Differentiating Between Dolomites and Limestones

Seismically derived photoelectric index volume can be used to characterize dolomite reservoirs.

By Ritesh Kumar Sharma, Satinder Chopra and Amit Kumar Ray, Arcis Seismic Solutions, TGS

Carbonate sedimentary rocks that have been dolomitized and laterally sealed by tight undolomitized limestone frequently produce hydrocarbons. Compared with clastic reservoirs, the characterization of dolomite reservoirs presents challenges as many of the conventional methods, comprising attributes such as Lambda-Rho and Mu-rho, are not very effective. Consequently, alternative methods are needed for the characterization of Upper Ordovician Trenton and Black River carbonates in eastern Canada as well as the ability to map the lateral extent of dolomite reservoir rocks that have a thickness below the seismic resolution.

While making measurements in the wells, the latest density logging tools make it possible to differentiate between dolomites and limestones using the photoelectric index log. The tool has a gamma ray source that emits radiation, which enters the formation (by about an inch or so), gets scattered and loses energy.

The intensity of the backscattered radiation is picked up by the detectors installed on the tool. While the higher energy part of the backscattered radiation is related to the density, the low-energy component is a measure of the average atomic number of the formation or the rock matrix properties (lithology). Fluids have very low atomic numbers and so have little influence. The limitation, however, is the availability of P_e (photoelectric index) curves only at well locations.

Arcis demonstrates an integrated workflow in which well data and seismic data from eastern Canada are used to discriminate between limestone and dolomite. The workflow begins with the generation of different attributes from the well log curves. As shown in Figure 1a, using the cross-plot between P impedance and S impedance, color-coded with Pe values, the blue and red ellipses are drawn corresponding to points that have low and high values of P_e to identify the dolomite zones.

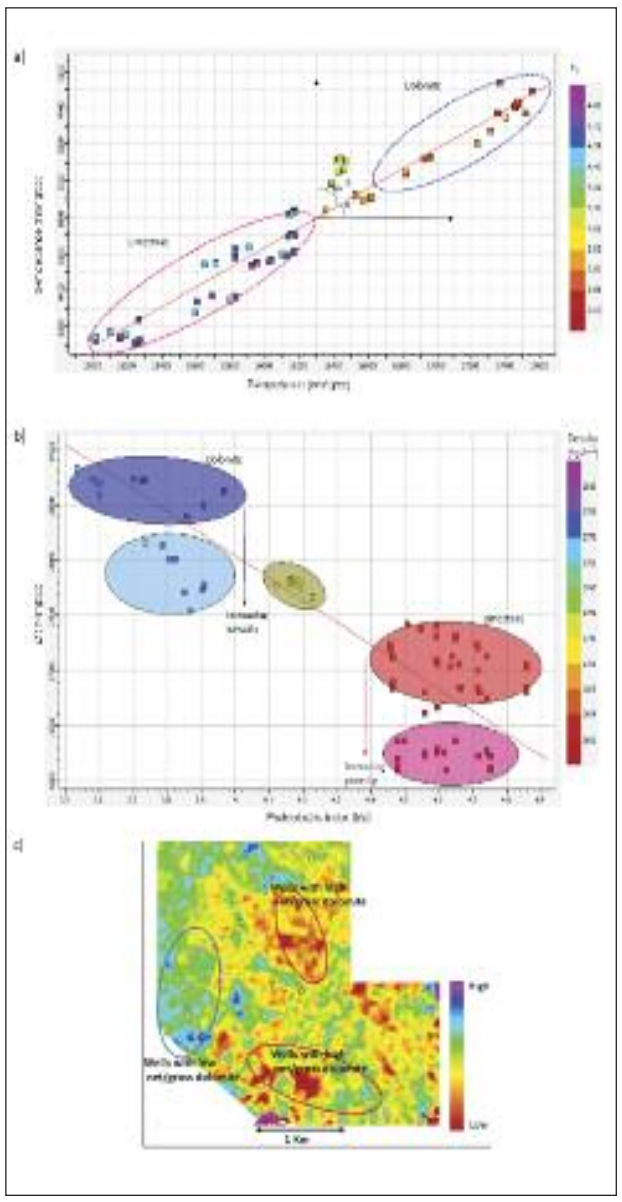

Figure 1. A cross-plot between P impedance and S impedance that is color-coded with P_e values is shown. A) The blue and red ellipses enclose the points corresponding to low and high values of P_e corresponding to dolomite and limestone, respectively. A crossplot between LI and P_e for well log data in the zone of interest that is color-coded with density values is demonstrated. B) The scatter of points exhibits a linear relationship. The blue and red ellipses enclose the points corresponding to low and high values of P_e corresponding to dolomite and limestone, respectively. A horizon slice from inverted P_e data is shown. C) The predicted response correlates fairly well with well data. (Image courtesy of Arcis Seismic Solutions)

Instead of using these two separate attributes, it is possible to differentiate between limestone and dolomite by rotating the clusters in a counter-clockwise direction. Such a rotation leads to new attribute, namely lithology impedance (LI) that incorporates the lithology formation and can be defined as $LI = I_P * \sin\theta - IS * \cos\theta$, where θ is the angle of the regression line intersection with the horizontal axis (Figure 1a). The purpose of generating this attribute is to be able to use a single attribute for distinguishing the dolomites from limestones.

