Seismic profiling by the TRANSALP working group: cross-line recording for 3-D control

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The central project of the TRANSALP traverse is a 340 km long deep seismic reflection line crossing the Eastern Alps between Munich and Venice (Fig. 1 of Lueschen *et al.*, 2003; TRANSALP Working Group, 2001; 2002). It has been acquired by partner institutions from Italy, Austria and Germany. Vibroseis near-vertical seismic profiling formed the core of the field data acquisition, complemented by explosive near-vertical seismic profiling, cross-line recording for three-dimensional control, wide-angle recording by a mobile array for velocity control and a stationary network for passive tomography and seismicity studies. Here we concentrate on details of the cross-line recording.

Seven receiver cross-lines (Q1-Q7, Fig. 1 of Lueschen et al., this volume), each approx. 20 km long, recorded off-end shotpoints and passively the sources of the main line in order to provide three-dimensional control. The cross-line recording spreads were partly directly connected to the main-line spread at the tiepoints or were operated by additional recording systems in slave mode connected to the main line via radio link. The cross lines were mainly designed to enable low-fold 3-D prestack depth migration along the whole line. Since their subsurface coverage was continuous, at least for greater depth, and since they exhibit much better noise conditions than parts of the main line, they provide a valuable aid to the main-line imaging by constructing alternative N-S sections as shown below. Additionally, complementary information in terms of seismic anisotropy could be gained. Thus, since the additional acquisition costs of passive cross-line recording were relatively low, the profits are considerably high. Fig 1 displays a typical cross-line configuration and its subsurface coverage in a schematic way.

The cross-line recordings were matter of a variety of different processing experiments. Not all of the experiments according to all available subsurface coverage shown in Fig. 1 can be presented here because of space requirements. We concentrate on some elements of major importance. Fig. 2 shows results of cross-line Q3 north of the Tauern Window according to the initial aims of 3D-prestack depth-migration with one 'inline' (N-S) and one 'crossline' (E-W) as examples. The technique behind corresponds to a Kirchhoff-type depth migration in three dimensions. Since the subsurface coverage is essentially one-fold in three dimensions, the preprocessing required a particularly careful trace editing. The N-S lines exhibit a pattern of south-dipping reflections. This pattern, when compared to the Vibroseis main-line depth section is another proof for the 'Sub-Tauern-Ramp'. On the 'crosslines', their signal energy is concentrated in the centre of the lines. This indicates that the 'crosslines' are parallel to the strike direction of the ramp implying that this structure is 2-dimensional and the main line has crossed it perpendicularly. When applied to the cross-line Q4 south of the Tauern Window, no indications of the Periadriatic fault system could be seen.

Fig. 3 describes a conventional processing approach, applied to the cross-line Q4 (south of Tauern Window) as an example. A north-south running binning line with a binning width of approximately 5 km has been used to select the traces and to construct CMP stack sections according to processing steps adopted from the main line. The sections of adjacent cross-lines, when mounted together, provide an alternative stack section, complementary to the main-line stack section of an almost identical subsurface coverage. The dominant reflection pattern on these sections correspond again to the south-dipping 'Sub-Tauern-Ramp', which is even more pronounced than on the main line. Particularly the cross-line stack section of Q4 provides further evidence that the 'Sub-Tauern-Ramp' is actually the most dominant feature in the Alpine crust. The section of Q4 is almost identical in its location with the complementary explosive section gathered in 2001 which also confirmed the dominance of the 'Sub-Tauern-Ramp' in the middle crust. In the section of Q4 it is even more evident that the zone above the ramp is actually void of significant reflections, located between the Tauern Window and the criss-cross reflection pattern south of the Periadriatic Lineament. Although also evident from the main line, there were doubts because of very noisy recording conditions of the main line here in the Valle di Tures due to dense population and heavy traffic. Correspondingly processed sections of Q5 show another proof of the criss-cross pattern. Experiments with varying azimuths of the binning line and corresponding stacking have shown that the dominant dip direction is South and, respectively, North. This pattern can therefore be considered as a 2-dimensional structure. We can show with these examples that passive cross-line recordings provide a very useful and economic way for confirmation and further constraints for 2-dimensional deep crustal reflection surveying.

