An Introduction to BGP's Seismic Acquisition, Processing and Interpretation Software Systems

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Introduction

As one of the leading geophysical service companies, BGP has more than four decades of accumulated experience and a solid technical foundation in seismic acquisiton and processing. This can be seen from BGP´s proprietary seismic software systems, KLSeis®, which is the seismic acquisition design software system, and GeoEast®, which is the integrated seismic data processing and interpretation software system. This article is intended to provide the readers with some overall information about these software systems in terms of history, main geophysical techniques and functions, and application examples.

KLSeis®

History and distribution

Table 1. History of KLSeis®

Release year	Version	Updates
2000	V1.0	Parameters analysis; Survey design and 2D Model building; On-site data quality analysis.
2002	V2.0	Survey data processing; LVL survey data processing; 2D Statics calculation.
2003	V3.0	Real-time QC; 3D model-based statics; 3D refraction statics.
2004	V4.0	3D Model building; P-sv Survey design; P-sv Statics.
2007	V5.0	3DV Survey design; 3DV Bin analysis; Illumination Analysis.
2010	V6.0	VSP survey design; Marine/OBC survey design.

The first official release of Version V1.0 with very basic acquisition design techniques and functions occurred in 2000. Through the intermediate versions with updates and additions of new techniquess, the latest version of KLSeis®, V6.0, was released this year. In this version almost all conventional surface seismic design functions and that of VSP, marine, TZ and even OBC have been added. Table 1 lists the overall information of KLSeis® ´s history. KLSeis® is being used in almost all oil fields in China and by many oil and gas companies around the world. Figure 1 displays the geographic locations where KLSeis® has been installed.

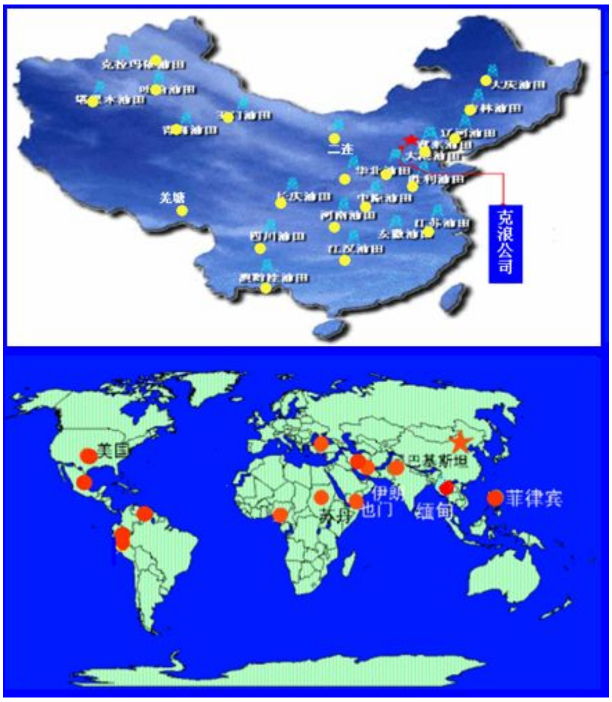

Figure 1. Places where KLSeis® is installed. Yellow dots indicate the places where KLSeis® are installed in China and red dots indicate the locations outside China.

Techniques and Functions

Table 2. Main techniques of KLSeis®

Operational category	Main techniques
Survey Design	3DV bin analysis; Marine, TZ and OBC survey design; VSP survey design; P-sv wave survey design.
Parameter optimization	Geological model building; Model based illumination analysis; Parameter analysis.
Data QC	Data quality analysis; On-site real-time QC.
Statics	LVL survey data processing; 2D & 3D statics; P-sv wave statics.

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The modules and geophysical functions of KLSeis® can be classified into four main categories. Table 2 lists the different categories and the main techniques of each category.

KLSeis® includes nearly all the techniques, and certainly all functions, for conventional surface seismic survey design and for VSP and OBC survey designs. BGP has expanded a great deal of effort to enhance the functionalities in KLSeis® based on our extensive experience and user feedback. As a result, it extremely convenient and efficient for users to carry out conventional survey designs. For instance, the incorporation of satellite imagery and digital elevation model (DEM) of a survey area generates a true 3D view of the survey area and, therefore, the obstacles to acquisition can be understood clearly when designing source and receiver locations (Figure 2). Furthermore, the function of flying over the scalable 3D survey display allows the user to "fly through" the whole survey area or to examine the details of any source or receiver point and make adjustments when necessary during survey design. Once the geometries are set, the depth and spatially variant fold coverage can be viewed in different ways (Figure 3).

