BRIGHT SPOTS

Allan Snyder

Abstract

In this report ray tracing methods are used to study direct hydrocarbon indicators (DHI's or "bright spot" effects) for several common hydrocarbon structures. Zero-offset synthetic seismograms are constructed for anticline, normal fault, unconformity, reef, and sand lens models, both shallow and deep. It is found that polarity reversal, velocity pulldown, flat spots, and high amplitude are important DHI's. Deep hydrocarbon accumulations turn out to be much more difficult to detect than shallow ones, and gas is much easier to find than oil using direct hydrocarbon indicators.

Introduction

Bright spots are very important today in the petroleum industry but are still poorly understood. In this project I wish to study bright spot effects for several common hydrocarbon geometries. There are several good methods for generating synthetic seismograms, including Kirchoff diffraction theory, finite differences with the wave equation, and ray tracing. Each has its advantages and disadvantages, but I have chosen ray tracing since it is the most convenient at this time. It has the advantages of being fast on the computer, not requiring much storage space (important on our minicomputer), and happened to ba available and easy to use. I decided to use zero-offset sections rather than CDP-stacked sections because zero-offset sections are much more quickly generated and require less storage space, and also since the whole object of stacking is to produce something resembling a zero-offset section. Therefore I might as well just produce it directly with no error rather than obtain a stacked section with all its inherent errors due to wrong stacking velocities.

Ray Tracing Procedure

I made a total of nineteen plots - ten models and nine seismograms. I used 99 shot points for each model, spaced 100 feet apart for the shallow models and 400 feet apart for the deep ones. With the zero-offset geometry there is only one trace per shot, which is at the shot point.

The ray tracing process proceeds as follows. Consider one shot-point at the ground surface (or datum plane) and one reflector. We choose bounding angles for the ray tracing cone and also the number of rays traced. Suppose we choose angles of $-20°$ and $20°$, and five rays. First a ray propagating at an angle of $-20°$ from the vertical will be traced to the first reflector and then reflected and propagated back to the surface. Had we specified the second reflector in a model (assuming there is one), the ray would have been refracted at the first interface by Snell's law, reflected at the second interface, and then refracted again at the first reflector on its way back to the surface. Assuming that we are once again just looking at the first reflector, the next ray is sent down at an angle of $-10°$, and similarly rays are sent down at angles of $0°$, $10°$ and $20°$, respectively. However, only those two adjacent rays which hit the surface bracketing the receiver are actually recorded. The actual travel time used for the reflector is the average of the travel times for the two rays bracketing the receiver. If we want, we can then trace more rays between the two bracketing the receiver to get as close as desired to it. One can also specify the difference in travel time allowed for these two rays. Any two adjacent rays with a travel time difference greater than this are not traced. This allows shadow zones to be recorded faithfully.

For a given shot point this procedure is followed for each reflector and then the program moves on to the next shot point, where it repeats the process. Amplitude effects that are accounted for include reflection coefficients, spherical spreading, and incident angles of rays as they hit the ground surface again. All seismograms are unmigrated. The data are then sorted and convolved with a source waveform, in this case a 10-50 Hz Butterworth filter, and then plotted.

Plots

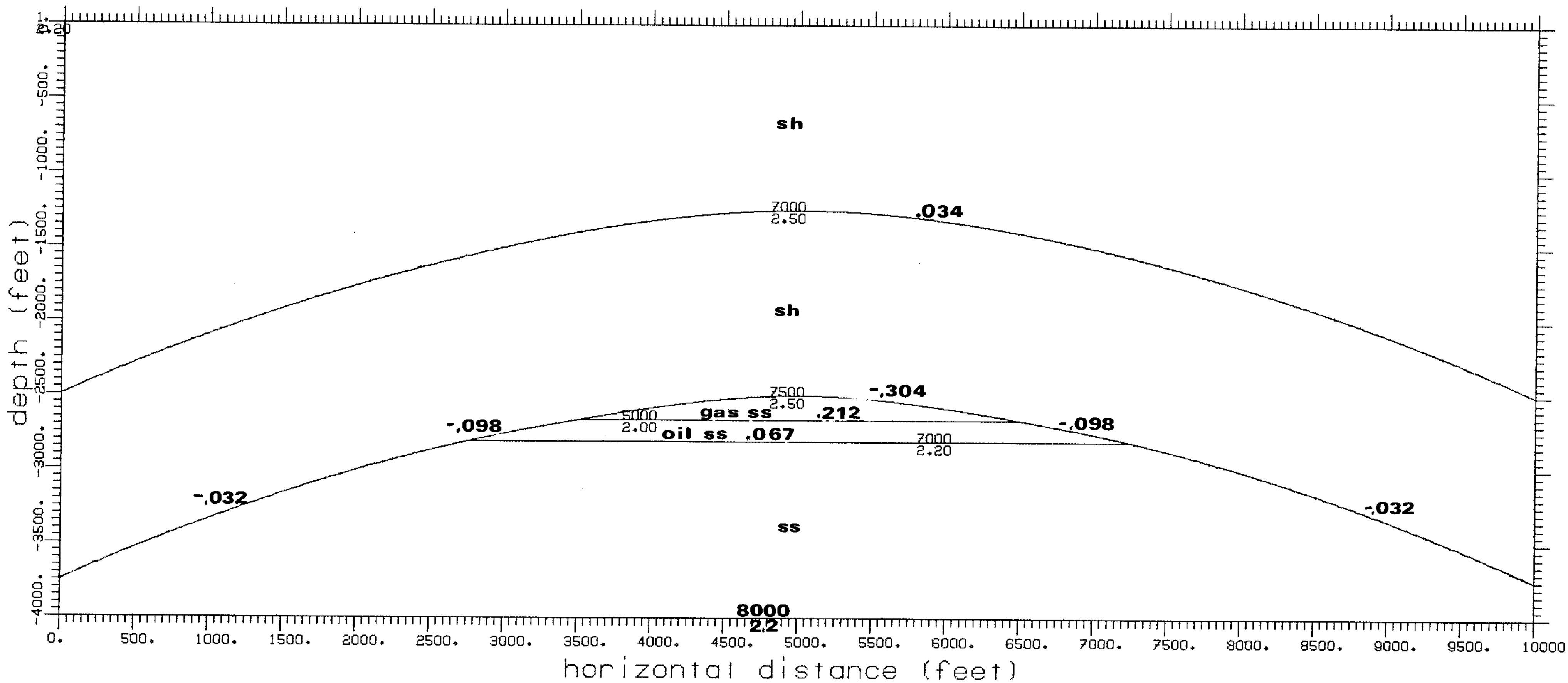
For the plots I chose the five most common hydrocarbon traps and constructed synthetic seismograms for both shallow and deep models, except for the reef, which I constructed a deep model of only, since I was very uncertain as to what parameters to use in a shallow model and for that matter my deep model is just an educated guess. I tried to make my models as geologically "average" as possible, so that when I later refer to something as geologically unacceptable, I mean that it is not average enough for me. I chose oil and gas pools combined because then I could observe their effects at the same time and also get an idea about how they would look separately. Some major conclusions can be drawn from considering all the plots in general. First, bright spot effects show up much more in shallow structures than in deep ones. Second, four important DHI's are high amplitude, polarity reversal, velocity pulldown, and flat spots. Third, it is much easier to find gas than oil using DHI's.

There are several other DHI's that I have chosen not to model which are sometimes important. These are diffractions, frequency change (greater attenuation of high frequencies than low ones), and attenuation (transmission coefficient and constant-Q effects). Another parameter that I have neglected is variation of reflection coefficient with angle. Possibly I may introduce a transmission coefficient effect in order to improve on these seismograms, but I will probably neglect the other parameters, since I do not feel that they are that important.

