New Seismic Images of the Earth's Crust: Migration before Stack

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1 Introduction

In wide-angle seismics surprisingly clear images of the middle to lower crust have been obtained by a recently developed true-amplitude prestack migration method, called isochron migration (SCHMIDT, 1991; SIMON, 1992, 1993). Figure 1 shows an application to DEKORP4 wide-angle observations in the offset range 42 to 58 km (SIMON, 1993). Conspicious features are the well-known Erbendorf Body (EB) in 11 to 13 km depth at the KTB-site, the highly reflective lower crust in the Moldanubian (southeastern) part of the section, and a steeply dipping reflector which is supposed to be the master shear zone between the Moldanubian and Saxothuringian units.

Now the same method has been applied for the reprocessing of two steep-angle seismic lines, KTB8502 and DEKORP4, in the same area of investigation (Fig. 3). Earlier evaluations of these profiles followed the conventional lines of CMP-processing (DEKORP RESEARCH GROUP, 1988).

2 Processing

True-amplitude prestack migration aims at a quantitative and geometrically correct reconstruction of the reflectivity distribution at depth. This implies a processing sequence that deviates significantly from standard CMP-processing in several respects (Fig. 2).

First of all, the requirement of amplitude preservation forbids the application of automatic gain control (AGC) with its benefit of noise reduction. Instead, a very careful editing and muting is necessary, and every trace has to be cleaned individually from signal generated and transient noise.

As another important step amplitude corrections are necessary for the individual coupling of geophones and sources to the ground. These source and receiver specific corrections are derived by using the RMS-amplitudes of CSP-gathers and CST-gathers respectively.

The most important difference consists in the migration process proper. The basic principle of the isochron migration consists in adding every sample of the preprocessed wave field to all bins of a subsurface grid, where it could have been reflected or diffracted, that is, where the isochron condition is met.

