Simultaneous Elastic Inversion within a Reservoir Modelling Environment.

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Introduction

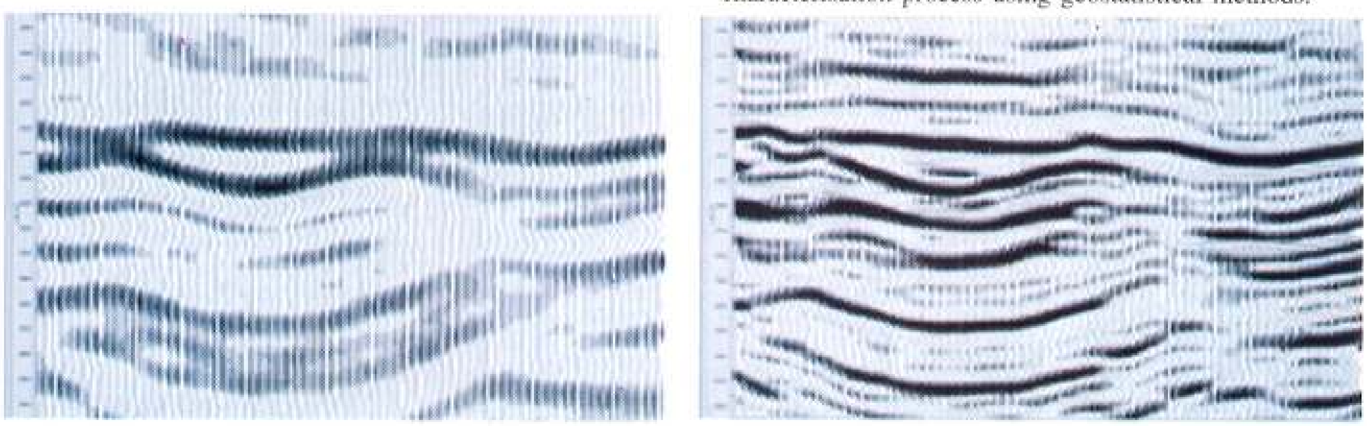
It has been clear, since the advent of 3D seismic, that there is a great deal of information contained in the modern seismic survey. Advances in recent years now provide us with accurate depth images in areas complex structure; seismic facies and attribute analysis can help us identify geological variations; acoustic and elastic impedance help us to identify stratigraphy, rock properties and fluid content; and multi-component technology is leading to fracture identification and rock property analysis. All of these properties assist in building a more accurate and common earth model. Time lapse or 4D seismic effects can be quantified in terms of reservoir production and thus feed back into the dynamic model and simulation process. Seismic then is becoming an engineering tool increasing our reservoir knowledge and adding value to the production cycle.

Data pre-conditioning

Careful pre-conditioning of the seismic data is essential prior to analysis. This includes state-of-the-art geostatistical filtering to address acquisition imprints and spectrum balancing to ensure the best quality broad bandwidth data is available for further analysis. As can be seen in figure 1 the benefits can be significant.

Simultaneous Elastic Inversion

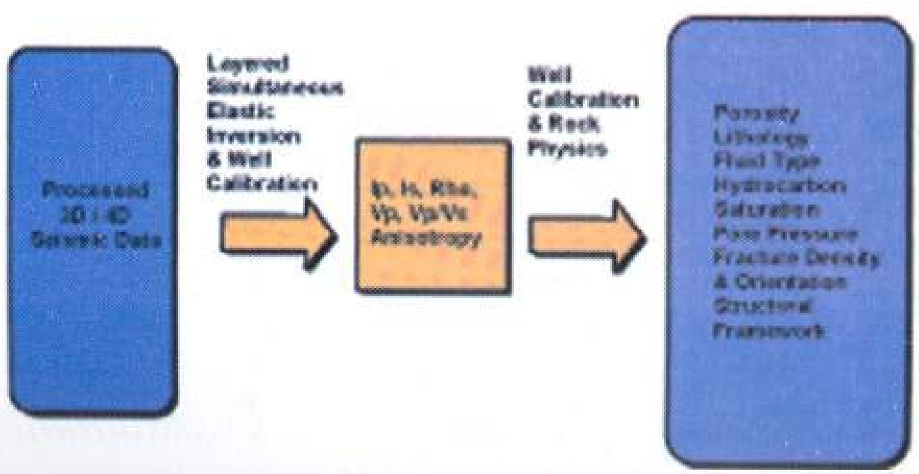
CGG has developed an extensive toolkit for Reservoir Characterisation. A critical feature of this toolkit is the implementation of a layered approach to simultaneous elastic inversion of angle volumes, which is performed directly in a stratigraphic grid. An arbitrary number of angle stacks are jointly inverted using a multi-trace simulated annealing optimisation algorithm to deliver estimates of Vp, Vs, density and all standard elastic attributes. After well calibration, the derived seismic attributes are integrated into the reservoir characterisation process using geostatistical methods.



