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变速三维地震速度场的构建与应用

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摘要: 二连盆地内的凹陷窄而狭长, 断裂发育, 构造变化剧烈, 速度横向变化快, 常规作图方法难以满足精细构造解释的要求。采用叠前时间偏移后的叠加速度谱生成速度模型, 并用井震标定速度进行校正, 形成高精度的变速三维速度场, 用它对地震层位作时深转换, 较大地提高了构造图的精度。

关键词: 3D地震变速场; 时深转换; 构造成图; 叠前时间偏移; 二连盆地

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0 前言

地震速度对地震勘探的各个环节都会产生影响, 直接影响构造图的精度, 影响井位的部署。提取、分析、利用好速度资料, 是地震解释的重要组成部分。常用的方便快捷的构造成图方法是: 用井资料(声波, VSP)进行时深转换。但该方法在速度横向变化较大地区达不到精度要求, 通常在实际工区中, 井的数量有限或井分布不均匀, 声波曲线长度有限等, 都会造成速度场求取不准确。对于地震解释中的速度问题, 前人已经做了很多工作和探索, 形成了各自的方法和经验(如时变空变速度成图法等)^[1~5]。借助于这些方法、经验, 结合本工区的实际地质情况和资料情况, 作者采用叠前时间偏移的叠加速度谱建立变速场, 并用井的速度进行标定与校正, 形成高精度的变速场, 时深转换精度更高。

1 工区概况

图1是二连盆地呼仁布其凹陷南洼槽研究区示意图(2D、3D联片)。该凹陷南洼槽整体表现为—东断西超的箕状凹陷, 东、西分带明显。自东向

西, 依次发育东部陡坡带、中部洼槽和西部缓坡带。缓坡带中部, 是自阿尔善末期开始发育并持续隆升的鼻状隆起。经研究认为, 该隆起对南、北两翼的构造和沉积, 具有重要的分异作用。洼陷的沉积, 具有近物源、多物源、相带窄、相变快等特点。凹陷受多期构造运动的影响, 断裂极其发育, 构造复杂。在工区有七口井的声波资料, 分布极其不均, 3D区面积约130 km²。

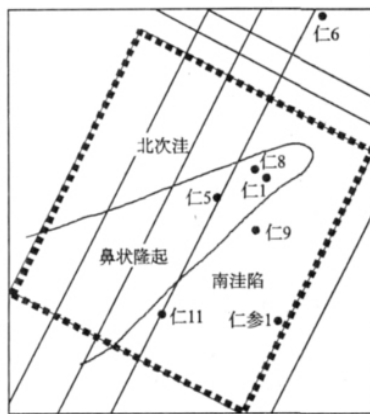


图1 工区示意图(虚线为3D区)

Fig. 1 Schematic map of 3D seismic survey block (dot line) in erlian basin

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在勘探生产中存在的问题之一是地震速度横向变化较快,构造变速成图难度较大。原因是凹陷沉积相带窄,储层横向变化快,造成地震速度横向变化大,使得构造的真实形态难以准确把握,给勘探带来较大困难。我们充分利用地震处理速度采样密集,井点时深关系采样稀疏而精度高的特点,互为补充,以实现高精度的构造成图。另外,通过对圈闭条件的分析认为,呼仁布其凹陷圈闭条件受到构造、岩性、地层等多种因素的影响,圈闭多以复合型圈闭为主,单纯的构造油藏或岩性油藏甚少。但在不同的层段,主要圈闭类型不同,例如:阿尔善组圈闭主要控制因素为构造因素;腾一下、腾一上及腾二段圈闭主要控制因素为岩性因素,构造次之。由此可见精确构造成图的重要性,特别是阿尔善组。

2 地震层位的精细解释

2.1 地质层位的精确标定

地震层位的标定,是构造精细解释的关键环节之一。在井资料处理的基础上,对七口井进行精细的合成记录制作。在单口井完成深时转换的基础上,以标准层(T6)为基础,对所有井的深时关系进行分析和连井地震剖面对比检查。对不合理的深时关系进行调整,最终建立全区各井的合理的深时关系(见图2)。由各井的标定结果看,少部份井的速度变化规律与区域变化规律存在一定差异,仁6井更突出。录井资料揭示,仁6井在腾格尔组钻遇了大套砂砾岩夹少许的薄层泥岩,而工区内的多数井录井显示腾格尔组以泥岩为主,夹薄层粗岩层,它们钻遇了不同的相带。仁6井速度偏高,就与其所处的相带紧密相关,这也说明了在地层内岩性对速度的影响。

