Side-scanning processing of 3-C field data: A proposal to analyse the Gulf Rumsey survey

Ye Zheng and Robert R. Stewart

ABSTRACT

We propose to process three-component seismic lines using a side-scanning procedure. The 3-C data potentially record reflection or diffraction events from off-line geology. A procedure is designed for using these off-line events to image from the geology directly below the line.

INTRODUCTION

There are many areas of hydrocarbon interest where the structure is not horizontally stratified. When the direction of the seismic line is not in the dip direction of the subsurfaces, or there is solitary structure around the investigated region, there will be some off-line energy in the recording. The existence of the off-line energy (French, 1974; Hospers, 1985) may result in the misinterpretation of the seismic data using conventional analysis. As shown in Fig. 1, there is a dipping subsurface L with the inclined angle θ. If we do not know the energy from L is an off-line energy, we may think it comes from the horizontal interface L' with the reflection point R'. In order to get a model closer to the actual structure, it is necessary to design a procedure to search and extract the off-line energy so as to construct a useful image perpendicular to the line. In other words, we are looking for a method to investigate three-dimension geological structure with seismic data provided by one line.

SURVEY AND GEOLOGY

The seismic data are collected on two lines(see Fig. 2) in the Rumsey region of Alberta. Both lines run north to south. On line 1, there are 41 shot-points and 157 receiving points. On line 2, there are 46 shot-points and 157 receiving points. The data of the all shots were collected at each station for each line. Two kilograms of dynamite were used for each shot. The depth of most shots is 18 m. All receivers were three-component geophones. The three recorded channels of one of the shots are shown in Fig. 3.

The lines lie on the central Alberta plain over preserved Devonian sediments. During the Devonian period, this area suffered many transgressive-regressive pulses correlating to the sea level change. As relative sea level rises, there is some token mound-building and active reef building. The existence of these reefs provides good scatterers for seismic wave as well as potential structures for oil accumulation. Several geological sections have been constructed in the region(Fig. 4). From the sections

CC'(Fig. 5) and MM'(Fig. 6), we can see the geologic structures which could cause scattering. We will attempt to find and use off-line energy in the two lines under consideration.

METHOD

Three-component recording provides the possibility of using off-line energy to construct images not directly below the line (Ebrom et al, 1989). If there is a point scatterer at the half way between source and receiver by the line (Fig. 7), the travel time of the diffraction wave from the scatterer is (Stewart, 1990):

$$t^2 = t_0^2 + \frac{4y^2}{V_{rms}^2(t_0)} + \frac{h^2}{V_{rms}^2(t_0)} + \frac{\Delta x^2}{V_{rms}^2(t_0)} \qquad (1)$$

where

t_0 is the zero-offset, two way travel-time
y is the off-line offset of the scatterer
h is the source-receiver offset
$V_{rms}(t_0)$is the RMS velocity at time t_0
Δx is the offset of the scatterer from the midpoint.

If the scatterer is a dipping interface and the line is parallel to the strike (Fig. 8), the travel time reflected from the midpoint is:

$$t^2 = \frac{h^2}{V_{rms}^2} + \frac{4Z^2\cos^2\theta}{V_{rms}^2} \qquad (2)$$

where

h is the source-receiver offset
Z is the depth of the intersection line of the profile section and the interface
θ is the inclined angle of the interface
V_{rms} is the RMS velocity over the interface.

From the equations (1) and (2), we can see that both types of the off-line events have a hyperbolic shape with the same velocity as the in-line events. It is not easy to reject these off-line events with the conventional technique. Polarization analyse of the three-component recordings is the procedure to distinguish off-line events.

At first, we will analyse the data of vertical and transverse components. We may find some events whose raypath is not along the Z axis but have an angle φ with the Z axis. These events are off-line events. Let's design a polarization filter to reject those events coming along the Z axis. The off-line energy is extracted so far. To turn the coordinate system around X axis with the angle φ, so that in the new coordinate system XY'Z', the off-line energy coming along the Z' axis. Therefore, now the off-line events become "in-line" events. The conventional technique can be applied to process the new data. Furthermore, we can polarization-analyse the radial component and the new vertical component to see where the energy came from. If the raypathes (for common-shot gather) focus at the depth of the reflector, it means the scatterer is a point scatterer. If the off-line energy comes from a dipping interface, the raypathes must focus below the reflector.

