SEAM Phase I
Interpretation Challenge 1

Description of the challenge

Society of Exploration Geophysicists
The international society of applied geophysics
SEAM
SEG Advanced Modeling Corporation

Overview

- The task of the challenge taker
- Data Description
  - SEAM Phase I model
  - SEAM Phase I simulation
  - Interpretation Challenge 1 RTM
  - Interpretation Challenge 1 datasets
- Summary

The Task of the Challenge Taker

- Interpret key structural horizons
  - Water bottom
  - Salt body
  - Top Miocene
  - Top Oligocene
  - Top Cretaceous
- Find 3 reservoir prospects
  - Map the prospects
  - Determine gross rock volume (GRV) P10 – P50 – P90
  - Determine net present value (NPV) P10 – P50 – P90
  - Evaluate reservoir seal
  - Determine 1st drill location

Background

Geophysical techniques have routinely proven helpful, and sometimes fundamental, in reducing the uncertainty in this integrated process involving the geological, geophysical, and reservoir engineering disciplines. The goal of a reserves evaluator is to use all of the interpretations from these disciplines to obtain low (P90), best (P50), and high (P10) estimates of the reserves and/or resources. It is clear that each of the disciplines has its strengths and weaknesses. Rather than focusing on these, the reserve/resource evaluator should utilize the combined contributions of each discipline to minimize the global uncertainty in these low, best, and high reserve and resource estimates (figure 1).

http://cseg.ca/assets/files/members/cgf/Chapter3_PRMS_COGEH_CGF_DEC2011_FINAL.pdf

