BRITISH LIBRARY

DOCUMENT SUPPLY SERVICES

Your order details

Our Order Ref: 01006131-001
Your Ref: 439520US
Despatched on: 10/10/2014

Your shipping address

Your item details

UIN: ETOCEN015628327
Title: World oil.
Publisher: GULF PUBLISHING CO
Year: 1994 **Volume:** 215
Issue: 4
Pages:
Author name(s): Risch, D. L. Chowdhury, A. N. Hannan, A.

Comments

Thank you for using Document Supply Services!

Copyright Statement

Unless out of copyright, the contents of the document(s) attached to or accompanying this page are protected by copyright. They are supplied on condition that, except to enable a single paper copy to be printed out by or for the individual who originally requested the document(s), you may not copy (even for internal purposes), store or retain any electronic medium, retransmit, resell, or hire the contents (including the single paper copy referred to above). However these rules do not apply where:

1. you have written permission of the copyright owner to do otherwise;
2. you have the permission of The Copyright Licensing Agency Ltd, or similar licensing body;
3. the document benefits from a free and open licence issued with the consent of the copyright owner;
4. the intended usage is covered by statute.

Breach of the terms of this notice is enforceable against you by the copyright owner or their representative.

This document has been supplied under our **Copyright Fee Paid** service. You are therefore agreeing to the terms of supply for our Copyright Fee Paid service, available at:

http://www.bl.uk/reshelp/atyourdesk/docsupply/help/terms/index.html

The British Library Document Supply Service, Boston Spa, Wetherby, United Kingdom, LS23 7BQ

DOCKET ALARM Find authenticated court documents without watermarks at docketalarm.com.

How modern techniques improve seismic interpretation

Part 1—Seismic interpretation has evolved from basic 2-D structural mapping of vague anticlines observed on single seismic trace paper records in the 1920s to sophisticated stratigraphic mapping with lateral resolution from 3-D data

David L. Risch, Abu N. Chowdhury, Andrew E. Hannan, Project Geophysicists, and **George A. Jamieson,** Senior Geophysicist, Geco-Prakla, Houston, Texas

Reflection seismology was first applied to hydrocarbon exploration in the 1920s and today is an integral part of oil and gas business. As technology evolves, more information is derived from seismic and used in many interpretation modes. Interpreter demands are also becoming greater as more data of higher quality is available for incorporation into integrated interpretation.

Part 1 of this article describes the planning involved for seismic surveys, along with current methods and equipment used for acquisition, processing, display and interpretation of seismic data. Major points covered include:

- Interpretation objectives
- Seismic acquisition, processing and display
- Structural interpretation organization and procedure.

BACKGROUND

Acquiring continuous datasets along traverses provides a vast amount of data compared to single data points given by well control. It has been used for years in exploration and, with the advent of 3-D seismic, field development use has increased. Seismic data was first used to map subsurface geologic features.

Seismic signatures visible as direct hydrocarbon indicators (DHI), such as *bright spots* and AVO (amplitude variation with offset), are important tools. Seismic sequence stratigraphy adds another dimension to exploration with an understanding of geologic depositional process.

INTERPRETATION OBJECTIVE

Geological interpretation begins by defining problem scope and area. Studies range from large to small scale, i.e., from regional to reservoir. Techniques and data types vary depending on the problem size. For example, basin and regional studies involve interpreting large scale features from a few widely spaced seismic lines, and from gravity and magnetic data, often with little or no well control. Objectives are to obtain regional overviews and identify anomalies that warrant further study.

In contrast, detailed reservoir characterization requires integrating closely-spaced, high-quality/frequency (resolving power) 3-D seismic lines, data from many wells, petrophysical measurements, production histories and extensive modeling. Geological models are essential to begin interpretation and are based on literature and personal experience. Models are used initially but interpretation comes from working with data.

SEISMIC METHOD

Exploration reflection seismology uses induced acoustic reflections of rock layers. Vibrations are generated in the earth with acoustic sources, and reflections are recorded with receivers. Reflection intensity depends on velocity and density contrasts of rock layers and contained pore fluids.

