Summary. The recently introduced common-reflection-surface (CRS) stack (Müller, 1999) provides (a) a simulated zero-offset (ZO) section from 2-D multi-coverage seismic reflection data and (b) certain useful data-derived wavefield attributes with the knowledge of the near-surface velocity only. However, for seismic reflection data containing many diffraction patterns the simulated ZO section is far from representing a structural image of the subsurface. Conventionally, a subsequent post-stack time or depth migration, which requires the a priori unknown velocity model, is performed to collapse the diffraction patterns.
Following a similar macro-model independent approach as the CRS stack, we propose an approximative pre-stack time migration method that only depends on the data-derived kinematic wavefield attributes. This new approach is based on the fact that the CRS stacking operator can be tailored on account of the data-derived attributes to provide an approximation of the pre-stack migration operator.
The new time migration output can therefore be obtained quasi as a by-product of the CRS stack. In other words, the new macro-model independent time migration output can be obtained with very little additional effort, since only the CRS stack results have to be re-mapped to new time-domain output locations. The application of the new method to a marine seismic data set, strongly dominated by diffraction patterns, revealed many interesting subsurface structures.

Theory. The proposed method extents the 2-D theory of the CRS stack (Müller, 1999; Mann et al., 1999b), which is closely related to the polystack method (Höcht et al., 1999) and Gelchinsky's multifocusing method (Landa et al., 1999). The macro-model independent CRS stack provides a simulated ZO section and a set of three kinematic wavefield attributes at each stack output point, which are related to the location, orientation, and local curvature of curved interfaces in the subsurface (Mann et al., 1999a).
For diffraction events, the macro-model independent CRS stack approximates in the vicinity of the stack output point the macro-model dependent operator of a pre-stack migration. The relation between CRS stack and pre-stack migration is discussed by Hubral et al. (1999). The aim of both imaging processes is to sum up the trace amplitudes along spatial operators which are tangent to the actual traveltimes of the reflection events in the multi-coverage pre-stack data. Due to optimizing the data-derived CRS stack operators, they adapt in general very well to the actual reflection events. A basic difference between the CRS stack and the pre-stack migration is the time-domain output location to which the summation result is assigned: the CRS stack assigns the stack result to a ZO sample (thus simulating a ZO section), whereas the pre-stack migration places the stack result into the associated depth point (depth migration) or the apex of the pre-stack stacking operator in the time domain (time migration).
Obviously, there cannot exist a straightforward way to migrate a ZO section to the depth domain

without the macro-velocity model. Although less sensitive to the accuracy of the velocity model, time migration likewise requires a macro-velocity model. This is, however, not the case for the time migration proposed here, where the data-derived attributes provide the information commonly provided by the macro-velocity model.
For diffraction points in the subsurface, the CRS stack operator approximates the pre-stack migration operator and, thus, provides an approximate apex location. This would—for constant velocity models—exactly coincide with the apex of the pre-stack migration operator. In terms of the kinematic wavefield attributes provided by the CRS stack, a diffraction point is characterized by the identity $R_N = R_{NIP}$ of two of the three wavefield attributes explained below.
In other words, for constant-velocity models the CRS wavefield attributes provide the necessary information needed to calculate the accurate apex location of the associated pre-stack migration operator. This would permit an exact time migration. This is, however, not the case for inhomogeneous velocity models.
The approximative diffraction-type stack operator follows from the CRS stack operator (see e. g. Mann et al., 1999b) for identical radii of curvature $R_N = R_{NIP}$:

$$t^2 = \left[t_0 + \frac{2\sin\alpha\,(x_m - x_0)}{v_0}\right]^2 + \frac{2\,t_0\cos^2\alpha}{v_0\,R_{NIP}}\left[(x_m - x_0)^2 + h^2\right]\;, \tag{1}$$

with the near-surface velocity v_0, ZO output location (x_0, t_0), the half-offset h, and the shot/receiver midpoint coordinate x_m. The two wavefield attributes, normal ray emergence angle α and the radius R_{NIP}, are provided by the CRS stack.
To further improve the signal/noise ratio of the new migration we propose the following: use the "full" CRS stack operator, depending on all three wavefield attributes, rather than the "tailored" CRS stack operator (1). The full operator fits better to the actual events than the tailored diffraction-type operator (1). Thereafter, we assign the full operator stack result to the apex of the diffraction-type operator (1).