You are the early explorationist

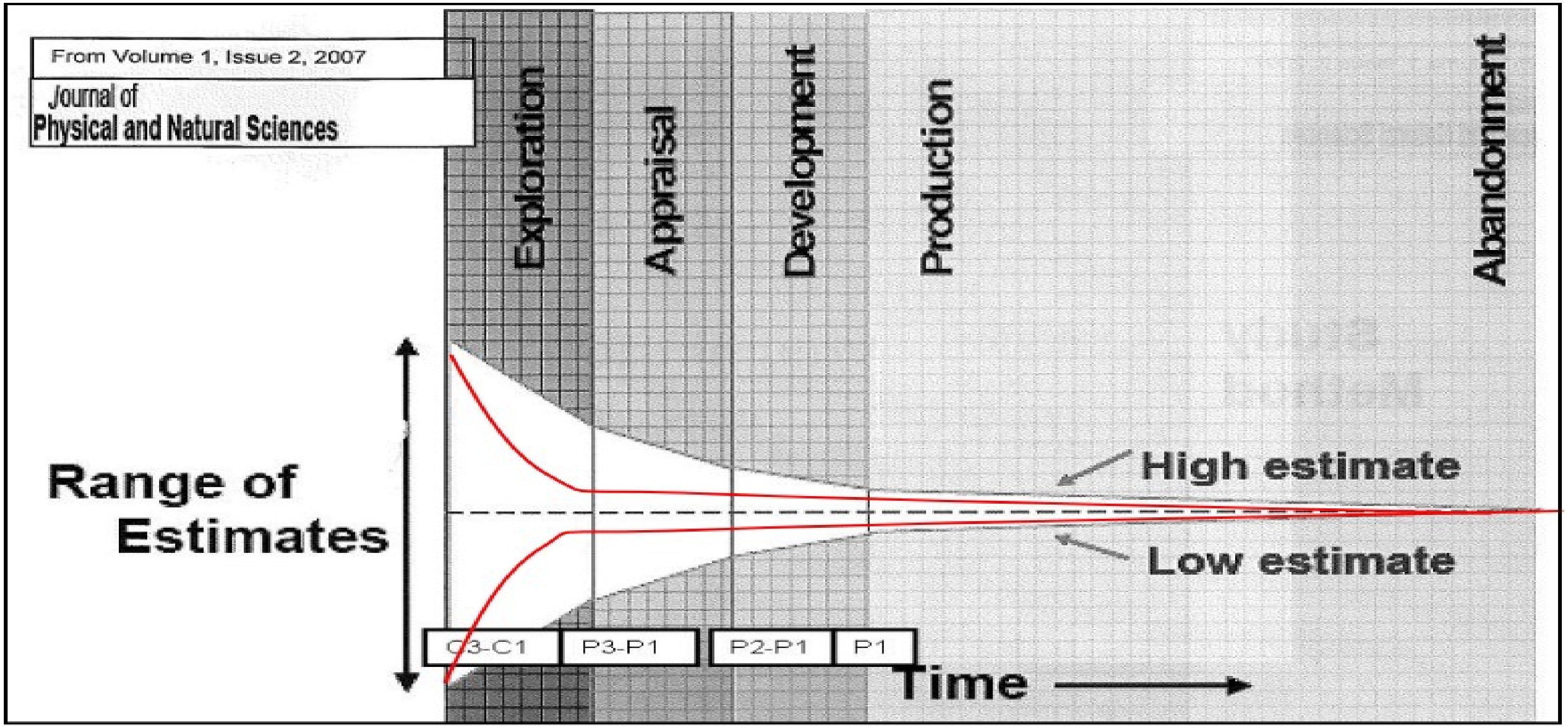


Figure 1. Temporal trends in reserves estimates. As more data (primarily production data) is collected over time, the range of uncertainty in reserves diminishes; an estimate incorporating geophysical data (red lines in figure) reduces the uncertainty of the estimate in the life of a hydrocarbon Pool/Field.

SEAM Phase I model

The SEAM Phase I Earth Model is a generalized 3D representation of petroleum interests in the deep-water Gulf of Mexico. It included a complex salt body and Green Canyon like fine-scale stratigraphy with oil and gas reservoirs. The model covers a 1400 km^2 area (approximately 60 OCS blocks) and measures 35 km east-west by 40 km north-south by 15 km of depth. It was built on a 20 x 20 x 10 m gridded interval. Construction of the model is an excellent example of multi-company sharing and volunteerism. A huge amount of hands-on work was done in gOcad by ConocoPhillips with the methodology defined by Chevron. It started with a complex salt body donated by Hess. The salt body was altered, using several different company suggestions, to increased rugosity on a dirty salt top, addition of suturing and trapping of sediments internal to the salt, the addition of a winged base to the allochthonous salt, and a deep grotto creating more extensive overhangs. Realistic sedimentary macro layers, overturned bedding, and radial fault structures were offered by BHPBilliton. They were designed to have realistic edge truncations to the depositional growth of the glaciated diapered salt body. Within the macro layers stratigraphic variation were created parametrically using a geostatistical method developed and offered by Chevron. All model properties are derived from fundamental rock properties including Vshale (volume of shale) and porosities for sand and shale that follow typical Gulf of Mexico compaction gradients below water bottom. Hence, properties have subtle contrasts at macro layer boundaries, especially in the shallow Pleistocene section, generating very realistic synthetic data. Well control was used to define the general physical sedimentary properties that were correlated to the rock properties and extrapolated throughout the model. The much finer scaled stratigraphic elements represent the rich fabric of depositional variation near and below the seismic resolution. They also provide a natural framework for the inclusion of reservoirs. 15 oil reservoirs, 3 with gas caps, were added as stacked braided stream channels, local turbidities, or sheet turbidities. The reservoirs have a variety of incorporated fluid properties. The end results is a realistic earth model that is 100% fully known.

SEAM Phase I simulation

The SEAM Phase I project generated several simulations over the model with a variety of technologies. Both seismic and non-seismic data were acquired. Seismic included isotropic acoustic with density, anisotropic (TTI) acoustic with density and isotropic elastic with density. Collections were made with or without free surface conditions (with and without free surface multiples). The data were recorded by surface hydrophones, ocean-bottom 4-component, and/or borehole 4-component receivers. Marathon donated the free-air and Bouguer gravity at both sea level and 150 m altitude. Other non-seismic simulations were contracted and include a very dense controlled source electromagnetic (CSEM), and two versions of magnetotelluric (MT). Many classic datasets were created from the variety of simulations over the model.

