The use of Cone Penetration Tests in paleoseismological investigations: 2 case studies

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ABSTRACT

We present the results of cone penetration test (CPT) profiles applied to visualise and locate active faults as part of our paleoseismologic investigations at trench site 4 along the Bree fault scarp of the Neeroeteren Fault and at one of the sites we studied along the Rauw Fault. These CPT profiles are relatively fast and provide a good depth penetration and vertical resolution but a rather poor horizontal resolution. A combination of different geophysical, geological and geomorphologic techniques is recommended for detailed fault mapping

KEYWORDS

Cone penetration test, active fault, paleoseismology

Introduction

In our paleoseismologic investigations (Camelbeeck & Meghraoui, 1998) we routinely apply different geophysical techniques to image and precisely locate faults (Demanet et al., 2001) that can afterwards be investigated in shallow trenches. Each geophysical profiling method has a specific depth penetration, thickness of superficial data gap and vertical and horizontal resolution (Table 1). The depth penetration of electrical tomography fills the gap between high resolution seismic profiles and Ground Penetrating Radar (GPR) and profiles with hand borings but it has a rather low vertical resolution. At locations where the geology is poorly known, as is mostly the case in the vicinity of an active fault, it is helpful to additionally carry out a CPT profile which has a better vertical resolution for a comparable depth penetration.

Table 1. Averaged characteristics (in metre) of geophysical profiling methods used in paleoseismologic investigations.

	Penetr. depth	Data gap	Vert. Res.	Horiz. Res.
Seism. Refl.	1000	100	10	10
High-res. seism. Refl.	250	40	5	5
Electr. Tomo.	20	1	5	2
CPT	20	0	0.2	20
GPR	5	0.3	0.5	0.5
Hand borings	4	0	0.1	15

Cone Penetration tests consist of pushing a tube with a cone-shaped head into the ground with a constant force. During this process the friction at the head of the tube, the Cone Bearing Resistance (CBR), and the friction between the tube and the surrounding sediment, the sleeve friction (SF), are recorded at regular intervals. From these two parameters the Friction Ratio (FR) is calculated as (SF/CBR)*100. Coarse-grained sediments have high CBR and low FR values while this is the opposite for fine-grained sediments (Grant et al., 1997).

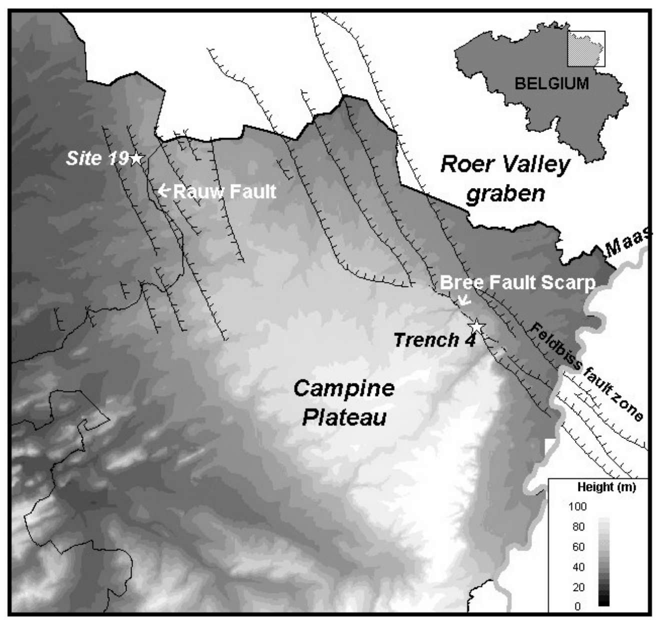

Figure 1. Elevation map of NE Belgium with indication of major Roer Valley graben faults and location of investigated sites.

Case studies

Trench site 4: Bree fault scarp, Neeroeteren Fault

We first applied CPT measurements at trench site 4 (Vanneste et al., 2001) along the Bree fault scarp of the Neeroeteren fault, western border fault of the Roer Valley Graben (Fig. 1). Parallel to the trench (Fig. 2) a profile of 9 CPT's (Fig. 3) was done to extend our view below the trench bottom. For the same reason a GPR profile (Demanet et al., 2001) and hand borings (Fig. 2) were carried out at the bottom of this trench. We specifically wanted to find the depth to the Main Terrace deposits in the hanging wall to

