Migration of Slant-Midpoint Stacks
Field Data Example

Rick Ottolini

Motivation

The migration of slant-midpoint stacks, as a method of migration-before-stack, counters the defects of migrating CDP stacks. These defects include attenuating steep dips, dip selectivity, and ineffective use of wide offset information. Figure 1 shows a migrated CDP stack of a growth fault dataset. Stacking had obliterated the fault plane reflections present on the constant offset section as shown in figure 2. Fortunately, slant-midpoint stack migration recovers these fault plane reflections as shown in figure 3.

The migration of slant midpoint stacks is a method of migration-before-stack which retains the practical advantages of operating in CDP coordinates, but with a migration operator which makes no approximations for steep dips, wide offsets, and depth velocity variations as do most migration algorithms in midpoint-offset coordinates. Midpoint sections are more desirable to work with than shot profiles or the entire field dataset because truncation and aliasing are far less. This is probably why constant offset section migration is more popular than s-g migration. Also CDP gathers are less sensitive to dip: minimum travel time is always at zero offset. However, field coordinates have a theoretical advantage over midpoint coordinates when there are lateral velocity variations.

The Method of Slant-Midpoint Stack Migration

The mathematics of migration slant-midpoint sections has been most recently discussed in chapter 4.3 of Claerbout's text "Imaging the Earth's Interior" (SEP-30). Essentially, most migration geometries can be shown to be special cases of a general non-zero offset seismic experiment (embodied in the "double square root equation"). A formula for migrating slant-midpoint stack sections is derived, with *no approximations for dip or offset* when no