Acquisition. Data acquisition begins by laying out seismic programs with parameters designed for geologic objectives based on study-area understanding. Parameters include: seismic frequency for vertical and horizontal resolution (horizontal resoulution also depends on source, receiver and line spacing); depth to target (distance between source and farthest receiver, i.e., far offset); rock layer dip; and envi-

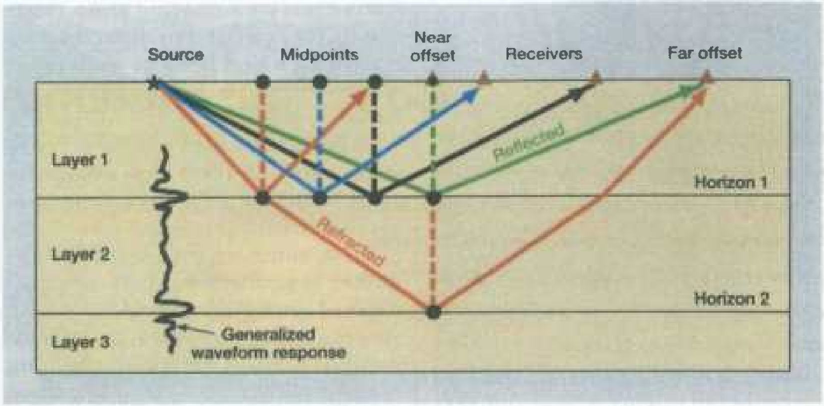

Fig. 1. Simplified diagram of seismic principle used in exploration.

ronmental, cultural and geological conditions.

Most marine acquisition sound sources are air guns that repeatedly displace water volumes. On land, sources are explosives or truck mounted vibrators. It is common to use synchronized source arrays to increase, or focus, energy at each shot. Vibrators can generate more high-frequency energy, compensating for the earth's natural attenuating frequencies.

Geophones are land receivers that detect slight ground movements. Marine receivers are pressure sensitive devices called hydrophones. Each receiver converts pressure or ground disturbances to electrical impulses. The digitally recorded electrical pulses of an array or group of receivers are summed for each station and transmitted, via cable or telemetry, to recording computers.

Electric response amplitude is directly proportional to reflection strength. Increases or decreases in acoustic impedance (velocity × density) across reflectors are displayed as peaks or troughs on seismic waveform displays. Receivers record reflections every 2 msec for a chosen time (commonly 4–10 sec) resulting in a well sampled vertical seismic record called a trace.

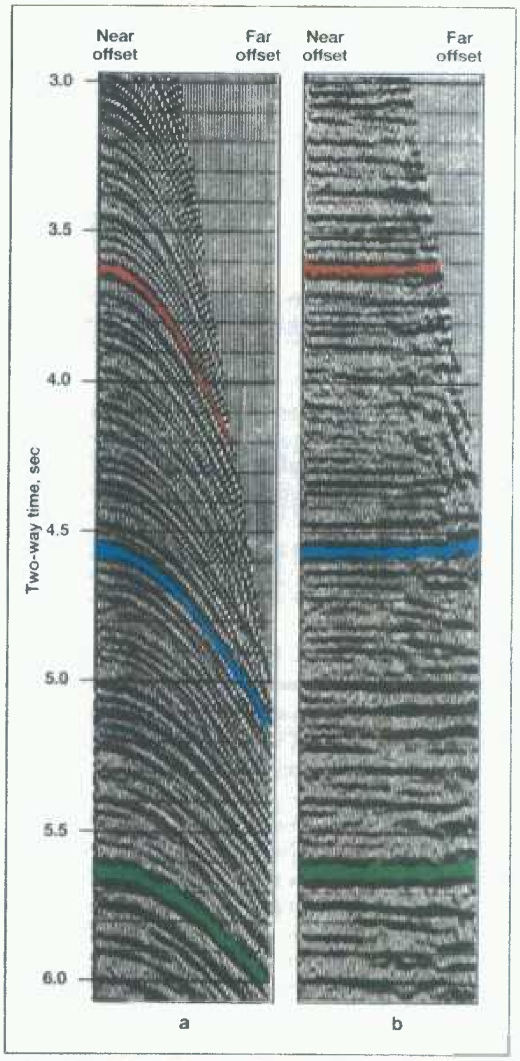

Fig. 2. CMP gathers with hyperbolic *move-out*, **(a)**, and velocity corrected to horizontal alignment for stacking, **(b)**.

In the seismic principle example, Fig. 1, the Horizon 1 reflection results from an impedance contrast between Layers 1 and 2; likewise for Reflection 2 emanating from Horizon 2. Ray paths are described by Snell's Law and bend at each layer interface (horizon). Subsurface horizons are imaged at midpoints between source and receiver. These points are imaged repeatedly by source-receiver pairs as shooting progresses to each consecutive line location. A common midpoint (CMP) gather is a collection of all combinations of source-receiver pairs which records energy from the same midpoint location, therefore containing travel paths from near to far offset traces. This redundancy increases the signal to noise ratio when traces are processed and summed.