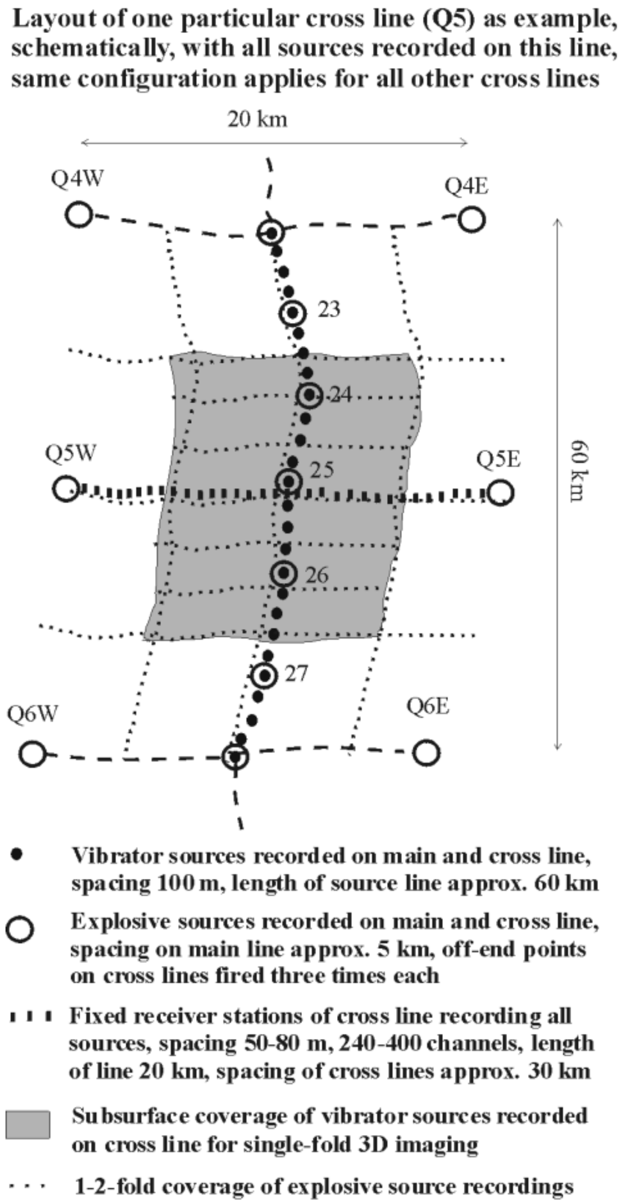

Fig. 1 – Schematic cross-line configuration and subsurface coverage.

The cross-line recording also allow observations which depend on azimuth between source and receiver. Azimuthal variations of the P-wave velocity have been depicted from common-shot gathers of the cross-lines. Average velocities as calculated by the distance between source and receivers and by the corresponding traveltime of the P-wave first arrival were plotted against distance and azimuth. Although some scatter is visible because of near-surface and topography effects, a clear relationship of velocities with azimuth and offset is discernible. As expected, the velocities increase with offset according to the increasing depth of these diving waves, until they stay at a constant level at greater offset. This behaviour is also known from numerous velocity measurements in the laboratory, when the confining pressure of the rock samples is increased simulating greater depth by closing cracks and microcracks. Additionally, velocities for wave propagation in E-W direction (azimuth 90 and 270 degree) are systematically more than 10 % higher than velocities of waves travelling in N-S direction (azimuth 0 and 180 degree). This behaviour is compatible with microfabric observations in and around the Tauern Window (Lammerer and Weger, 1998) showing a E-W elongation of the rock texture caused by N-S compression and E-W stretching. A similar observation has been made by studying the azimuthal variations of cross-line Q3 at the northern rim of the Tauern Window. In this cross-line, S-wave splitting as another direct prove of seismic anisotropy has been observed in shot gathers recorded in E-W direction. On the contrary, all other cross-lines do not exhibit such an azimuthal variation of velocities. This is clear evidence of seismic anisotropy caused by rock anisotropy due to tectonic paleostrain constrained to the Tauern Window and their surroundings.