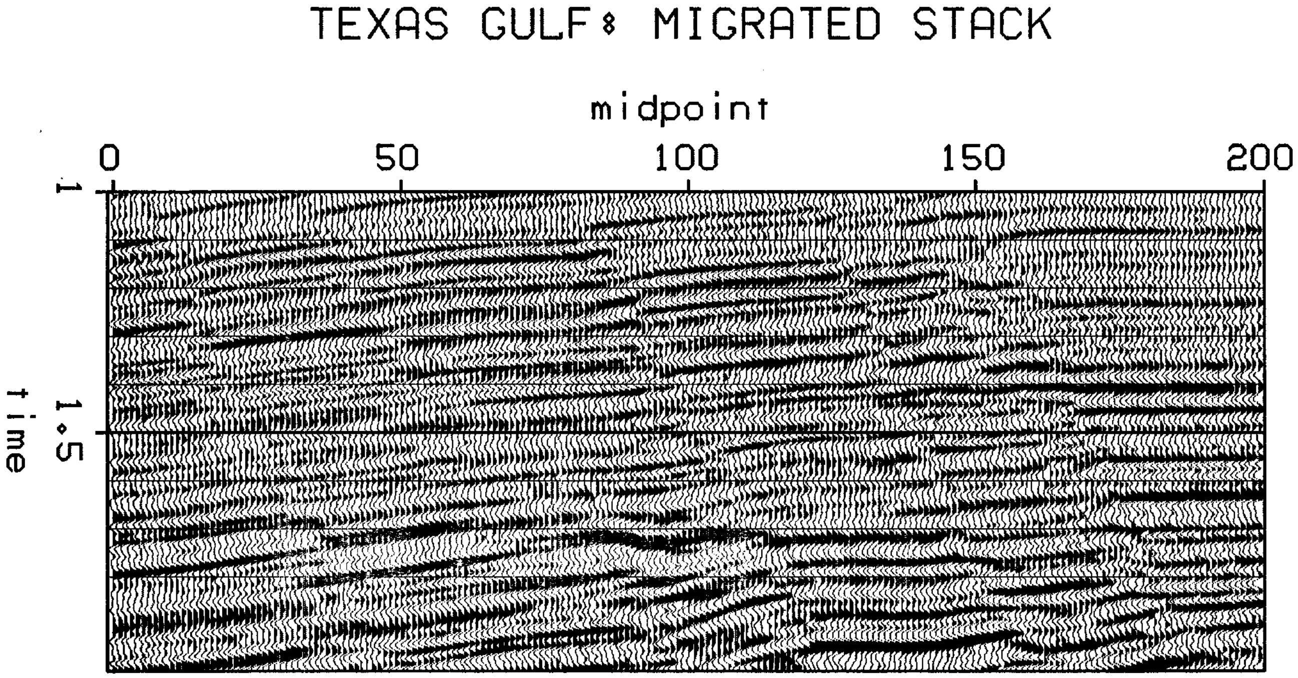

FIG. 1. CDP stack migration of dataset from the Texas Gulf coast. The geology consists of several steep dipping growth faults. The zero-offset migration was implemented using a phase shift algorithm (accurate for 90 degree dips, if present).

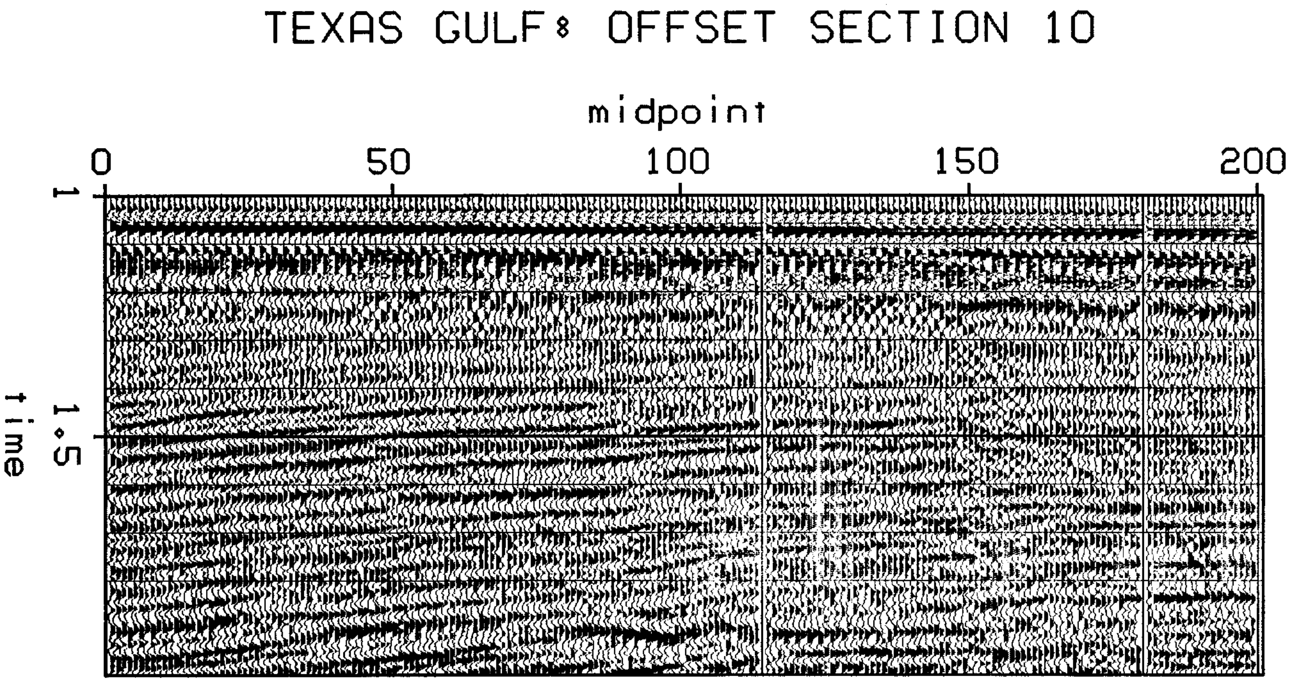

FIG. 2. A constant offset section from the same dataset. Faint fault plane reflections are present at most offsets. The near offset is the same on every other gather, causing the saw tooth appearance at short travel times.