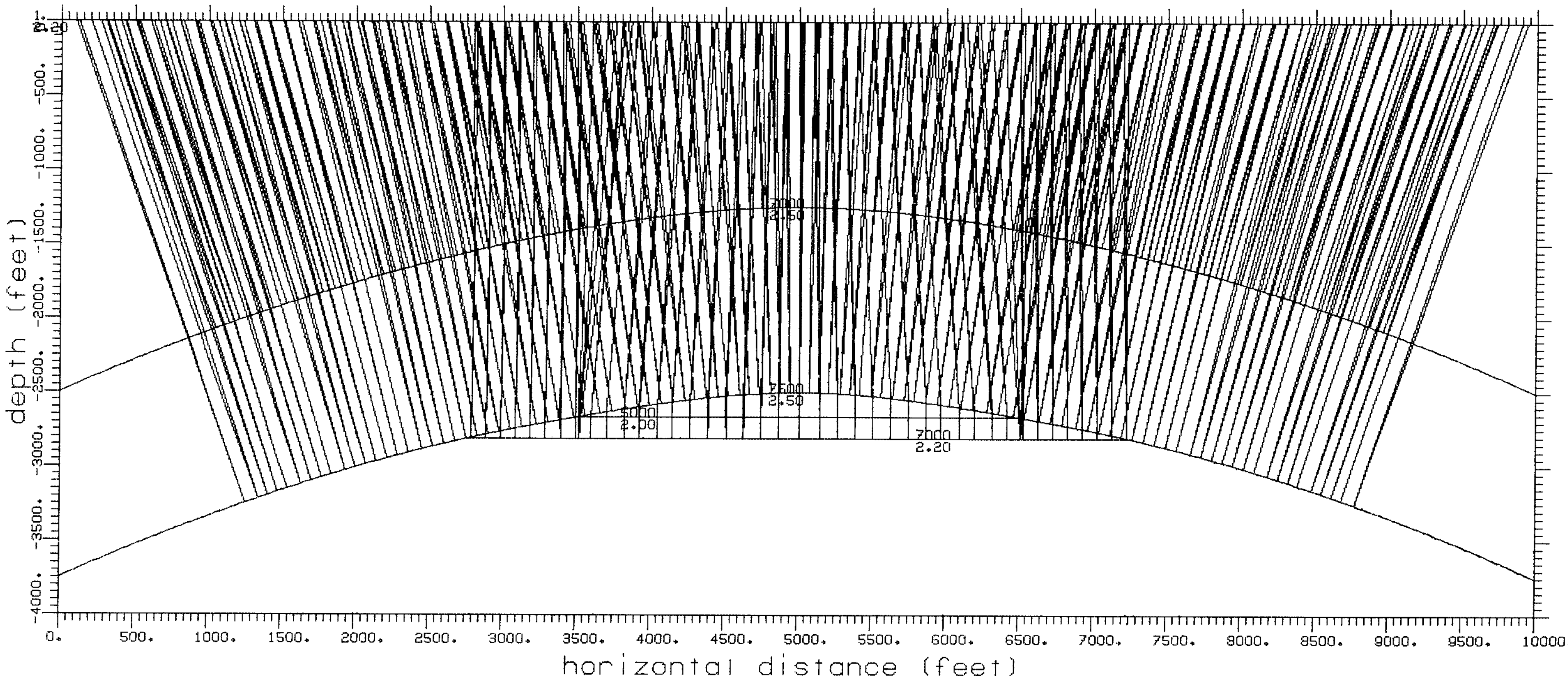
The following pages show for each model first the depth section and then the synthetic seismogram associated with it. A ray path diagram is included for the shallow anticline model. First come the shallow models and then the deep ones, except for the reef, which is in with the shallow models.

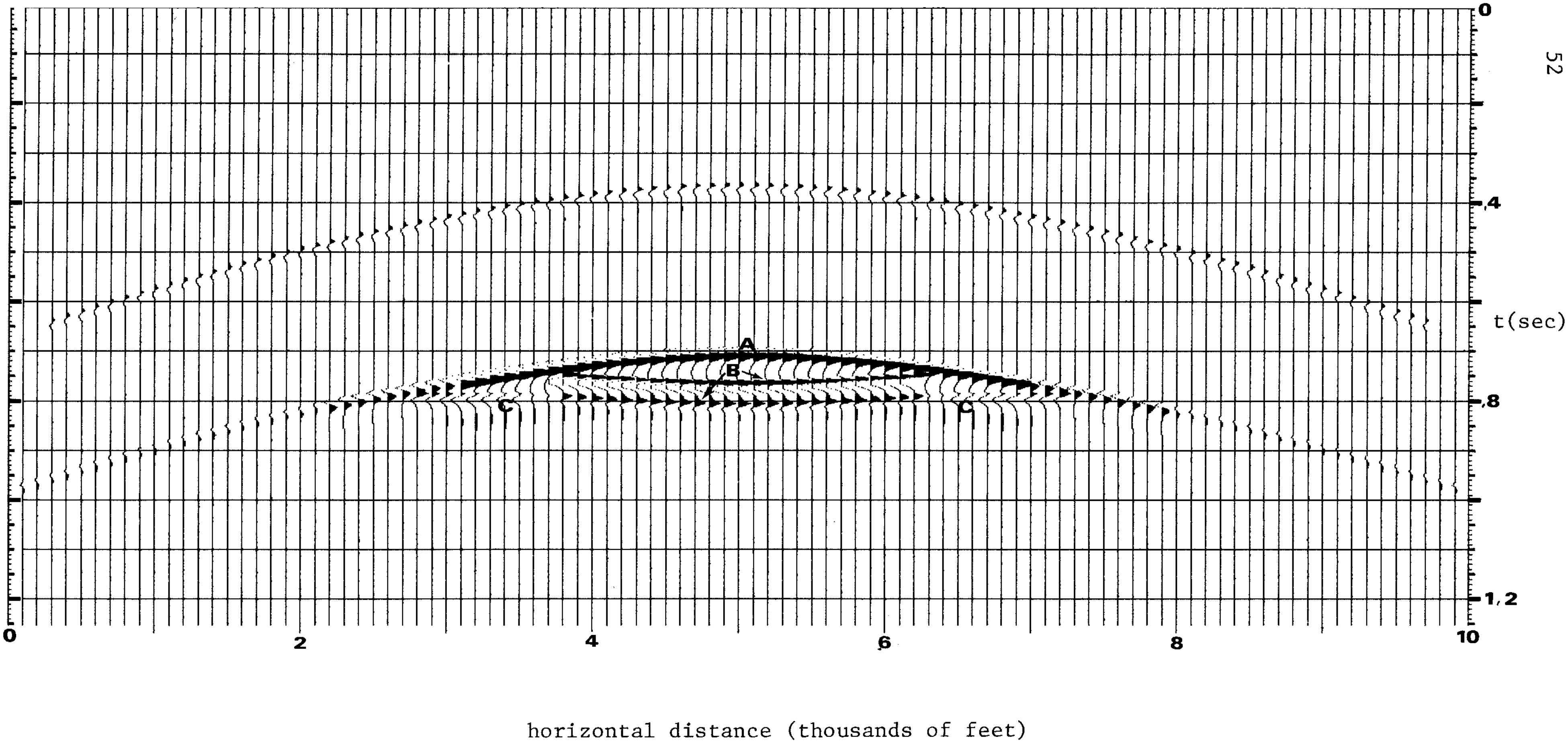
SHALLOW ANTICLINE MODEL

On each model, velocities in feet/second, densities in grams/cubic centimeter, reflection coefficients, and rock types are indicated. The velocity and density information refers to the layer above the labeled interface.