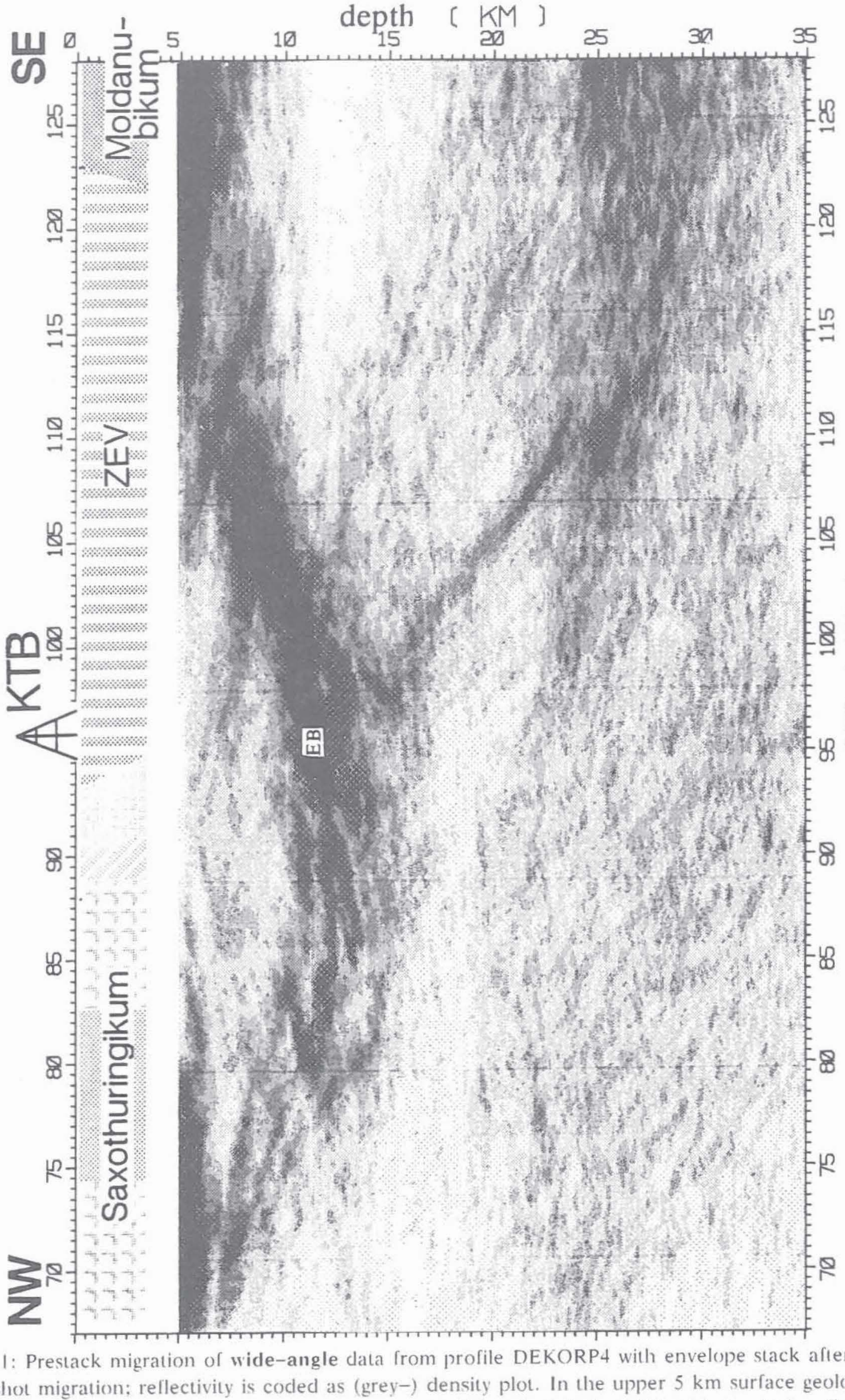

Fig. 1: Prestack migration of **wide-angle** data from profile DEKORP4 with envelope stack after single-shot migration; reflectivity is coded as (grey-) density plot. In the upper 5 km surface geology is marked. The SE-dipping reflector – connecting the Erbendorf Body (EB) with the high reflective lower crust – could be a major shear-zone between Moldanubian and Saxothuringian.