Input Data

Spectral Balanced Data

Figure 1: Input data and Spectral Balanced data



From Seismic Data to Reservoir Properties

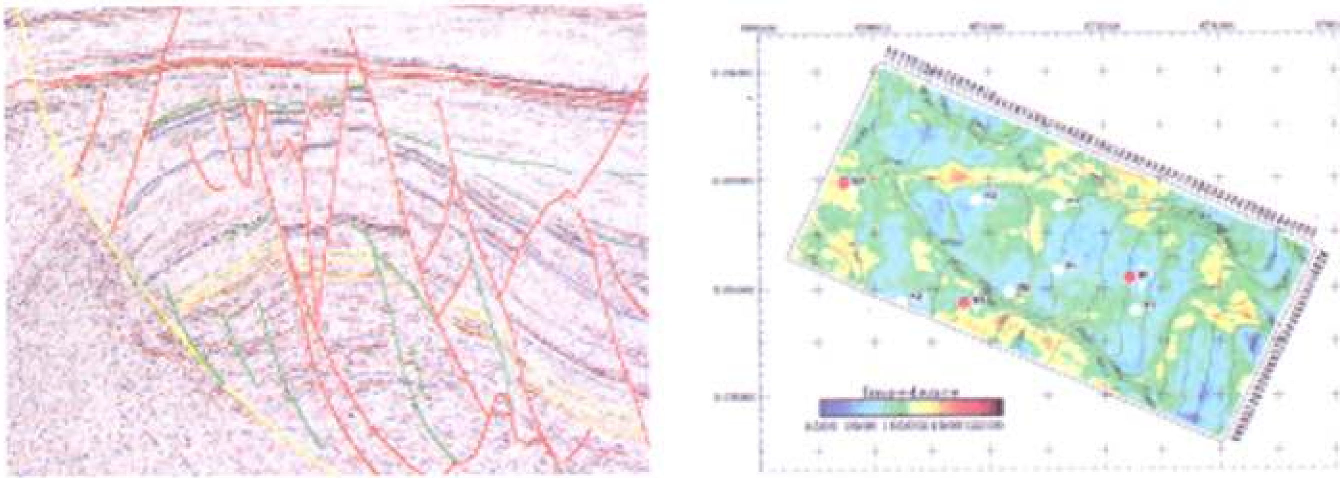


Figure 2 : Case example 1 - complex fault geometries coupled with thin beds resolution - impedance map for main reservoir.

Case Studies

Application of the techniques outlined above is illustrated through a number of examples Complex fault geometries coupled with thin beds resolution presents a challenge to reservoir characterisation. The layered acoustic impedance inversion solution helps to characterise the main reservoir, we see the lower impedance (colder blue colours) indicating the better porosity and thus better reservoir quality areas. Good communication and a good match is confirmed by the existing well data. Furthermore subsequent wells further confirmed the impedance results

Resolution to image thin layers

The layered inversion approach updates layer thicknesses (two-way time) and elastic parameters in a blocky earth model. Thin layers can be detected and elastic parameter contrasts are accurately positioned in two-way time. Figure 3 shows seismic data with a matched synthetic (red traces) at the well location. The inserted curves show the P-wave

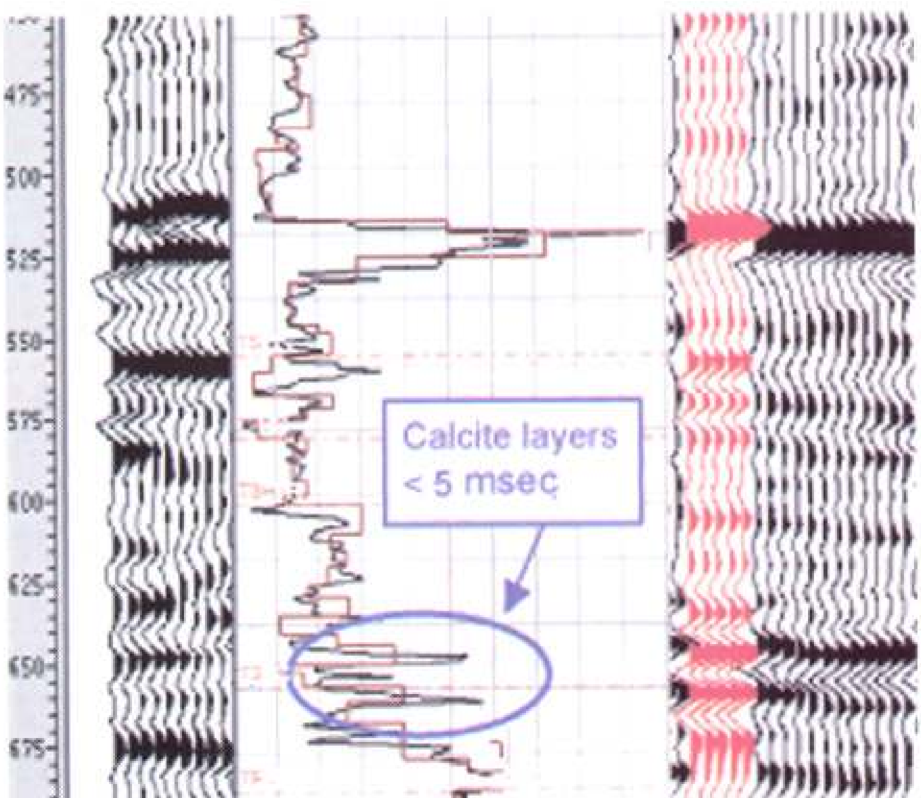


Figure 3 : Case example 2 thin bed resolution – indentification of thin calcite stringers.