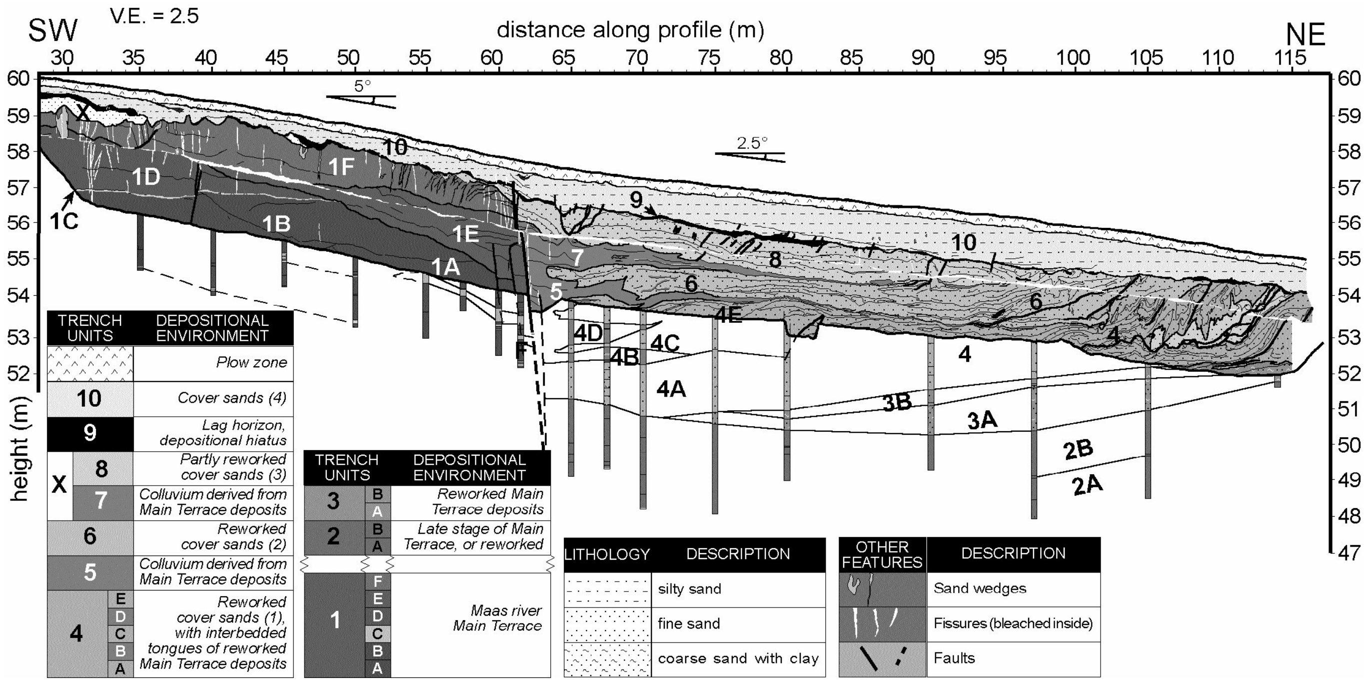

Figure 2. Trench log of site 4 along the Bree fault scarp with boreholes at the bottom of the trench.

