Trabajos de Geología, Universidad de Oviedo, 29 : 250-252 (2010)

Oviedo (Spain) 1-3 July 2008 International Meeting of Young Researchers in Structural Geology and Tectonics
YORSGET

Structural 3D modelling using GPR in unconsolidated sediments (Vienna basin, Austria)

D. Spahic[1]*, U. Exner[1], M. Behm[2], B. Grasemann[1] and A. Haring[3]

[1]*Department of Geodynamics and Sedimentology, University of Vienna, A-1090 Vienna, Austria.*

[2]*Institute of Geodesy and Geophysics, Technical University of Vienna, Austria.*

[3]*Institute of Photogrammetry and Remote Sensing, Technical University of Vienna, Austria.*

**e-mail: darko.spahic@univie.ac.at*

Abstract: In a gravel pit (SE Vienna basin), metre-thick bedded successions of conglomerate and sand layers of Miocene age are exceptionally well exposed along a W-E-striking wall. The sediments are cut by numerous N-S-striking, high-angle normal faults. The faults have a marked displacement gradient and offset marker layers of up to several metres. Using ground penetrating radar, we measured ten sections parallel to the W-E-striking wall in order to construct a three-dimensional structural model. Exact positioning of the radargrams was achieved with the help of differential GPS and compilation of the data with a terrestrial laser scan of the outcrop.

Keywords: Vienna basin, ground penetrating radar, structural modelling, light detection ranging, normal fault.

The Vienna basin is a pull-apart basin developed during the Oligocene-Miocene extrusion of the Eastern Alps towards the Pannonian region in the east-along sinistral, NE-SW-trending strike slip faults and roughly N-S-trending normal faults. Part of this regional geodynamic setting is recorded in extensional tectonics in unconsolidated sediments of the Neogene Eisenstadt-Sopron basin, a sub-basin of the Vienna basin. Along a W-E-striking wall in a gravel pit 5 km SSE of St. Margarethen several generations of conjugate sets of

Figure 1. W-E-striking outcrop wall in the gravel pit 5 km SSE of St. Margarethen. Picture looking towards north. The darker layer in the middle of the wall consists in coarse grained pebbles, which has been offset by numerous extensional faults mainly dipping towards west.

W- and predominantly E-dipping normal faults are exposed in unconsolidated sediments (Fig. 1). These sediments were deposited during the Middle Miocene (Sarmatian and Pannonian age) and are successions of deltaic gravels with intercalations of shallow marine calcareous sands (Sauer *et al.*, 1992). The faults range in length from several decimetres to several tens of metres (or probably much larger beyond the level of exposure) and register a marked displacement gradient. Measured offset of marker layers along exposed faults ranges from centimetres up to several metres. Due to a marked difference in the compositions of the layered sequences (e.g. well sorted conglomerate consisting of coarse-grained pebbles alternating with fine grained carbonate rich sands), the markers are easily identified on the hanging wall and footwall side of the faults.

Applied methodology

In order to extend the information of the two-dimensional exposure in the St. Margarethen gravel pit into the third dimension with the aim of constructing a three-dimensional structural model, ground penetrating radar (GPR) measurements were carried out in

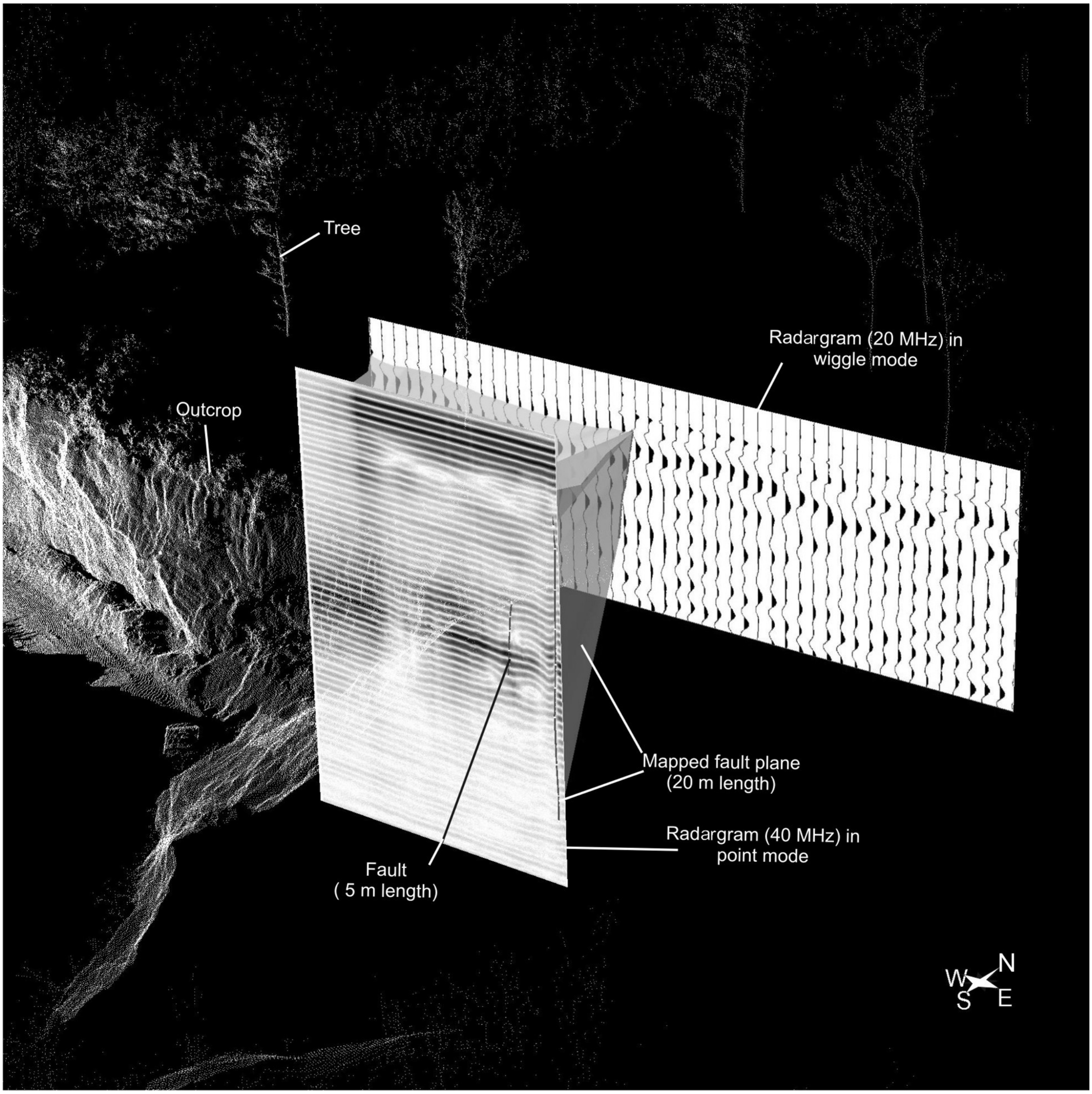

Figure 2. Terrestrial laser scan of the W-E-striking wall of the gravel pit, selected radargrams and a mapped fault.

ten sections parallel and perpendicular to the outcrop wall using different transmitter antennas of 20 and 40 MHz (Reiss *et al.*, 2003; Sauer and Felix-Henningsen, 2004). The quality of recorded GPR data depends on a variety of factors, such as soil humidity, prospecting method and frequencies. In order to locate the sections as accurately as possible, the geographical positions were recorded with a differential global positioning system (DGPS).

The recorded radargrams were processed in Reflex (Sandmeier Scientific Software), a software for seismic reflection/refraction and GPR processing and interpretation. The processed radargrams were georeferenced using the recorded DGPS data in the three-dimensional visualisation software Gocad (Earth Decision). In order to interpret the sections and to construct a structural model, the data were compiled in Gocad with terrestrial laser scan of the W-E-striking wall in the gravel pit. We used a *RIEGL* LMS-Z420i system, consisting of a high performance long-range 3D laser scanner and an attached calibrated high-resolution digital camera (Fig. 2).

Results and discussion

Extensional fault sets having lengths of less than 5 m that have been mapped in detail on the terrestrial laser scan and on the outcrop cannot be observed on the radargrams since the resolution of the GPR reflection data is not sufficiently high. However, the reflection of particular marker horizons and their offset along faults with offsets larger than 10 m can be clearly mapped from the radargram sections using line-based fault and horizon picking techniques.

Measurements from the structural model and field observations of displacement magnitudes (from centimetres up to several metres) vary significantly among the different fault sets but also along the individual fault traces. At outcrop scale, three different types of host rock deformation can be observed: (i) normal drag along sets of normal faults dipping in the same direction, (ii) reverse drag of horizontal layers cut by isolated high-angle normal faults, and (iii) tilting of blocks between closely spaced normal faults or conjugate sets of normal faults (Passchier *et al.*, 2005).

Conclusion

Three-dimensional, shallow subsurface structural models of extensional faults in unconsolidated sediments were constructed by applying different techniques: (i) GPR recording of coulisse sections, (ii) DGPS recording of the GPR sections, (iii) terrestrial laser scanning of an outcrop wall parallel and perpendicular to the recorded radargrams, and (iv) field mapping of the outcrop. The three-dimensional structural model can be further analysed by calculating and contouring geometric parameters such as curvatures, fault dip and displacement magnitude and gradients (Exner *et al.*, 2004).

Acknowledgements

We thank the Austrian “Fonds zur Förderung der wissenschaftlischen Forschung“ (FWF grant P20092-N10 Research Project). We also thank Cristoph Tuitz and Herbert Pretsch for help during field observations and data collection.

References

Exner, U., Mancktelow, N. S. and Grasemann, B. (2004): Progressive development of s-type flanking folds in simple shear. *J. Struct. Geol.*, 26: 2191-2201.

Passchier, C. W., Mancktelow, N. S. and Grasemann, B. (2005): Flow perturbations: a tool to study and characterize heterogeneous deformation. *J. Struct. Geol.*, 27: 1011-1026.

Reiss, S. Reicherter, R. K. and Reuter, C. D. (2003): Visualization and characterisation of active normal faults and associated sediments by high-resolution GPR. In*:* C. S. Bristow and H. M. Jol (eds): *Ground penetrating radar in Sediments. Spec. Publ. Geol. Soc.*, 211: 247-255.

Sauer, R., Seifert, P., Wessely, G., Piller, W. E., Kleemann, E., Fodor, L., Hofmann, T., Mandl, G. and Lobitzer, H. (1992): Guidebook to excursions in the Vienna Basin and the adjacent Alpine-Carpathian thrustbelt in Austria. *Mitt. Österr. Geogr. G.*, 85: 1-264.

Sauer, D. and Felix-Henningsen, P. (2004): Application of ground penetrating radar to determine the thickness of pleistocene periglacial slope deposits. *J. Plant Nutr. Soil Sc.*, 167: 752-760.