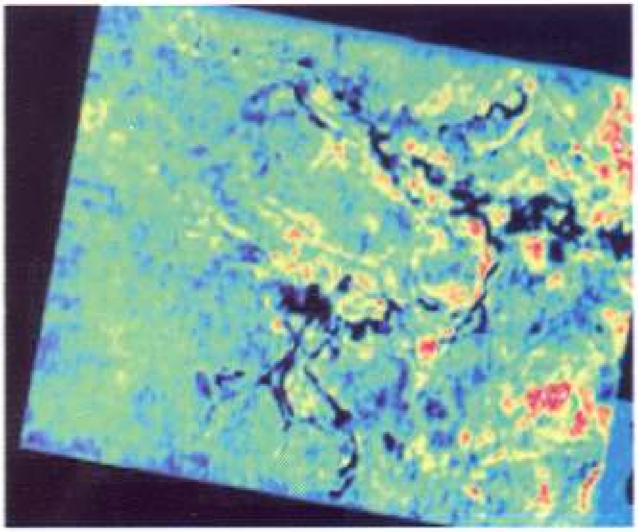


Figure 4: Elastic impedance response indicates good match to wells

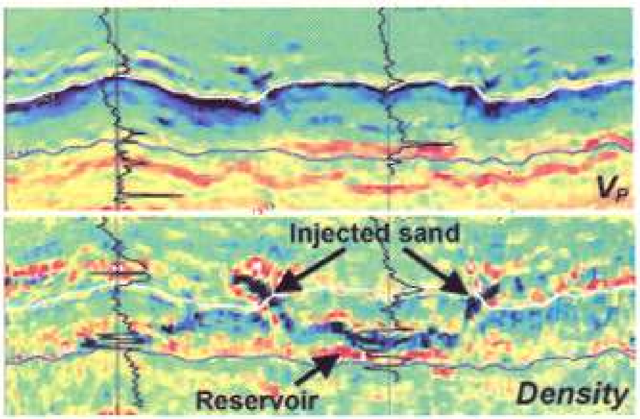


Figure 5: After application of careful seismic pre-conditioning five angle stack volumes (max. 56 degrees) have been inverted to derive VP, VS and r cubes. The good well match validates the reliability of the results, which clearly identify injected sands as having low density.

impedance log (black curve) and the inversion result (dark brown curve). The inversion was able to resolve thin calcite stringers within the reservoir which could then be avoided for horizontal drilling.

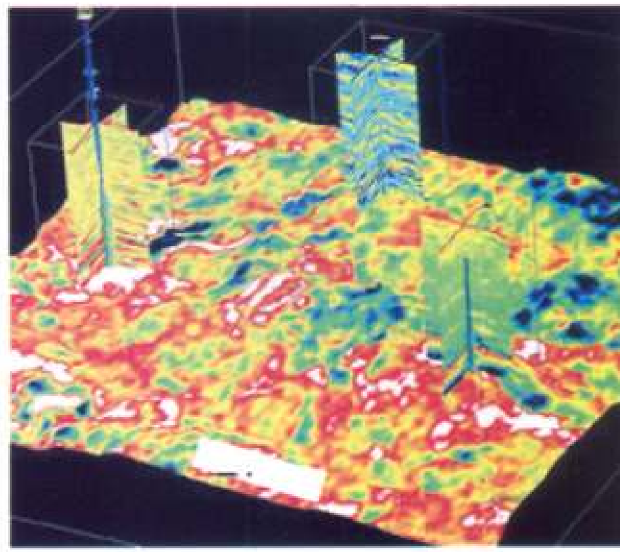


Figure 6: Multi-properties management in a 3D environment: Vp, Vs and density displayed on RhoLambda surface

Large angle inversion

4D pre-stack stratigraphic inversion was performed on a Tertiary reservoir composed of massive, well-sorted, high porosity sands. Due to compaction and dewatering, the sands have been remobilized and injected into shallower formations. Six angle time-migrated angle volumes were used for the simultaneous inversion to elastic properties. There is no limitation on the maximum offset or angle that can be used, except that all events should correspond to pre-critical reflections. Full Aki-Richards or Zoepprtiz equations are used for the AVA modelling within the inversion engine. RhoLambda was particularly relevant for identifying fluid movement.

The results revealed an area of poor reservoir sweep which in turn, enabled the identification of an infill well. Subsequent drilling has led to a substantial uplift in field production.