Processing. Stored reflection electrical pulses are sorted and merged with geographic location data to create CMP gathers. Reflection travel time increases with receiver offset distance and shows a hyperbolic geometry called *move-out*, Fig. 2a. Move-out is corrected by selecting a velocity that aligns reflectors horizontally so they can be summed to one average output trace. Layer velocities are picked by computer algorithms and human evaluation. Velocity analysis is critical to processing and may be done more than once to fine-tune seismic images.

Land data frequently requires an additional static adjustment which accounts for varying travel times through near-surface layers. Fig. 2b shows corrected traces of a CMP gather ready for summing. Trace summing process is called stacking and final output is a seismic section or line. A final process, migration, is used to reposition misplaced events associated with dipping interfaces and collapse diffractions caused by discontinuities (faults).

Display. Horizontal scale of seismic sections is measured in shot-point number, corresponding to seismic basemaps. The vertical scale is 2-way seismic travel time in sec. A typical seismic section has a grid of vertical lines every 20th shot-point and horizontal lines every 0.01 sec. A sidelabel provides line number and information about acquisition, processing, and display parameters. Data is displayed at various scales and trace gains depending on the exploration objective.

Reflections recorded as electrical pulses are small and must be amplified to be seen. The processor has a variety of gain functions to compensate for energy loss with depth. One gain function identifying amplitude or reflection anomalies preserves relative amplitudes of all trace reflections so largest reflections are easily visible. Data can also be used with an interactive workstation. Coffeen (1986) offers a review of the seismic exploration method.[1]

STRUCTURAL INTERPRETATION

Structural interpretations have been the foundation for prospect development and usually precede stratigraphic analyses. Structural interpretation of seismic data involves organization of data, selecting horizons to map, integration of well and seismic data, loop-tieing seismic sections, transferring interpretation to basemaps and contouring time values. A final step sometimes involves depth-converting seismic time maps to remove false structures caused by abrupt lateral velocity changes.

The database. First steps in seismic interpretation, after exploration objectives are defined, are to collect and organize required data. A seismic base map is generated and inspected for locations and orientations of seismic lines and well locations.

Well data consists of checkshot survey and sonic log velocity data; rock cores and well logs to predict litholo-

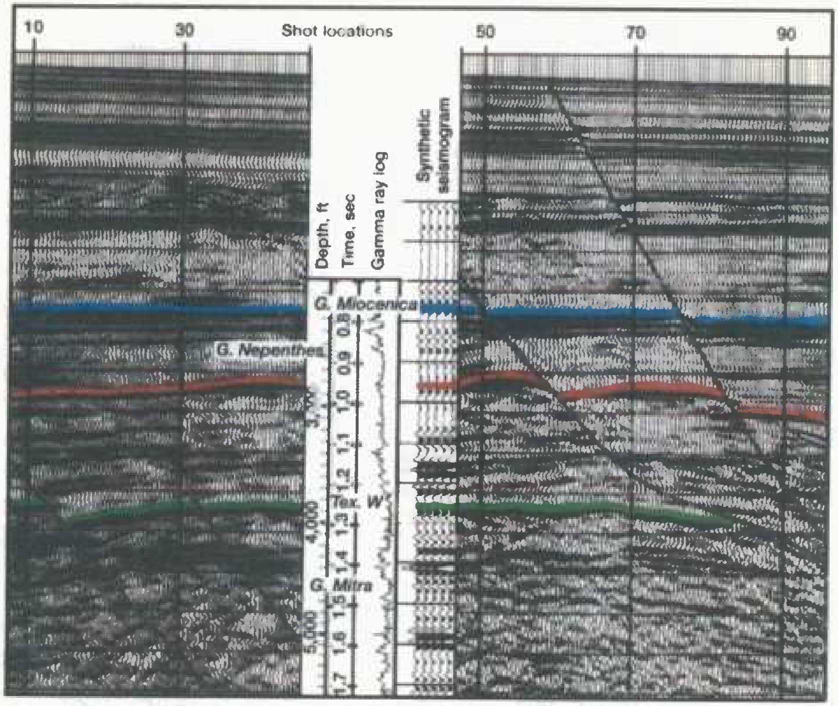

Fig. 3. Tieing well and seismic data example using a synthetic seismogram. Shifting the synthetic is common to obtain optimum character match with the seismic data. Microfossils for dating are in italics.