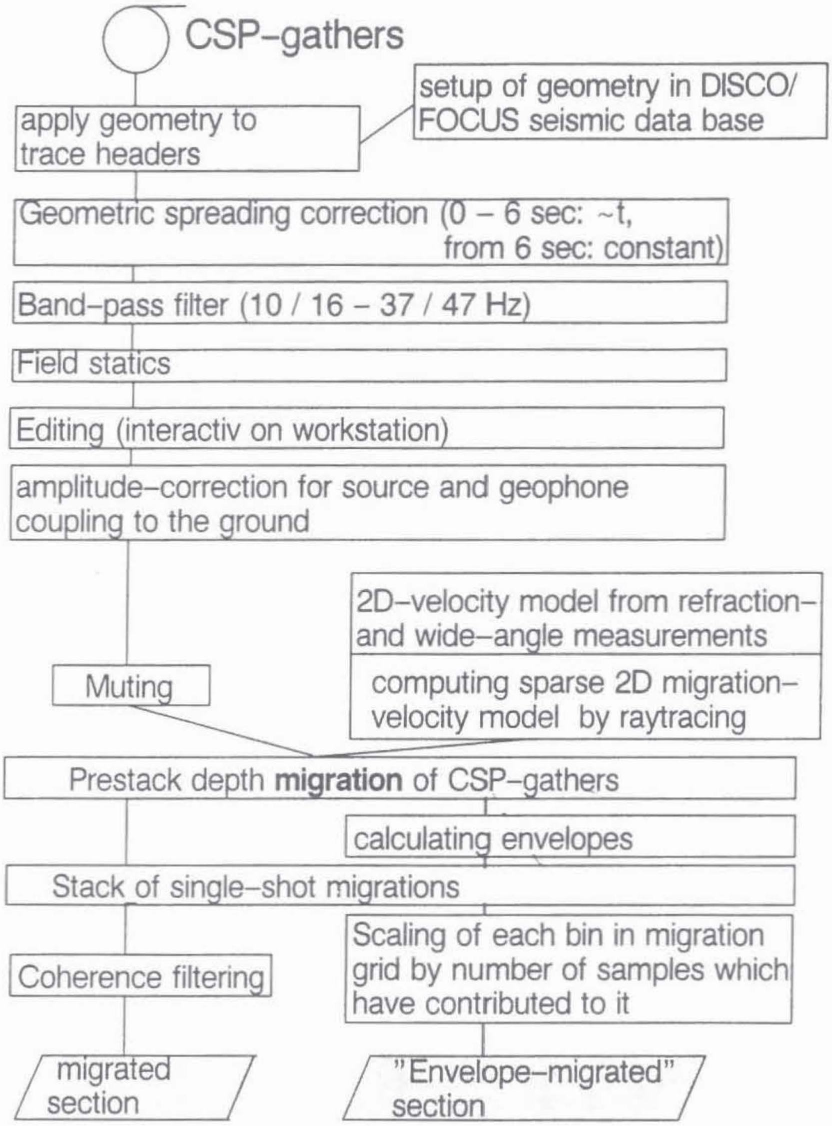

Fig. 2: Processing scheme for the reprocessing of steep-angle profiles KTB8502 and DEKORP4.

The isochron migration velocity is basically an average velocity, and is computed by ray tracing from a macro velocity model prior to migration. It is stored in the seismic data base in a very sparsely sampled grid (5 km) and interpolated in the migration lateron. In contrast to CMP-stacking velocities the migration velocities are not dip-dependent and therefore horizontal and steeply dipping reflectors are resolved simultaneously.

It is most promising to apply prestack migration to single shot ensembles; furtheron the processing follows two parallel paths (Fig. 2). On the left hand side single shot migrations are stacked to a final image which can be improved by coherence filtering. This section shows good resolution with fine details of the structures. As a shortcoming of this procedure destructive interference may occur in some parts due to differences in source-signature and defective migration velocities.

On the rigth hand side a second path yields a very robust image - but not with this good resolution - by forming envelopes after single shot migration before stacking them up.

Finally, for the simulation of an uniform coverage each sample of the migrated image is scaled by the number of samples, which have contributed to it. The presentation of the migrated image can be done either in the form of a (grey-) density plot (Fig. 6 and 7) or color-coded (see color plot in appendix).

