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Research paper

Applications of 3D seismic attribute analysis in hydrocarbon prospect identification and evaluation: Verification and validation based on fluvial palaeochannel cross-sectional geometry and sinuosity, Ness County, Kansas, USA

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ABSTRACT

Due to their high resolution and established success rates, the analysis of geometrical and stratigraphic 3D seismic reflection data attributes have become one of the most important tools in many hydrocarbon exploration and development programs. In areas with high drilling risk as a result of the lack of spatial continuity and lithological variation of potential prospects, analysis of relevant seismic attributes is essential to successful placement of wells. This study of the York field, Ness County, Kansas, presents a corroborative finding, based on the analysis of a set of 3D seismic attributes, revealing a meandering fluvial channel system incised on the Mississippian stratigraphic unconformity north east of a previously interpreted Weirman field palaeoshoreline and submarine channels. The York field prospect identification and appraisal program targeted the Cherokee sands where reservoir properties are favorable and where it was thought that thick Cherokee sands correlate with structural Mississippian highs. We produce evidence that Cherokee sand-prone fluvial facies is mappable based on synergistic analysis of seismic arrival time, amplitude, spectral decomposition, acoustic impedance, and waveform attributes. Seismic amplitude highs and relative acoustic impedance lows showed moderate conformance with Mississippian-horizon time lows. Controls exerted by channel post-confluence water and sediments supply provide corroborating hydraulic geometry aspects for the interpreted fluvial system.

Time-structural maps, in addition to time and horizon slices of several 3D seismic attributes including amplitude, spectral decomposition components, and relative acoustic impedance all seem to indicate that five previously drilled dry wells within the study area were outside the boundary of a meandering, Cherokee fluvial system of potential reservoir quality. Additionally, comparisons of the results of this research to previous studies conducted in the south west of Ness County have provided an opportunity to support and contribute to, interpreted paleodepositional setting established by Raef et al,, 2015 where a palaeoshorline was interpreted. The results of this study support a broadly NE–SW trending meandering channel system with SE flow direction.

1. Introduction

1.1. Background relevant studies

Reducing drilling risk when targeting thin, very often below seismic temporal resolution, Cherokee group basal/fluvial sands prospects of Kansas is an industry priority amid low-price commodity environment and the need to optimize placement of multiwall pads. Since their introduction in the 1970s, seismic attributes have allowed geoscientists to break down and view seismic traces in terms of unique, quantifiable components such as frequency, phase, and amplitude (Mourning, 2014). Several authors (e.g. Chopra and Marfurt, 2008; Suarez et al., 2008; and Verma et al., 2009; Bahorich and Farmer, 1994) have reported on the use of seismic attributes in the characterization of hydrocarbon reservoirs and their utilization in defining channel fill zones. A comprehensive classification of seismic attributes and the different modes of extraction and application is covered by Chen and Sydney (1997). Imaging channels boundaries based on most-negative

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curvature was shown, by Suarez et al. (2008), to suffer from acquisition footprints in a study to calibrate the response of various attributes to a well-understood fluvial system.

The challenges of detecting and undertaking a seismic based channel systems characterization calls upon adopting corroborating sources of independent information such as those based on hydraulic geometry in response post-confluences changes in sediments and water supply. The York Lease in north east Ness county (Fig. 1), Kansas, poses a drilling risk that has manifested itself when five unsuccessful wells were drilled. This drilling risk is to a great extent related to the targeted basal/fluvial Cherokee sands as very narrow and thin, as well as highly discontinuous spatially. This study will utilize several different seismic attributes, including acoustic impedance, amplitude, spectral decomposition, two way travel time (TWTT) and amplitude, in order to properly delineate potential hydrocarbon reservoirs (e.g. meandering channel sands) in an area of Ness County, Kansas, USA. To this end, we find it essential to shed some light, in the following three paragraphs, on previous efforts of Cherokee sand, for which palaeodepositional setting was described by Walters et al., 1979 prospect identification and evaluation in Ness County area.

In 2003, Coral Coast Petroleum drilled wildcat well, Keith #1, targeting a Cherokee sandstone west of northeastern Ness County, Kansas. This well was part of the Wierman field (see Fig. 1) and produced 162 barrels before it was plugged as dry and abandoned (Abbas, 2009). The well was close to a reservoir, but the operator concluded that not enough sand development was present for economic reserves, and that the well was on the edge of a channel.