The seismic data simulation used in this Interpretation Challenge 1 function were completed in December 2009 by Tierra Geophysical (now part of Landmark). The isotropic acoustic with density Finite Difference forward modeling code was benchmarked for accuracy with the interest in minimizing numerical artifacts. Each shot record was quality controlled to insure fidelity of positioning, amplitude, and artifacts.

Interpretation Challenge 1 RTM

The input dataset used for the Interpretation Challenge 1 is called the “Acoustic Free Surface 2793-shot Classic”. The decision on which input data set to use was driven by minimizing cost with a fast Reverse Time Migration (RTM) and to leave the free surface multiples in the data as noise. This classic dataset consists of sparse shots on a 600 x 600m grid and a huge collection of hydrophones spaced every 30 m in a square patch around the shot (figure 2). The data preparation step only included the designature of the delayed seismic wavelet to zero phase. The volume was migrated twice. The first migration was with the true interval P-wave velocity, from the “Acoustic Isotropic Earth Model”, to provide an optimal results with this input volume. The second migration was with a perturbed velocity volume that contained increasing P-wave travel-time error in the west to east direction and increasing travel-time error in the south to north direction (figure 3). Additionally, velocity error was introduced in some areas from an incorrect definition of the salt (figure 4). The travel time error is like having migration velocity error resulting in varying degrees of poor focusing of the acoustic waves during imaging. Post migration it was found that the stacking power of the full azimuth spatially sampled data effectively attenuated the free surface multiples. To increase the challenge and make the data appear more realistic, a low level of band-limited random noise was added to the stacked volume. The noise level was defined with a SNR power set to 100. The low-fold migration edges were cropped in both N-S and E-W directions (figure 3). The processing and RTM migrations were completed in October 2014 by Advanced Geophysical Technology Inc. (AGT).

Figure 5a in RWB color and figure 5b in gray scale show an example cross-section from the 3D volume. It may also be useful to have migrated offset gathers near the wells to help understand the offset contributions to the stack. Offset gathers in an RTM procedure are much less typical than angle gathers. In order to produce a 2D line of offset gathers, 30 offset specific RTMs were run using only 3 rows of shots centered over the output line. Figure 6 shows the sparse 2D pre-stack offset dataset consisting of 33 gathers spaced every 900 meters. A full collection of 2D offset gathers spaced every 30 meters is also available.

Interpretation Challenge 1 datasets

Listing of datasets in both depth and stretched to TWT that can be used:

- Final RTM stack
- Sparse 2D offset RTM image gathers
- Full collection of 2D offset RTM image gathers
- Well #1

Name	Size
Well_1	
SEAM_Interpretation_Challenge_1_2DGathers_Depth.sgy	95,043 KB
SEAM_Interpretation_Challenge_1_2DGathers_Time.sgy	106,762 KB
SEAM_Interpretation_Challenge_1_2DSparseGather_Depth.sgy	3,140 KB
SEAM_Interpretation_Challenge_1_2DSparseGather_Time.sgy	3,527 KB
SEAM_Interpretation_Challenge_1_Depth.sgy	3,710,766 KB
SEAM_Interpretation_Challenge_1_Time.sgy	4,168,320 KB

