Comparison of Spectral viz a viz Continuous Color Domain Attributes in Delineation of Thin Bed Sedimentary Geometry; A Case Study from Stratton Field Seismic Data, Texas.
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Summary
Identifying structural and stratigraphic features from seismic data is a challenge, especially for thin bed reservoirs. As a practice, seismic attributes (spatial or spectral) are used to extract such features. Most of the time this geological information is hidden within a cloud of multiples, artifacts and noise, regardless our best seismic processing efforts. Risk related to drilling hazards, such as unstable seafloors, active faults, fault scarp's and gas hydrates could be reduced if the geological information could be isolated and removed from this clutter.

The objective of the present study is to identify the architecture of thin bed sub seismic depositional features based on the resampling of seismic data into continuous color domain. A novel method based on continuous color rendering in red-green-blue (RGB) color space and hue-saturation value allows the extraction of heterogeneities from seismic data cubes that are representative of geological features such as sedimentary channels, fracture zones etc. The present study highlights how this new technology can be used to enhance the stratigraphic and structural features present in the seismic data.

Introduction
Conventional seismic attributes depend on vertical window based averaging, due to which identifying thin vertical features is very difficult (Laake; 2012). The eXchromaSG software plugin in Petrel transforms 3D seismic volume into a continuous color domain, where the data is processed similar to the processing of satellite image data. The analysis in continuous color space enhances the dynamic range of the studied data, which allows for image processing to sharpen the heterogeneities representative of geological structures, facies discontinuities. The process produces a family of attributes consisting of red-green-blue (RGB) volumes, structurally sharpened SRGB volume, and structurally enhanced amplitude SAMP volume. Simultaneously, unwanted noise that might be present in the seismic data is attenuated. The structurally sharpened RGB method does not rely on spatial averaging in any direction, which is conventionally required during the generation of seismic spatial attributes (Laake, 2013).

Openly available data set of a large Gas producing, Stratton field in South Texas Kleberg and Nueces counties have been analyzed for the study.

Regional Geology
The Stratton field is in South Texas approximately 30 miles southwest of Corpus Christi in Kleberg and Nueces counties (Figure1). About 20 square-km time migrated 3D seismic volume, containing 309 in-lines and 230 cross-lines spaced at 55 feet intervals, sampled at 2ms, together with data from 21 well logs and one Vertical Seismic Profile (VSP) is available in public domain, which has been provided by the Texas Bureau of Economic Geology (Hardage et al, 1994).

Figure 1: Location of Stratton Field (Hardage; 1994)
The major producing formations are the nonmarine fluvial Upper Vicksburg and Middle Frio formations. The Frio Formation is composed of a series of deltaic and marginal-marine sandstones and shales that are the downdip equivalent of the continental Catahoula Formation (Galloway et al., 1982, 1991). Several studies during the development phase of the field and well data reveals that the reservoir section is stacked series of meandering channel fill deposit (Pennington; 2001) (Figure 2). Texas Bureau of Economic Geology (BEG) interpreted some channels, however challenges of continuation of thin bed reservoir remain.

The available data set has the challenge of imaging stratigraphic features below the resolution of seismic data. At the shallow levels some of the channels are readily seen but most of the channel sections can only be inferred by well correlation and through subtle features on seismic.

**Concept and Method**

The Stratton field have multi-level of producing reservoir zones. The current study is concentrated between F21 and F39 reservoir levels. The presence of thin beds in the interval are well established through drilled well data.

F21 and F39 chronostratigraphic units are continuous throughout the seismic data and thus correlated using 2D guided auto-track and 3D auto-track method. F39 is the blue horizon in the seismic section (Figure 3), the deepest Frio reservoir. F21 is the orange marker about 50ms above F39. Horizon guided volume probes were created which are alternate to the conventional way of flattening the volume and looking at the data along horizontal slices.

Primarily, the conventional post-stack seismic attributes RMS and Variance were blended, which is
expected to provide visual for both structural and stratigraphic features together.

Root mean square attribute helps to measure the reflectivity. It emphasizes the variations in acoustic impedance over a selected sample interval. It reflects the acoustic impedance of a body in contrast to its surrounding bodies. For example, channel sands show relatively high RMS value due to the acoustic impedance contrast with their surroundings. Thus, RMS amplitude attribute helps us to identify some of the channel related facies, Whereas Variance attribute, which is an edge method measures the similarity of waveforms or traces adjacent over given lateral and/or vertical windows. Therefore, it can image discontinuity of seismic data related faulting or stratigraphy.