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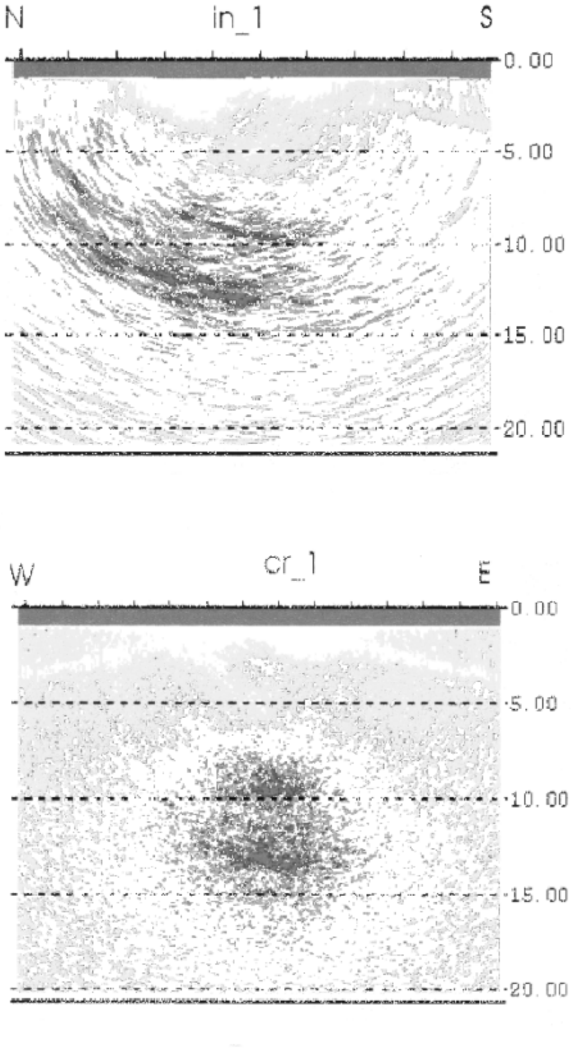

Fig. 2 – Examples from Vibroseis 3-D prestack migration of cross-line Q3. 'In-line' section (top), 'cross-line' section (bottom) out of a net of sections. Amplitudes plotted as envelopes, color-coded. Length of sections is 26 km, vertical scales in kilometers.

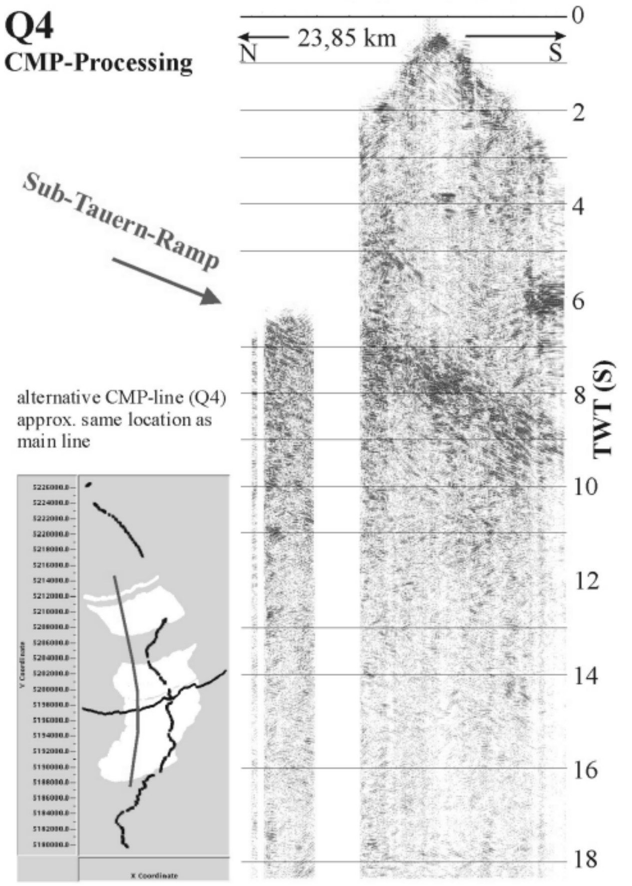

Fig. 3 – Example from Vibroseis standard CMP processing of cross-line Q4 in N-S direction.