Acquisition specifications

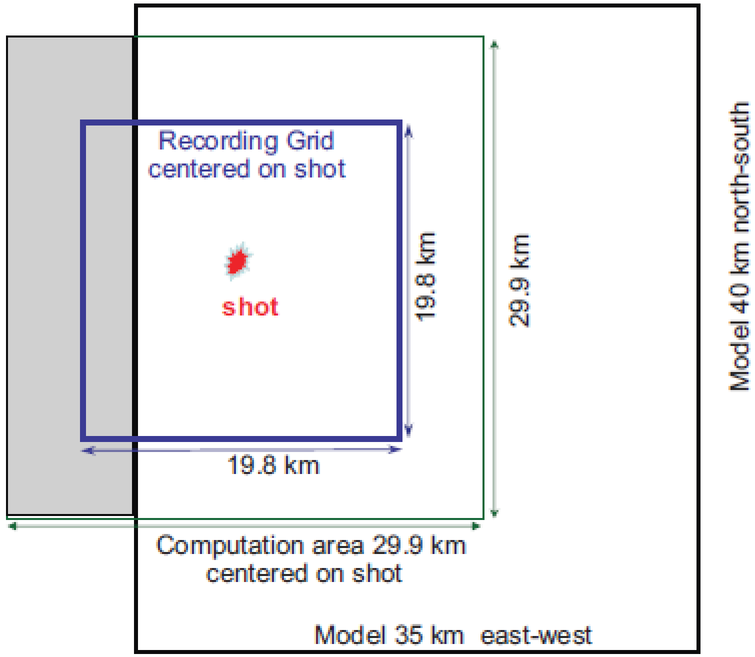


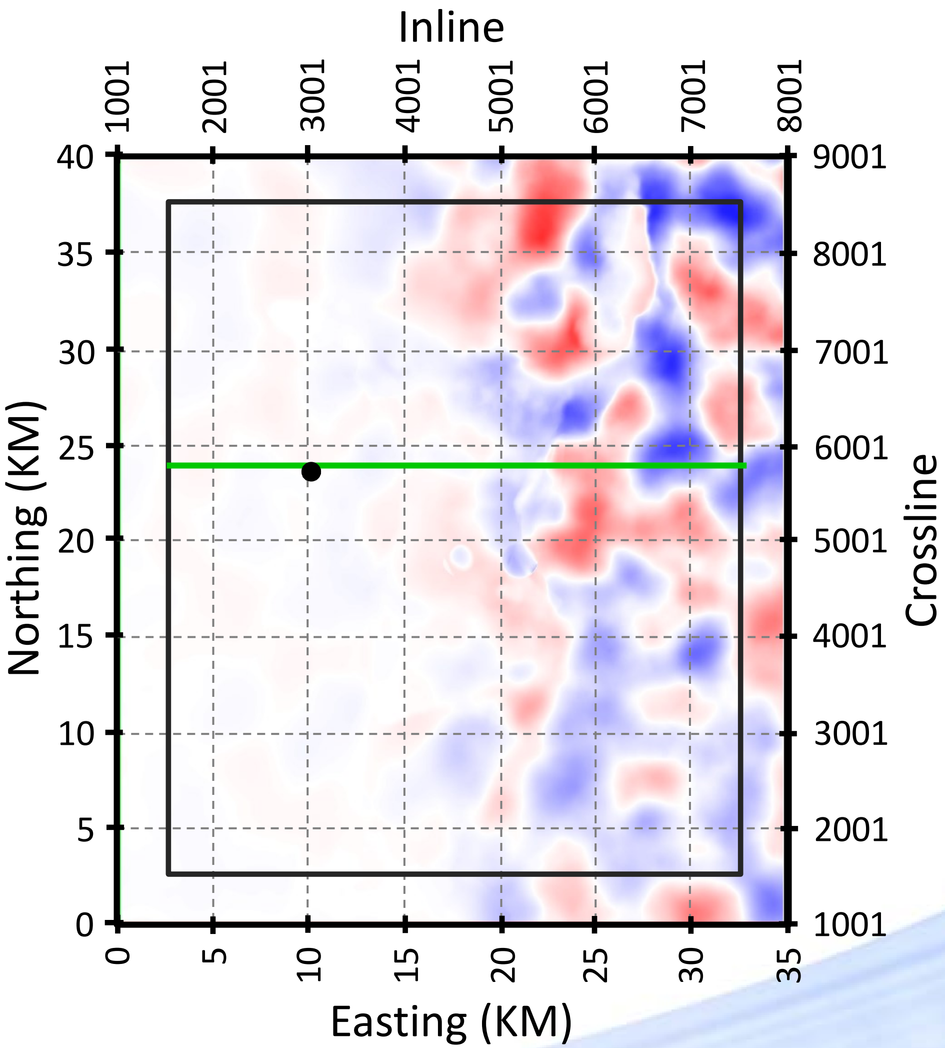
Figure 2. Recording and simulation patch geometry. The portion of any patch outside the model (shown in gray) is not computed or recorded. Some shots have a full complement of 436,921 traces collected at the hydrophone positions.