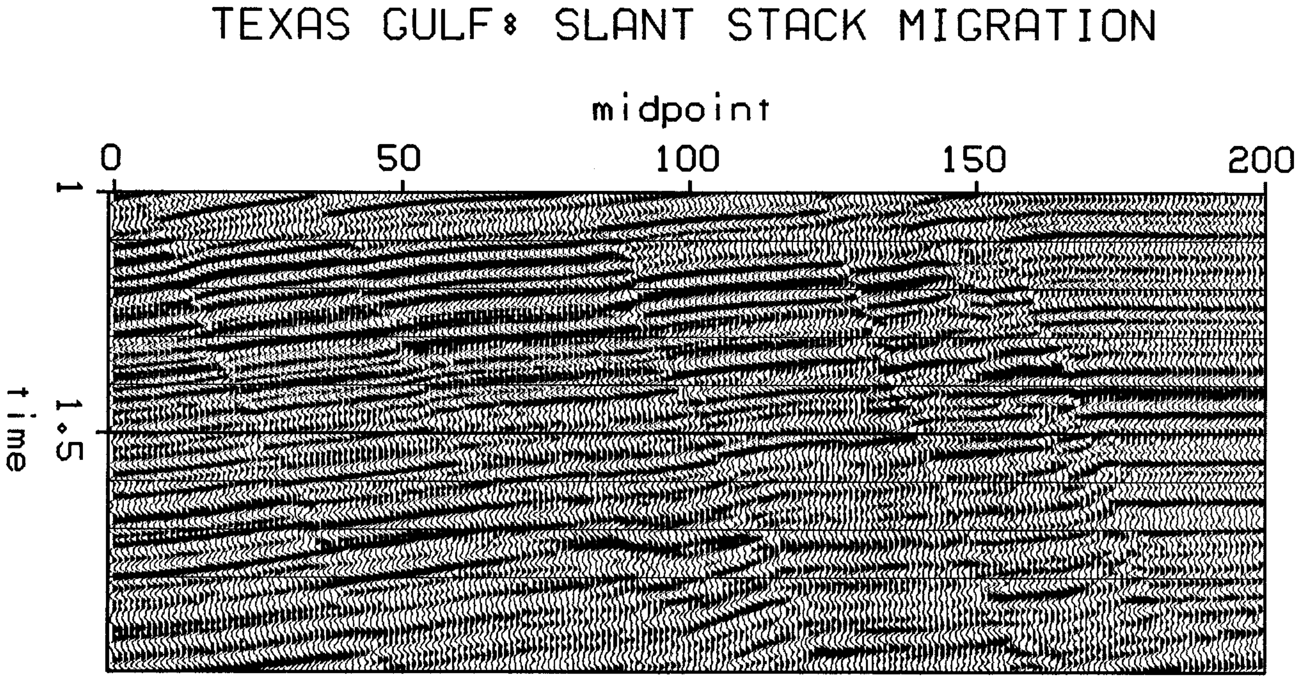

FIG. 3. Slant-midpoint stack migration of the same dataset. Fault plane reflections are now visible. Lateral resolution is increased as compared to figure 1.
For both the CDP and slant-midpoint migrations, the same extrapolated gather (24 to 106 traces) and direct arrival mutes were used. The Snell parameter range used is displayed in figure 6.

lateral velocity variation is assumed.

The basic procedure of slant stack migration is:

(1) Construct one or more sections containing a slant stack trace for the same Snell parameter at each midpoint.

(2) Migrate each of these midpoint sections.

(3) Stack together one or more migrated sections to remove patches of missing data and to improve signal-to-noise.

The Importance of Good Slant Stacks

The difficulty of obtaining good slant stacks was one of the main obstacles in previous field data experiments. In a previous paper, Ottolini (SEP-28) discusses slant artifacts and their cure. In summary, the most serious problem is aliased offsets. This is better cured by extrapolating intermediate offsets than by applying a anti aliasing mute as suggested by Shultz (SEP-8), because this mute introduces a velocity bias. Of next importance is restoring missing inner offsets. Missing inner offsets tend to distort reflection travel times and leave linear artifacts. Ottolini also describes a method of extrapolating inner offsets in the above citation.