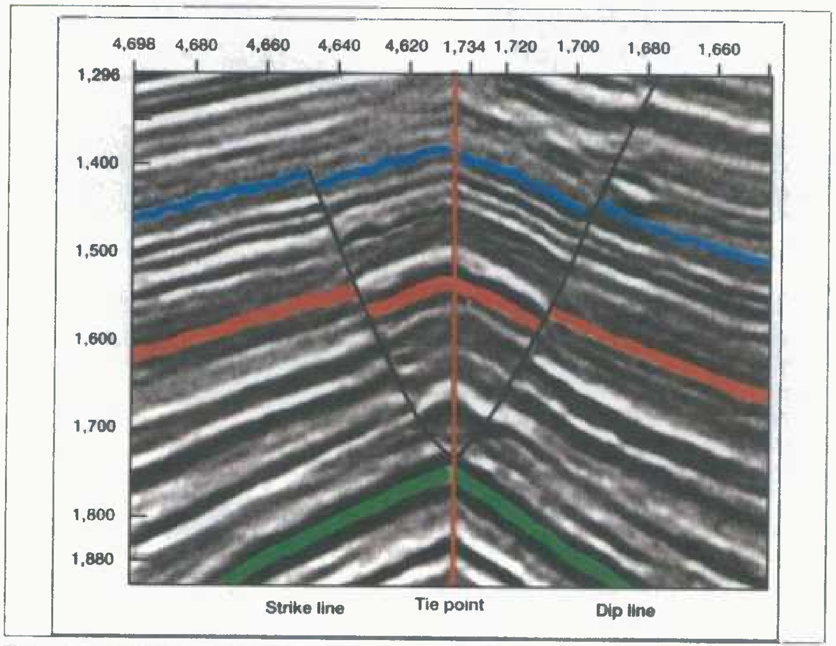

Fig. 4. Seismic lines tieing at an intersection. Seismic reflectors, horizons and faults match at the tie.

gies and fluids; and rock samples with microscopic fossils for age dating. Well data, in depth, is converted to 2-way time using synthetic seismograms, checkshots or vertical seismic profiles, (VSPs).

A synthetic seismogram is a continuous vertical record that looks like a seismic trace but is derived from sonic and density logs, Fig. 3. Checkshot surveys are collections of several pairs of travel-times and known depths within wells. A VSP is similar to surface seismic sections but has receivers in the well instead of along the surface; it is the best way to convert between seismic and well data.

Seismic data is sorted into dip lines (acquired in structural dip direction) and strike lines (perpendicular to dip lines). Lines are examined for quality, depth of reliable imaging, structural complexities, and frequency content (determines thickness of beds).

Procedure. Mapping horizons are selected in correspondence with known productive reservoir rocks observed on well logs. Seismic characteristics (reflection amplitude and continuity) and depositional environments associated with reservoir rocks are noted for future reference as analogs.

Well data constrains seismic interpretation, so well trajectories are projected onto the nearest seismic line. Well data in depth is converted to seismic 2-way time and plotted along the seismic-line well trace using synthetic seismograms or checkshot velocities. Microfossil datums or extinctions are plotted on the seismic data for age dating and correlating from one well, or area, to another, Fig. 3. This is important where complexities exist. Correlated well logs provide more information to aid seismic interpretation where fossil data is lacking.

Interpretation begins at well control-data, and well information is extended by following selected seismic reflections. Horizons are distinguished by color-coding chosen reflections. The *least complex structural path* is chosen to establish a framework of interpreted lines incorporating all available well data. The seismic grid of intersecting lines provides numerous pathways minimizing ambiguous correlations across faults and other features.

Each line intersection is a *tie point* with common reflections on both lines. When paper sections are used, one seismic line is folded with a vertical crease at the intersection and placed on the intersecting line so surface datums match (sea level or a predetermined elevation common to the seismic data grid). Reflections should match if structural dip is nearly flat, or compensation is made. Interpreted horizons are identified on the new line and tracked to the next intersection. If done properly, a *loop* of interpretation results in horizons linking back to the first tied intersection. Workstations (see Part 2) display *loops* as a single image.

Fault cuts are interpreted at offsets in reflections and tied at grid intersections. Fault points are connected in a trend honoring reflection offsets observed on the *tie* line,

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.

WHAT WILL YOU BUILD? | sales@docketalarm.com | 1-866-77-FASTCASE