The conventional seismic attributes mostly follow the “top-down” approach, which is usually wavelet-based signal correlation along individual seismic traces or using adjacent traces. This requires minimum 5 samples to establish stable wavelet/or provide acceptable signal-to-noise ratio. Five sample window requirement results in spatial averaging of analysis result (“bleeding” or “smearing”).

According to a demonstration by Widess (1973), when λ is predominant wavelength in the data, λ/8 is the resolution limit. As wavelength depends on velocity and frequency and the presence of noise is inevitable, the subsequent broadening of the wavelet is normal in its subsurface journey and thus resolution usually taken to be only λ/4 (Chopra et al.2006). This approach suggests a resolution efficiency of seismic data of 100-120 ft (30-40 m) at a depth of ~6000ft with average velocity approximately 12,000ft/s in Stratton Field (Hardage et al, 1994), indicates the target sedimentary features (here channel morphology) which are typically less than 40-50ft thick, are beyond the seismic resolution, if studied using conventional attributes.

For the second part of the study, we experimented with an unconventional approach of continuous color space by using the new tool in Petrel called eXchroma. eXchroma is based on the “image-approach” which is a point-based correlation. With no averaging or windowing, eXchroma uses Red, Green, Blue (RGB) colors to represent three layers of seismic amplitude data. Each layer of seismic data is at least one sample, e.g.2ms, apart. The three layers are combined into a single RGB layer with intensity of each Red, Green, and Blue representing amplitudes values (Figure 4). By combining RGB into one layer, the dynamic color range can be greatly increased which then can be used to visualize subtle geologic boundaries and features. The process is repeated for each sample interval until the full 3D cube is represented.

Heterogeneities in the seismic data cube are now represented by boundaries between the colors in the RGB image. We enhance the contrast of the RGB image through image processing to sharpen the boundaries, hence, we improve the signal-to-noise ratio of the structural information. Extracting the structural boundaries from continuous color images is facilitated by converting the RGB image to a hue-saturation-value (HSV) image (Figure 5).
Through projection of the RGB image into a different color space, we separate the color information which is now contained in the hue (H) component, from the structural information, which is represented in the saturation (S) component of the HSV image. We run edge detection on the saturation component to extract the structural information results the SRGB structural cube. This SRGB cube is exported in the format of a seismic cube and is available for direct analysis for the structural sharpening of the seismic input data.

Results and Discussion

The conventional attributes like RMS amplitude and Variance have been blended and visualized in a 30ms window below F21. The output (Figure 6) shows good amount of high amplitude patches with few sinusoidal features possibly meandering channel system. The patchy high amplitude responses indicate probable stacking or overlapping of channel morphologies in the area.

However, a blend of the continuous color space in horizon probe gives a finer insight on the data. RGB output of eXchroma directly converted into HSV domain where the saturation axis gives more structurally sharpen image. Blending of SRGB and SAMP continuous color space volumes reveals a much more sharpen output which distinctly identified the morphology boundaries. The ambiguous patchy high amplitude response in previous run is now resolved and give rise to a clear visual of classical meander pattern, channel stacking and overlapping features with some possible ox-bow morphology.

Conclusion

Based on the analysis carried out, we could identify the thin channels present at the deeper level between F21 and F39 by using the RGB method on horizon probe. We notice that the features which could not be identified by using traditional seismic attributes can be extracted using the color attributes generated by eXchroma.

We can find that the SRGB method maps the geological features clearly. In the seismic amplitude cube, the changes in the amplitude often mask channels and fracture zones. In contrast to the study of the amplitudes, the SRGB method uses a correlation-type approach that mostly removes the impact of the absolute amplitudes, thus resulting in a more continuous mapping.

Furthermore, the continuous color rendering provides a smoother transition between the colors. Finally transforming RGB volumes into HSV domain, the SRGB and SAMP blending benefit to inherent noise attenuation. This is a desirable side effect of the continuous color rendering, as it enhances features coherent between the three input layers and

Figure 6: Spectral blending of RMS and Variance attribute (Left) and Structurally enhanced continuous color domain blending (Right) in Horizon probe between F21 and F39
attenuates incoherent features.

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