Figures 4 and 5 show a gather of slant stacks formed for a raw and extrapolated CDP gather from the dataset used in this paper. Figure 6 gives the Snell parameter range actually used to migrate the result in figure 3. The fault plane reflection occurs over this range, and there are no missing data gaps. The number of Snell parameters is about the same as the number of offsets in the original CDP gathers in order to achieve similar stacking noise reduction.

Conclusions

Migrating slant-midpoint stacks alleviates the steep dip and dip selectivity problems present when migrating CDP stacks. This method appears to increase lateral resolution, probably for reasons similar to those discussed by Rocca and Ronnen elsewhere in this SEP volume.

Slant-midpoint stack migration works well when several conditions are satisfied:

(1) There is little lateral velocity variation in the dataset.

(2) The receiver arrays have not attenuated the reflections from steep reflectors. This may be checked by observing constant offset sections and high velocity CDP stacks.

(3) Care is taken during the construction of slant stacks.

ACKNOWLEDGMENTS

We thank Western Geophysical for providing the dataset.

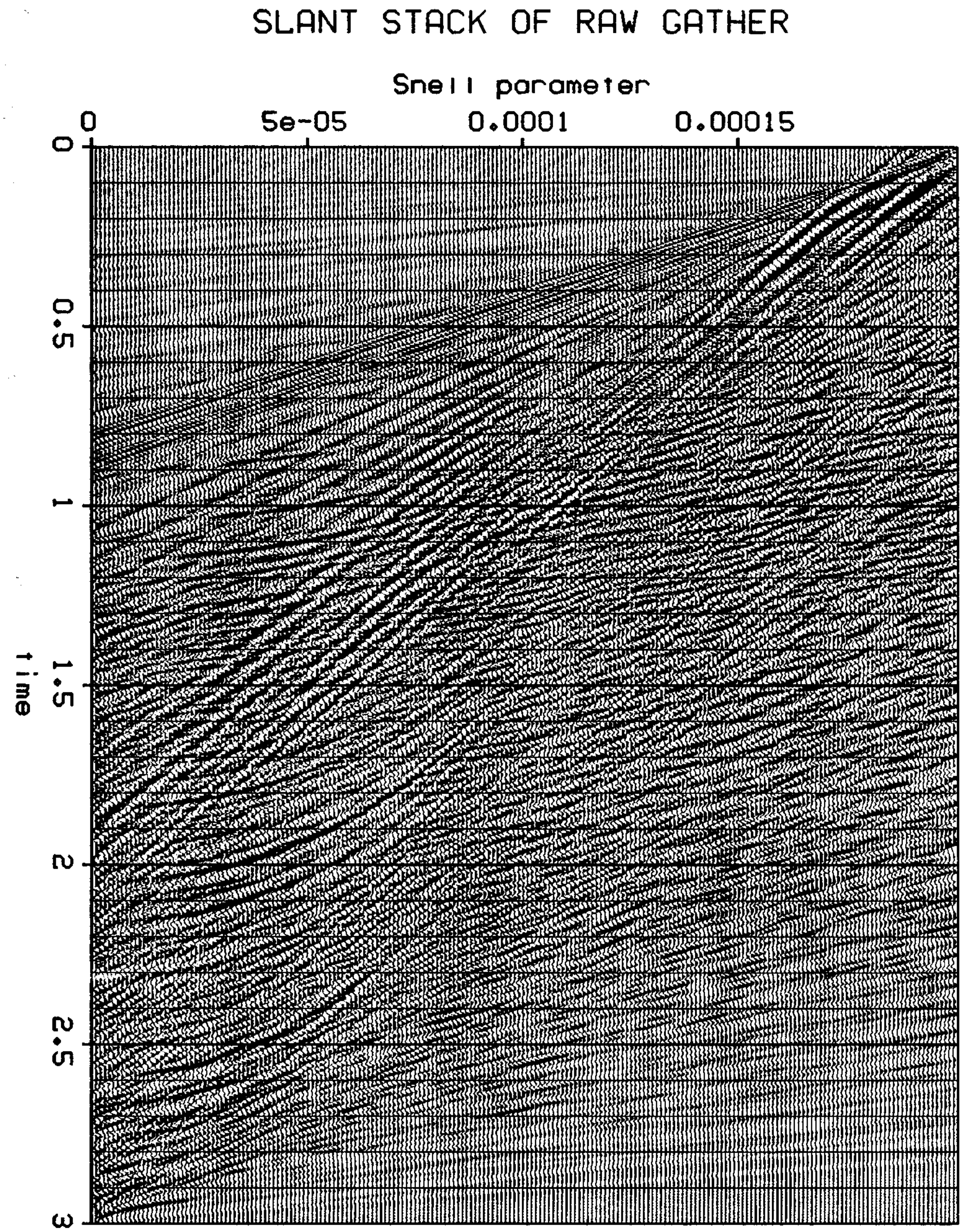

FIG. 4. Slant stacks constructed for raw 24 fold gather. Offset spacing is 440 feet and time sampling is 4 milliseconds. The major linear artifacts are caused by that the receiver spacing is too wide. In addition, missing inner offset falsify the travel times of reflectors for small Snell parameters. The reflector moveout should be elliptical and intersect zero Snell parameter horizontally.