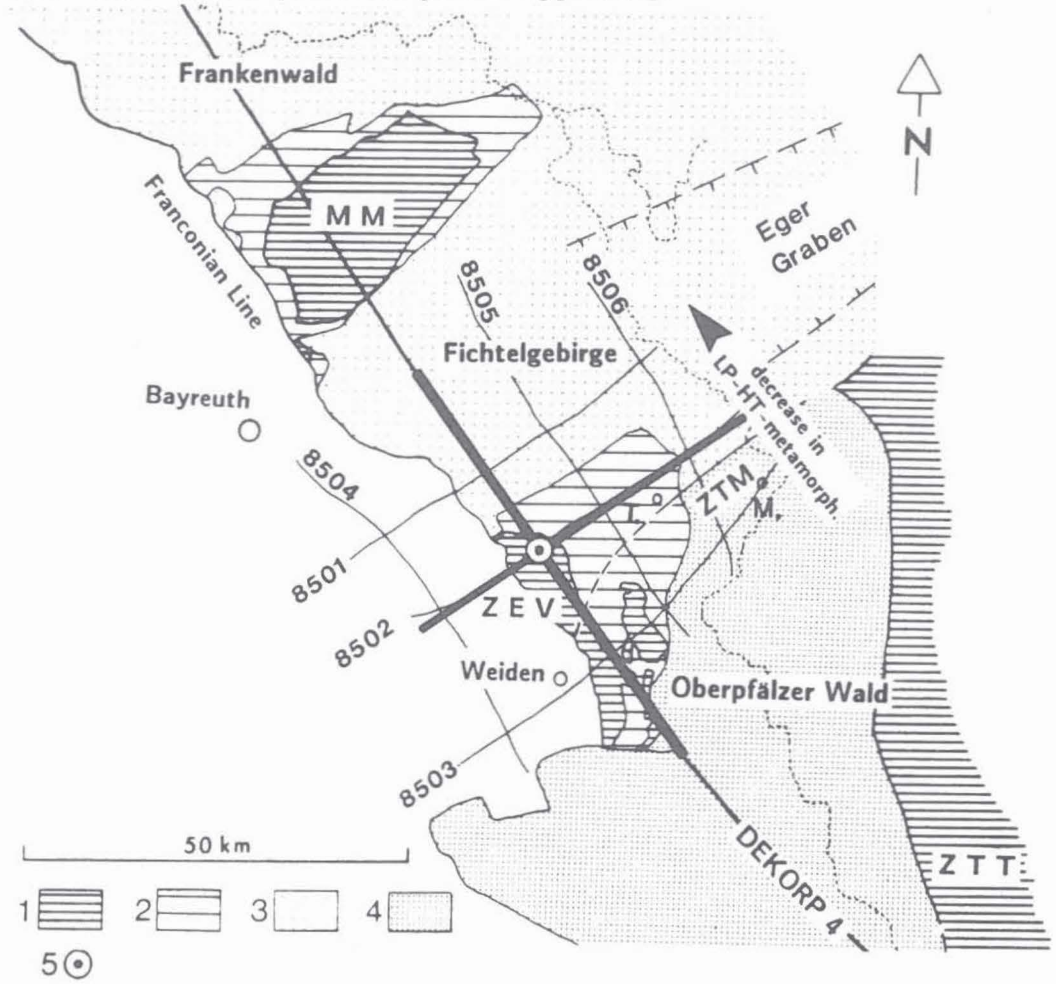

Fig. 3: Geological sketch map (after WEBER et al., 1989) showing the location of the reprocessed parts (heavy line) of profiles KTB8502 and DEKORP4. 1 crystalline nappe complexes; 2 lower and less metamorphic parts of the nappe units; MM Münchberg nappe complex; ZEV nappe complex of the zone of Erbendorf-Vohenstrauß; ZTT Zone of Tepla-Taus; 3 Saxothuringian; 4 Moldanubian; 5 KTB; ZTM Zone of Tirschenreuth-Mähring

3 Results for steep-angle profiles KTB8502 and DEKORP4

The two profiles KTB8502 and DEKORP4 are crossing at the location of the German Continental Deep Drillling Project (KTB) in the region of the Oberpfalz in Bavaria (Fig. 3). This gives the opportunity to control at least some of the seismic reflecting structures by drilling.

One of the most prominent reflectors on KTB8502 is a major fault zone associated with the Franconian Line, dipping with about 55° to NE and drilled through by KTB at about 7 km depth (Fig. 5 and 6). It is also known under the name "SE1" (WIEDER-

HOLD. 1992) and shows strong reflections in the envelope-CMP-stack of ISO89 3D steep-angle seismics (STILLER, 1992). With a standard poststack migration of KTB8502 (Fig. 4) it could not be imaged before applying unusual high NMO-velocities in the CMP-stacking (KÖRBE and REICHERT, 1992). The price for a good imaging of