2.2 地震层位的精细解释

在地震层位精细标定的基础上,作者展开了全工区的地震层位解释。工区断裂发育,地震反射特征横向变化快,特别是断裂两盘,可比性差。在解释过程中,充分利用解释系统给我们提供的对比手段,进行多相位以及波组波系的对比,综合判断确定同一界面。在3D区我们还采用绕过断裂,抽取多个方向的多条任意线及过井线,用于层位的确定与解释结果的检查,并利用三瞬剖面、COSIN剖面、相干体切片等资料辅助解释。在低点、高点加

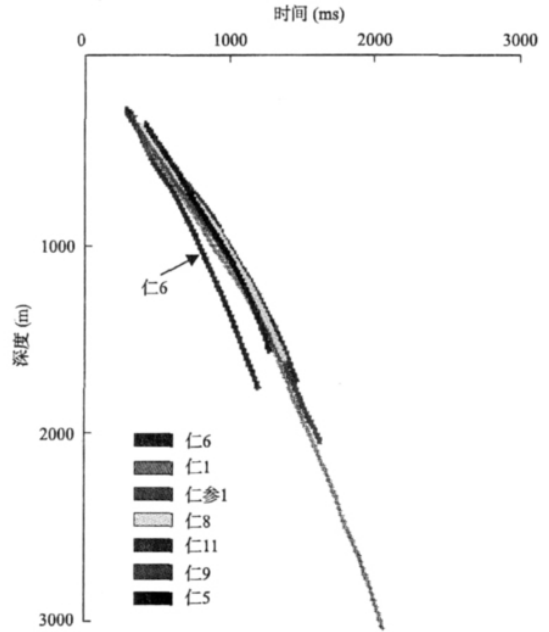


图2 七口井的时深关系叠合图

Fig.2 Time ~ depth relations from 7 wells

密解释网格,以确保解释的层位、断层更精细准确,为构造成图奠定基础。

3 用叠加速度谱建立高精度的速度场

由于工作区内钻井少,分布局限,而且仁6井区存在高速异常,要恢复真实构造形态,空间速度场的建立是核心^[5,9]。

3.1 用 DepthTeam Express 建立本工区速度模型的流程

精确的速度建模,是关系到构造解释精度的关键因素之一。本工区断裂多,钻井少,构造起伏大,结合具体情况,我们用井上的TD关系、叠加速度谱、地震解释层位等,综合建立工区的速度模型,流程如下页图3所示。

建模过程都有3D可视化实时监控,随时发现异常,分析原因,及时修正。

3.2 叠加速度谱分析

叠加速度平面上分布均匀而密集,纵向、横向的变化是地下地质情况的综合反映。3D区在In-Line和CrossLine上,每500m有一个速度谱点,可见速度谱资料的丰富,这为建立高精度三维速度场提供了基础。我们知道,地震叠加速度是基于传统