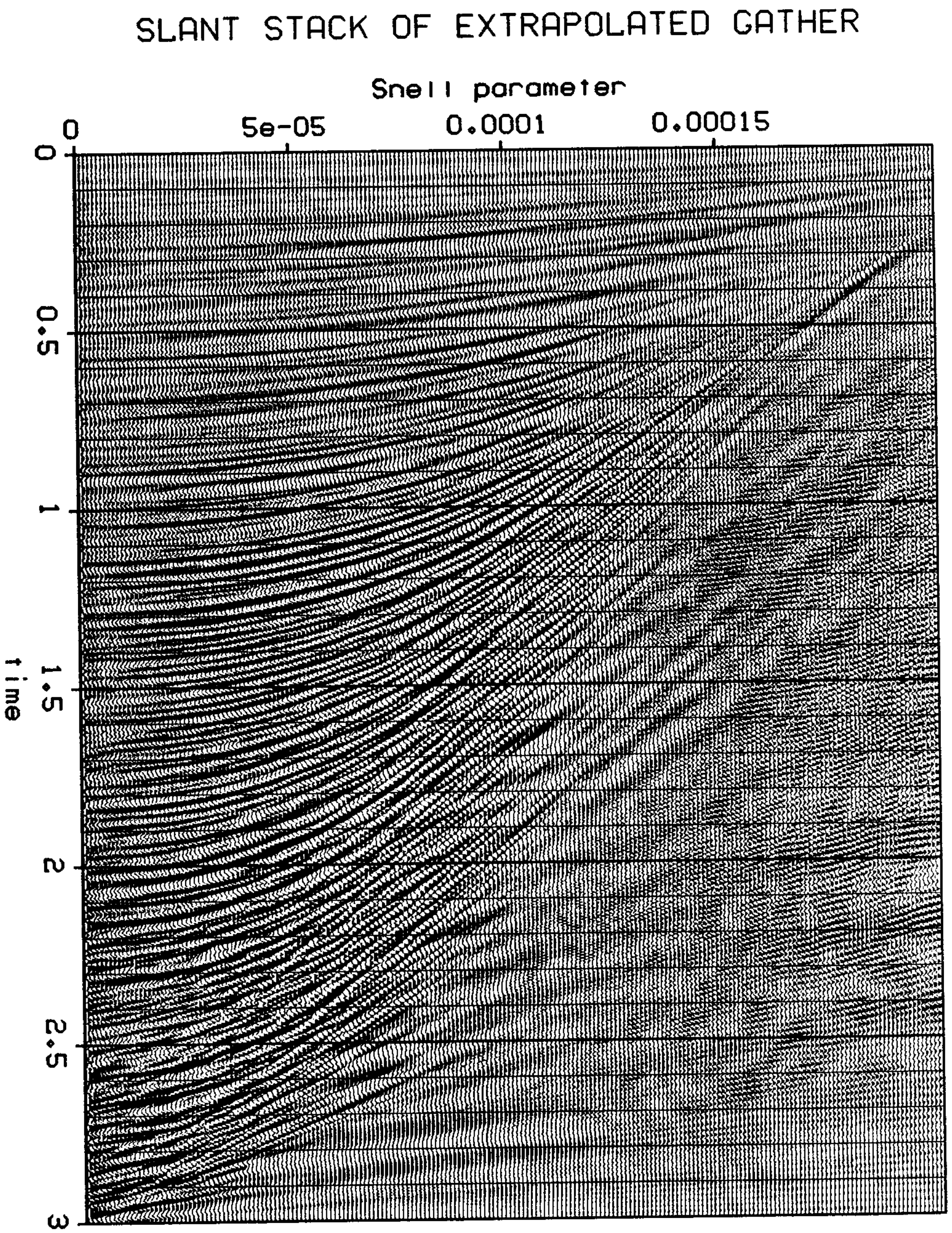

FIG. 5. Slant stacks constructed for the same gather extrapolated to 106 traces. Eight inner offsets were restored and three offsets inserted between each original offset. Most