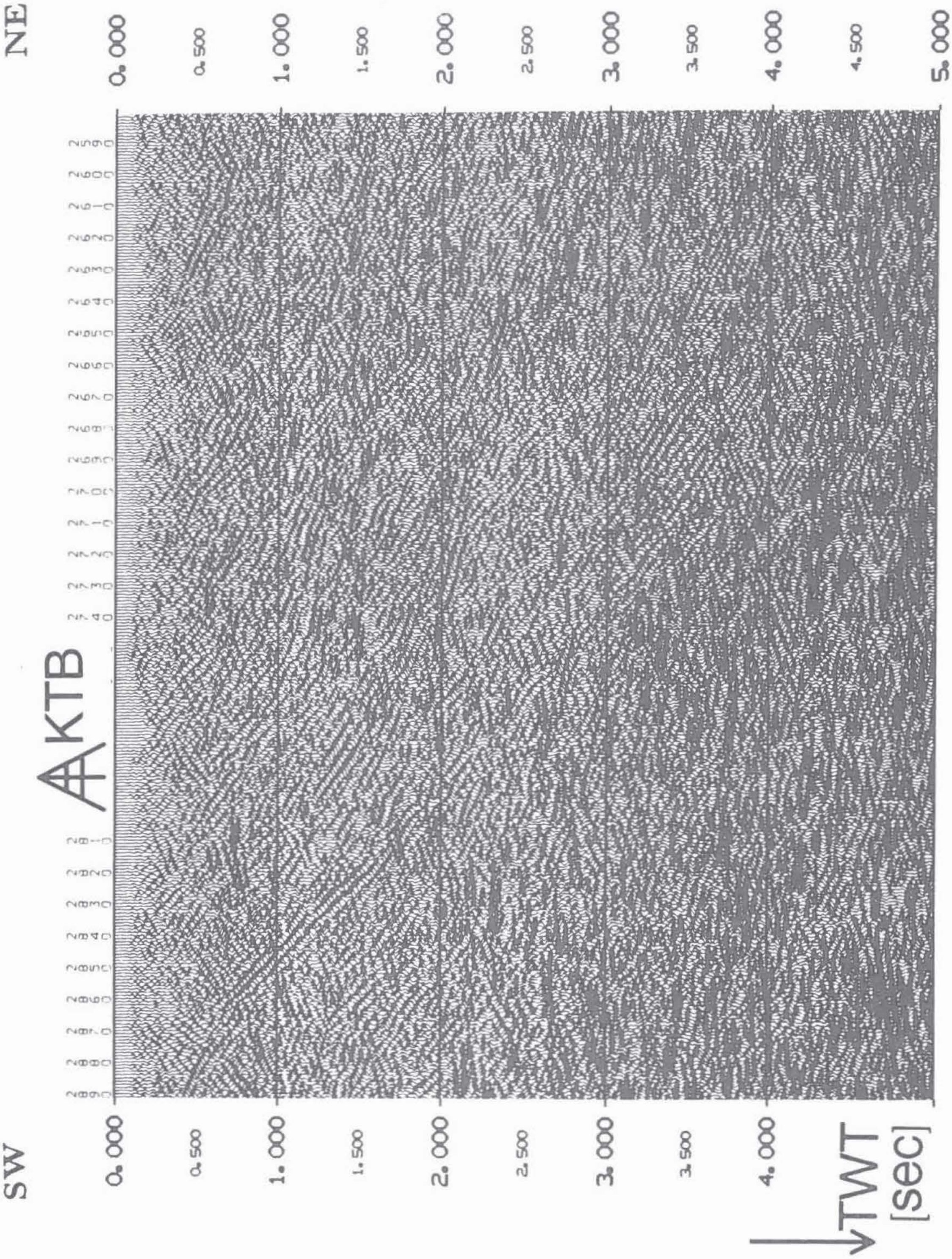

Fig. 4: Detail of coherence-filtered **poststack** migration from profile KTB8502 (after KÖRBE et al., 1992).