SHALLOW ANTICLINE MODEL WITH RAYPATHS

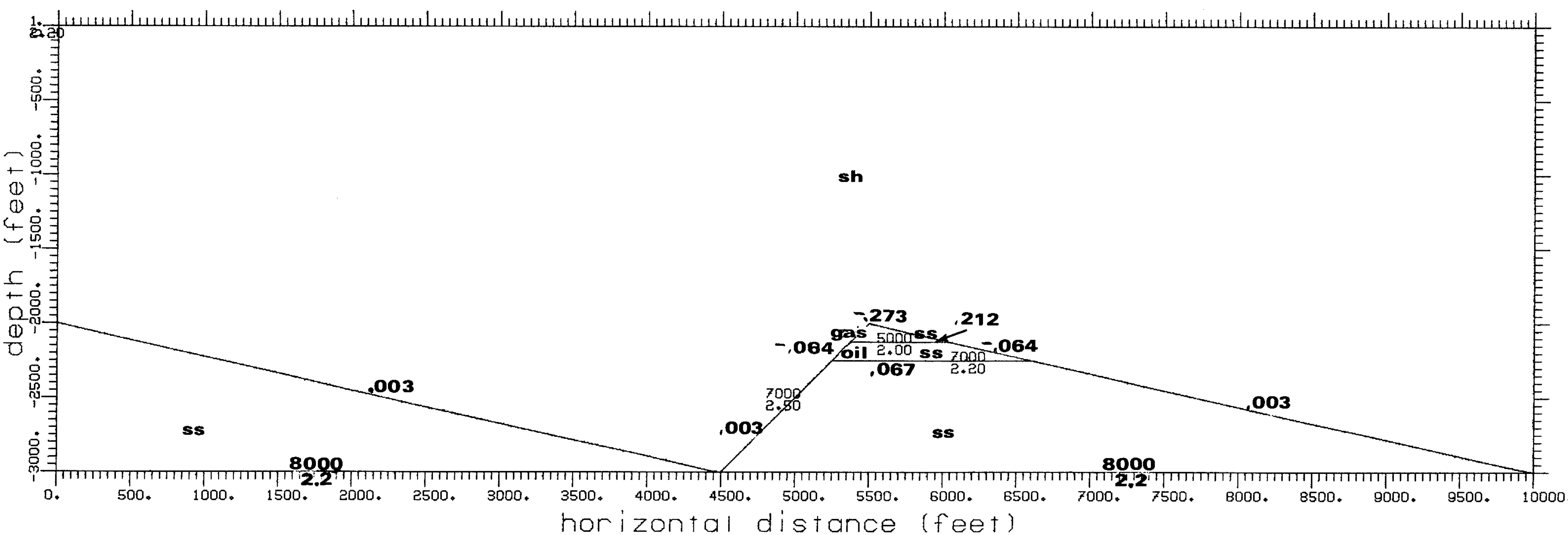


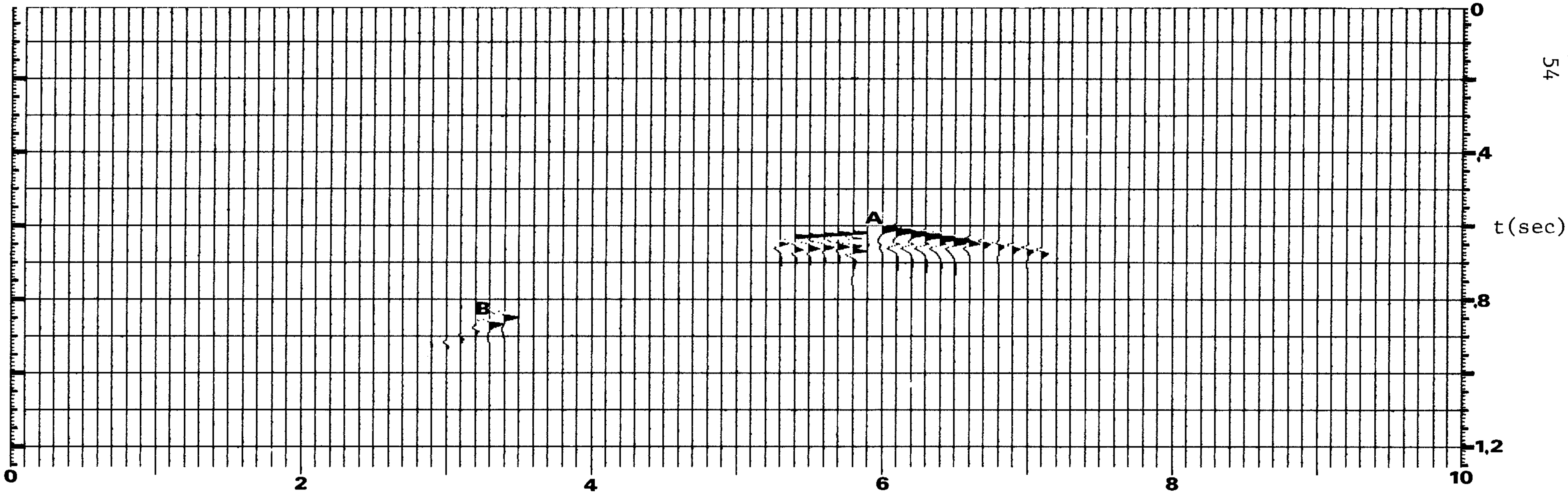


SHALLOW ANTICLINE SEISMOGRAM

Observe bright spot (A), velocity pulldown on oil-gas and oil-sandstone contacts (B), and interference effects (C). Interference effects can occur with or without hydrocarbons, though.