A key point in side-scanning analysis is extracting the off-line energy efficiently. We will consider the P-wave data and S-wave. There are some important factors affecting the extraction of the off-line energy:

(1) Interference of the in-line events;

(2) Weakness of the energy from off-line.

We will address these problem in our research.

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REFERENCE

Ebrom, D.A., Tatham, R.H., Sekheren, K.K., McDonald, J.A., and Gardner, G.H.F.,1989, Nine-component data collection over a reflection dome: A physical modeling study; 59th Ann. Internat. Mtg. Soc. Expl. Geophys.

French, W.S., 1974, Two-dimensional and three-dimensional migration of model-experiment reflection profiles; Geophysics, 39, 265-277

Hospers, J., 1985, Sideswipe reflections and other external and internal reflections from salt plugs in the Norwegian-Danish basin; Geophys. Prosp., 33, 52-71

Moore P.F., 1989, the Kaskaskia sequence: reefs, platforms and foredeeps, in ed., Ricketts, B.D., Western Canada sedimentary basin, a case history, Can. Soc. Petrol. Geol., Calgary

Stewart, R.R., 1990 Side-scanning seismic, CREWES project research report, Vol. 2.

Stewart, R.R. and Marchisio, G., 1991, Side-scanning seismic: Analysis and a physical modeling study, presented at the 1991 Annual CSEG National Convention

