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Stratigraphic Volume Visualization - Work Flows and Strategies

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ABSTRACT

The digitization of stratigraphic facies and depositional systems is one of the most difficult challenges for the geoscientist. Abrupt and subtle three-dimensional lateral and vertical changes in geology with respect to their geophysical representation often require the skills of experts and considerable time investments to map. The challenge is further magnified as the numbers of stratigraphic plays and the size of 3D volumes increase. Current mainstream workflows utilizing conventional digitizing methods are simply difficult to do, especially in complex stratigraphic zones. It is important to emphasize that its not the interpretation or recognition of stratigraphic features that is difficult and costly, but the act of digitizing, the "pushing" of a horizon through complex data in an efficient and accurate manner. Volume visualization methods and strategies can by-pass significant amounts of digitization and result in better stratigraphic interpretations. Stratigraphic volume visualization utilizes technologies involving transparency, new workflows and strategies that are well suited for mapping in complex stratigraphic systems. The three key stratigraphic volume visualization strategies are "time windowed", "detection" and "horizon keyed". Each key strategy is discussed with examples of application to reveal and map stratigraphic systems.

INTRODUCTION

Volume visualization assumes that the seismic reflectivity of the sub-surface represents an inherent 3D model according to its acquisition and processing history. The role of the visualization geoscientist is to "enter into" and probe within the data volume and visually interpret as much paleo-geomorphologic features as possible so we may minimize the digital process. Surfaces in volume visualization are often used as devices, and transformed into pseudo-formations with thickness, which provide more geologic detail than a surface. It is important to recall the difference between a surface that represents a time line and volume visualization where the "surface" is represented with thickness, therefore behaving more as a formation, sequence or interval. Strictly speaking, surfaces do not apply in volume visualization, because a surface has no thickness, however, "formations" do. Complex stratigraphy can only be partially represented by time lines, due to the intersection point between the surface (single z value) and the 3D nature of stratigraphy. Volume visualization utilizes "optical voxel stacking" [footnote1] technologies which preserves the 3D spatial relationships (dip) of all stratigraphic features within the interval. Hence, volume visualization is very well suited for complex stratigraphic packages. An overall work flow is presented with three critical visualization strategies that address different interpretation needs and goals. A brief description of an overall work flow and discussion of each visualization strategy with examples, is given below.

WHAT IS A VOXEL?

Voxel based visualization tools utilize "voxels". The term "voxel" is an acronym for "Volume Pixel Element", a three dimensional pixel that is equivalent to a seismic sample, Figure 1a. Each voxel is associated with an "alpha variable" which allows its transparency to be modified and allowing us to see volumetrically into the volume. The strategies of volume visualization are essentially procedures that promote the optimal application of transparency, through the utilization of the "Zone System"[footnote 2] (Figure 1b) to create high quality perspectives of the subsurface.

WORK FLOWS

The overall workflow is shown in Figure 2. Beginning with the 3D volume, initial quality control measures are performed to check the seismic data for scaling problems, and pre-volume scanning parameters are set. Then initial scanning is performed for regional overviews and for the identification of prospective zones. Potential objectives are reviewed to the degree such that "focusing" volume visualization strategies are formulated. There are three primary focusing strategies which are performed prior to prior to the application of opacity are, "time windowed", "detection" and "horizon keyed". The purpose of all three is to remove as much excess data from above and below the objective interval which will significantly improve the visual clarity of the objective. After the focusing strategy is performed, the application of opacity is made utilizing the "Zone System" to create the best image possible of the subsurface. With stratigraphic features, facies and the overall depositional system identified, detailed mapping of critical elements and key surfaces begins.

In general the workflow performed should be in order of simplicity and efficiency. For example, even though the best strategy may be to utilize two surfaces to encapsulate the zone of interest, time windowed visualization is often performed first because of its simplicity and ease of operation. It is commonly used as a quick reconnaissance process because from little effort, much useful information can be acquired.