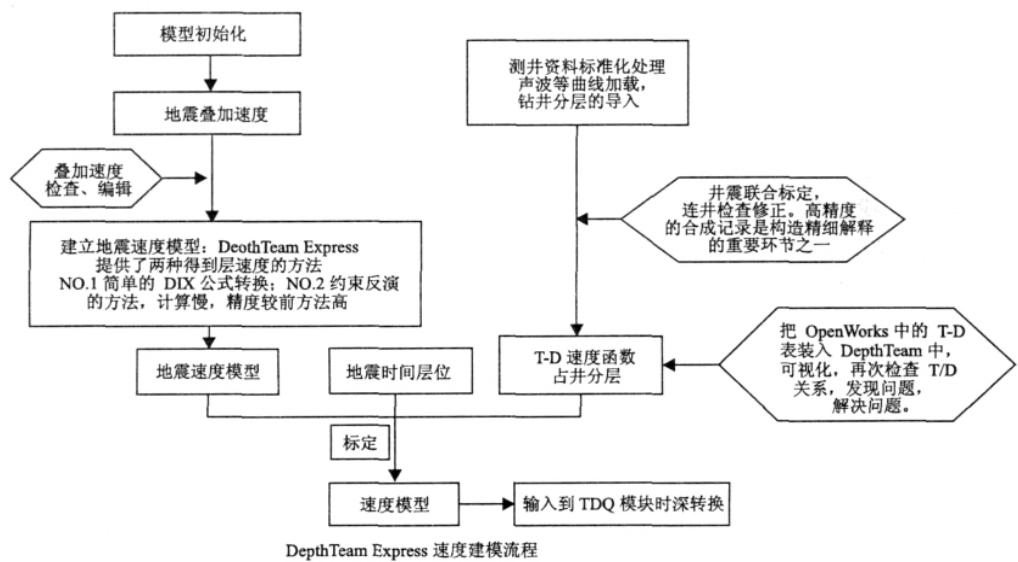


图 3 速度建模流程

Fig. 3 Flowchart of velocity model building

的水平层状介质和共 CMP 道集反射波时距曲线为双曲线的假设进行分析的。尽管采用的是叠前时间偏移后的速度谱资料, 我们仍然需要对叠加速度进行分析和必要的编辑。整个速度分析是在 DepthTeam 软件中完成的。首先我们把叠前时间偏移的迭加速度数据, 加载到 DepthTeam Express 模块中, 继而可以得到各种速度, 对这些速度体进行 3D 显示, 调整透明度, 旋转目标, 动画显示, 从多方位的展示和观察速度体, 找到异常点, 对异常的速度, 结合地震剖面、相邻的速度谱和所在层段的沉积相, 分析其原因, 保留真实的变化。在对速度谱精细分析编辑后, 并进行适当的平滑, 为三维速度场建立打好基础。

图 4 是抽取的北次洼和南洼中几个点的平均速度, 南洼的地震平均速度特别是在 1.4 s 以下, 明显低于北次洼。从我们的地震层位解释来看, 北次洼基底埋藏浅, 沉积盖层薄, 这也说明速度受构造起伏的影响, 所以在模型建立时, 应该利用构造信息。

3.3 井上 T/D 函数的速度场检查

尽管做了单井、连井的时深标定, 但由 T/D 函数建立的速度场在空间上是否合理, 需要在 3D 可视化中观察。把数据库中经过标定校正后的各井的时深关系, 加载到 DepthTeam Express 中进行立体显示, 多方位观察, 检查各井之间的协调性, 对不合理的时深点进行剔除编辑, 并在窗口内显示所有

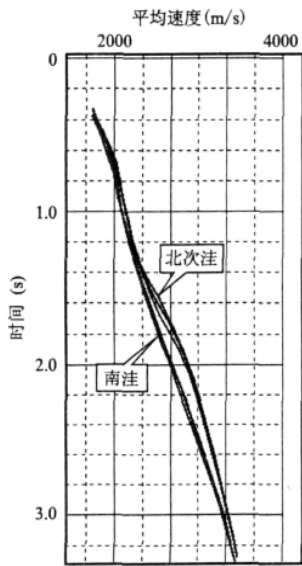


图 4 地震平均速度

Fig. 4 Seismic average velocities

被编辑曲线的综合图, 判断编辑的结果, 建立可靠的井上 T/D 函数的速度场。

3.4 层速度场的建立

在速度谱精细分析及编辑的基础上, 在层位约束下建立速度模型。用 DepthTeam Express 提供的约束反演的方法, 把叠加速度模型转换成层速度模型, 并用井震标定后的时深关系, 钻井分层, 时间层位, 对速度模型进行标定^[2~9]和层位约束下的插值, 形成精度较高的速度模型。

3.5 沿层平均速度的求取及比较

将 DepthTeam Express 建立的速度场传输到 TQD 中,这样既可以直接对层位作时深转换,也可以提取平均速度体,并按公式: $H = V * T/2$ 进行深度求取,二者差异较小。为了直观地反映不同速度体的沿层展布情况,我们沿层提取了平均速度。

