# DUPLEX WAVE MIGRATION

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## ABSTRACT

When a seismic dataset is acquired all types of wave modes are recorded. These include primary reflected energy, as well as direct, multiple, shear and mode converted waves to name a few. Conventional data processing is targeted towards enhancement and positioning of primary reflected energy while the other wave modes are deemed noise and suppressed. One type of wave mode, duplex waves, is routinely found in seismic datasets that contain sub-vertical subsurface features. The term duplex wave describes propagation paths with a double reflection involving a reflecting base boundary and a sub-vertical feature. The purpose of this paper is to introduce the possibility of using duplex waves to directly image vertical features such as faults and fractures. Here, we demonstrate concepts through the use of synthetic and a 2D field data example.

## INTRODUCTION

Conventional time-domain data processing discriminates against duplex waves through the explicit use of hyperbolic moveout assumptions. Modeling results show that duplex waves have kinematics that severely differs from primary reflected waves, thus procedures such as NMO, DMO, and pre-stack time migration stack out duplex waves. Pre-stack depth migrations are still designed to correctly image primary reflected energy and thus experience a challenging problem of imaging vertical features such as faults and fractures.

In this paper we introduce a newly developed pre-stack depth migration (PSDM) technique by expressly designing a migration operator for duplex waves in order to directly image sub-vertical features such as faults and fractures. A brief overview of theory will be provided before two processing examples on synthectic and 2D field seismic data are illustrated.

## THEORY

The term duplex wave describes propagation paths with a double reflection involving a reflecting base boundary and a sub-vertical feature (Figure 1). Many

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authors have proposed various operators to perform duplex wave migration. In this paper we briefly introduce the method proposed by Dr. Kostyukevych at Tetra Seis Inc, Canada. Migration of duplex waves is based on the Kirchhoff transformation in which the Green's function is changed according to the kinematics for duplex waves.

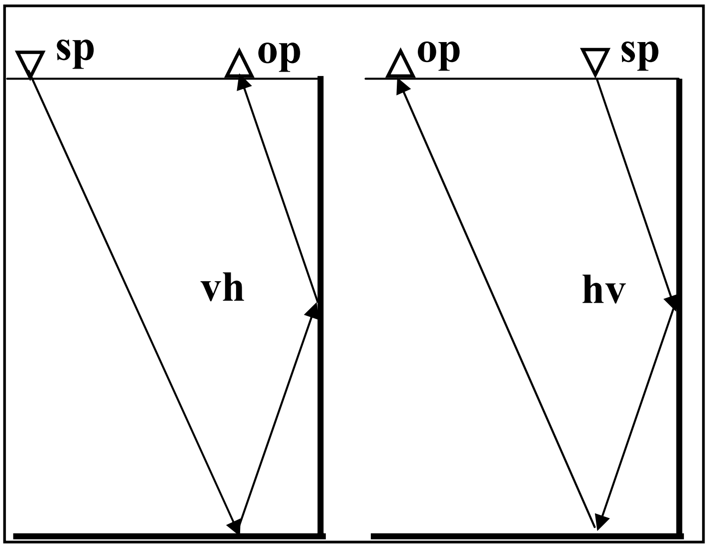


Figure 1. Raypaths of duplex waves: vh – reflecting at base boundary first; hv – reflecting at vertical features first.

For real field datasets the interval-velocity model obtained from conventional PSDM is used to migrate duplex waves. In order to enhance the stability of the process as well as speed it up, a base sub-horizontal reflection boundary should be specified. The base boundary is chosen based on its pervasive continuity throughout the survey and proximity to the subvertical feature to be imaged. More than one base boundary can be used and it is picked after the dataset has been conventionally migrated.

## SYNTHETIC DATA PROCESSING RESULTS

Synthetic seismic data were created by a 2D full waveform modeling scheme. The velocity model is illustrated in figure 2a. This model represents a thin-layer model with a zero-throw fault. Figure 2b shows synthetic shot gathers created by modeling at 500 and 600 m with duplex waves are highlighted by yellow arrows. The duplex waves appear similar to multiple reflections with a large moveout contrast with respect to primary reflections. Hence, they will be eliminated during conventional processing.

Figure 2c is a conventional Kirchhoff migration of the resultant stack. Notice that there is no suggestion of the duplex wave or the sub-vertical fault. This is because there is no diffraction energy which is used in conventional migration. Figure 2d is the result of pre-stack duplex wave migration. Traveltimes were computed via ray tracing through the known model for duplex waves and used in Kirchhoff depth migration. A sub-vertical event in the correct position of the fault was imaged.