Map view of survey area

Figure 3. Survey grid coordinates for the input seismic and velocity volumes.

- The color background is the cumulative vertical travel time error at a depth of 10KM. White is the true velocity and the red/blue show errors up to +/- 100 ms.
- The green line at 24,000N is the location of the sparse offset gathers.
- The black circle is the well #1 location: (23900N, 10075E)
- The inner gray rectangle shows the cropped output area for the interpretation volume with coordinates:

East	North	Inline	Crossline
2490	2490	1499	1499
2490	37530	1499	8507
32520	37530	7505	8507
32520	2490	7505	1499



Crossline section at 18,990 N

Figure 4. Section showing variation in depth of the perturbed velocity model.

- The color background is the travel time error. White is the true velocity and the red/blue show errors up to +/- 100 ms. This represents approximately a +/- 4% velocity error.
- There were some modifications added to the salt structure.

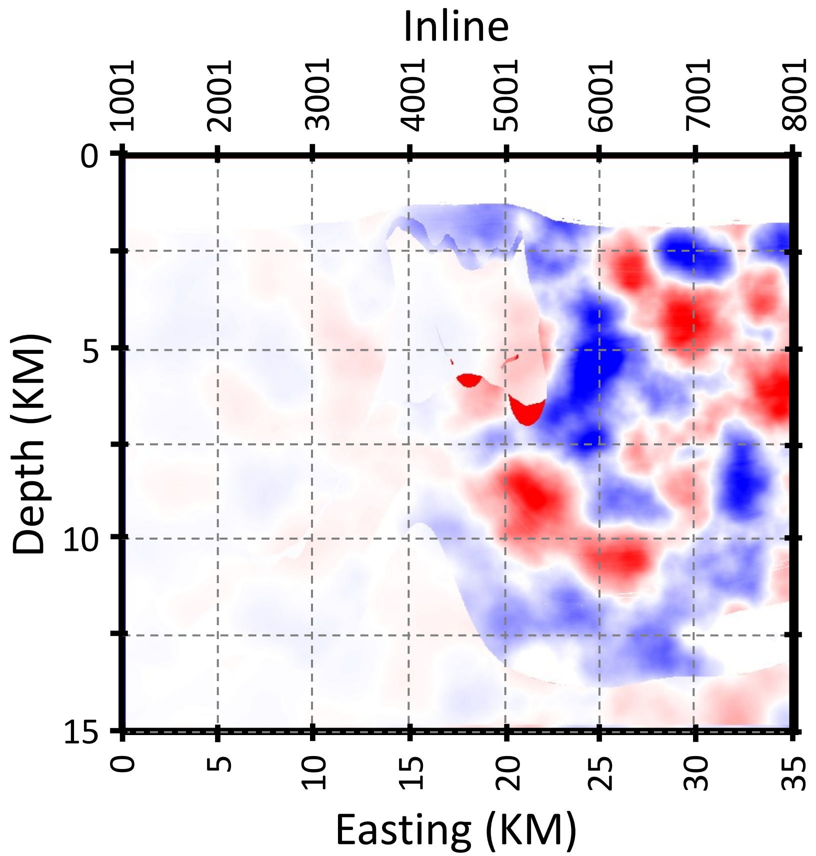


Figure 5a. Example Cross Section

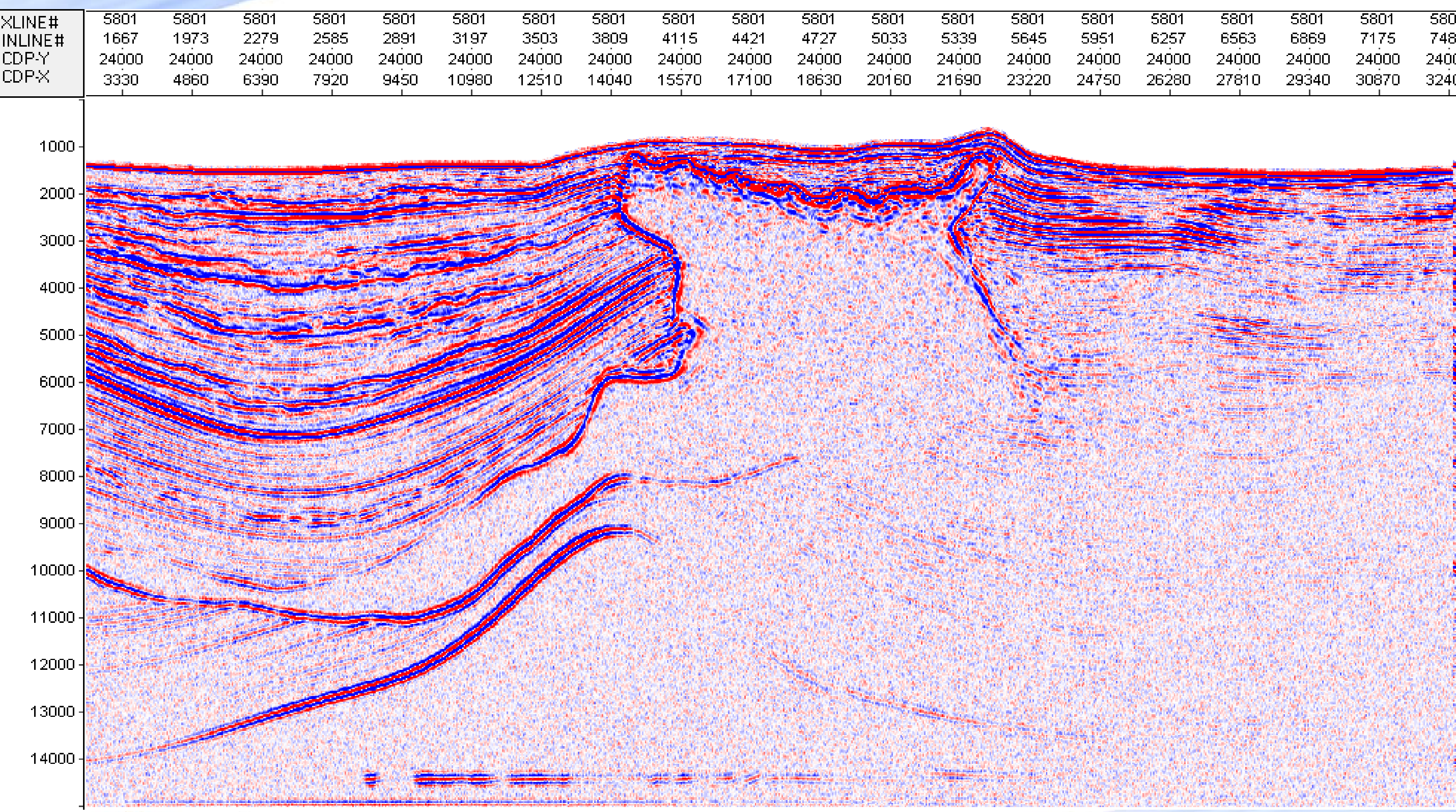


Figure 5b. Example Cross Section