现以腾一段的顶(T6)为例加以比较。图5是井震标定后,求得的沿T6层的平均速度平面图。

图6是用以处理速度为基础,建立的地震速度场沿T6层的平均速度平面图。

图7是地震速度体经过校正后,沿T6层位的平均速度平面展布(虚线)。经过分析比较我们认

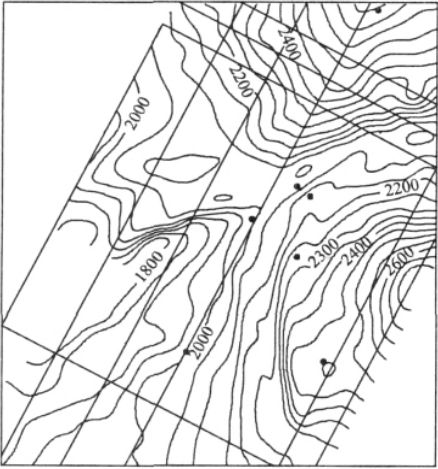


图5 井上的沿T6层的地震平均速度平面图
Fig.5 Seismic average velocity contour for layer T6 after calibration to well log

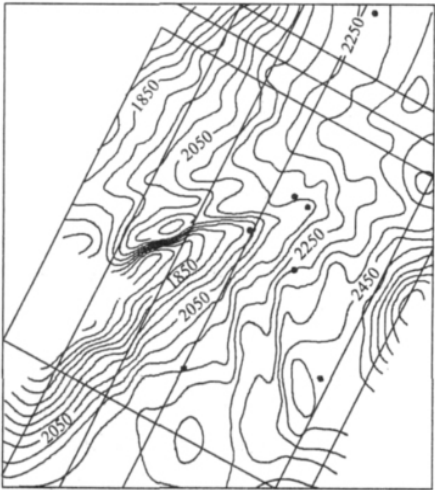


图6 叠加速度建立的速度体沿T6层的平均速度
Fig.6 Seismic velocity contour for layer T6 based on stacking velocities

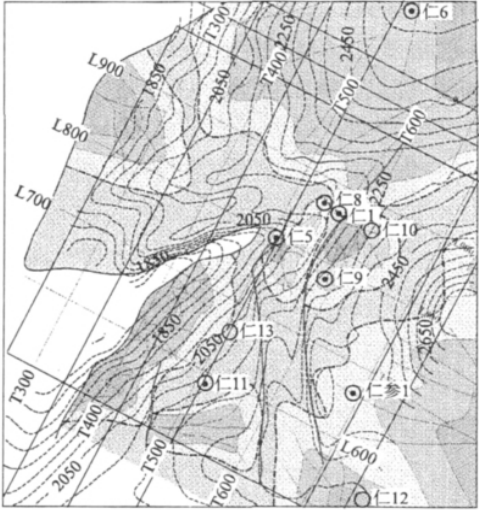


图7 校正后的平均速度(虚线)与腾二段沉积相图(灰黑色块)叠合
Fig.7 Revised average velocity contour plus sedimentary facies of formation Teng 2 (dash line - average velocity)

为,图7既反映了趋势,又能体现细节。

4 效果分析

我们用校正前、后的速度体,分别对T6和T8反射层进行了时深转换,并进行了误差统计(见下页表1)。从表1中可以看到,仁6井用校正前的速度计算的深度误差大,原因是仁6井在2D区,缺少处理的速度谱资料,2D区的速度来自3D的速度趋势外推,因此不能准确反映仁6井区的真实情况,造成了大的误差。而在3D区的井,除个别层位外,都在50m以内,利用处理速度资料建立地震速度场,用于无井区的变速构造图,是不错的选择,特别是浅层。而用标定后速度场做时深转换的误差(见表1),除个别层位外,均在十米以内。由此可见,经过标定后的速度模型,完全满足时深转换的需要。通过我们的实际应用,说明利用处理速度、钻井时深关系,建立变速场,实现变速构造图,在该凹陷的应用是成功的。

5 结束语

通过综合运用叠加速度信息、钻井资料信息、地震层位等多种信息建立变速速度场,用以恢复地下的真实构造,进行时深转换。通过与井的对比,

表 1 井上钻遇深度与计算深度误差表

Tab. 1 Errors between calculating depth and drilling depth for the same layers

井名	层名	地质分层	标定前速度体计算深度 (m)	绝对误差 (m)	标定后速度体计算深度 (m)	绝对误差 (m)
仁参 1	T6	1761	1744	- 17	1758	- 3
	T8	2681	2732	51	2684	3
仁 1	T6	1035	1022	- 13	1046	11
	T8	1419	1390	- 29	1411	- 8
仁 5	T6	753	722	- 31	754	1
仁 6	T6	1213	1101	- 112	1226	13
	T8	1622	1435	- 187	1620	- 2
仁 8	T6	1018	1042	24	1012	- 6
	T8	1302	1340	38	1308	6
仁 9	T6	1331	1324	- 7	1332	1
	T8	1971	2018	47	1960	- 11
仁 11	T6	956	1004	48	962	6
	T8	1437	1502	65	1430	- 7