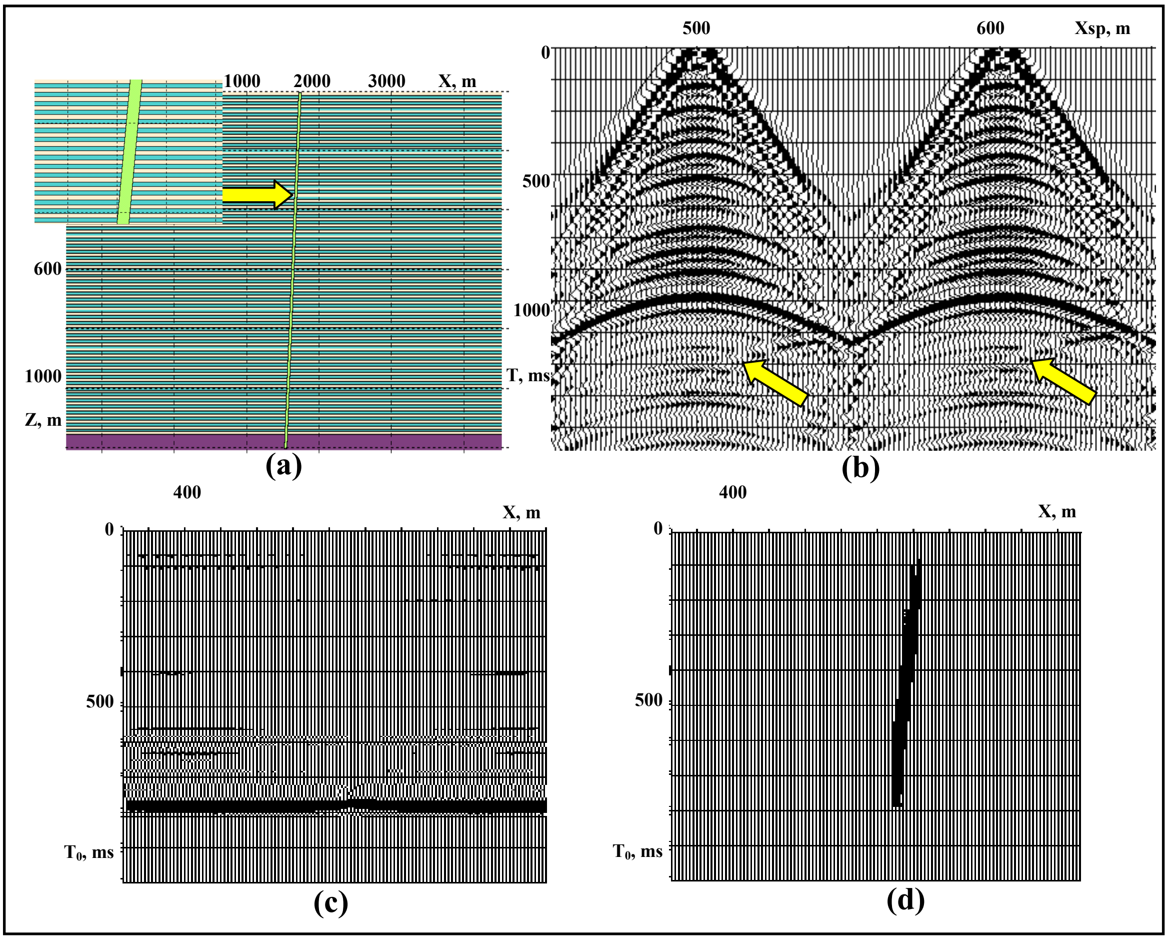


Figure 2: Synthetic data example: (a) thin-layer model; (b) synthetic shot gathers; (c) conventional stacked section; (d) stacked section after duplex wave migration.

## 2D FIELD DATA PROCESSING RESULTS

A 2D seismic line was used to field test the duplex wave migration. No special steps were taken during acquisition to collect the duplex wave information. Conventional data processing only shows sub-horizontal layers with some discontinuities (bottom image of Figure 3). As well as the synthetic example however, the duplex wave migration enables us to identify the sub-vertical faults at correct positions. During processing, no special procedures were used to enhance the duplex waves. Using the interval velocity model obtained from PSDM and interpretation of one strong reflector to serve as the base reflector, duplex wave migration was conducted over the entire line.