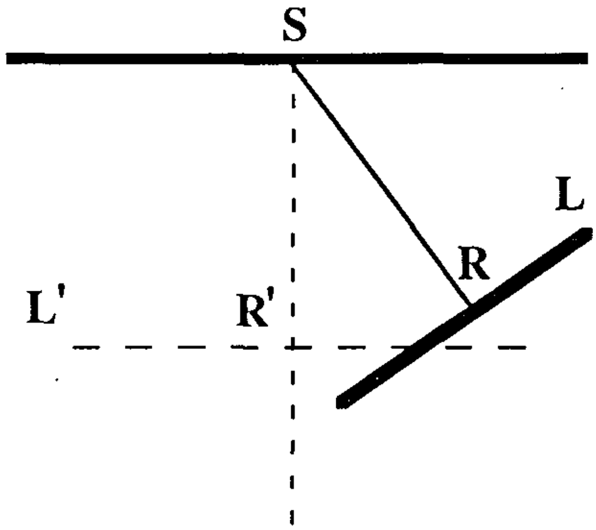


Fig. 1. The seismic profile is out of the plane of viewing

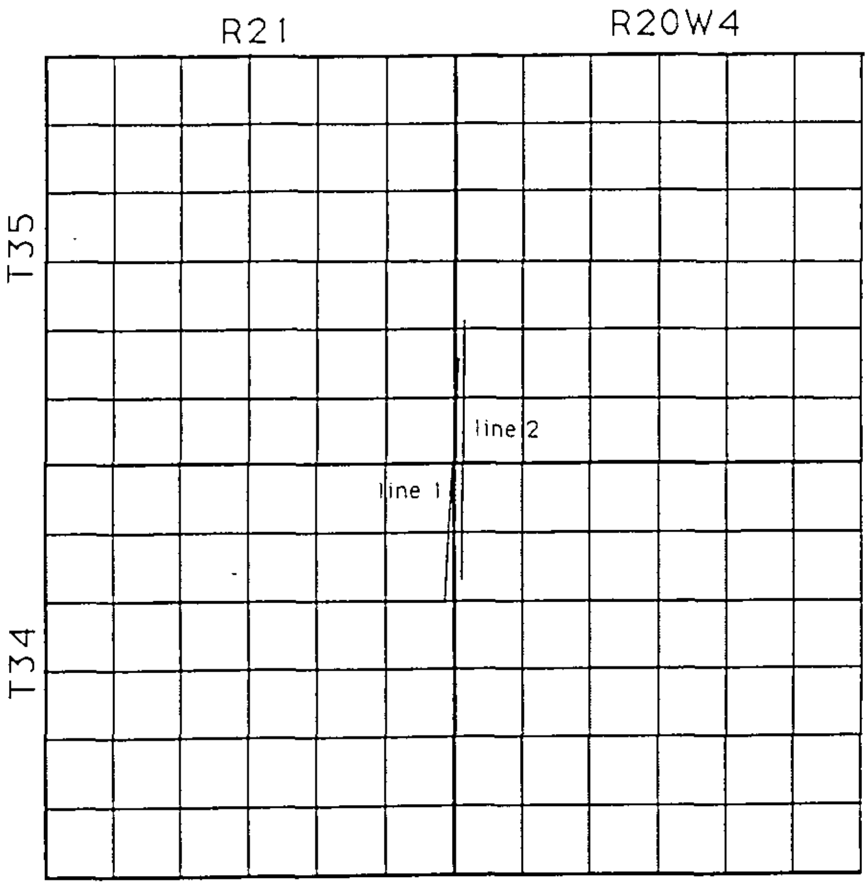
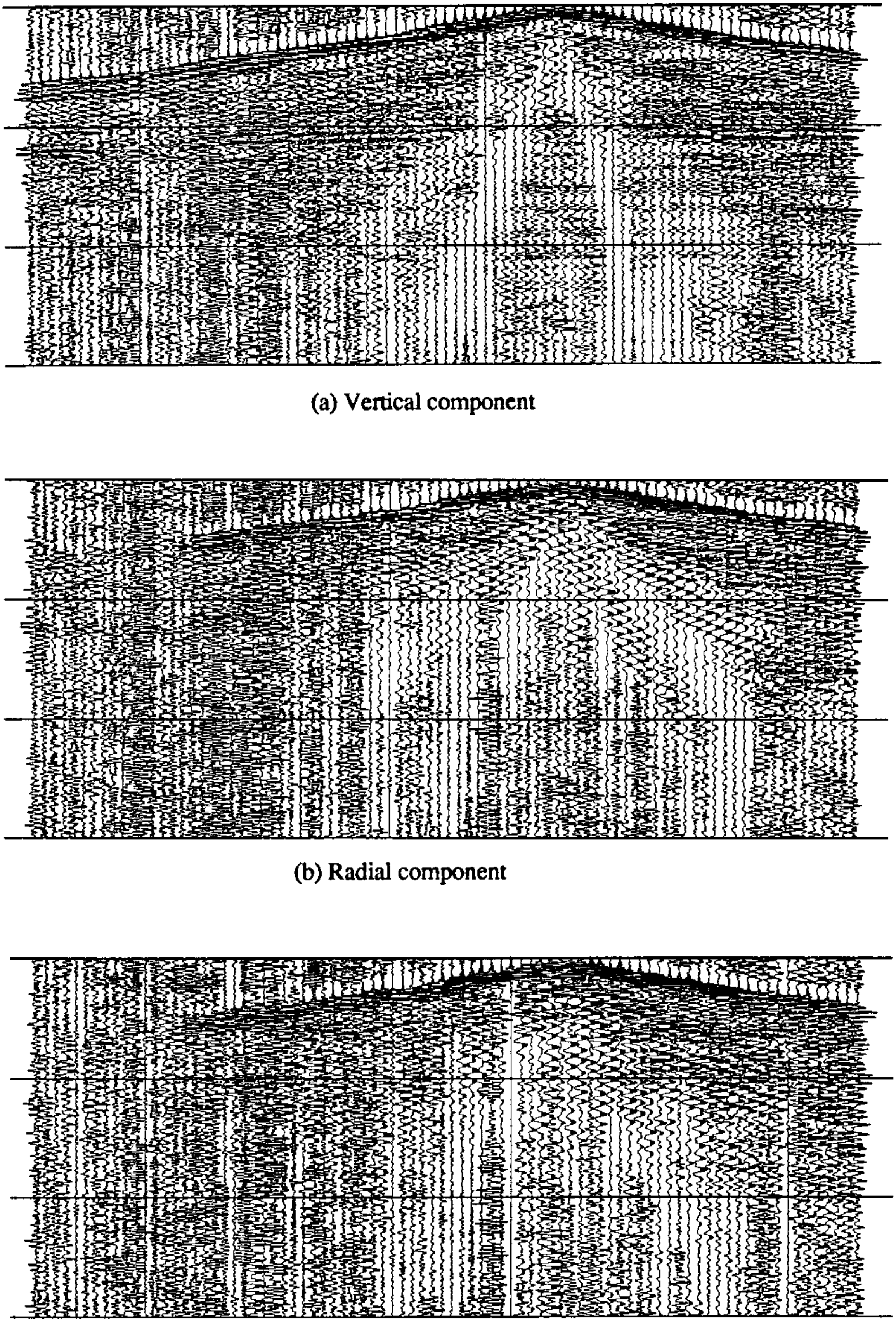