Application. We applied the new approximative pre-stack time migration to the 2-D line SO104-13 measured above the Peru-Chile trench. This marine seismic data set was acquired and pre-processed by the *Federal Institute for Geosciences and Natural Resources*, Germany. The CMP bin distance is 12.5 m with a maximum fold of 36 and a sampling rate of 4 ms.
The simulated ZO section shown in Figure 1 is the result of the CRS stack. Obviously, the data set is dominated by diffraction events generated by the rugged seafloor as well as by deeper structures. Only one optimized CRS stack operator was searched for each ZO output point in the section in Figure 1. This implies that conflicting dips are not yet resolved.
In Figure 2 the time migrated result is depicted. It was constructed without a macro-velocity model. Almost all diffraction patterns are collapsed, revealing a well defined image of the seafloor and several deeper structural features.

Conclusions. The proposed approximative pre-stack time migration method, based on data-derived kinematic wavefield attributes, results as a by-product of the CRS stack with little additional effort. As for the CRS stack (Figure 1) itself, no explicit knowledge of the macro-velocity model is required for the time migration (Figure 2) apart from the near-surface velocity. Similar to a conventional constant-velocity migration, our method approximates diffraction events also in laterally inhomogeneous media by means of stacking hyperbolae. However, the stacking hyperbolae are defined by wavefield attributes, implicitly accounting for the stacking velocities detected for each event. For inhomogeneous models our method is more accurate than a constant-velocity time migration. Of course, a conventional macro-velocity based migration would yield the most accurate result—providing, of course, that the model is sufficiently accurate. In contrast to conventional