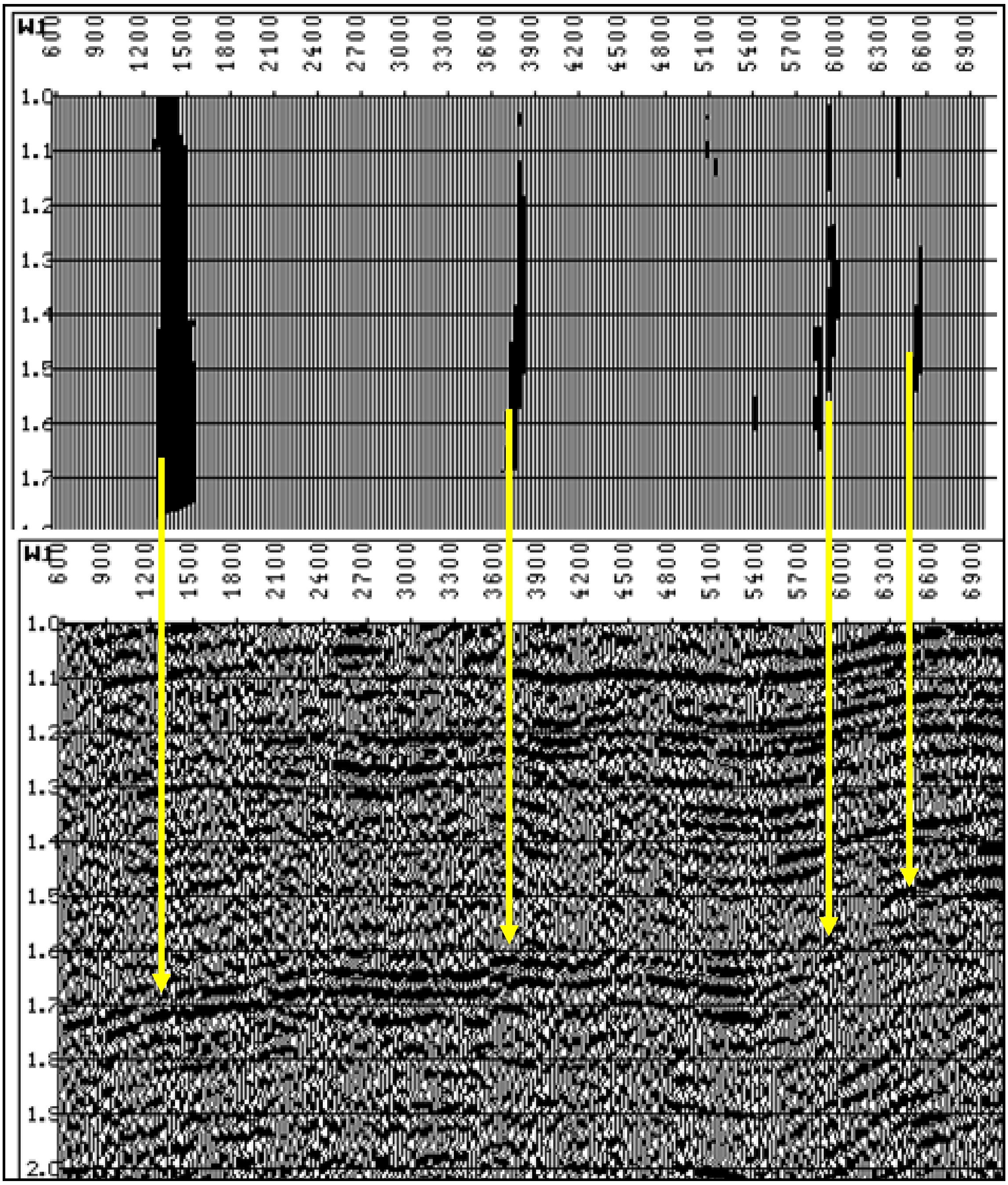


Figure 3. Field data example of duplex wave migration: Top – duplex wave migration; Bottom – conventional migration.

## CONCLUSIONS

Duplex waves are routinely recorded on seismic surveys in the vicinity of vertical features. As conventional processing is targeted to processing primary reflections, duplex waves have been suppressed. A 2D full-waveform modeling experiment has shown that duplex waves are readily identifiable and exist in reflection strength and abundance and they can be used to image sub-vertical features such as faults and fractures.

For the real data, using interval-velocity model obtained from conventional PSDM and a strong base boundary we can correctly migrate the duplex waves yielding a stacked section that accurately image sub-vertical features such as faults and fractures.

## REFERENCE

Presentations and Manual for using Duplex Wave Migration software. Tetra Seis Inc.