收到了良好的应用效果。在速度场的建立中,需要注意:

(1) 速度分析基准面与最终成果剖面基准面是否一致,若有差异,要把基准面统一起来。

(2) 在速度模型建立时,平面上的道间隔,纵向上的时间间隔参数需要调试,选取适合工区的参数。

(3) 利用 3D 可视化,速度体切片以及单谱点和多谱点叠合,综合分析原始速度谱的品质,对异常谱点进行编辑,并进行平滑去噪处理。

(4) 地震层位的解释追踪,尽量使层位与井震标定后的钻井地质分层相吻合,为了能控制工区地质构造特征,约束层位要多,至少要包括标志层、不整合面,以及能控制不同年代构造特点的反射层。

(5) 尽可能多地利用钻井资料,钻井资料越多,速度场精度越高。

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ABSTRACTS

CHARACTERISTICS AND IMPLICATIONS OF THE SEISMIC ABNORMAL RESPONSES OF CARBONIFEROUS HUANGLONG FORMATION IN FULING AREA, SOUTHEASTERN SICHUAN BASIN

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Fuling area is located in southeastern Sichuan basin. Through carefully seismic interpretation of Huanglong formation of carboniferous in Fuling area, there are four typical seismic responses in reflecting structure as follows: ① The amplitude of both peak and trough of seismic are medium to weak. ② Peak amplitude with phase axis pulled down present as strong or weak, and above trough amplitude is high to medium. ③ Seismic phase axis is pulled down clear and the amplitude is medium to weak, and amplitude is weakens lower with the seismic phase axis pulled down clear. ④ Seismic amplitude is weak and close to nil trace. Based on the theoretical models of karst units developing and sedimentary characteristics in this area, the four seismic responses in reflecting structure which we mentioned above probably means four different geologic origins, which respectively represented: A. developing of karst positive topography and karst negative topography; B. developing karst caves that are filled by mud completely or certain mud or developing high - porosity reservoirs; C. developing fissures and caves that are filled by much mud or not entirely filled that performances low speed in seismic profiles; D. identifier of Huanglong formation which is deposited seven to nine meters or the sediment thickness is less than that. Meanwhile, the seismic forward modeling for the four geologic origins is matching for the four typical seismic responses in reflecting structure well. All those study results based on specific structure in seismic profiles can be used to predict the new type of reservoirs and effective to search for new alternative exploration zones for more gas discovery in Fuling area.

Key words: seismic reflecting structure; seismic response; seismic forward modeling, Huanglong formation, southeast region of Sichuan basin

SEISMIC SPACE INSTANTANEOUS PARAMETER ANALYSIS AND ITS APPLICATION

HE Xi-lei^{1,2}, HUANG De-ji², WEN Xiao-tao², et al. (1. State Key Lab. of Oil and Gas Reservoir Geology and Exploration, Chengdu University of Technology,

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As a comparison to conventional instantaneous parameter analysis based on complex trace analysis in time domain, a new method, space-instantaneous parameter analysis (SIPA), is proposed in this paper, which changes the harmful singular values in seismic complex traces into effective information and is more useful in lateral prediction of reservoir. This method recombines seismic data along horizon to form varying reflection amplitude signal traces which are used as real traces to process space instantaneous complex trace analysis, and calculate out the space instantaneous parameters. The change points of lateral amplitude are just these singular points which are not satisfied with the summary of analysis conditions and characters, the singular point corresponding to the singular value are just correspond to geological structure catastrophe points along the horizontal layer, the relative change ratio of instantaneous phase and wave-number along the horizon is greater than that of amplitude. Consequently, SIPA can effectively detect fault, crack, fracture - rich zone, channel, fringe and other lithological pinch - out points. The results of numerical modeling and fractured reservoir prediction with real seismic data in Y area show that the above conclusion is correct.

