A converted-wave (P-SV) 3-D processing flow and applications to the Joffre Field, Alberta

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ABSTRACT

The proposed research will investigate aspects of processing 3-component, 3-D seismic data. Specifically we will develop a set of procedures for creating 3-D images of P-SV data. These procedures will be applied to physical modeling data and a field case from Joffre, Alberta.

INTRODUCTION

The acquisition and analysis of three-component (3-C) seismic is becoming a mainstream geophysical activity. Both shear (S-S) and converted-waves (P-SV) have been used in surface seismic and VSP data to detect shear wave splitting and fracturing in reservoirs (Alford,1986; Crampin, 1985; Winterstein and Paulsson, 1990). Shear waves inherently carry more information than P waves about the physical parameters of the rock that can lead to inferences of seismic lithology (Tatham and McCormack, 1991).

Three-dimensional (3-D) acquisition has become commonplace in the oil and gas industry and is the key to the future in exploration, exploitation, and development (Nestvold, 1993). Its use in the P-P mode has lowered exploitation and development costs, giving a higher return on investment (Taylor, 1993).

Recently, work has proceeded in combining pure S and P waves in 3-D into one encompassing reservoir characterization tool (Davis et al., 1993). However, converted-wave 3-D is a topic yet to be explored. The purpose of this work is to develop the appropriate processing flows and algorithms for 3-D P-SV imaging.

We are currently conducting physical modeling experiments to provide data for the processing flow. We also intend to process a 3-D, 3-C receiver dataset acquired by the Colorado School of Mines (CSM) over the Joffre field in Alberta. Our mandate in this work is to study the converted-wave (P-wave source), 3-C receiver data in terms of developing a 3-D converted-wave flow.

The Joffre survey was acquired in the spring of 1993 to assess Nisku porosity distribution. The acquisition parameters are shown in Table 1. Processing problems that we will attempt to address will be Common Conversion Point (CCP) binning and statics, 3-D P-SV DMO, 3-D inversion, and optimal 3-D converted-wave acquisition design.

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GEOLOGY

The Nisku Formation is a Late Devonian carbonate of the Winterburn Group (Figure 1). In Alberta, the Nisku is a laterally continuous, regressive shelf carbonate which surrounds the Winterburn Basin (Rennie et al., 1989). Figure 2 displays a Nisku field summary map which shows Joffre's relative location with other Nisku fields. Joffre is a stratigraphic Inner Shelf play.

The multicomponent survey was designed around the 11-22-39-26W4 well of the Joffre field. The productive porosity zones are located within the open marine interval of the lower Nisku (CSM, 1992). The preliminary work completed by CSM indicates that this region of the Joffre field has significant areal Nisku porosity variations. The predominate facies is completely dolomitized, but secondary anhydrite controls the porosity variability (Rennie et al., 1989). It is this variation due to anhydrite plugging that controls the reservoir heterogeneity, and consequently its production (CSM, 1992).

Anhydrite plugging of primary dolomitic vuggy and moldic porosity may contribute to velocity and density variations within the reservoir. Conventional P-wave seismic has not resolved Nisku porosity variations adequately, and it is hoped that shear-wave acquisition will help resolve the physical characteristics of the reservoir. It is under this premise that the 3-D, 3-C survey was acquired.

PROPOSED PROCESSING FLOW

The proposed flow (Figure 3) is a hybrid that combines the aspects of a standard single-component (P-P) 3-D with aspects of 2-D converted-wave processes that have been developed by previous CREWES researchers (e.g., Harrision, 1989). We propose to initially process two 2-D lines from the survey to establish P-SV processing parameters for Nisku targets. We will then consider the 3-D data volume. The first step will be to process the P-P 3-D volume to the migration stage (Figure 4) in order to provide a comparison with the P-SV case.

Special processes that we envision will need development in the 3-D realm for the P-SV case are:

• Coordinate transformation of the azimuthally varying source-receiver offset. This work will attempt to use both geometric and deterministic rotations and will have significance in anisotropy studies.

• Ground roll removal via polarization filters (Song and Stewart, 1993) and pre-stack filtering using 3-D median *f-k* filters (Stewart and Schieck, 1993).

• P-SV static corrections in the form of P- and S-wave refraction and receiver statics. This will expand the 2-D work of Eaton et al. (1991).

• Asymptotic and depth variant binning (Eaton et al., 1991).

• P-SV NMO (Slotboom et al., 1990) and P-SV DMO (Harrison, 1990). The DMO will be required in structural and isotropic areas.

• 3-D Inversion will be carried out with a P-SV extension to Hampson - Russell Software's new 3-D inversion package.

Interpretation processes will attempt to estimate lithology using T_p/T_s ratios (Harrison, 1989) and 3-D AVO analysis. The interpretation will also be tied to a 3-C VSP acquired in the 11-22-39-26W4 well inside the data volume.

CONCLUSIONS

We have proposed a processing flow for a 3-D converted-wave dataset. We will apply this flow to a physical model and field data.