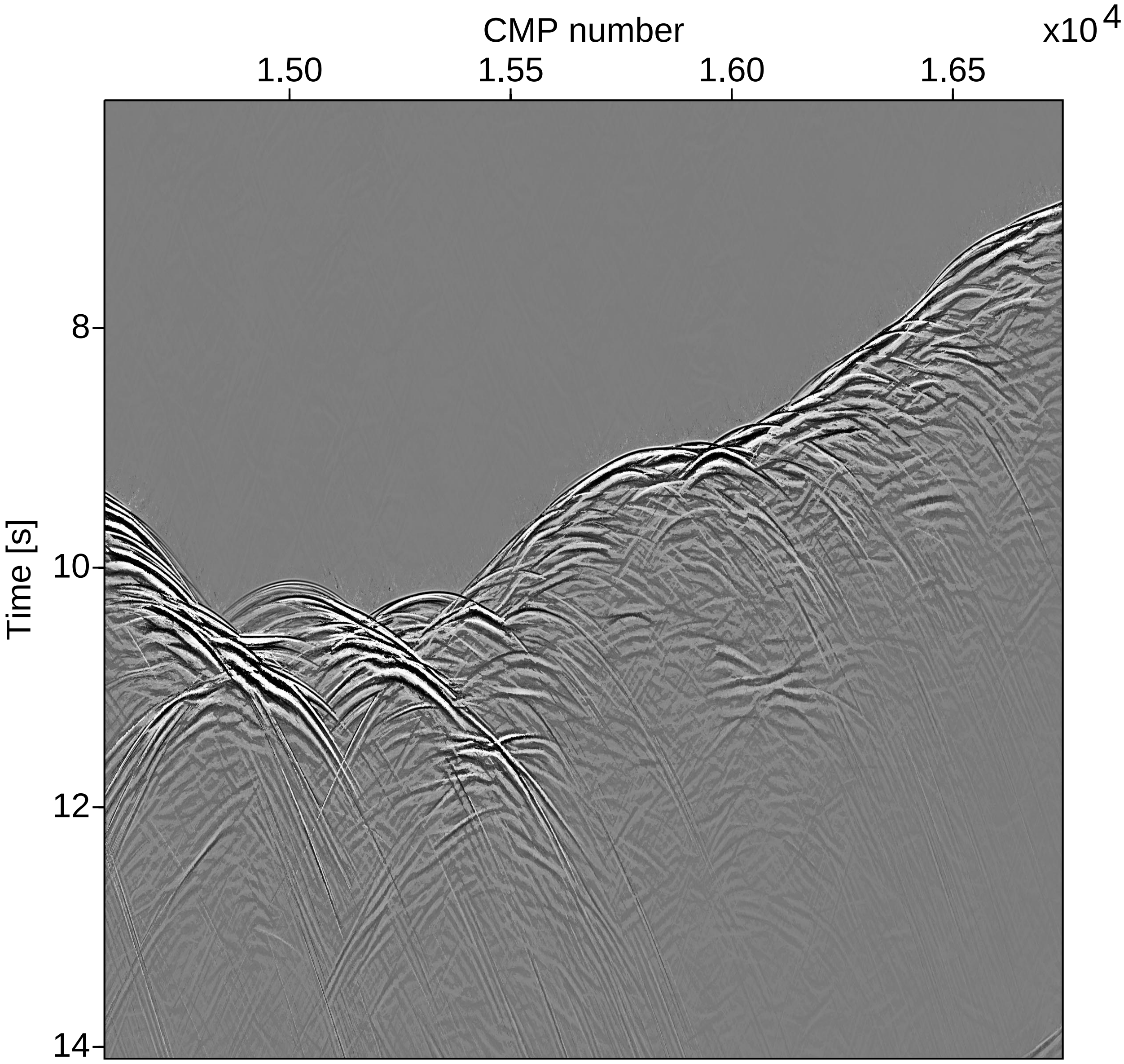

Figure 1: Zero-offset section simulated with the common-reflection-surface stack method.

stacking and migration operators, the CRS stack operator fits generally much closer to the actual reflection events in the pre-stack data. It is moreover also only restricted to the region of tangency between operators and the reflection events. Consequently, a higher signal/noise ratio is achieved than in traditional model-dependent time migration. In the view of the authors, the proposed method is a useful by-product of the CRS stack. It gives just one demonstration of the various applications that the data-derived attributes of the CRS stack can provide.

References

Höcht, G., de Bazelaire, E., Majer, P., and Hubral, P. (1999). Seismics and optics: hyperbolae and curvatures. *J. Appl. Geoph.*, 42(3,4):261–281.

Hubral, P., Höcht, G., and Jäger, R. (1999). Seismic illumination. *The Leading Edge*, 18(11):1268–1271.

Landa, E., Gurevich, B., Keydar, S., and Trachtman, P. (1999). Application of multifocusing method for subsurface imaging. *J. Appl. Geoph.*, 42(3,4):283–300.