SHALLOW NORMAL FAULT MODEL

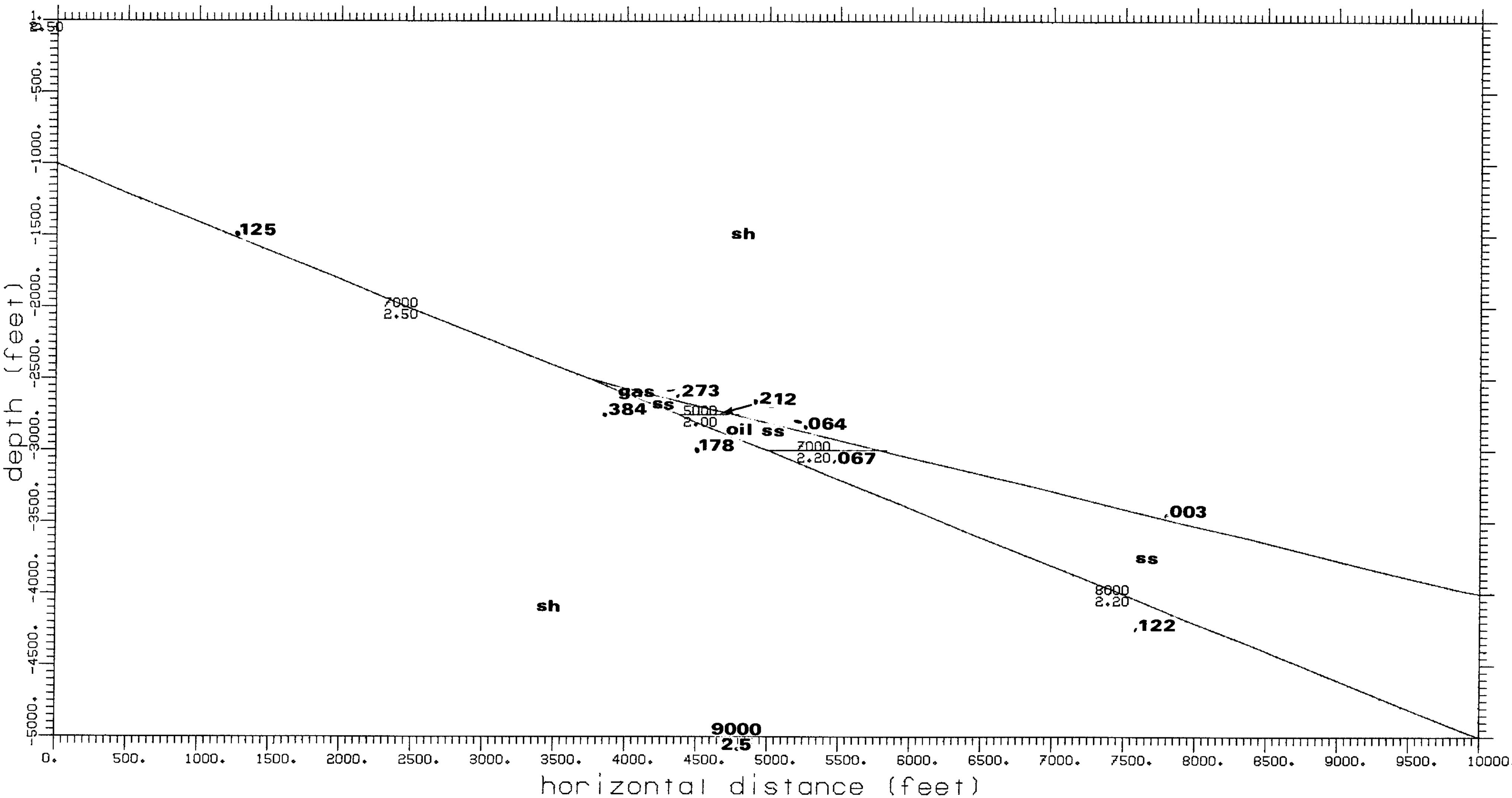


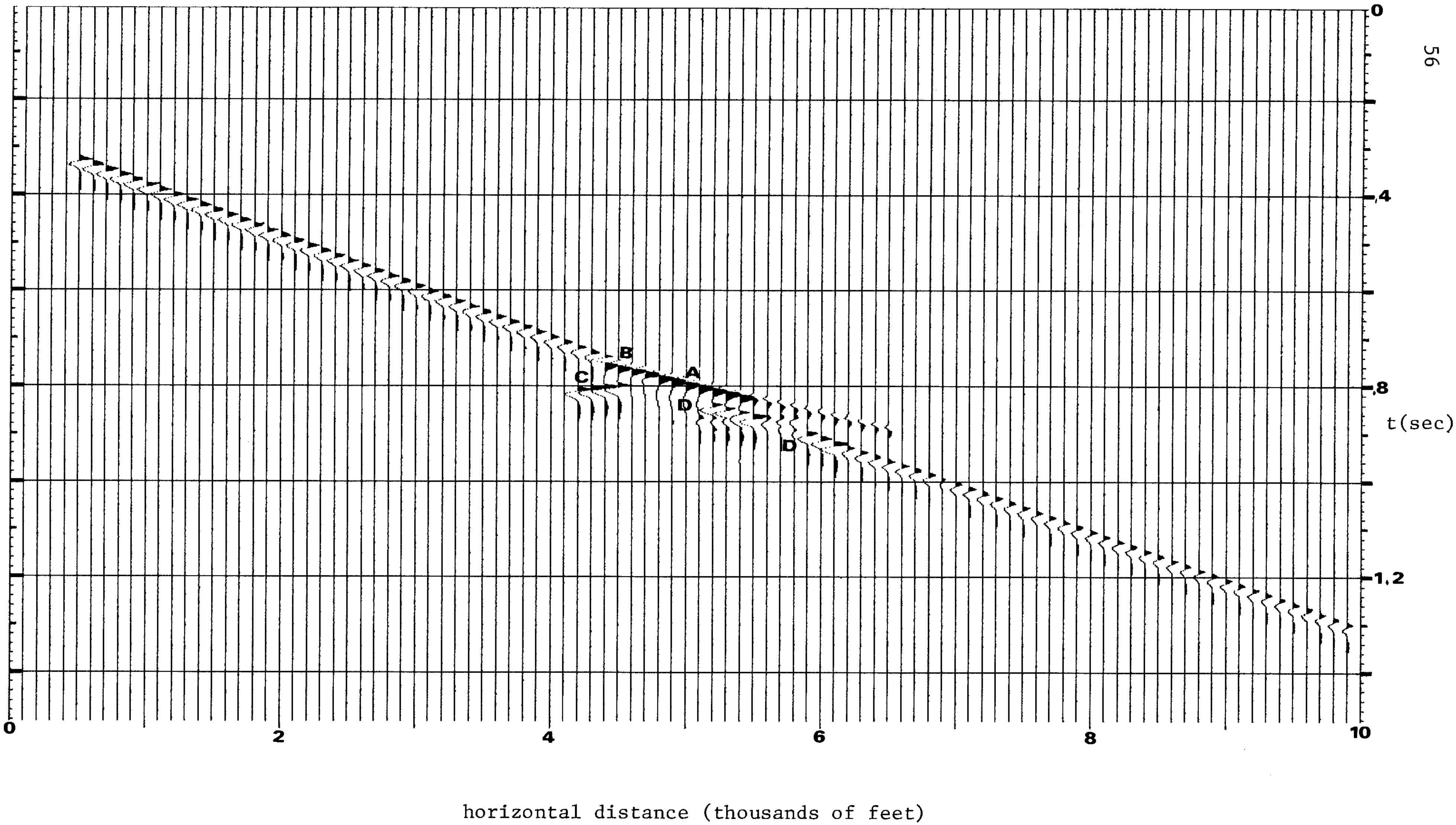


SHALLOW NORMAL FAULT SEISMOGRAM

Shale-sandstone reflection not seen due to low reflection coefficient. Note bright spot (A) effect. Oil-sandstone contact not observed due to lack of resolution. Several of my seismograms have this problem, but making my hydrocarbon pools larger would render them geologically unacceptable, however. Event on left (B) is fault surface.

SHALLOW UNCONFORMITY MODEL



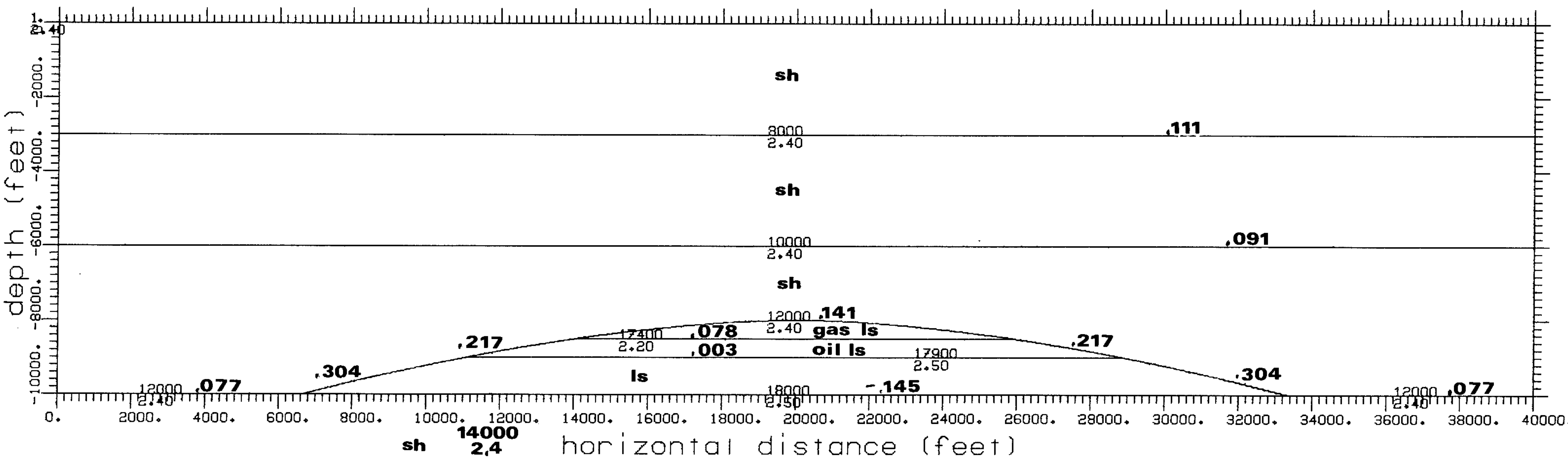


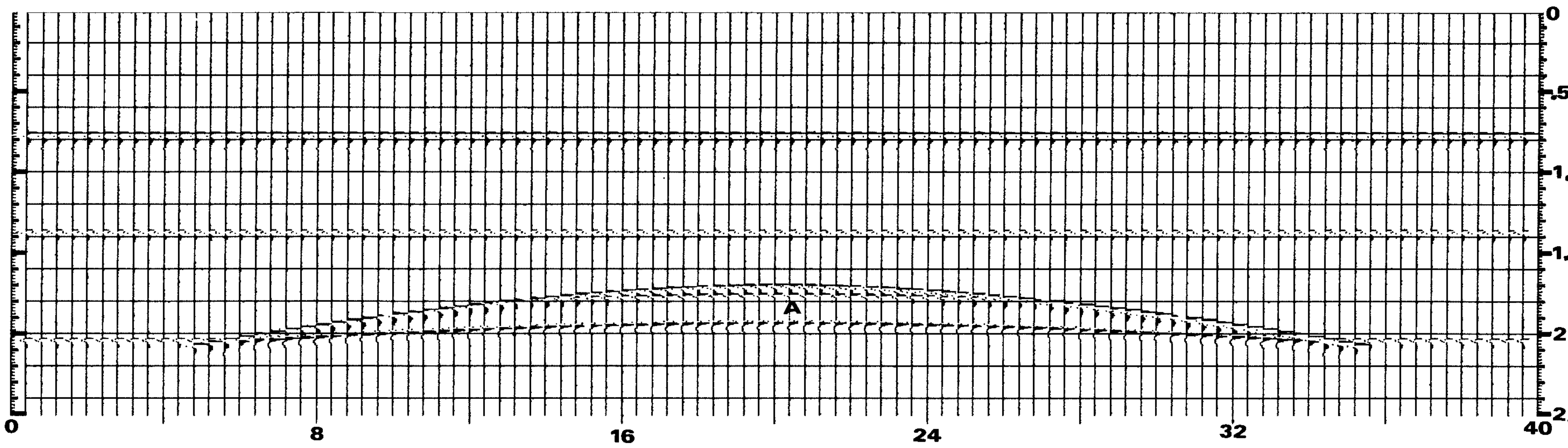
SHALLOW UNCONFORMITY SEISMOGRAM

Upper right interface has too low reflection coefficient to be observed. Bright spot (A), polarity reversal (B), near flat spot (C) (oil-sandstone reflection), and interference effects (D) are present.

REEF MODEL

Note: parameters below 10000-foot depth refer to layer underneathe 10000-foot deep reflector.



