Interpretation of Seismic Reflection Data

- ***Introduction:***

Seismic interpretation is the third and last stage in the seismic exploration project. In the two preceding stages (data acquisition and processing), reflected waves were first generated, then processed to give the stacked seismic sections (or data volumes) in a form ready for the concluding exploration stage which is the data interpretation. This involves transition of these seismic data into the corresponding geological information.

To aid in the interpretation process, additional geological and geophysical data are made available to the interpreter to use. These data include the velocity field, sonic logs, and density logs which are normally obtained from well logging and VSP surveys.

The interpretation process aims at extracting of geological information from the seismic stack data. The scope of interpretation is now extended to include exploring stratigraphic changes and direct hydrocarbon detection. In addition to isochrones and structural depth maps, modern interpretation activities include modeling (direct and inverse modeling) and computing of seismic attributes.

- ***The Seismic Interpretation Tools:***

The geological nature of an area can be divided into two main types of geological changes: the structural and the stratigraphic changes. On this basis, it is possible to divide the seismic interpretation techniques into two main approaches (interpretation tools). These are: the travel-time tool and the waveform tool.

1- The travel-time tool:

Reflection travel-time computations lead to the determination of the variation of the reflector depth along the seismic line, folding and faulting are mapped with this tool.

2- The waveform tool:

The spectrum structure of the reflection wavelet is a function of the physical properties of the rock medium through which the seismic reflection wave has traveled. The wavelet amplitude ,acoustic impedance and frequency are influenced by the rocks physical properties as lithology, porosity, and fluid contents. In other words, the waveform changes serve as an effective stratigraphic interpretation tool (fig 12.1).

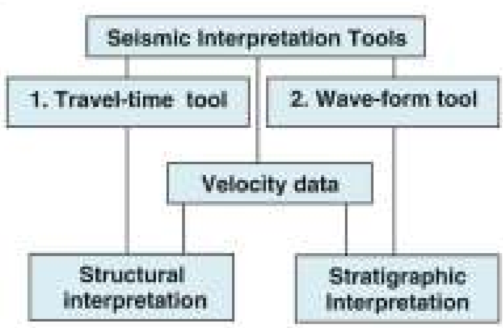

Fig. 12.1 The two interpretation-tools: the travel time tool for structural interpretation and the waveform tool for stratigraphic interpretation

➢ *The Seismic Structural Interpretation:*

This approach represents the conventional way of interpreting seismic reflection data Essentially, this involves measuring the two-way vertical time at the CMPs of the stack section (migrated stack section), and plotting the values, relative to a defined datum level, along the seismic line. For each reflector of the studied area, the three-dimensional structural picture is established. The end result is presented in the form of a time (or depth) contour-map. The interpreter usually produces a time-map (called time structural map, or isochron map) which can be converted into depth structural map using the appropriate velocity field of the area. Due to the velocity vertical and lateral variations, the two contour maps (the time- and the depth-maps) are expected to show some dissimilarity. In addition to the geometrical shape of reflectors, another set of maps showing changes of formation thicknesses are calculated. Reflection time-intervals between two adjacent reflectors are computed and converted into thicknesses using the corresponding interval velocity. The resulting maps (called isopach maps) are used in the studies of sedimentary environments, in sediment-source zones, and other geologic changes.

➢ *Structural Interpretation Sequence:*

The standard sequence involves four main steps: 1-reflection identification,2- the isochron map, 3-the velocity map, and 4-depth map computations (fig12. 2).