Next, to be able to derive the P_e attribute from seismic data, Arcis investigated the relationship between the LI and P_e well log curves, which can

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Redefining Seismic Inversion

Bayesian inversion system can work with both sparse and dense well control and can be operated within reasonable time constraints.

By Michel Kemper, Ikon Science

Seismic inversion aims to extract rock properties such as porosity, saturation and Vshale from seismic. Seismic, however, responds to changes in impedance at the interface of two formations, so the seismic inversion challenge breaks into two steps (even though it is sometimes "hidden" in one application): (1) obtaining from seismic the impedance of each interval, which is known as seismic inversion; and (2) deriving rock properties from these impedances, which is known as reservoir characterization.

Reservoir characterization relies on per-facies rock physics modeling, with the facies being an elastic-seismic facies such as shale, water-sand or gas-sand.

Today's technology

Even though in step 2 it is common practice to derive rock properties per facies, to date seismic inversion algorithms overwhelmingly invert for impedances only, i.e., not per facies—even though seismic modeling conclusively shows that facies transitions form a primary control on the impedance changes that in turn control the seismic response. The exception is certain laborious geostatistical algorithms that do invert to facies and impedances per facies. However, these have certain shortcomings: They require a relatively dense amount of well control; typically use variography, which is not suited to the simulation of facies; and can take weeks, if not months, to set up and run.

Ji-Fi

As the name indicates, joint impedance and facies inversion (Ji-Fi) performs the inversion for both facies and impedances per facies. Ji-Fi, therefore, fully captures the physics of the seismic inverse problem. Compared to today's technology this leads to:

- Better impedance estimates;
- A more consistent facies model of great help to geomodelers (as compared to facies models obtained using Bayesian classification—see Figure 1); and
- Improved reservoir properties as steps 1 and 2 are now both facies-based.

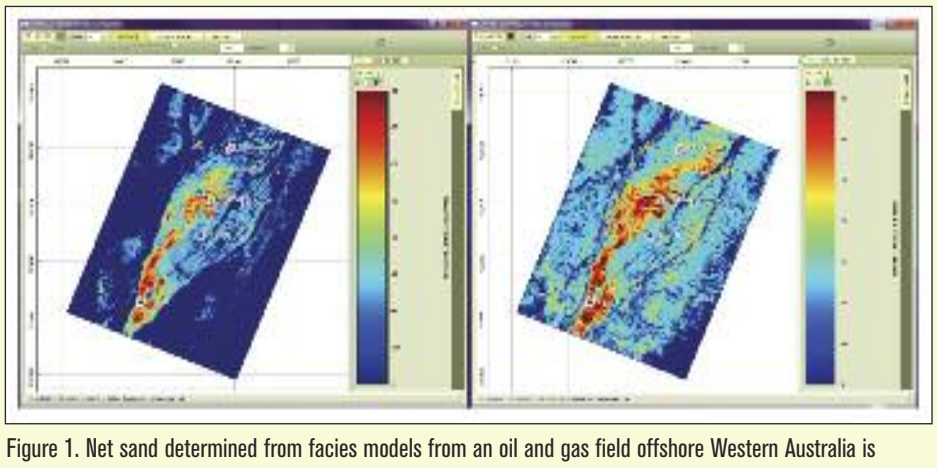

Figure 1. Net sand determined from facies models from an oil and gas field offshore Western Australia is shown. At left, the facies model is obtained by Bayesian classification on simultaneous inversion derived impedances. At right, the facies model is Ji-Fi derived. The model shows that the Ji-Fi results match the five wells, the Ji-Fi derived channel is continuous and that Ji-Fi predicts water-bearing sands off structure. (Image courtesy of Ikon Science)

Ji-Fi is a Bayesian inversion system that supports the control of lateral facies continuity and inhibits facies transitions that are not geologically or hydrologically plausible (e.g. water-sand on top of gas-sand). It works equally well with sparse or dense well control and can be operated within reasonable time constraints.

The Ji-Fi method is the culmination of four years of research in partnership with Australia's Commonwealth Scientific and Industrial Research Organization and with funding from Tullow Oil.

Results

Ji-Fi has been operated on a number of hydrocarbon assets, and the results are impressive (see Figure 1). In some cases where no well control was available within the area of the seismic survey, per-facies trend information derived from nearby wells or even per-facies analogue trends were used to initiate the process, with surprisingly good results.

Ji-Fi will be commercially available beginning Dec. 1, 2014. Attendees can visit with Ikon Science at booth 1208 to pick up the recent article by Dr. Michel Kemper and Dr. James Gunning that was published in the September 2014 issue of *First Break* or for a demonstration. ■