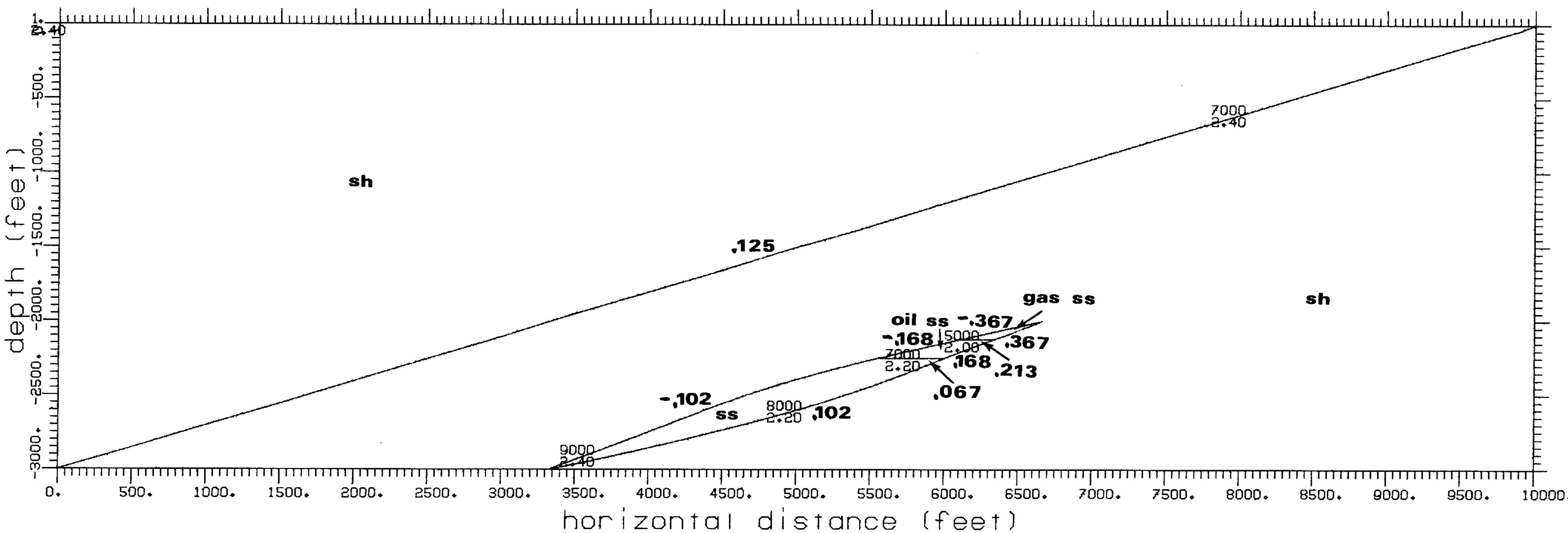


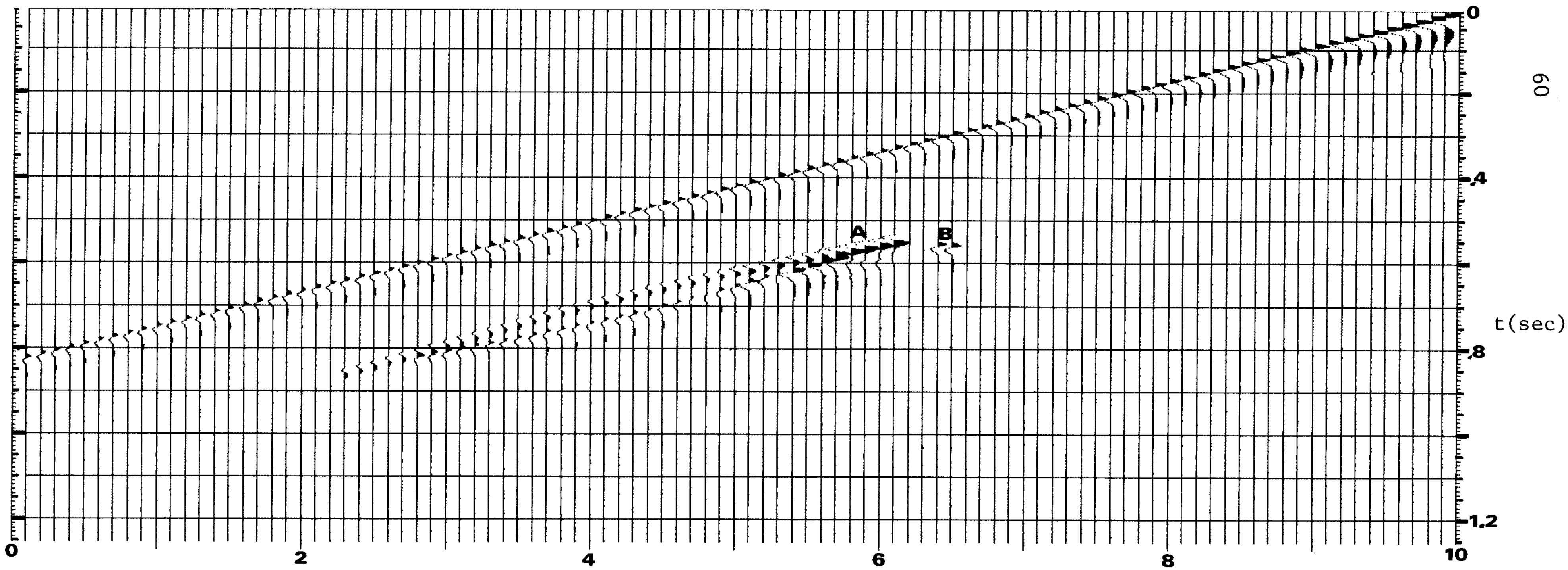
horizontal distance (thousands of feet)

REEF SEISMOGRAM

Note velocity pullup (A) in bottom reflection and oil-gas interface. This is not a DHI, however, as it is not connected with hydrocarbons. Oil-limestone reflection not observed due to lack of resolution and low reflection coefficient.