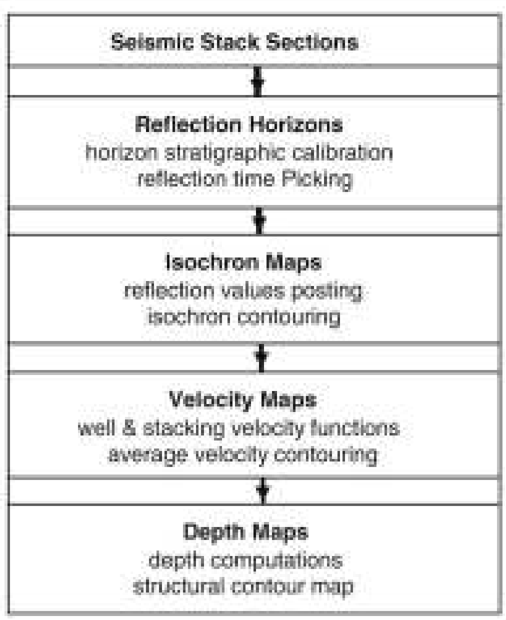

Fig. 12.2 Standard sequence normally followed in seismic structural interpretation

- ❖ Reflection horizons are chosen based on their continuity and amplitude strength (high signal-to-noise ratio).
- ❖ The picked reflection values are posted onto the seismic lines at regular intervals, and then a contour map is drawn to produce the isochron map.
- ❖ The velocity functions obtained from well velocity surveys, or VSP surveys, and the stacking velocity.
- ❖ At each CMP of the area, a depth value ($z = vt/2$) is computed from the velocity value (v) and the reflection two-way vertical time (t) which is known at that point.

➢ *The Seismic Structural Features:*

The simplest structural form of a reflection event appearing in a seismic stack section is the horizontal reflection horizon that has no geometrical deformations. In real world, reflection events are often affected by structural distortions of different types and different forms. The most common types of distortions of reflection horizons are <u>folding and faulting features</u>.

1- The Seismic Image of Folding:

Reflection horizons can be simple linear horizontal or dipping events. The horizons may be affected by folding of various degrees of intensities (Fig. 12.4). Most common folding features which may be observed in seismic sections are anticlines, synclines, and monoclines.

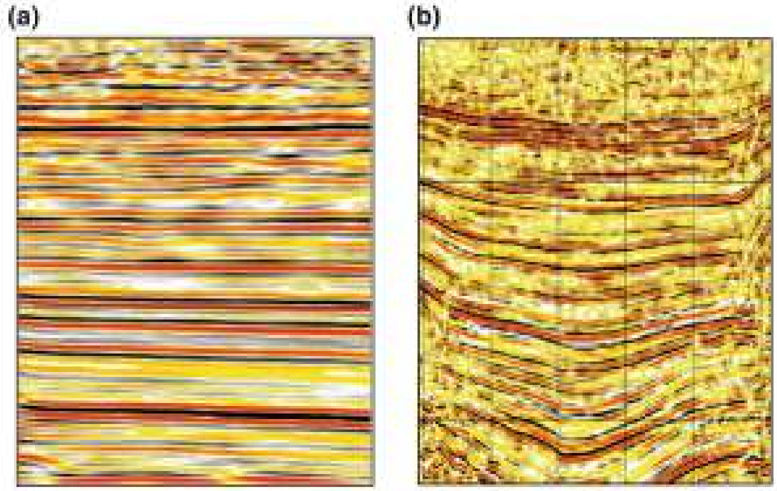

Fig. 12.4 Examples of seismic stack sections showing **a** practically horizontal and **b** folded horizons

2- The Seismic Image of Faulting:

A fault feature appears on a seismic section as a break in the reflection event with some shift in the vertical (and/or horizontal) of the two faulted parts(Fig. 12.5). The fault zone is appear with some local deformations (as layer dragging or sagging) in addition to rock fracturing. In unmigrated sections, terminating reflectors show diffraction events due to the arrivals of diffracted waves from reflector termination points. The hyperbolic diffraction curve is located directly over the diffraction source which is the faulted end of the affected reflector(Fig. 12.6).