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TABLE 1 - 3D - 3C Survey Design Parameters

Survey Size: 3240m (N-S) x 4200 m (E-W)
    Note: We will receive a 1 square mile patch of the total survey

Source Points: 742
Receiver Stations: 810
Receiver Lines: 15
Total Bins: 15 650
Bin Size: 30m x 30m
Number of Patches: 4

Fold
    Maximum: 44
    Average: 15

Patch Details
    Number of Patches: 4
    Size: 3240m (N-S) x 1500m (E-W)
    Receiver Lines (N-S)
        Number: 6
        Line Spacing: 300m
        Receivers/Line: 54
        Receiver Spacing: 60m
    Source Points/Patch: 159 to 212

    Source Lines (E-W)
        Line Spacing: 60m
        Source Spacing: 300m

Source Details
    Compressional
        1 Vibrator/Source Point
        Sweep Length: 12 Seconds - Linear
        Frequency Range: 10-120 Hz - Up Sweep
        Number of Sweeps : 7
        Listen Time: 4 Seconds

    Shear
      Note: We will only be receiving the Compressional source data

        2 Vibrators/Source Point (1 Radial and 1 Tangential)
        Sweep Length 12 Seconds - Linear
        Frequency Range: 10-80 Hz - Up Sweep
        Number of Sweeps: 7
        Listen Time: 6-8 Seconds

Geophones
    3 Component

Instrumentation
    I/O System 2
    Sample Rate: 2ms

(From CSM, 1992)

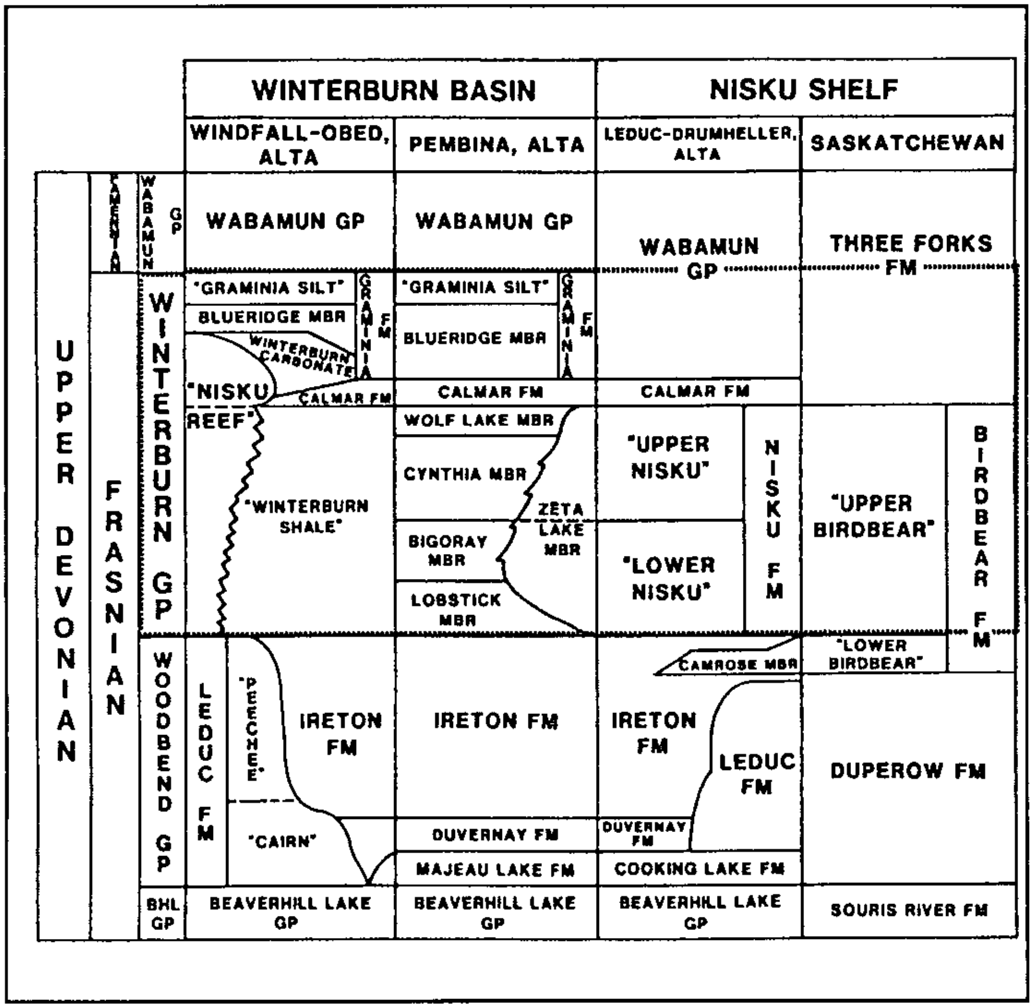

Figure 1: Stratigraphic chart of the Upper Devonian. The nomenclature for Joffre is the Nisku Shelf (Leduc-Drumheller). From Rennie et al., 1989.