SHALLOW SAND LENS MODEL



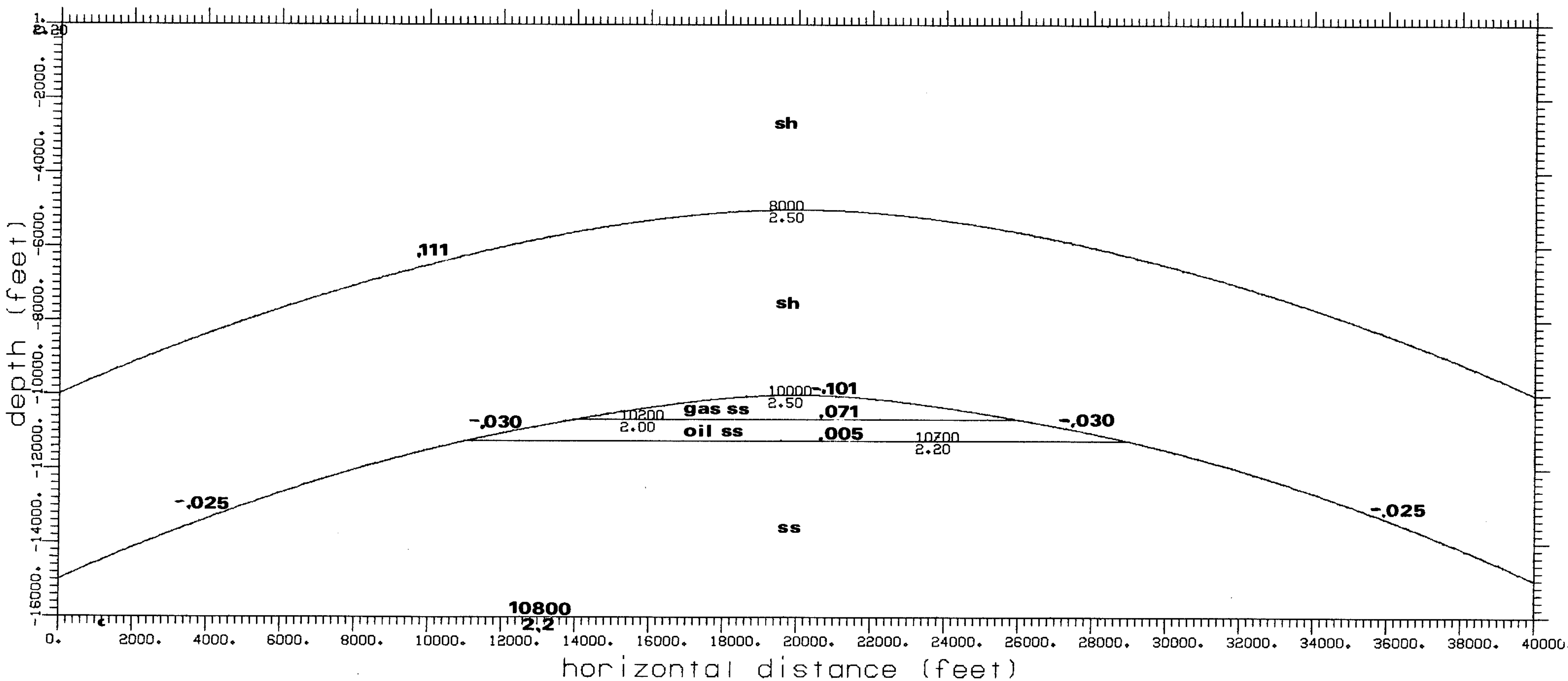


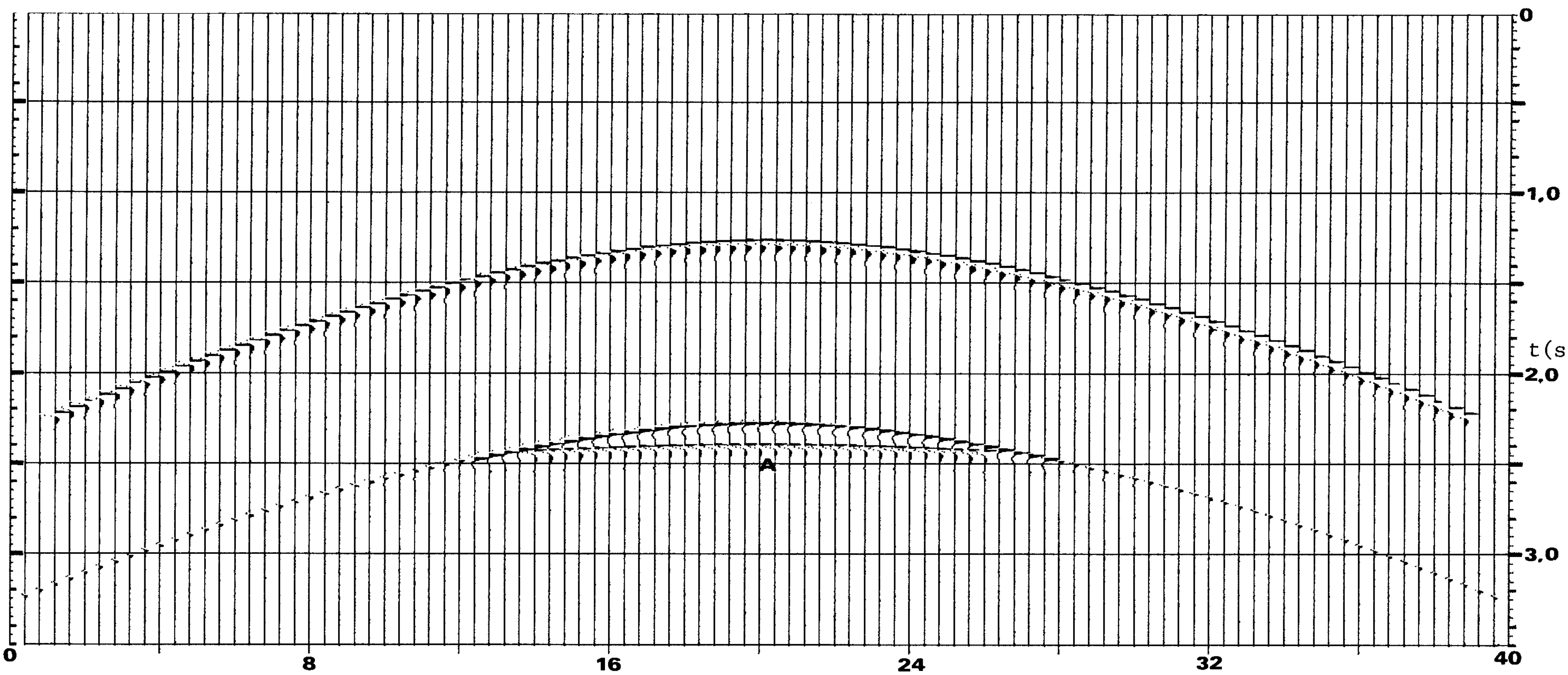
horizontal distance (thousands of feet)

SHALLOW SAND LENS SEISMOGRAM

Bright spot (A) is present. Bottom right event (B) is oil-gas contact. Lack of resolution prevents oil-sandstone interface from being seen.

