2022_“ShuWei Cup”

Problem A：Automatic seismic horizon tracking

With the economic and social development of our country, the importance of geological work is also increasing. Seismic data interpretation is an important stage of seismic exploration engineering, which can clarify subsurface tectonic features for oil and gas exploration and can provide good and favorable reservoirs for oil and gas exploration; accurate stratigraphic information is the basis of seismic data interpretation and is an important basis for storage prediction. Seismic horizon tracking is one of the key technologies in seismic data interpretation, a good seismic horizon tracking method can greatly improve the efficiency and accuracy of seismic data interpretation.

It is the main goal of seismic exploration to obtain the information of underground structure lithology and reservoir, because the main formation interface is generally a good wave impedance interface, the seismic wave is affected by the formation interface when it propagates in the underground medium, and finally shows different seismic reflection characteristics, such as the morphology, intensity, frequency and continuity of the homogeneous axis of seismic reflection. Structural information such as the shape and burial depth of the stratigraphic interface can be obtained directly from seismic data. Since this kind of structural information is the most intuitive and easily used information of seismic data, it has become one of the most important targets of seismic exploration to extract structural information from seismic data since the birth of seismic exploration technology.

In reflected seismic data, the seismic wave impedance interface usually corresponds to the formation interface or lithologic interface, but the lithologic interface can not always form wave impedance interface, only in those adjacent formations with large enough wave impedance difference can form wave impedance interface. Although the lithology of strata formed in different geological ages is usually different, only through the alternation of sedimentary compaction and sedimentary hiatus in millions of years can the differences in rock physical properties (density, porosity, etc.) between adjacent strata be revealed, the combination of lithology and rock physical properties (differences) will form significant wave impedance differences, therefore, seismic reflection events axis on seismic profiles usually correspond to sedimentary isochronous surfaces rather than macroscopic lithological interfaces. According to this theory, the stratigraphic interface indicated by seismic events axis is the discontinuity of the stratigraphic deposition process, because of its relative isochronism, this sedimentary discontinuity is basically consistent with the structural characteristics of the stratum, therefore, seismic events axis is the main signs to identify the stratigraphic interface. The spatial distribution characteristics and time domain variation characteristics of seismic events axis are the main basis for horizon interpretation. Seismic events axis can also be used to obtain information such as stratigraphic dip and azimuth.

In the era of two-dimensional seismic exploration and the early stage of three-dimensional seismic exploration, the horizon interpretation of seismic data is mainly single-layer, that is, several seismic events axes with good continuity corresponding to the strong stratigraphic reflection interface are selected from the seismic profile for tracking. Because of the low efficiency of this horizon interpretation method and the small number of seismic event axis that can be easily traced on the seismic profile, the number of horizons that can be obtained is limited, resulting in the traditional seismic structure interpretation model unable to obtain detailed geological structure information, so the detailed description of geological structure characteristics is not clear enough. In other words, the traditional seismic horizon interpretation method ignores or wastes a lot of seismic information, and it has been unable to meet the requirements of modern seismic structure interpretation and geological comprehensive research in terms of accuracy and efficiency. With the development of three-dimensional seismic exploration, especially high-density seismic exploration technology, the accuracy of seismic data obtained is getting higher and higher, and the number of seismic data is increasing, automatic extraction of structural, lithological, fluid and other information from seismic data has become the key to the progress of modern seismic data interpretation, it is also the goal that geophysicists and geologists are striving for.

The existing seismic horizon tracking methods are usually done manually by seismic horizon interpreters. In the interpretation of seismic data, the tracking of the event axis is very important. Interpreters are mainly based on seismic wave dynamics and kinematics characteristics, namely amplitude, in-phase or continuity, waveform similarity three criteria, and artificial contrast tracking. The artificial horizon tracking is to manually track the continuous reflection events axes of the bottom layer on the two-dimensional seismic profile by using the waveform similarity to obtain the horizon line (stratigraphic interface), and then interpolate all the horizon lines to form the horizon surface. However, artificial horizon tracking labor cost demand is large, not only time-consuming, but also has a great impact on the efficiency of seismic exploration.

In order to overcome the problems of low tracking time efficiency and poor reliability of results, researchers have begun to attach great importance to the automatic horizon tracking method in recent years. The automatic horizon tracking method is to search for ' seed points ' with similar characteristics on seismic traces, search through these characteristics, and search the next region repeatedly after meeting the conditions. This method solves the problem that it is difficult to obtain artificial horizon information when the terrain is more complex, and the information obtained is more accurate than that obtained manually.

At present, there are two better automatic horizon tracking criteria, namely automatic tracking based on waveform characteristics and automatic tracking based on correlation. Automatic tracking based on waveform features is to find only similar waveform structures (crests, troughs, zero crossings, etc.) of feature points in the search time window, but no correlation calculations are performed between the seismic traces, and the defined troughs, crests, and crossings are searched one by one. Because the continuity and stability between the local areas of the underground are reflected in the seismic time profile, it is the similarity and continuity of the seismic wave reflection layer in the amplitude of the seismic wave reflection layer on the adjacent seismic channel. Therefore, based on the relevant horizon automatic tracking algorithm, the seed point is taken as the center, according to the relevant time window range, a seismic channel is selected, and the seismic data of this section of seismic data is correlated with the seismic data in the search time window of the adjacent channel, if the characteristic point that meets the conditions is found in the search time window, the point is fixed as a new seed point, and then the next trace is picked up.

Please establish a mathematical model based on the attached data to solve the following problems:

（1）There are often a lot of noise in seismic data, please use effective methods to denoise the accessory data.

（2）Establish the correlation of seismic strata automatic tracking model or design the corresponding new tracking algorithm, and track the attachment data.

（3）Establish an automatic tracking model based on waveform features or design a corresponding new tracking algorithm, and track the attachment data.

（4）Evaluate the results of two automatic tracking models (or algorithms), verify the rationality of the model, analyze the error between the data obtained from the experiment and the actual data, and make a reasonable explanation.

（5）Establish a three-dimensional horizon automatic tracking model based on correlation and waveform, and an algorithm is implemented on the data given in the annex to realize horizon tracking and identify and analyze the fault data.

Notes:

A profile is made up of a set of curves, horizon tracking, is to trace the event axis. An event axis on a profile is a curve, and multiple event axis bar curves, make up the horizon.