Fig. 2. Location of the lines



(a) Vertical component

(b) Radial component

(c) Transverse component

Fig. 3. Real seismic data from Rumsey

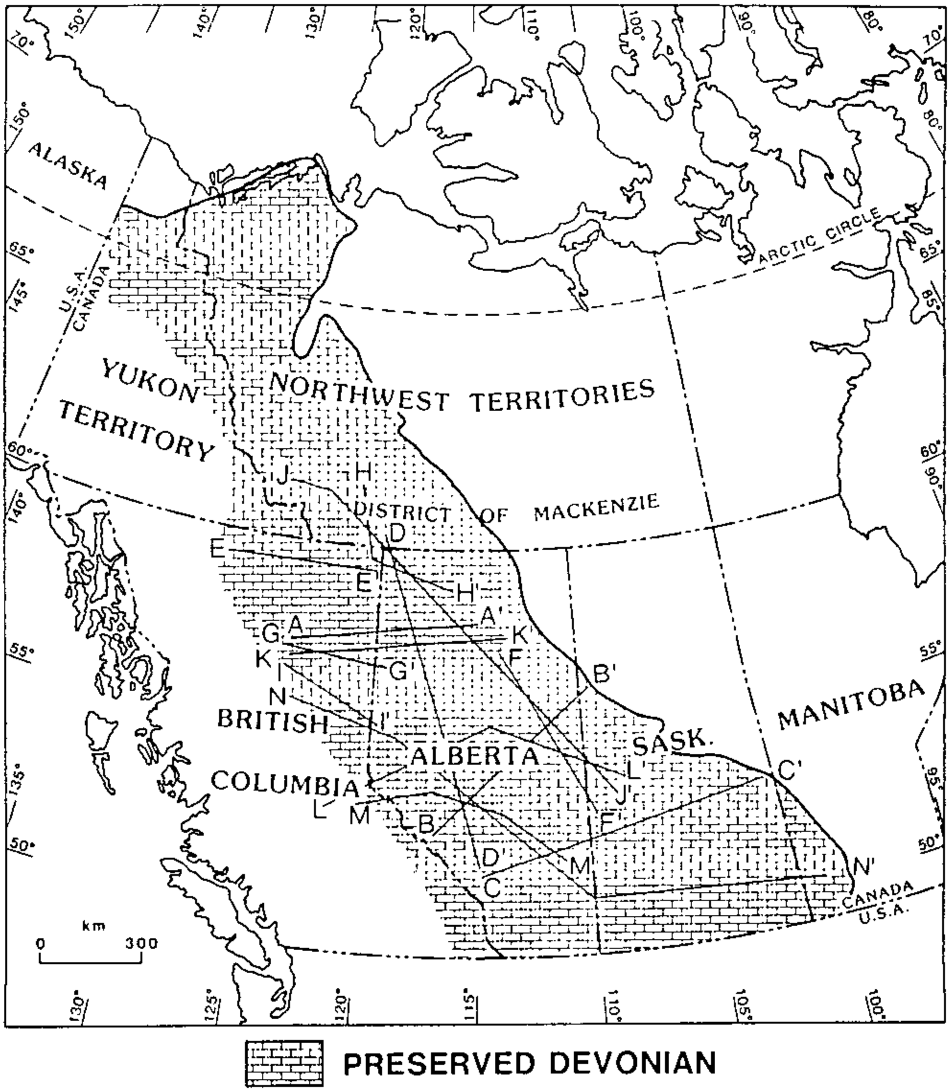


FIG. 4. Locations of the geological sections (from Ricketts, B.D., 1989)

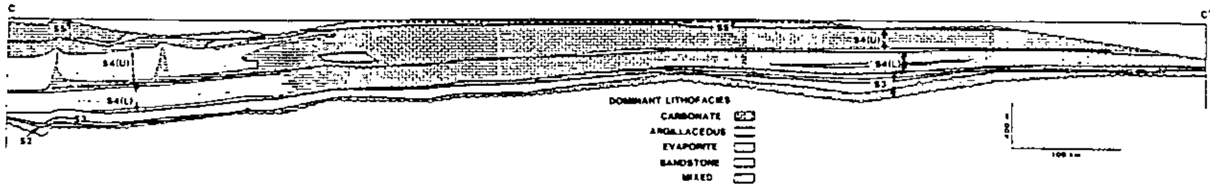


FIG. 5. Section CC' (from Ricketts, B.D., 1989)