Application examples

The following shows some application examples of the techniques and functions of KLSeis®. Figure 2 shows a 3D vision of a survey area by the incorporation of satellite image and surface elevations where farm fields, roads and other obstacles can be clearly seen during survey design. What is shown in Figure 3 are the different displays of the depth and spatially variant fold coverage of a 3D survey.

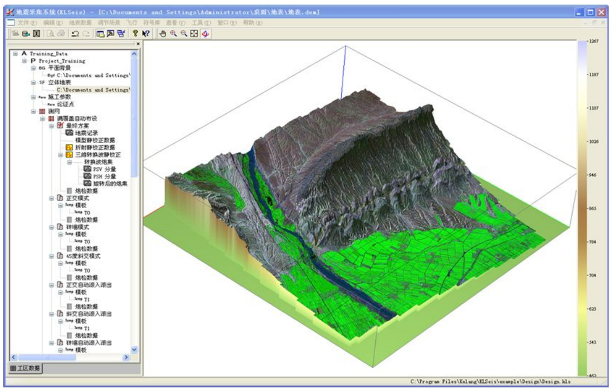

Figure 2. The 3D view of a survey area incorporating a satellite image and digital elevation model (DEM). Farm fields, roads, and obstacles can be clearly seen during survey design.

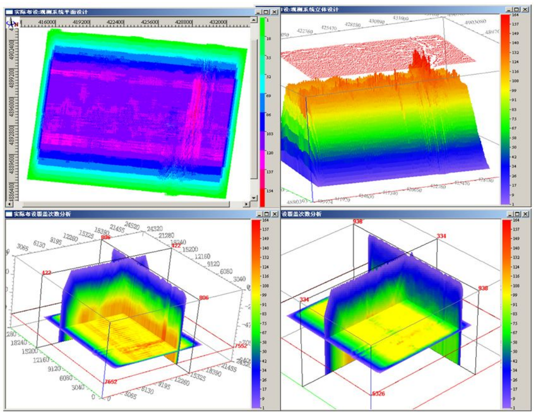

Figure 3. Different displays of depth and spatially variant fold coverage. Upper left panel is a map view of the fold coverage of a survey. The other panels display different perspective views of the depth and spatially variant fold coverage of this survey.

GeoEast®

History and distribution

The design and development of GeoEast® began in 2003, and BGP officially released the first version of GeoEast® (V1.0) in 2005. Following the initial release, new updates and newly developed techniques were added to GeoEast®, forming the intermediate version V2.0. The latest version, GeoEast® V2.2, was released in 2009. The main processing and

interpretation techniques and functions in each version of GeoEast® are shown in Table 3. GeoEast® is currently used in China and has been installed on 7749 CPUs.

Table 3. History of GeoEast®

Release year	Version	Updates
2005	V1.0	Conventional data processing techniques; Structure interpretation techniques.
2008	V2.0	Velocity model building; Prestack time migration; Marine data processing; VSP data processing; Seismic attribute extraction.
2009	V2.2	Prestack depth migration; Seismic attribute extraction, processing and analysis; post stack and prestack seismic inversion.

Techniques & Functions for data processing

Table 4. Main techniques of GeoEast®

Operational category	Main techniques
Statics	Tomo−statics; Total differential refraction statics; Auto reflection statics; Simulated annealing.
Resolution enhancement	Surface consistent deconvolution; Multi−trace predictive deconvolution; Single−trace predictive deconvolution; Spectral modeling decon. & blue filtering; Q−absorption compensation.
Noise attenuation	Linear noise attenuation; Deglitches; Random noise attenuation; Demultiple (SRME, WE, Radon, Beam).
Migration	F−X domain post−stack time migration; Kirchoff PSTM (from rugged surface); Kirchoff PSDM; One−way wave equation PSDM.
VSP	Zero−offest VSP; Non−zero−offset VSP; Walk−away VSP and 3D VSP.
Structure interpretation	Well data processing; Seismic−geology correlation; Seismic data interpretation; Velocity model building and Time−depth conversion; Structure mapping.
Seismic inversion	Broadband Constraint Inversion; Back Propagation Neural Network; Amplitude Versus Angle Inversion; Elastic Parameter Inversion.
Seismic attribute extraction	Dip and azimuth; Curvature; Coherency gradient; Texture; T−F analysis (SFT, GST); Edge detection (1´st−, 2´d−Derevertive, Generalized Hilbert transformation).
Attribute analysis and seismic facies classification	Attribute processing (PCA, KPCA); Attribute analysis and seismic facies classification.

The techniques and geophysical functions of GeoEast® are organized into nine main categories, among which the first five are for seismic data processing and remaining four for seismic data interpretation. Table 4 shows the different categories and the main techniques of each category.