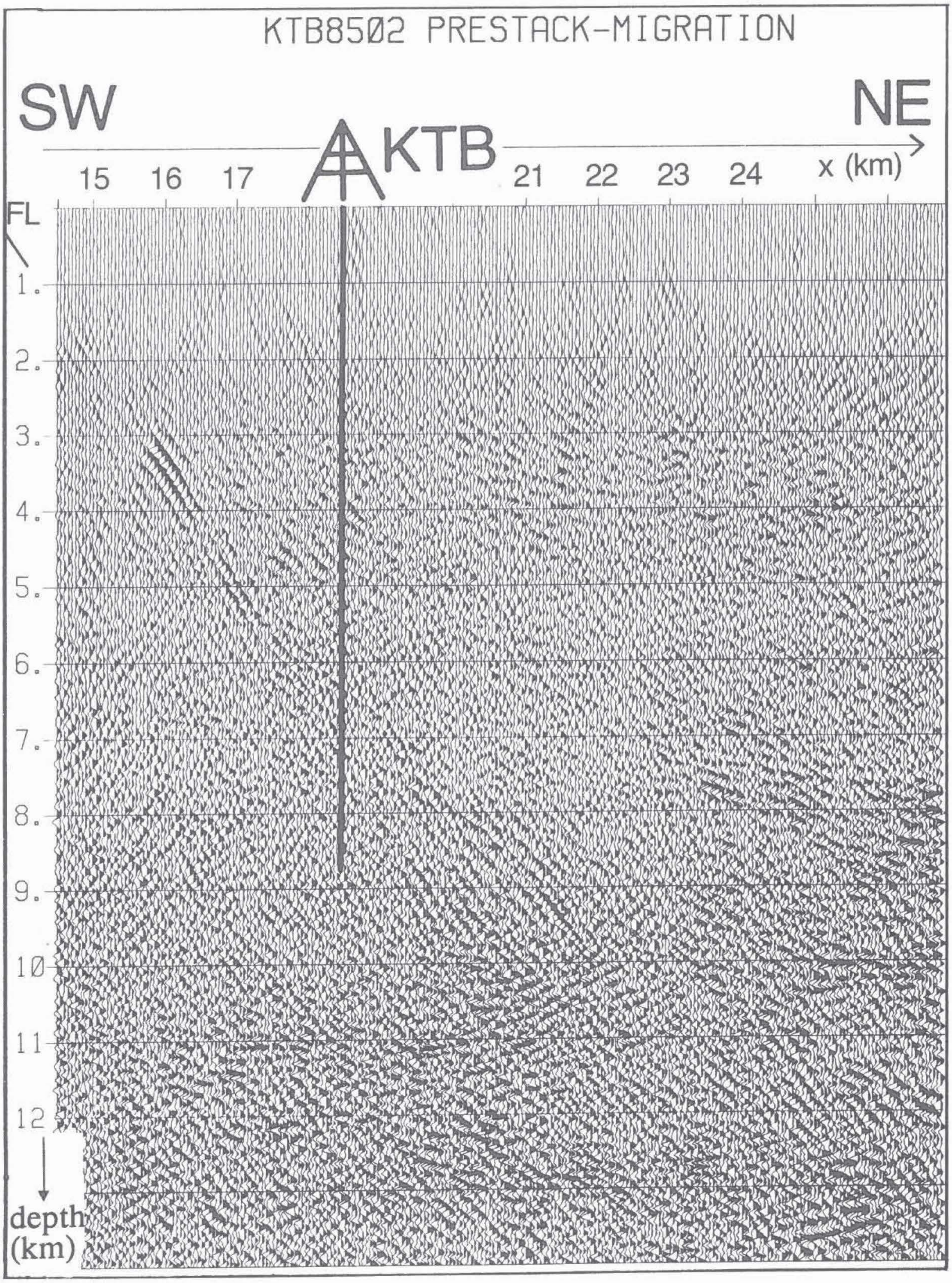

Fig. 5: Detail (comparable with Fig. 4) of phase-correct **prestack** migration from profile KTB8502. (FL = Franconian Line)

this steep reflector was worse quality of subhorizontal reflectors. In contrast to this the prestack migration (Fig. 5 and 6) images dipping and subhorizontal reflectors equally well by use of physically meaningful migration velocities.

This fault zone seems to cut across the high reflective structure of the so-called Erbendorf Body in 11 to 13 km depth. Due to the limited extend of the profile to NE the steeply dipping reflector is only illuminated down to about 17 km depth. Reflections from greater depths could have been recorded beyond the Czech border.

In the upper crust low reflectivity in the area of the Falkenberg granite contrasts with high reflectivity in the zone of Tirschenreuth-Mähring and in the sedimentary cover west of the Franconian Line. In the lower crust noticeable high reflectivity is found in the NE parts of KTB8502 and in the SE of DEKORP4 (Fig. 7). SE-dipping reflectors seem to connect the Erbendorf Body with the high reflective lower crust at DEKORP4. This feature is even more clearly imaged in the prestack migration of DEKORP4 wide-angle data (Fig. 1).

It seems reasonable to identify the seismic transparent zones on both sections below 30 km depth with the upper mantle; this would imply an updoming of the Moho beneath the KTB site consistent with SCHMOLL et al. (1989). In contrast to wide-angle observations (GEBRANDE et al., 1989) however, the steep-angle migration does not show a distinct Moho reflection. A Moho transition zone could explain both observations.

For further interpretation of the prestack migrations attention should be payed to the following remarks:
In the uppermost 5 km of the sections the resolution is limited by poor coverage and first break muting. Furthermore, in spite of careful editing, the possibility of minor artifacts due to not totally eliminated shear and surface waves cannot be ruled out.

It should also kept in mind that 2D-data can contain side-effects. That means that reflectors with cross-dip will be imaged at too small depths. One example for this effect is the reflector SE1 with a depth of 7 km beneath KTB in the profile KTB8502. In DEKORP4 it is imaged in only about 3.5 to 4 km depth due to its cross-dip (SCHMOLL et al., 1989).