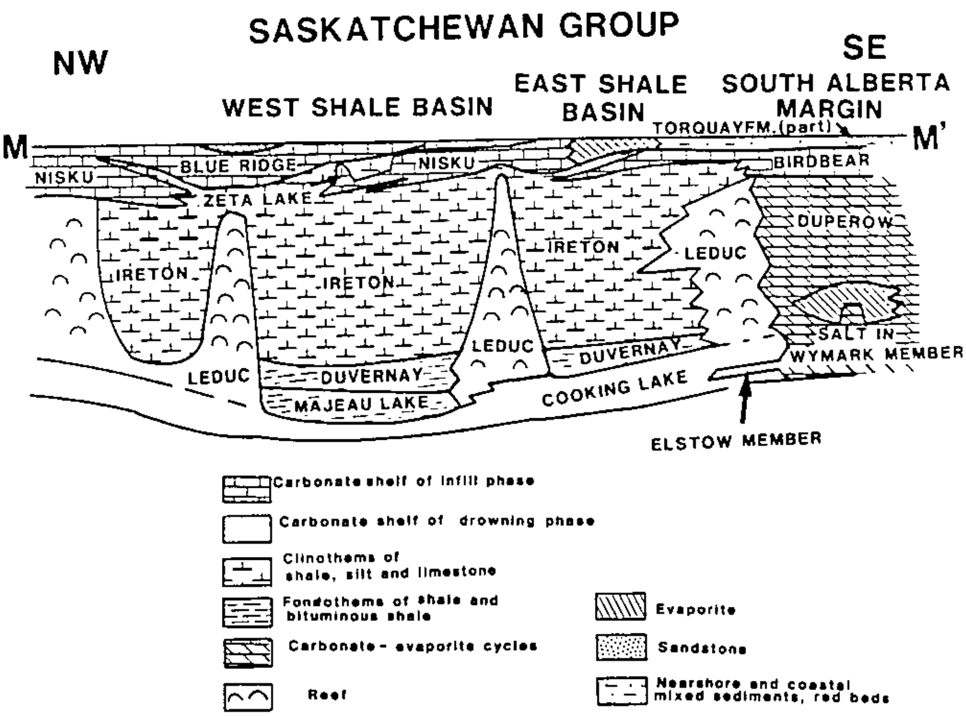


FIG. 6. Section MM' (from Ricketts, B.D., 1989)

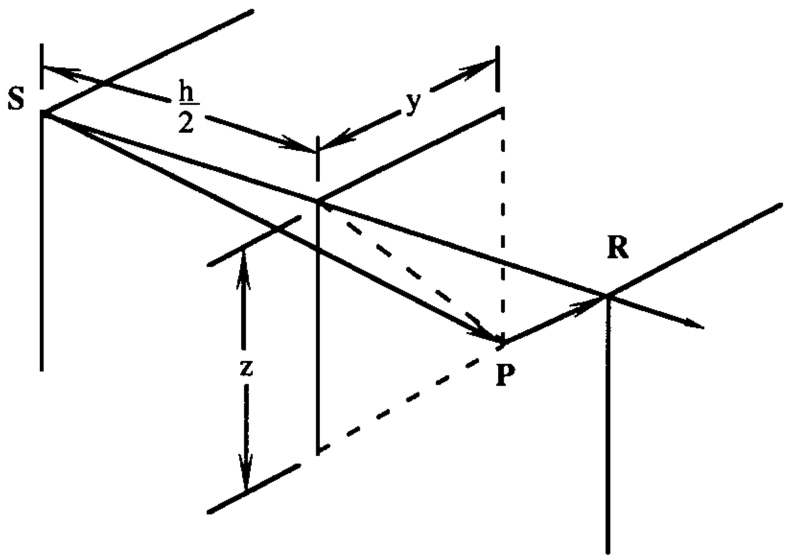


Fig. 7. Geometry of a point scatterer

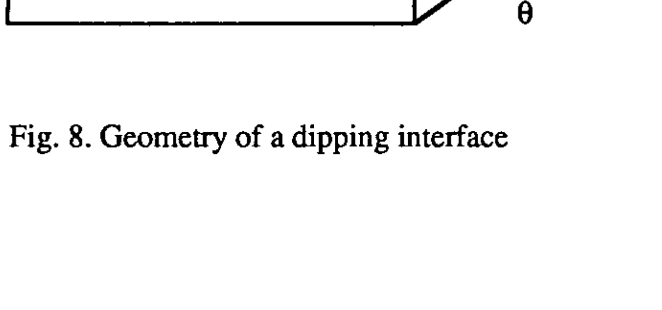


Fig. 8. Geometry of a dipping interface