Key words: space-instantaneous parameters; complex trace analysis; reservoir prediction; fracture-rich zone

STRUCTURE MAPPING WITH TRANSVERSELY VARIABLE 3D SEISMIC VELOCITY MODEL IN ERLIAN BASIN

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Depressions in Erlian Basin are long and narrow with complex faults and structures. Challenges for correct structure mapping include complex structure imaging and sharply lateral variable velocity analysis. Traditional methods by using stack velocity spectrum do not meet the demands of high precision seismic interpretations. The improved structure mapping in this paper involves the following steps: (1) creating velocity model by stacking velocity spectrum based on seismic pre-stack time migration data; (2) calibration of the velocity model with well log and seismic data and building up a transversely variable 3D seismic velocity

model; and (3) implementing time-depth conversion for target layers using the revised velocity model. Real seismic data processing in Erlian Basin shows that the transversely variable 3D seismic velocity model can be used to improve complex structure mapping.

Key words: 3D seismic velocity model; time-depth conversion; structure mapping; pre-stack time migration; erlian basin

SUPPRESSING NUMERICAL DISPERSION IN FINITE DIFFERENCE MODELING BASED ON ACOUSTIC AND ELASTIC EQUATION USING FCT SCHEME

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Numerical dispersion inevitably exists in numerical simulation based wave equation, which is also called grid dispersion and usually affect the result of numerical simulation badly, therefore, in the process of numerical simulation, the problem must be managed to solved. On the basis of the research result the other people have achieved, the paper uses the flux-correction transformation scheme to eliminate numerical dispersion existing in numerical simulation based on elastic wave equation in isotropic media. The result of numerical simulation shows that the scheme can eliminate the numerical dispersion effectively and improve the quality of numerical simulation greatly.

Key words: elastic wave equation; isotropic media; finite difference; numerical dispersion; FCT scheme

JOINT S TRANSFORMATION AND TT-TRANSFORMATION METHOD OF SURFACE WAVE SUPPRESSION

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TT transformation (Time-Time transformation) is a new method to process non-stationary signal based on S-transform, it has a good ability of frequency conversion. The surface wave, with lower frequency compared with other seismic wave, can be suppressed through extracting the TT spectrum's diagonal elements of seismic data. However, this method has a deficiency that in pressing low-frequency signal, a part of high-frequency interference is retained that can be eliminated by S transformation. Firstly, we apply S transform time-frequency filtering for each trace seismic data to suppress the high frequency interference and random noise, then, use TT filtering to suppress the surface wave with low frequency. Finally, we use this method to real seismic data processing, and compare it with the traditional high-pass filter method. The result reflects the effective of TT transform in suppressing surface wave.

Key words: surface wave suppression; time-frequency analysis; S-transformation; TT-transformation

WAVEFORM CONSISTENCY SHAPING METHOD AND APPLICATION IN SEISMIC MERGING PROCESSING IN DAQING XUJIAWEIZI DEEP GAS RESERVOIR

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Waveform consistency is an important factor in seismic merging processing, the waveform difference is small in seismic data processing of single block because the properties of the sources and receivers are similar. The wavelet amplitude, frequency and phase are different in multi-blocks processing because the data acquisition is in different time and also, the data has different source and receiver properties. The method of frequency consistency, amplitude consistency and deconvolution are applied to adjust the relationship between wavelet frequency and phase for different seismic data and different blocks in conventional seismic data processing, but the above consistency processing can reduce the seismic data prestack processing quality. The unified waveform consistency processing is presented in this paper, the proposed method can eliminate the waveform difference which results from the source type and acquisition factor in different blocks, the crosscorrelation coefficient of wavelet in different block is above 0.9, that means, the original data quality is kept efficiently during the course of prestack consistency processing. We have got good result in waveform consistency processing in 19 blocks, about 5 058.8 km² in Xujiaweizi, this is also the biggest 3D seismic onshore data merging processing in China.

Key words: seismic data merging processing; waveform consistency; wavelet shaping; crosscorrelation coefficients; prestack migration

ABSORPTION COEFFICIENT EXTRACTING METHOD BASED ON DYNAMIC WAVELET ESTIMATION

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Wavelet extraction based on convolution-model, we often assume the minimum-phase wavelet. Although phase shift and Q-compensation can be adopted in seismic data processing, the extracted wavelets from real seismic data is mostly mixed-phase. The most common way to extract absorption coefficient is seismic trace spectrum modeling, i. e. using the smoothed amplitude spectrum of the seismic trace to substitute wavelet amplitude spectrum, but this brings in error, also create more uncertainty while interpreting.