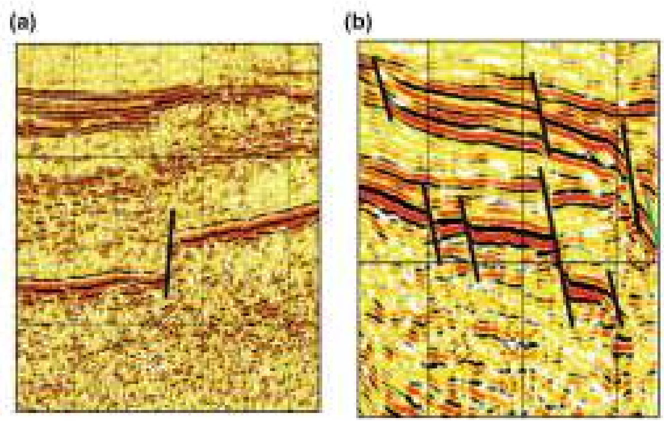

Fig. 12.5 Examples of seismic stack sections showing faulted reflection horizons. **a** Section showing one normal fault and **b** Section showing several normal faults

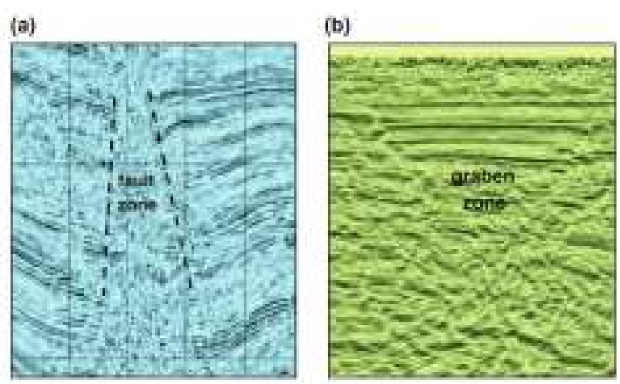

Fig. 12.6 Examples of seismic stack sections showing, **a** Deformation in the fault zone, and **b** Double-fault (graben) zone

- ***The Seismic Stratigraphic Interpretation:***

As it is mentioned above, this approach is depending on interpreting the changes of the reflection waveform rather than the reflection travel-time. The main objective of stratigraphic interpretation is the determination of the types of stratigraphic features appearing on seismic sections. Typical examples of such features are: facies changes, sand lenses, reefs, and unconformities. Each physical property of the travel path has its own signature on the travelling seismic wavelet. These changes imposed by the different properties of mineral and fluid contents (water, oil, or gas) can be considered as messages waiting for unraveling and understanding their geological implications.

- ***Basic Stratigraphic Concepts:***

In studying a stratigraphic phenomenon, two closely related aspects need to be considered, geological and geophysical aspects. A summary of the basic definitions and concepts of seismic stratigraphy is given as follows:

1- Seismic Stratigraphy and the Depositional Sequence:

Seismic stratigraphy, that includes sequence analyses and reflection events configuration patterns. A depositional sequence (time-stratigraphic unit) is therefore defined as a set (package) of sedimentary layers . The unit-package (sequence) is usually bounded by an unconformity surface at both its top and its bottom.

2- The Seismic Sequence:

This is the expression of a depositional sequence as a seismic image appearing on a seismic section. It is a group or package of seismic reflection events which are bounded by unconformity surfaces at both of its top and base.

3- The Seismic Facies:

This is a genetically related set of seismic reflection events appearing on a seismic section, corresponding to a given set of sedimentary rock-types (lithofacies).

4- The Seismo-Stratigraphic Analysis:

Seismo-stratigraphic analysis is the interpretation-process to extract stratigraphic features from seismic data. It involves two levels of analysis: seismic-sequence analysis followed by seismic-facies analysis that deals with the seismic lithofacies within each seismic sequence.

- ***Reflection Configuration Patterns:***

Reflection configurations representing seismic facies found within a seismic sequence can appear in the form of simple or complex patterns. Simple parallel reflection events are generally representing shallow-water shelf deposits, while complex, sigmoidal-shaped events are representing down-slope depositional environments, as those deposits taking place at shelf edges. The main seismo-stratigraphic patterns are briefly presented as follows: