Using an industrial 3D seismic dataset from the central part of the Vienna Basin (Austria), we investigate fault growth by studying marker horizons within the hanging wall and footwall of the Markgrafneusiedl fault, a large-scale normal fault. The fault geometry and throw distribution of individual horizons show a remarkable variability, both along strike and along dip of the fault. Quantification of this large-scale fault drag allows identification of linked individual fault segments constraining the fault evolution.

Near-fault deformations are common phenomena that frequently occur in both extensional and compressional tectonic systems. Two fundamentally different explanations for the origin of fault drag in extensional regimes have been proposed. One very popular model explains the development of rollover anticlines by the existence of a listric normal fault (e.g., McClay & Scott 1991), which connects a steep upper part of a fault to a low angle detachment horizon at depth. Alternatively, the occurrence of reverse fault drag, comprising an anticlinal structure in the hanging wall and a synform in the footwall of a planar normal fault, has been explained by the decrease of displacement from the center to the tips of the fault surface both laterally and vertically (Grasemann et al. 2005). The latter model, which we favor for the interpretation of structures along the Markgrafneusiedl fault, additionally offers a solution to the observation of „compressional“ structures, i.e. folds surrounding fault planes with normal displacement, which in conventional tectonic models require for a regional compressional phase and basin inversion.

The investigated Markgrafneusiedl fault, crosscutting the clastic Miocene sedimentary pile deposited from Carpathian up to the Pannonian age, represents the southeastern border of the Matzen oilfield. At depth, the fault displaces seismic horizons up to the decollement level, with a maximum throw of ~400 m.

In order to document marker horizons for the analysis of fault drag, several most distinctive seismic reflectors were mapped throughout the entire 3D time-migrated seismic cube. In addition to the two well-documented stratigraphic markers, the chronostratigraphic framework was constrained at the basis of seismic calibration with numerous deep exploration boreholes. After seismic amplitudes were mapped in TWT by using a Landmark/Geographix software, a depth conversion applying a generalized equation assuming an exponential increase of seismic velocity with depth was calculated in the 3D modeling software Gocad (Paradigm). This conversion ensured a better geometric representation of the fault drag geometries, additionally enabling a 3D displacement measurement in meters.

The additional documentation of fault drag permits a more detailed identification of individual fault segments, which cannot be so accurately achieved by using conventional parameters, such as fault dip, azimuth and throw. Moreover, using a complex 3D attributes derived from a 3D surfaces, we identified that the two scale-dependant generations of a fault drag correspond to a similar number of fault segment orders. Thereby, it is possible to constrain the relative timing of faulting with respect to coalescence of individual initial fault segments. Therefore, a study of a fault drag around complex mature fault surfaces can help to identify pre- and post-coalescence time of differently sized fault segments, and to distinguish fault drag along normal faults from folding due to tectonic inversion.

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Frontier seismic exploration in the North Atlantic

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The North Atlantic continental margin was formed by continental break-up in the early Tertiary, which led to stretching and thinning of the continental lithosphere, accompanied by massive magmatism, producing flood basalts which covered pre-existing sediments and extensive igneous intrusion. Industry and university goals coincide in the North Atlantic region where low frequency seismic energy, together with high-density, long-offset, single-sensor recordings, are used to penetrate volcanic overburdens and illuminate both the deep structure of magmatic margins and potential hydrocarbon-bearing sub-basalt sediments.

This paper briefly summarizes the seismic results of the iSIMM project (integrated seismic imaging of magmatic margins). The industry-university collaboration aimed to develop a structural model from seabed to Moho to image the stretched crust and the extruded, intruded and underplated igneous material, and sediment structures in this area within and overlain by the basaltic sequences of stacked flows up to several kilometers thick.

The present paper further highlights the implications of basalt-tuned acquisition and processing techniques for OMV, which is successfully exploring the remote region of the North Atlantic margin. Examples illustrate developments in intra- and sub-basalt seismic acquisition (e.g., over-under shooting) and consequences for processing such target-focused seismic data sets (e.g., LF-processing).

Marine Isotope Stage 3 recorded in palaeolake sediments in the Eastern Alps

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While Oxygene Isotope Stage (OIS) 2 and Holocene palaeoclimate and palaeoenvironments are relatively well documented in the Eastern Alps, little is known about the MIS 3 („Middle-Würmian") in this region. A tunnel prospection campaign carried out by the Brenner Eisenbahn GmbH (Projekt Unterinntaltrasse) in the Lower Inn Valley of Tyrol (Austria) yielded a large number of drill cores. They offer the unique opportunity to study sediments of the OIS 2 and older. Our project focuses on the investigation of four long cores from the river terrace at Unterangerberg near Wörgl.

The drill cores reveal that the Unterangerberg terrace consists of long sequences of clay/silt, intercalated with sand, gravel, diamictic beds, and peat layers. The fine-grained sediments partly contain organic material and striated drop stones, pointing to a lacustrine or glacio-lacustrine environment. This three-dimensional information offers the possibility to establish a facies model of the terrace and to spatially reconstruct the lake genesis and its sedimentary filling.

Chronological information was obtained from radiocarbon (charcoal and other plant macro remains) and luminescence (fine grain polymineral samples) samples collected in the lake sediments. The radiocarbon results show that the sedimentation of a large portion of the cores is older than ~55 ka. For the younger samples, the recently published IntCal09 calibration curve makes it possible to calculate calibrated 14C ages.

Initial luminescence tests show that the quartz signal in these samples is very weak and close to saturation. Therefore, feldspar was chosen for further analyses and the 4-11 µm polymineral sediment fraction was analysed using a modified SAR protocol. Preheat tests and dose recovery tests of seven samples analysed so far were positive. OSL and radiocarbon data indicate that the lacustrine sediments from the Unterangerberg river terrace were deposited during the last glacial period, i.e. during MIS 3, possibly reaching back to MIS 5. Further investigation will focus on quantified sedimentological analyses, pollen and macro-remain analyses, along with further dating, to identify regional sedimentation patterns and potential palaeoclimatic signals.

Unravelling the polymetamorphic (Variscan vs. Permian) history of the Michelbach Complex (Deferegger Alps, East Tyrol) by using REE-phosphates (monazite, xenotime)

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Monazite is common in metapelitic rocks in a wide range of *P-T* conditions from the greenschist-facies on (Spear & Pyle 2002). The chemical distribution of elements in REE phosphates like monazite ($CePO_4$) and xenotime (YPO_4) therefore provides useful information about the metamorphic evolution of rocks. For instance, chemical zoning in monazite allows it to distinguish between different episodes of growth phases. Between coexisting monazite and xenotime there is a temperature-dependent exchange of LREE and (HREE, Y) and the miscibility gap between the REE + Y exchange allows determining geothermometric conditions (Heinrich et al. 1997, Gratz & Heinrich 1997).

An extremely powerful application of monazites is the possibility of geochronological investigations by using U-Th-Pb electron microprobe dating (Montel et al. 1996). Therefore, it is possible to link the obtained mineral chemical and geothermometric data to age constraints.

In the metapelites of the Michelbach Complex monazite frequently occurs as accessory mineral. Coexisting xenotime was only found in the sillimanite-zone of the Michelbach Complex. In all analyzed monazites two different substitutions occur: all monazites show the exchange
$(U, Th)^{4+} + Ca^{2+}$ <--> $2REE^{3+}$ (brabantite vector)
in the cores and in the rims. The exchange
$(U + Th)^{4+} + Si^{4+}$ <--> $REE^{3+} + P^{5+}$ (huttonite vector)
is present in the sillimanite -zone only in the cores.

In contrast to monazites from the andalusite-zone monazites from the sillimanite-zone show considerable zoning with respect to their major elements and REE, like Ca, Si, Ce, P, Sm and Th. Correlating these zoned areas with geochronological data shows that the zones can either be related to the Variscan event with an age around 330±50 Ma or to the Permian HT overprint with an age of 240±50 Ma.

The occurrence of two different ages in only one mineral grain is thought to be the consequence of resetting the U-Th-Pb system of certain micro-domains due to the infiltration of fluids at high temperatures (Parrish 1990). Monazites from the andalusite-zone only show single ages because no chemical zoning occurs. Although most ages are around 320±50 Ma, which can be related to the Variscan event a few monazites also yielded Permian ages of 250±50 Ma.

Geothermometric calculations using coexisting monazite and xenotime yielded temperatures of 600 to 650 °C for the metapelites of the sillimanite-zone. In the andalusite-zone unfortunately no coexisting monazite-xenotime pairs were found.

This study shows that linking textural, chemical, petrological and geochronological data allows the reconstruction of polymetamorphic histories of rocks.

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