4 Conclusions

The true-amplitude prestack migration method developed originally for wide-angle applications has proven effective also in steep-angle seismics. Obviousely the diffraction concept - on which prestack migration is based - is better adapted to the structural complexities of the crystalline basement than the reflection concept of CMP-processing.

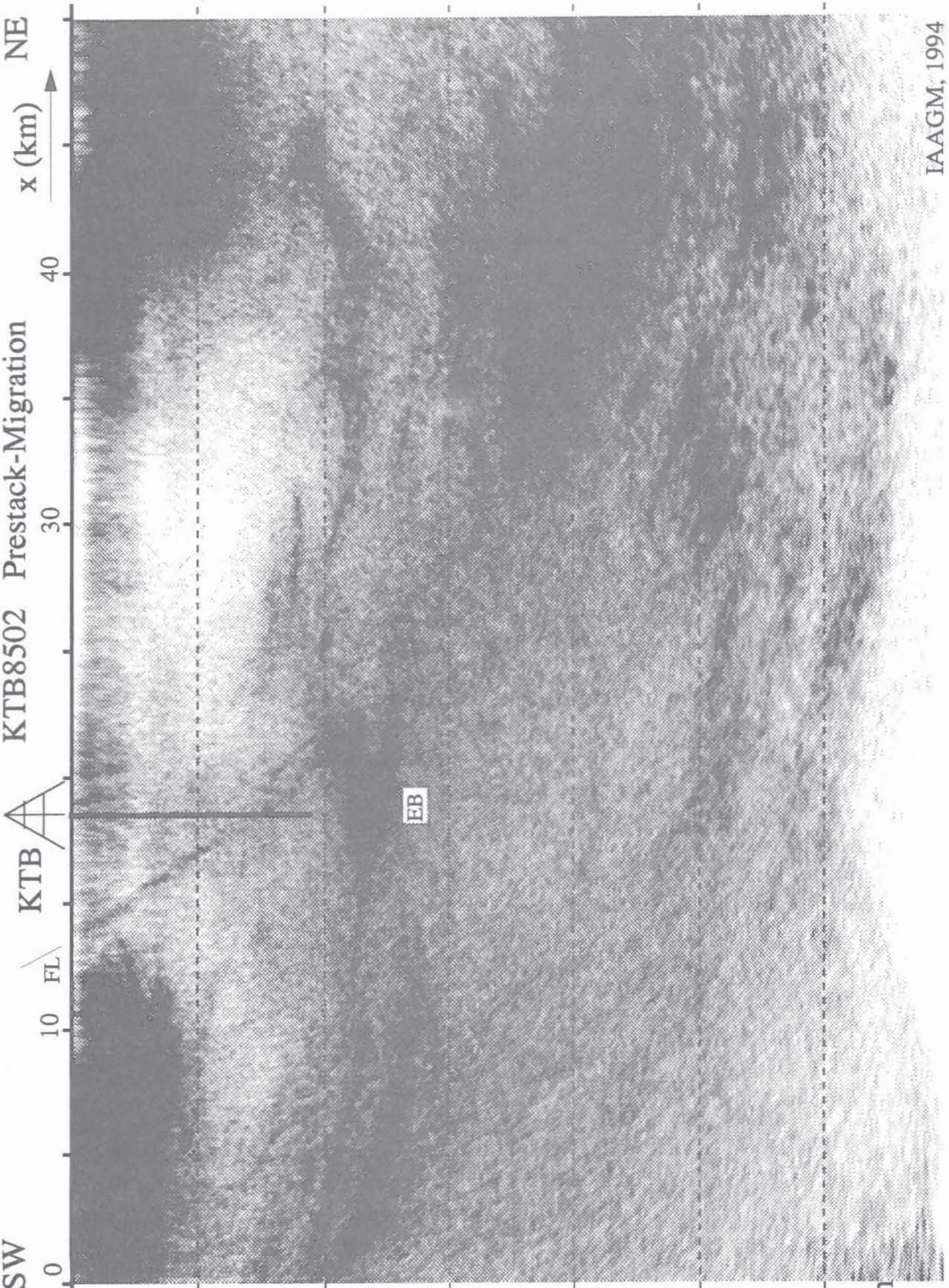

Fig. 6: Prestack migration of steep-angle profile KTB8502 with envelope stack after single-shot migration; grey-coded density plot of amplitudes; increasing reflectivity from white to black. (EB = Erbendorf Body, FL = Franconian Line)

