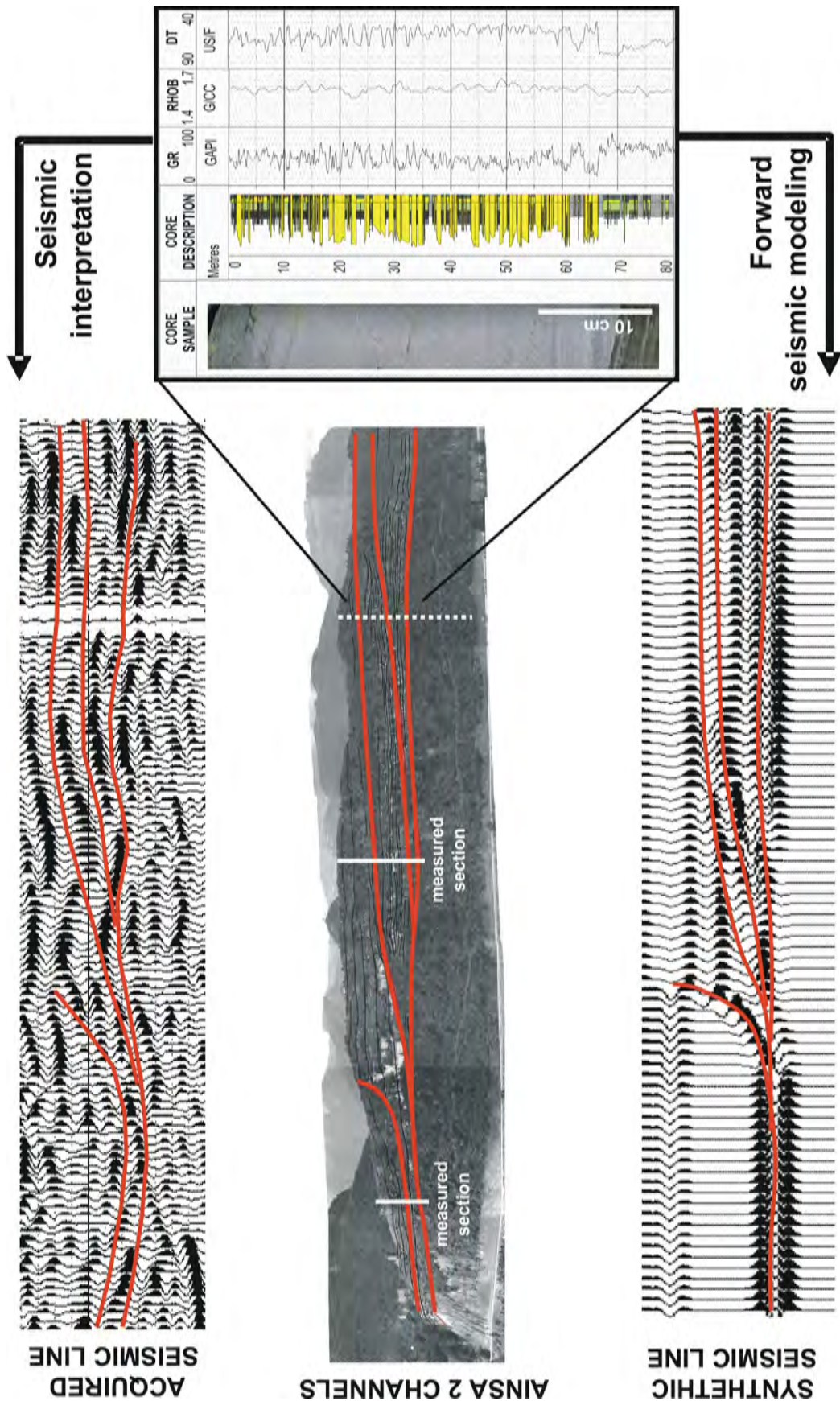


Figure 1 - Seismic expression of the outcropping Ainsa 2 channels.

to compare the synthetic seismic line with the acquired one, we choose a zero-phase, 100 Hz Ricker wavelet (fig. 1).

The seismic-modeling software offers the possibility of generating synthetic seismic lines with different frequency. So we generate seismic lines with progressive higher frequency in order to test what frequency is needed to resolve complex stratigraphic features accurately. The synthetic seismic lines were compared with the recorded seismic lines (interpreted after well-seismic tie) to validate the results of the modeling and check the match of the seismic image with the geological model.

## SEISMIC PROCESSING AND INTERPRETATION

The acquisition of the seismic lines with very shallow or near-surface targets involve many problems related in particular to the acoustic inhomogeneities (e.g., Henley, 2001). Due to this fact, raypaths are strongly distorted and affected by random and coherent noise, thus providing a disrupted seismic stack section. The base of the Ainsa systems lie only about 200 m deep from the surface, so much effort was made to obtain the best seismic image of the outcrop. The field geologic observations and well data allowed to guide the different step of the seismic processing and to constrain the seismic interpretation by means of the calculation of the synthetic seismograms.