Examples application of data processing

BGP has a long and successful history of seismic exploration in mountainous and desert region. As a result, we have developed a suite of effective and unique techniques processing techniques such as statics estimation and resolution enhancement.

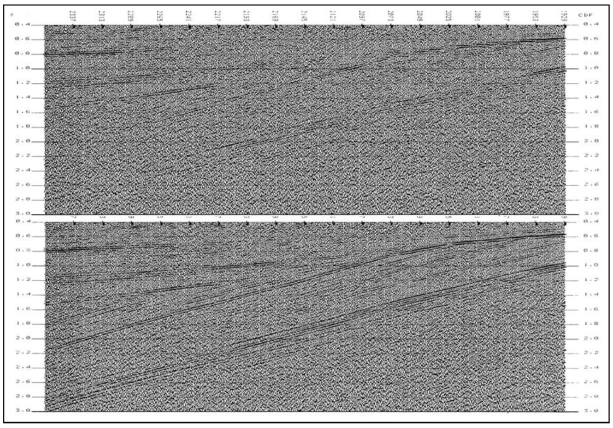

Figure 4. A comparison between BGP´s Refraction−based Total Differential (RTD) statics estimation method and a widely used refraction−based statics method on a 2D desert line. Top panel is the result with field statics followed first by the statics estimated using the widely used refraction−based statics method and then by reflection−based residual statics. Bottom panel is the result using the same statics procedure, but replacing the refraction−based statics with RTD.

Figure 4 shows a comparison of BGP´s Refraction−based Total Differential (RTD) statics estimation method with a widely used refraction−based statics method on a 2D desert line. The top section is the result obtained by first applying field statics and then applying statics estimated by the widely used

refraction –based statics method followed and reflection–based residual statics in that order. The bottom section is the result obtained by using a similar statics procedure that replaces the refraction–based statics with RTD statics. The relevant processing parameters, such as NMO velocities, and mute function are all identical in the two procedures. The difference between the two sections shows dramatically that the result from BGP´s approach is much better.

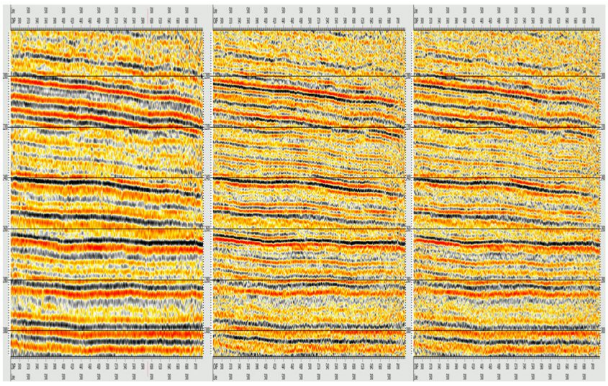

Figure 5 . An application example of BGP´s resolution enhancement techniques on one of the in–line sections of a 3D seismic data. Left: The section with prestack multi –trace predictive deconvolution applied; Middle: The section with first poststack spectral simulating deconvolution and then blue –filtering applied; Right: The section with prestack Q –compensation applied.

Figure 5 shows an example application of BGP´s resolution enhancement techniques. The difference between the results of conventional deconvolution and the other two in terms of both vertical resolution and lateral amplitude consistency is apparent. To meet the ever –growing requirement on multiple attenuation for marine seismic data processing, BGP has developed different multiple attenuation techniques under GeoEast® . These include SRME, wave equation –based, Radon transform –based and time difference–based beam forming techniques. One example application of the wave equation –based multiple attenuation method is shown in Figure 6. It can be seen that the water bottom–related multiple energy is well attenuated.

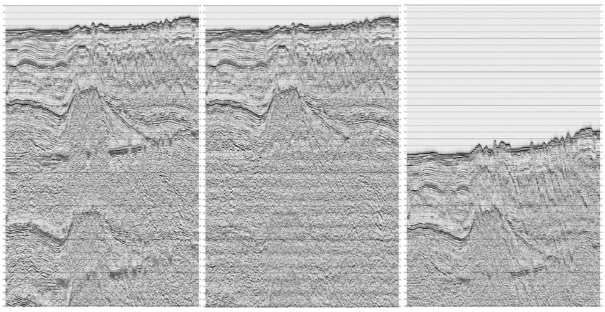

Figure 6. An application example of the wave equation–based multiple attenuation on one of the in–line sections of a marine 3D seismic dataset. Left panel is the section before multiple attenuation; middle panel, the section after multiple attenuation; and right panel, the attenuated multiple energy.