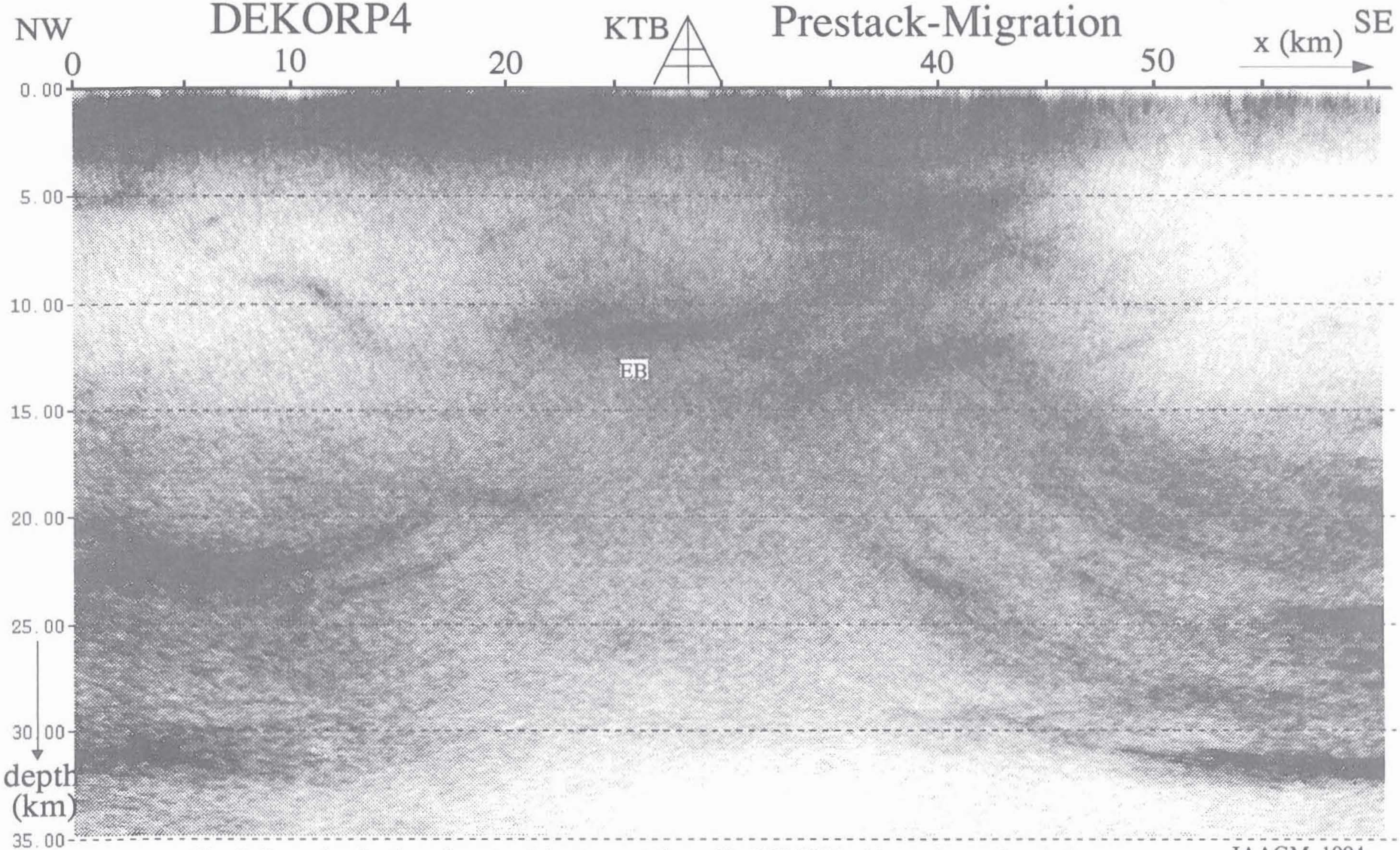

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Fig. 7: Prestack migration of a part of the steep-angle profile DEKORP4 with envelopes after single-shot migration. Grey-coded density plot of amplitudes as in Fig. 6. (EB = Erbendorf Body)

5 References

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