of the artifacts from figure 5 have been attenuated.

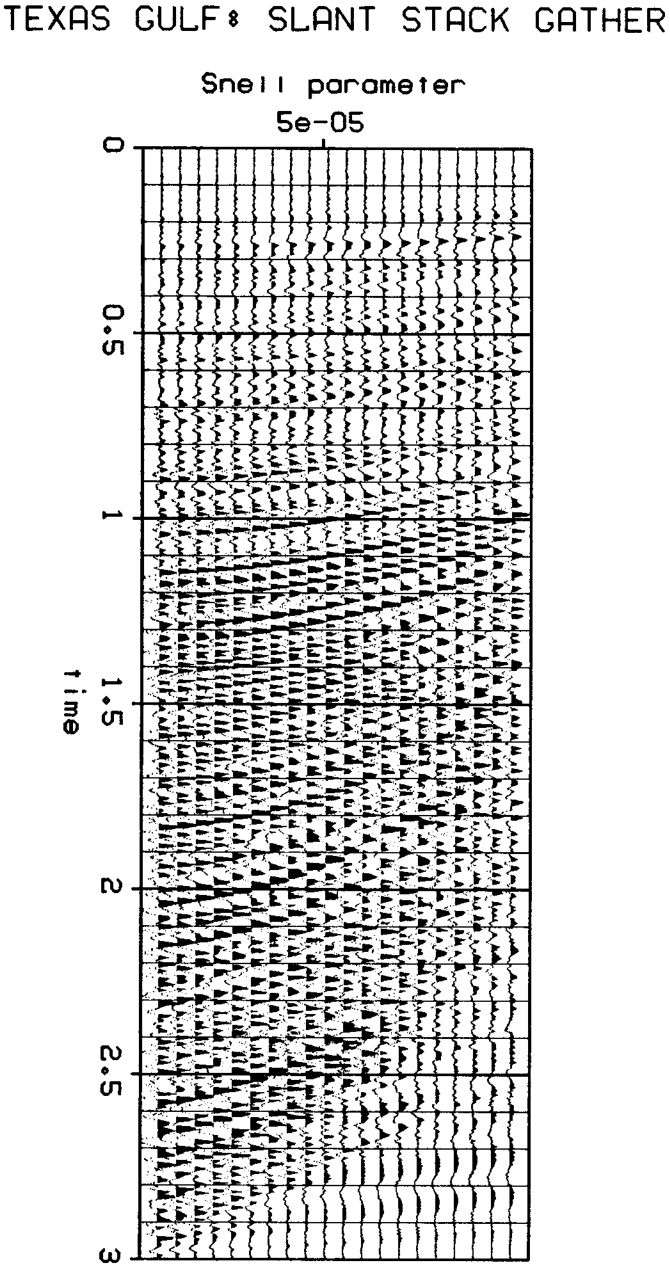

FIG. 6. Range of Snell parameters used for migration of figure 3. The first is 1.5e-5 and are spaced by 4.e-6 second/feet.