Following data acquisition and a preliminary time processing, further processing on Ainsa high-resolution seismic data was undertaken. A non-conventional approach based on tomography was performed with the final objective of obtaining a reliable velocity model to be used for a successive depth imaging through pre-stack depth migration. The obtained seismic line clearly shows the geological features of the exposed channels and lobes and can be interpreted through a detailed well-to-seismic tie (fig. 1).

## CONCLUSIONS

The geophysical characterization of outcrop-based geological models aimed at constraining reservoir geometries and properties involve many theoretical and technical problems. The applied interpretative methodology, integrating data from different sources at different scales, suggests a careful utilization of outcrop analogues. Only a continuous feedback between all the data allows to control all the procedure and to improve confidence in seismic interpretation. The comparison between different synthetic seismic lines, generated from the same geological model, and the recorded seismic lines has also permitted the discussion of the problem of the capability of the seismic tool to record the geological events. This study can help us to reduce geological risk by increasing the confidence in the geological interpretation of seismic data, and to enhance production performance, by a more robust constraint of reservoir geometry and properties of subsurface analogues.

## ACKNOWLEDGEMENTS

The authors would like to thank the many people of the ENI E&P Division that contributed to the analysis of the subsurface data and in particular M. Barnaba, M. Buia, M. Fervari, O. Meazza, F. Onorato, L. Tatarella and E. Visigalli. They are grateful to E. Mutti, G. Cavanna, J.J. Melick for the fundamental contribution in the field analysis of the Ainsa systems and L. Papani for the detailed analysis of the cores. They also wish to thank D. Colombo (Geosystem s.r.l.) for acquisition and depth processing of the seismic data.

## REFERENCES

- BATZLE M. AND M.H. GARDNER (2000) - Lithology and fluids: seismic models of the Brushy Canyon Formation, West Texas. In: *Fine-grained Turbidite Systems*. AAPG Mem. N° 72/SEPM Spec. Publ. N° 68 - Bouma A.H. and Stone C.G. (Eds), pp. 127-142.
- BENEVELLI G., G. CAVANNA, J.J. MELICK, L. PAPANI, F. FONNESU, R. TINTERRI AND E. MUTTI (2003) - The Middle Eocene Ainsa Mixed Depositional System: a Model for Turbidite Deposition in Tectonically Mobile Slope Basins. AAPG International Conference, 21-24 September 2003, Barcelona, this volume.
- CAMPION K.M., A.R. SPRAGUE, D. MOHRIG, R.W. LOVELL, P.A. DRZEWIECKI, M.D. SULLIVAN, J.A. ARDILL, G.N. JEUSEN AND D.K. SICKAFOOSE (2000) - Outcrop expression of confined channel complexes. In: *Deepwater Reservoirs of the World*. Annual GCSSEPM Conference, 3-6 December 2000, Houston, pp. 127-151.

- HENLEY D. C. (2001) - Challenges in imaging shallow high resolution seismic data. SEG 2001 extended abstract, pp. 1373 - 1376.
- MUTTI E., M. SEGURET AND M. SGAVETTI (1988) - Sedimentation and Deformation in the Tertiary Sequences of the Pyrenees. AAPG Mediterranean Basin Conference, Spec. Publ. University of Parma, Field Trip, 7, pp. 153.
- MUTTI E., R. TINTERRI, G. BENEVELLI, D. DI BIASE AND G. CAVANNA (in press) - Deltaic, mixed and turbidite sedimentation of ancient foreland basins. *Marine and Petroleum Geology*.
- PACHT J. (2001) - Matching outcrops to seismic can model deepwater reservoir deliverability. *Offshore*, v. 61, pp. 85-172.
- REMACHA E., L.P. FERNANDEZ AND E. MAESTRO (1998) - Relationships between lobes and basin plain elements in the Hecho turbidite basin (Eocene, south-central Pyrenees, Spanish). 15th International Sedimentological Congress, Alicante, pp. 144.
- SULLIVAN M.D., G. JENSEN, F. GOULDING, D. JENNETTE, L. FOREMAN AND D. STERN (2000) - Architectural analysis of deep-water outcrops: implications for exploration and development of the Diana sub-basin, western Gulf of Mexico. In: *Deepwater Reservoirs of the World*. Annual GCSSEPM Conference, 3-6 December 2000, Houston, pp. 1010-1031.
- VALDISTURLO A., M. BERRA AND R. LOTTI (1996) - Seismic modeling from outcrop sections of a conglomeratic deep-sea fan complex (Gonfolite, Southern Alps, Lombardy). Wessely, G. & Liebl, W. (eds.), 1996, *Oil and Gas in Alpidic Thrustbelts and Basins of Central and Eastern Europe*, EAGE Special Publication No. 5, pp. 155-168.