The focal point of Abbas (2009), was essentially answering the question of "what went wrong" with this particular prospect. In his thesis, Abbas stated that personal communications with the well operator revealed that the potential sandstone target was identified primarily through the occurrence and tracking of a doublet signal reflection found on a seismic section at the base of the Cherokee formation, just above the top of the Mississippian formation (Fig. 2).

In order to assess the situation, Abbas used surface 3D seismic reflection data, well logs, and drilling reports or documents related to the Weiman field, and then created a workflow incorporating 3D seismic attributes in an attempt to explain the results of the Keith #1 well. Ultimately, despite the appearance of this doublet event within the seismic data, analysis of relative acoustic impedance, RMS amplitudes, average energy, and amplitude attenuation indicated that Keith #1 and several surrounding dry holes all fell within unfavorable areas. Similarly, Philip (2011), attempted to further develop the use of post-stack 3D seismic attributes in the Wierman field and apply them as part of an integrated workflow incorporating well logs, core data, production data, and modern depositional analogs. The attributes Philip selected for the study area were: acoustic impedance, amplitude attenuation, RMS amplitude, and spectral decomposition, as well as curvature and coherence attributes. Many of these attributes have been similarly utilized in this particular study, and more detailed explanations of these attributes and their applications can be found later within the body of this text.

This leads into some of the most recent work in the area, with emphasis on Cherokee sands, by Raef et al. (2015); this study presents a synergistic approach integrating post-stack seismic attributes (TWTT, amplitude, coherency, parallel-bedding indicator, and curvature) and well-log facies analysis in order to understand the development and depositional setting of the Cherokee sands of Wierman Field in central Kansas. The ultimate conclusion of this study is that the dimensions and spatial relationships of the interpreted geobodies are in conformity with the modern shoreline analogs of a barrier beach or strand-plain adjacent to an estuary. Fig. 3 illustrates interpreted paleovalleys, structural closure, and the interpreted paleoshoreline.

Raef et al. (2015), suggests that "higher rates of drilling success in the basal Cherokee sands are attainable by:

a) focusing on the proximity of thicker sands, as evidenced by amplitude brightening of seismic reflections close to the Cherokee basal reflections,
b) [considering] the proximity of identified amplitude anomalies to the interpreted paleoshorline,
c) favoring locations of paleotopographic highs on the Mississippian unconformity, when associated with brightening of seismic amplitudes in the basal Cherokee reflections and dimming amplitudes below the Cherokee bottom reflection,
d) [locating] structural closures, [which] in association with the above factors, are of significant weight in reducing drilling risk."

Thus, the focus of this new study is three-fold: [1] apply methodologies guided by three previously mentioned studies to a seismic attribute analysis being conducted in a nearby area of Ness

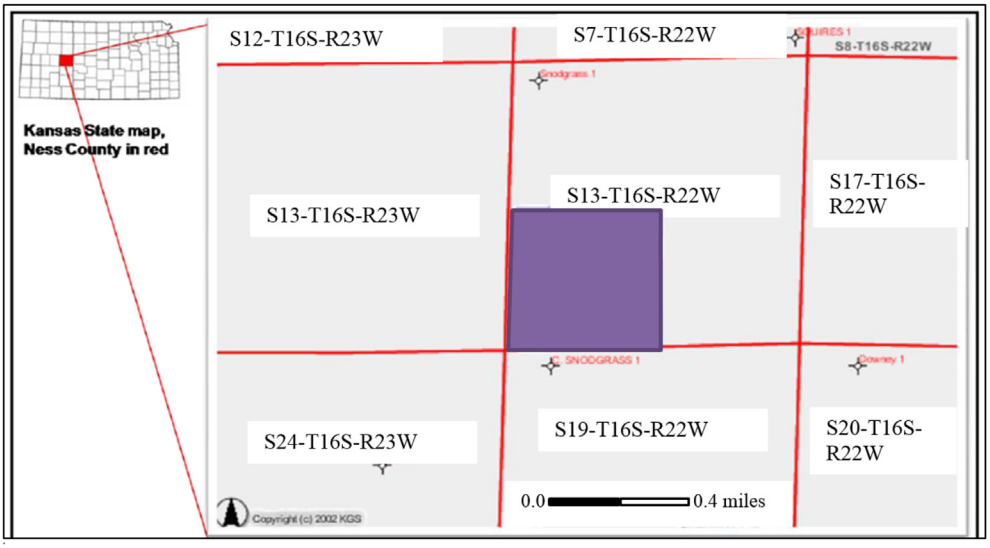

Fig. 1. Location of Ness County within Kansas, and the location of the Wierman Field within Section 18 of Township 16 south, Range 22 west (modified after: Abbas, 2009).