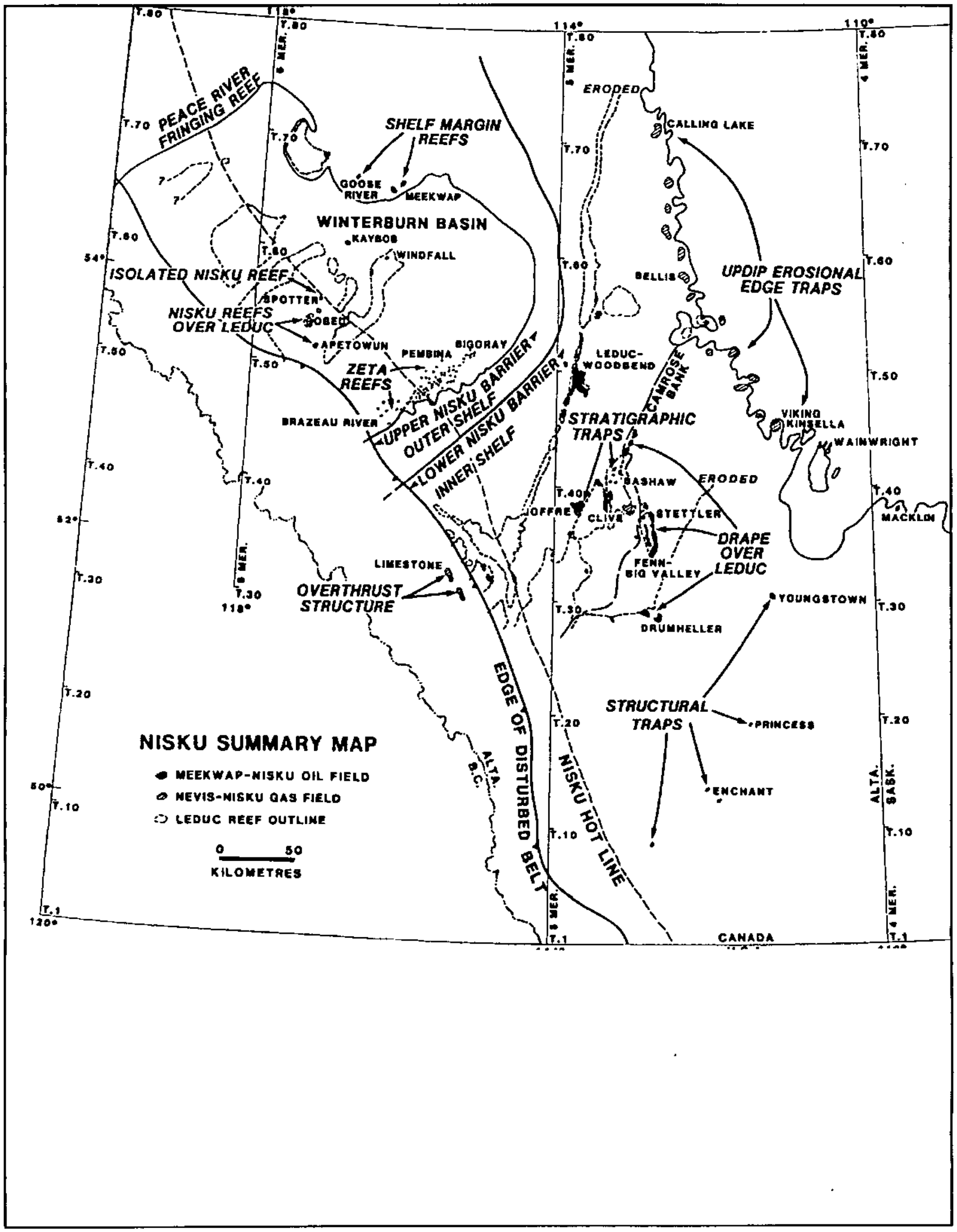

Figure 2: Nisku Field Summary Map for the Western Canadian Sedimentary Basin. The Joffre field is located near Twp. 40 and Rge. 5W6. From Rennie et al., 1989.

Process P-P 3-D to Migration

Coordinate Rotations
(Transverse and Radial)

Birefringence Analysis
(Harrison Rotations)

Natural Coordinate Rotations

Spreading Gain Correction

Deconvolution

Source Statics (P)

P-P Velocity Analysis

Receiver Statics (S)

P-SV Velocity Analysis

Ground Roll Rejection
(Pre-stack Filters)

3D Binning
(Asymptotic)
(Depth-Variant)

P-SV NMO

P-SV DMO
(in structural areas)

STACK

Migration

P-P/P-SV Inversion

INTERPRETIVE PROCESSES

3D AVO Analysis

Vp/Vs Ratios

Figure 3: Proposed 3D P-SV Processing Flow

Demultiplex

Geometry Assignment

3D Refraction Statics

Spreading Gain Correction

Surface Consistent Deconvolution

Brute Velocities

Brute Stack

Surface Consistent Statics

Final Velocity Analysis

Surgical Air Blast Filter

Zero Phase Deconvolution

Trim Statics

Mute

Stack

Migration

Figure 4: Proposed 3D P-P Processing Flow