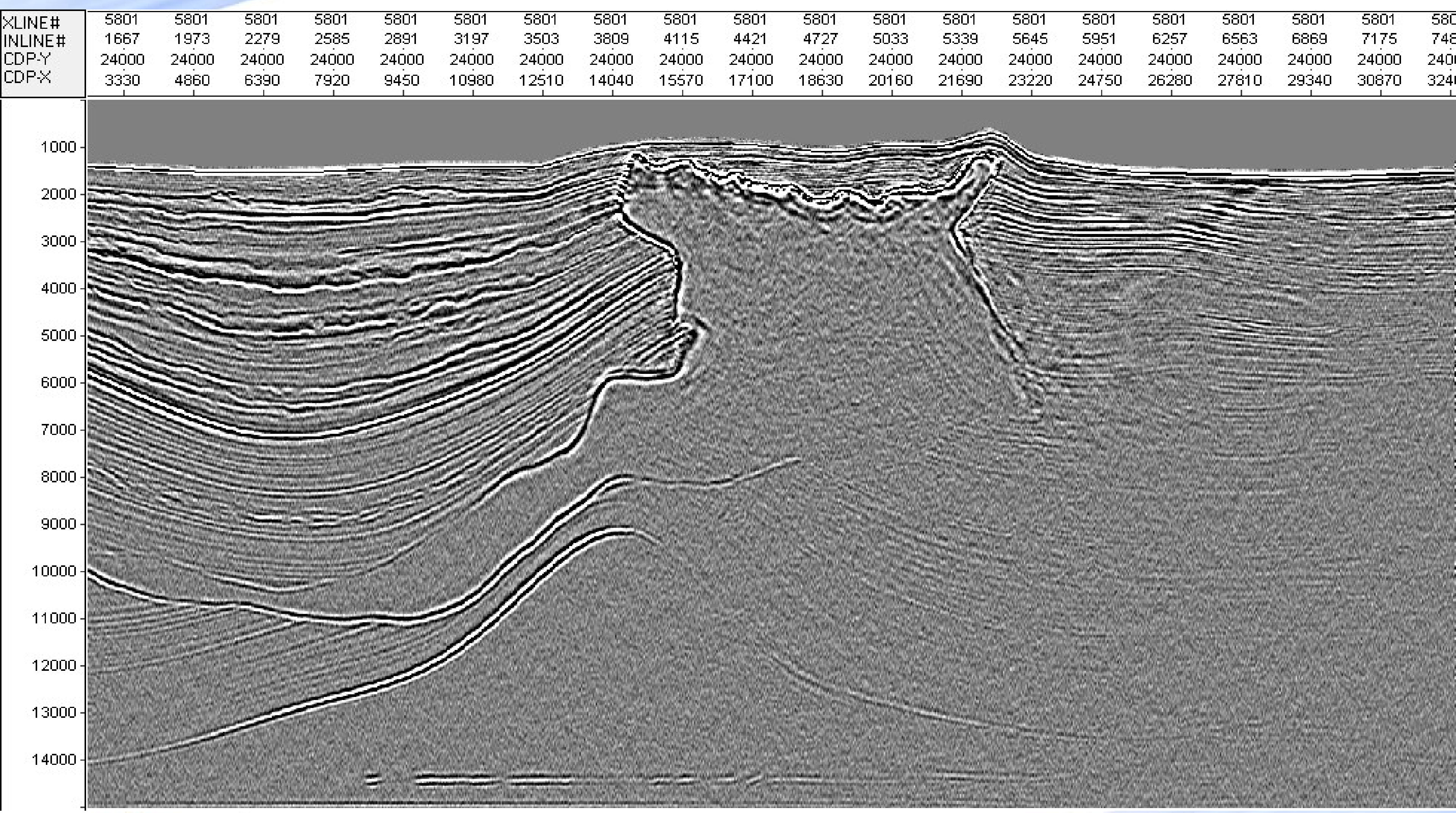
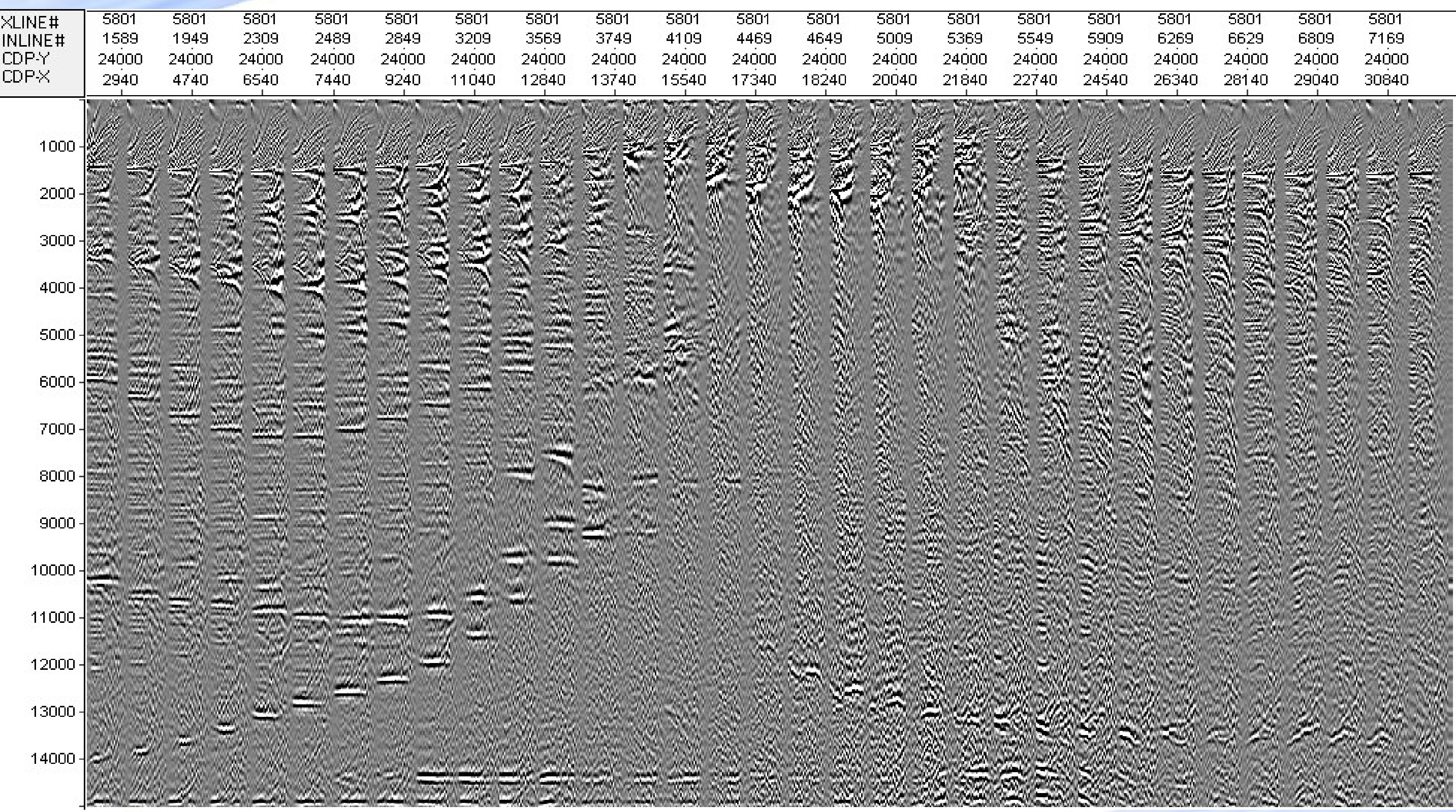


Figure 6. 2D Offset image gathers



Summary

- The SEAM Interpretation Challenge 1 offers an excellent opportunity to:
  – learn interpretation skills
  – Evaluate interpretation software on a small well known dataset
  – Determine the uncertainty in determining important steps in risking a well being drilled