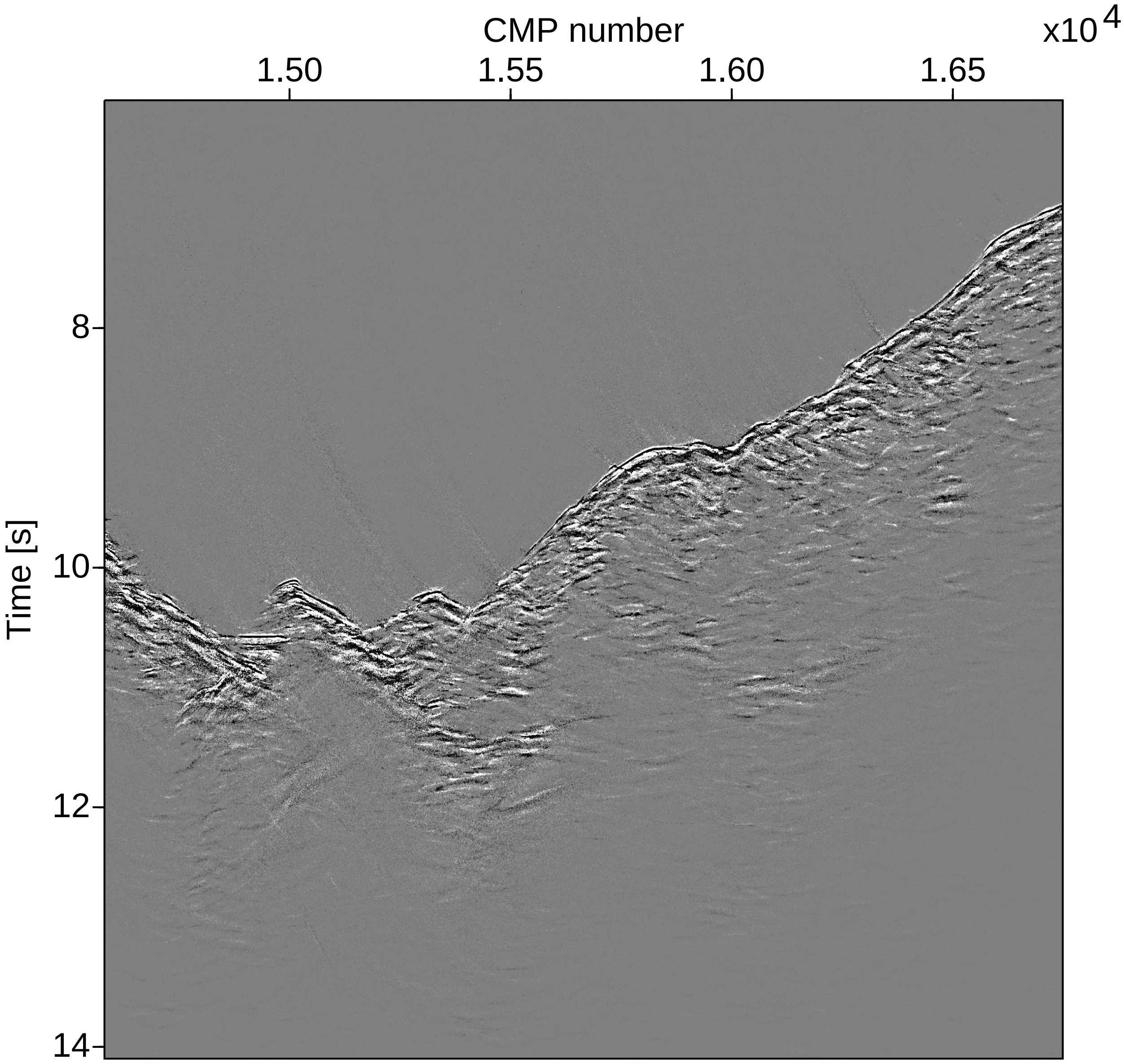

Figure 2: Result of the approximative pre-stack time migration based on CRS wavefield attributes.

Mann, J., Höcht, G., Jäger, R., and Hubral, P. (1999a). Common Reflection Surface Stack – an attribute analysis. 61th Mtg. Eur. Assoc. Expl. Geophys., Extended Abstracts. Session P140.

Mann, J., Jäger, R., Müller, T., Höcht, G., and Hubral, P. (1999b). Common-reflection-surface stack - a real data example. *J. Appl. Geoph.*, 42(3,4):301–318.

Müller, T. (1999). *The common reflection surface stack - seismic imaging without explicit knowledge of the velocity model*. Der Andere Verlag, Bad Iburg.

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