TIME WINDOWED STRATEGIES

Time windowed strategies are the most simple and time efficient method for visualizing flat to semi-flat strata. Detailed images of complex stratigraphy can be quickly obtained because the time windowed volume mimics the attitude of the strata. Figure 3 shows relatively flat geology with channels within the objective interval. In Figure 5, the Zone System is applied and results enlarged showing the geology within the 72 ms time windowed interval. With seismic facies visible, facie boundaries are interpreted and a facie and depositional system map is constructed (Figure 5).

DETECTION STRATEGIES

Detection strategies utilize an automated voxel tracking technology to isolate and determine the extent of the feature. The tracking is based on the physical connectivity of a user-defined amplitude range. Individual features facies or extensive reflectors may be tracked, and converted into surfaces for horizon-keyed visualization or contoured and converted to depth. Figure 6a-c, illustrates the workflow from volume scanning, lead identification to detection. Note that the detection (Figure 6c) totally isolates the feature from the rest of the volume where you may temporarily lose the visual relationship between the feature and the surrounding data. By trimming the volume to the upper and lower time limits of the detection and carefully raising the opacity level of the undetected background, (but not higher than the detection) the detection is integrated with the surrounding data. Once the detection has been isolated (Figure 7a), the workflow is to apply visualization to reveal internal amplitude variations (Figure 7b), and then, by shifting the color scale into Zone 1 amplitudes, additional details are revealed (Figure 7c).

Individual facies may be detected and converted into color-coded surfaces for insertion into 2D lines to serve as helps for further interpretation. Another useful tip is to iterate through various detection ranges to determine if any stratigraphic patterns can be discerned.

HORIZON KEYED

Horizon keyed visualization requires horizons. Rough digitized grids (spacing of 40-100 lines) often provide sufficient control for satisfactory regional visualization. The strategy being, to create a “container” for the zone of interest, either by taking advantage of younger and older low amplitude zones and or by taking advantage of the objectives seismic signature. A key flavor, that should be permeated throughout all workflows is reducing cycle time and receiving greater benefits. The nature of volume visualization allows much creativity that can be used to steer workfows in achieving maximum benefits. Full detailed and accurate interpretations which are usually time intensive should only be performed when and where it is absolutely necessary, where it is not, generate quick grids and utilize volume visualization to provide the information. Figure 8 illustrates the importance of horizon keyed visualization where every reflector within a stratigraphic package will contribute to the overall visualization of a depositional system. Figure 9 illustrates various horizon and sequence keyed visualization options, for focusing on an objective. Figure 10 is an example of a surface to surface, sequence keyed visualization.
Figure 11a is an example of applying a horizon-keyed visualization strategy to solve a complex interpretation problem. Cycle splitting and numerous discontinuities characterize the objective interval. Automatic detection and tracking tools do not operate well under these conditions; however, a simple, carefully designed horizon-keyed visualization strategy quickly solves the problem. The continuous underlying sequence is quickly mapped and used as a device to create two upward bulk-shifted surfaces to encapsulate the zone of interest (Figure 11b). Once the areas between the bulk shifted surfaces have been isolated, opacity is applied and the internal details revealed for interpretation (Figure 12). In this case, note that the surfaces are “throw away surfaces”, that they are only used as a device to visualize the zone of interest. In volume visualization workflows, the decision to use rough surfaces, to obtain great detail, reduces interpretation cycle time. Horizon keyed and or sequence keyed strategies often provide the best mechanism for accurate visualization of stratigraphic packages.

In conclusion volume visualization is most suitable for interpreting in complex stratigraphic packages. Creative workflows can be designed to address both technical and business objectives. The benefits are higher quality interpretations with significant timesaving. Today, with tight economic constraints and with overwhelming amounts of data, new workflows and processes may provide the competitive edge.

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- 1 Optical Voxel Stacking is the application of opacity that visually aligns data in 3D space.
- 2 Zone System is a volume visualization process where color-coded amplitudes correspond to specific features within the visualization allowing for direct enhancement of specific features.