Techniques & Functions of data interpretation

The main techniques and functions for data interpretation in the latest version of GeoEast® are listed in Table 4 under the last four categories. From basic structure interpretation to seismic attribute extraction, to post– and pre–stack seismic inversion, and to attribute process and analysis and hydrocarbon prediction, GeoEast® has a complete set of interpretation techniques and functions to meet the needs of contemporary seismic interpretation.

Application examples of data interpretation

In recent years, GeoEast® has been used in many seismic interpretation projects with different objectives. The following are some application examples of its interpretation techniques or functions. In data interpretation, it is often difficult to track seismic responses of subtle geologic features, for instance, those of subtle faults from isolated seismic sections. However, when the parallel sections are put together, the subtle responses form patterns or trends that are much easier to

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identify. Based on this, we developed a function called "Multi-parallel-section-display-based interpretation" in which the segments of the target horizon on different parallel sections are sequentially displayed in the same window. It is necessary that they be able to communicate simultaneously with each other and to the base map This function is instrumental for the work efficiency and the resultant accuracy. Figure 7 is an example of this function.

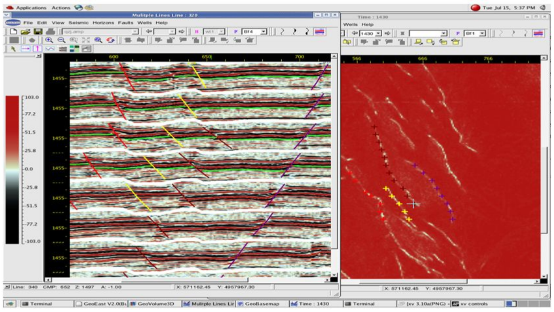

Figure 7. Multi-parallel-section-display interpretation. Left: The parallel sections with different subtle faults picked;Right: Base map showing the picked subtle faults.

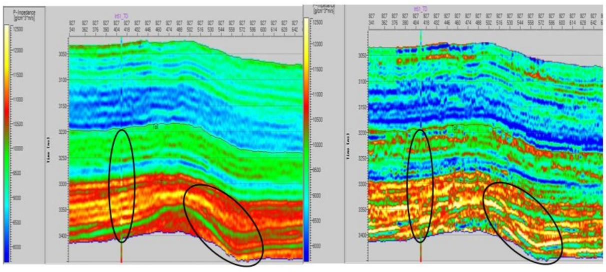

Figure 8. An application example of BCI and BP
Left: BCI results; Right: BP results. The vertical ellipse indicates the only well data that was used for the inversions. The slanted ellipse marks obvious resolution differences.

GeoEast® has four seismic inversion algorithms: post-stack inversion algorithm, Broad-band constrained inversion (BCI) and back propagation neural network (BP), and the prestack inversion algorithm, Amplitude Versus Angle inversion (AVA); Elastic Parameter Inversion. Figure 8 gives an application example of BCI and BP. It can be seen from this example that the BP results provide a much better consistency between well and seismic data (highlighted by the vertical ellipse) and much higher resolution (the slanted ellipse).

GeoEast® has many seismic attribute extraction and processing techniques. Principal component analysis (PCA) and Kernel Principal Component Analysis (KPCA) are the two primary ones for attribute processing. When a linear relationship exists between different attributes, PCA yields betters results. However, when a nonlinear relationship exists between different attributes, KPCA gives much better results. Figure 9 presents an example in which applying KPCA in the case of a nonlinear relationship yields a much clearer delineation of the subtle collapse features.

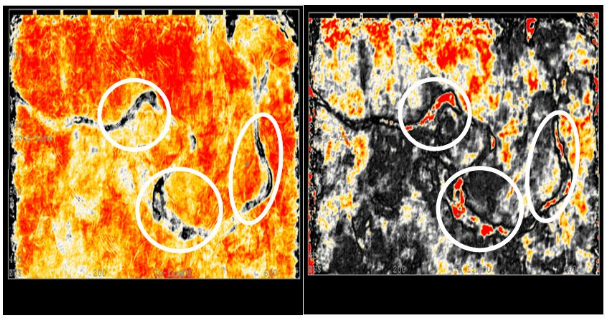

Figure 9. An example of PCA and KPCA results for a case that nonlinear relationship exists between different seismic attributes. Left: the PCA results; Right: the KPCA results. Circles mark the collapse features.

In the near future, we plan to do the following to further improve the abilities of the seismic software systems: 1)Geometry design and analysis for areas with rugged topography and complex subsurface geology. 2)Enhancing and application test of RTM. 3)Development of 3D multi-component data processing techniques. 4)Enhancing and improvement of prestack inversion.