DEEP ANTICLINE MODEL



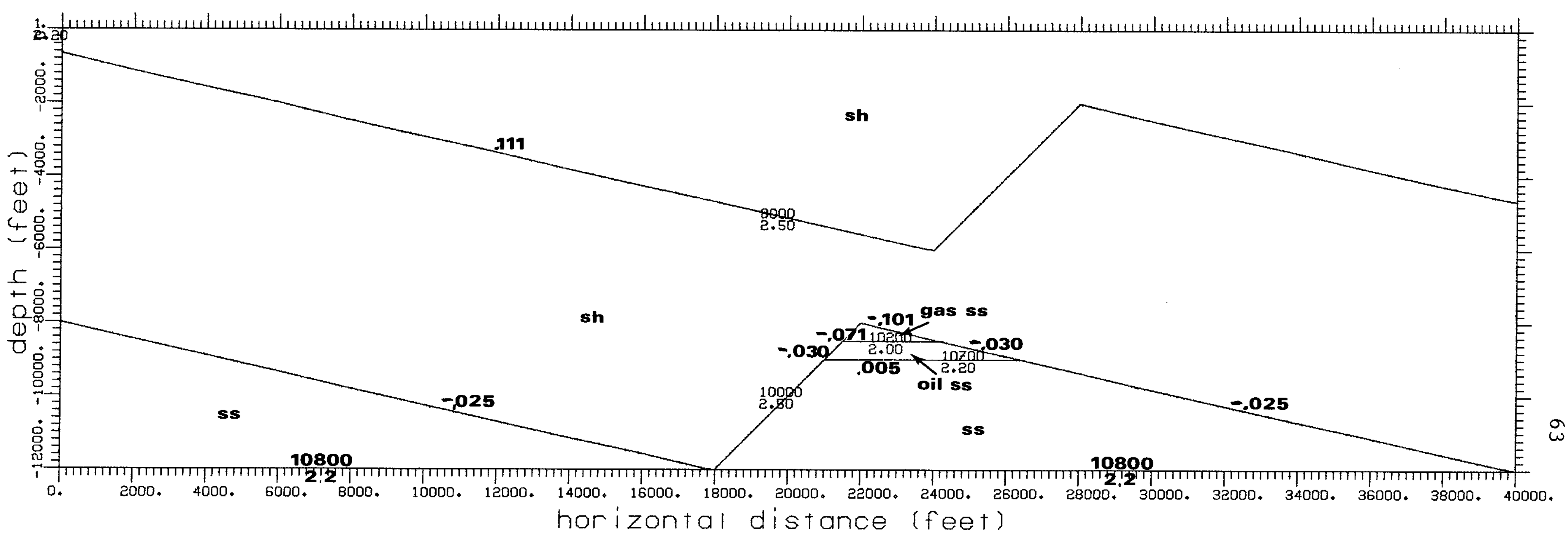


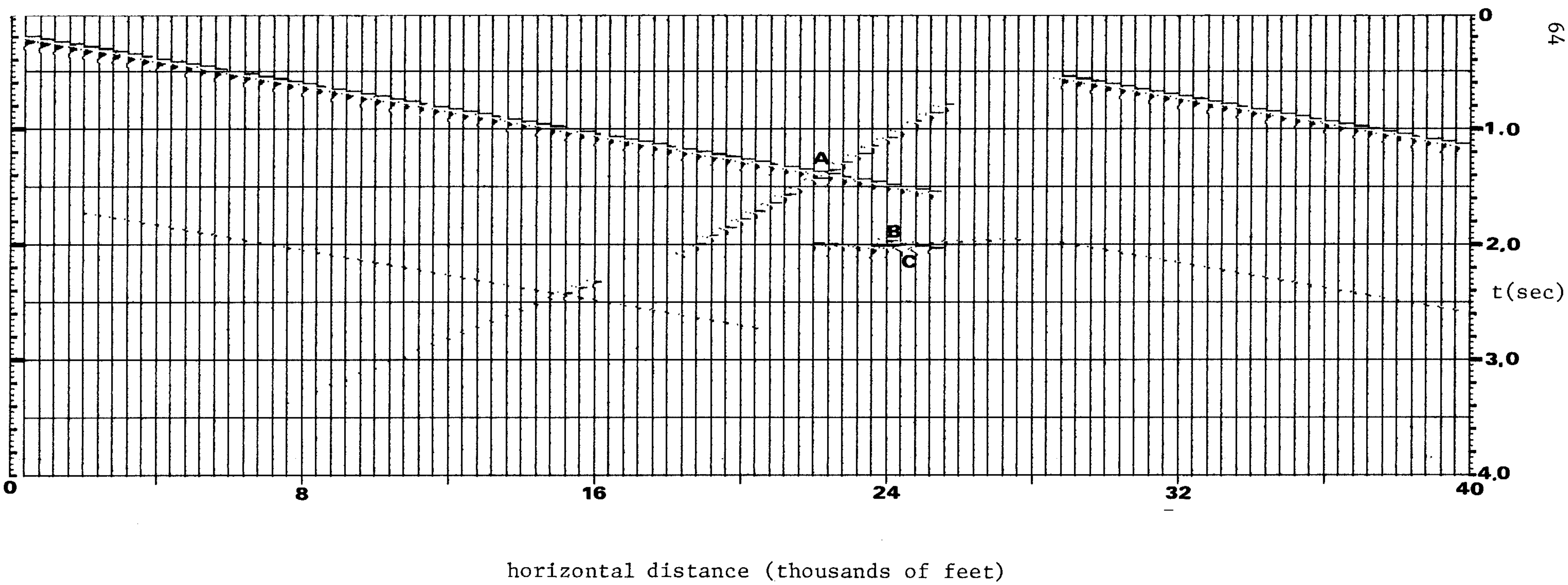
horizontal distance (thousands of feet)

DEEP ANTICLINE SEISMOGRAM

Observe velocity pullup of oil-gas interface (A). Oil-sandstone contact not seen due to low reflection coefficient.

DEEP NORMAL FAULT MODEL

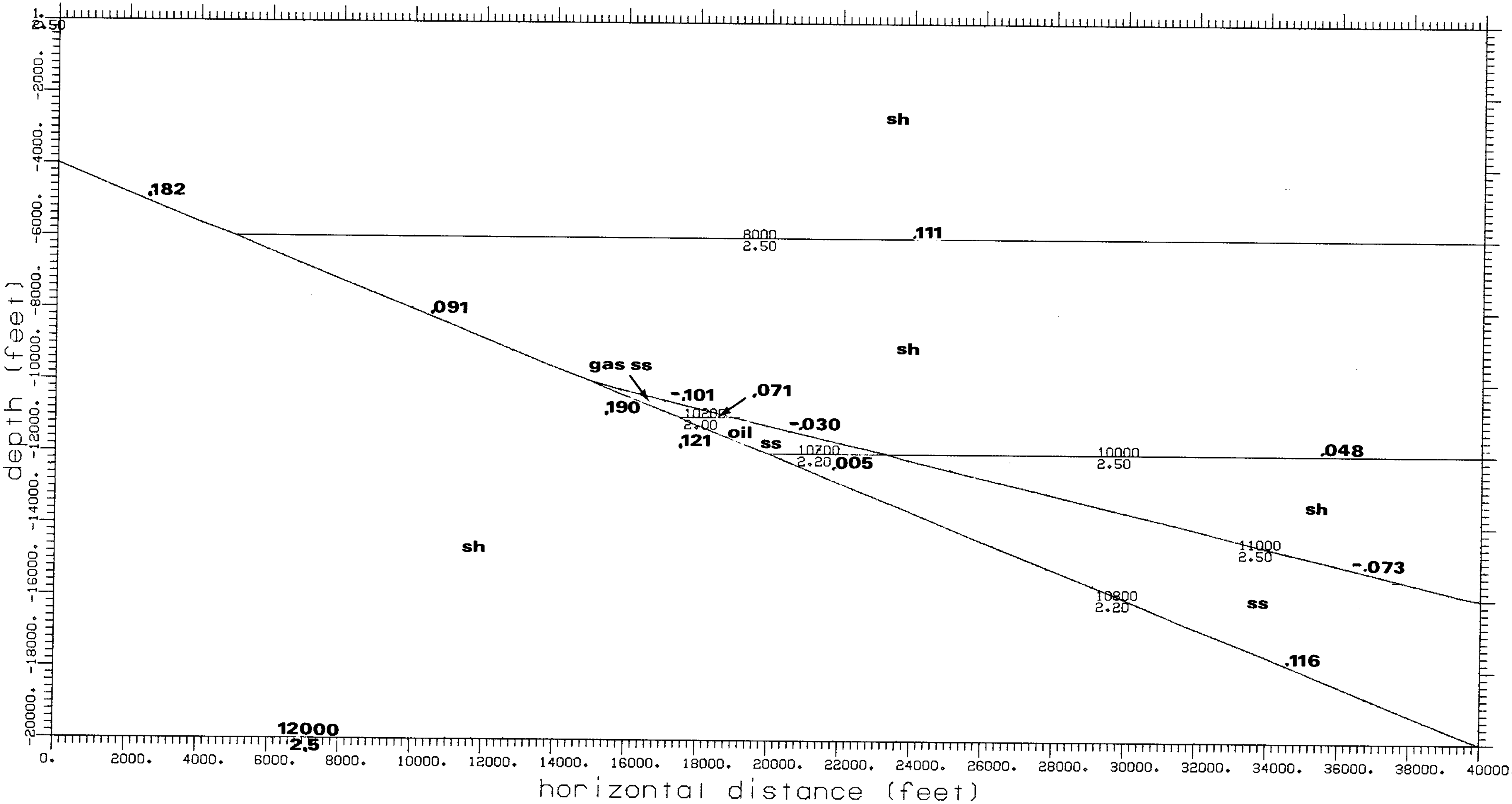


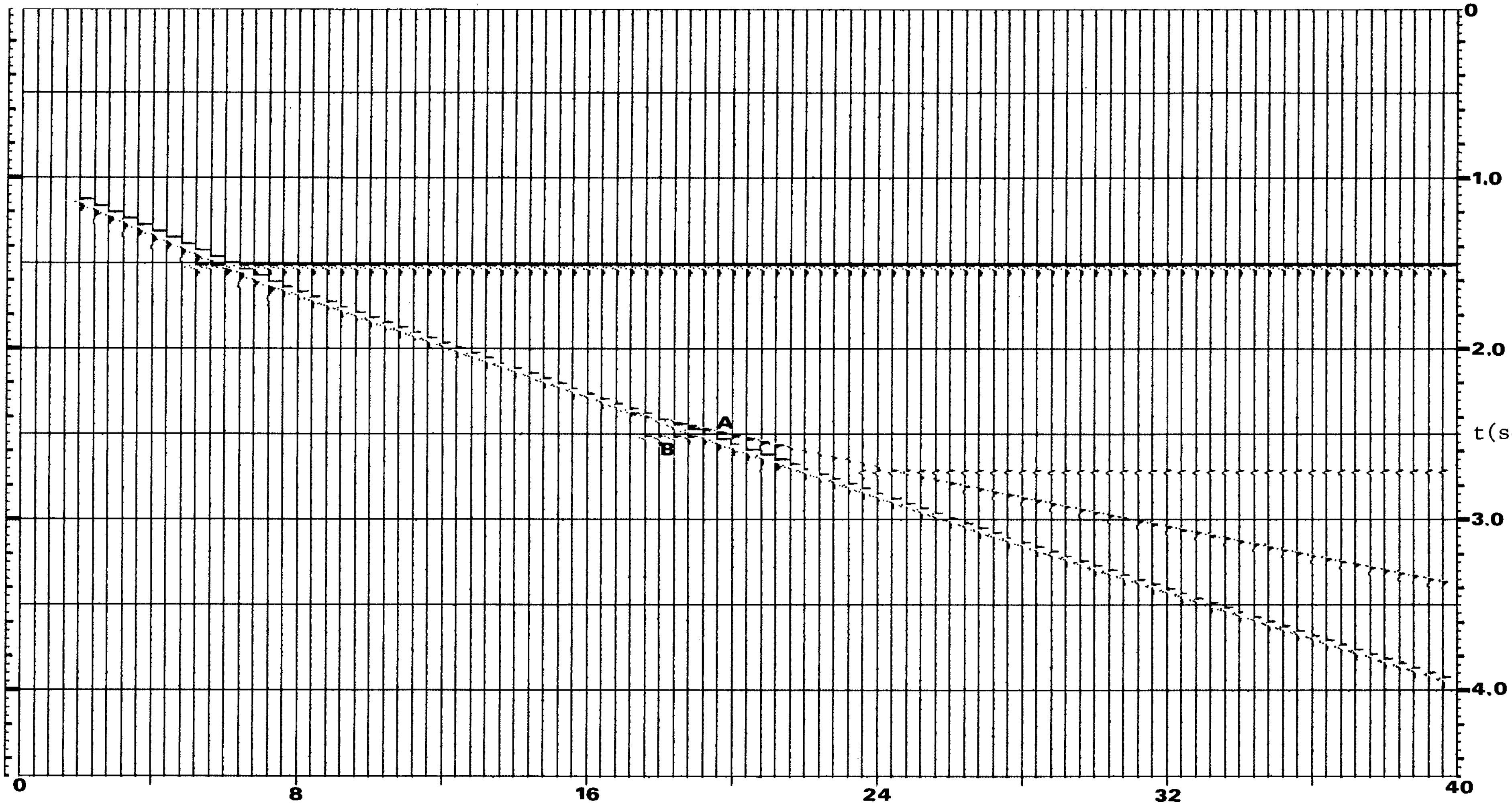


DEEP NORMAL FAULT SEISMOGRAM

Bow-tie effect (buried focus)(A) observed for top reflector. It severely distorts data of bottom reflector, but removing it would make model less geologically acceptable. Slight bright spot (B) can be observed. Oil-sandstone interface invisible, oil-gas interface just barely visible (C). Flat event (B) appears to be combination of fault surface and right shale-sandstone reflection, distorted by top reflector.

DEEP UNCONFORMITY MODEL



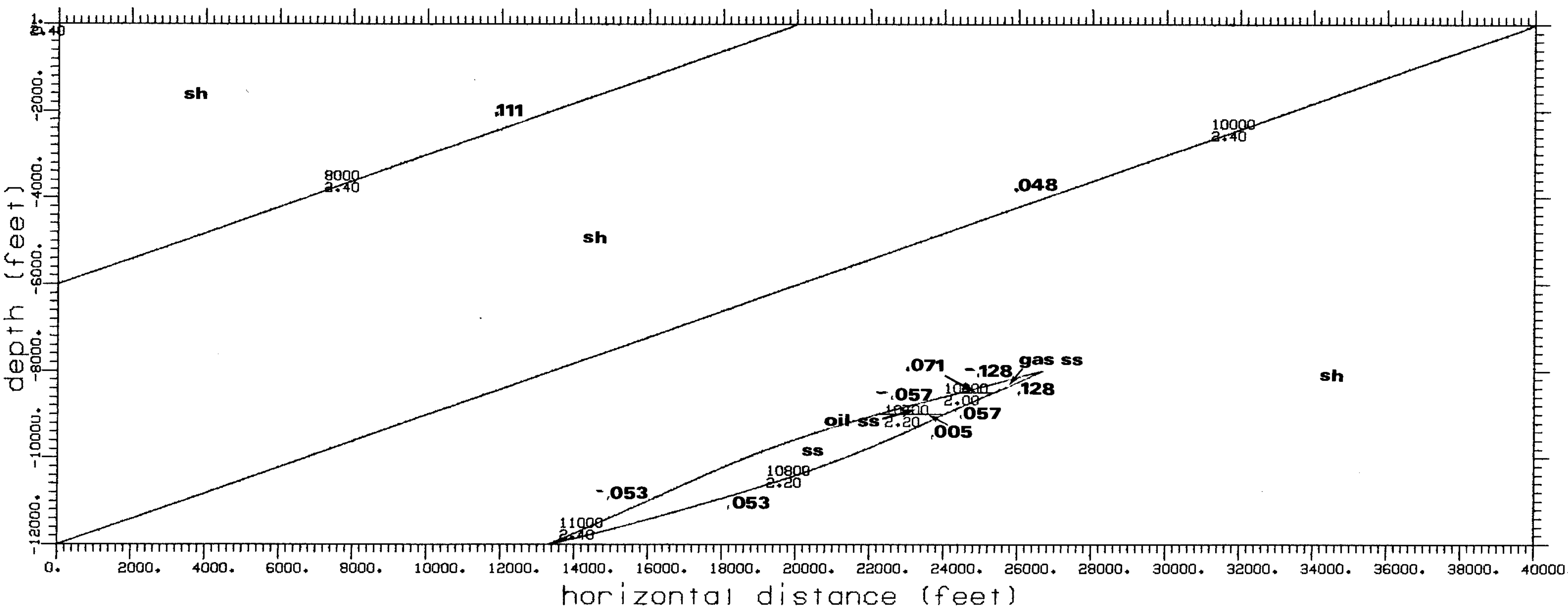


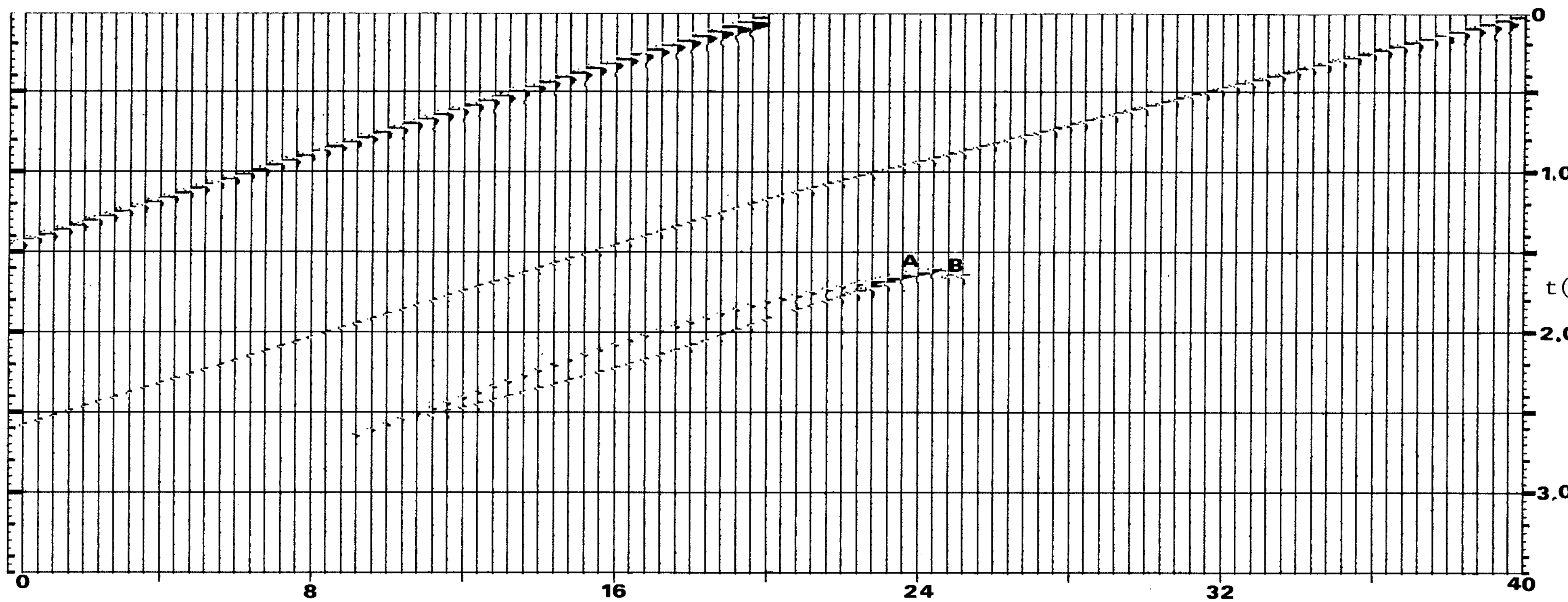
horizontal distance (thousands of feet)

DEEP UNCONFORMITY SEISMOGRAM

Note small bright spot in center (A). Oil-gas interface is flat spot (B). Oil-sandstone contact cannot be seen due to low reflection coefficient.

DEEP SAND LENS MODEL





horizontal distance (thousands of feet)

DEEP SAND LENS SEISMOGRAM

Slight bright spot (A) can be observed. Minor event (B) is oil-gas interface. Reflection coefficient too low for oil-sandstone contact to show.