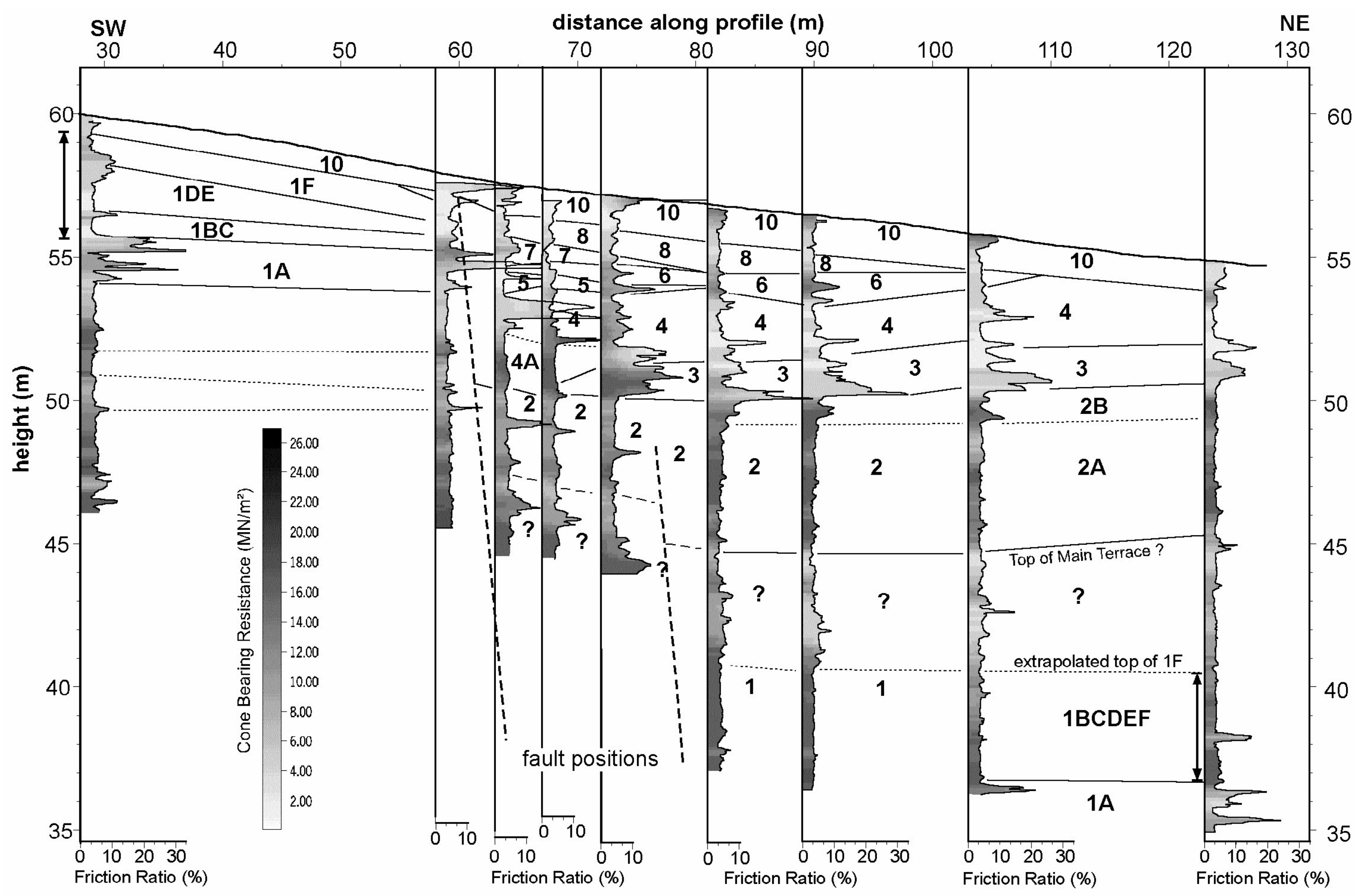

Figure 3. CPT profile at trench site 4 with both CBR (greyscale) and FR (graphs). Unit numbers correspond to those used in the log of the trench (Fig. 2).

estimate their displacement by the fault. For the description and paleoseismological interpretation of the trench we refer to Vanneste et al., 2001 and we will use the same names for the lithological units (Fig. 2). The correlation between the trench log and the CPT profile is relatively straightforward apart from the rapid lateral changes close to the fault. The clayey unit 3 and its transition to the coarse sands of unit 2 is especially well visible in the hanging wall. The base of the Main Terrace deposits was not reached in the profile. We correlate unit 1A, consisting of clayey fine sand intercalations in the coarse Main Terrace deposits, at about 55 m height in the footwall with a comparable unit at about 36 m in the hanging wall. If this correlation is correct this would mean that this unit of the Main Terrace has a vertical displacement of about 19 m along the Neeroeteren fault. Considering the age range of the Main Terrace (770 – 350 ka BP) (Paulissen, 1983) the long term average displacement rate would then be between 0.025 and 0.054 mm/yr for the Neeroeteren fault. This is slightly higher than the average displacement values for the Weichselian of 0.018 to 0.024 mm/yr (Vanneste et al., 2001) estimated from the trench record.

Unit 2 is slightly less coarse and contains less gravel and clay than unit 1. The base of this unit can be located at about 45 m height according to a change in the CPT records (Fig 3). Between this base and the extrapolated top of unit 1F in the hanging wall, a slightly less coarse, less gravelly and more silty or clayey unit than unit 1 can be interpreted from the CPT records. This might correspond to the top layers of the main terrace (possibly containing the As soil) that are only preserved in the hanging wall. After several fault displacements, totalling about 10 m of vertical displacement this unit was eroded from the footwall and redeposited in the hanging wall as unit 2. The clay and/or silt was washed out and part of it was later deposited as the clayey unit 3 in a lacustrine environment in front of the fault scarp.

Site 19: Rauw Fault

The second CPT profile was realised in the framework of a study of the activity of the Rauw and Poppel faults that was ordered by NIRAS in 2000 (Verbeeck et al., 2001). It is located between Rauw and Postel in the community of Mol (Fig. 1) and consists of 12 CPT records on a W-E oriented profile (Fig. 4). Only the cone bearing resistance and not the sleeve friction was measured in these records. At this site we also carried out topographical and electromagnetic measurements, hand borings and electrical tomography. Based on anomalies in these measurements (especially the boreholes) we expected a fault between 90 and 100 m along our profiles but we were not sure if the anomaly continued at depth. The CPT profile however clearly shows a 6 m displacement of a compact layer, probably gravel, that separates 2 different units. Close to the surface it is less clear but it is probable that this fault connects to the anomaly between 90 and 100 m, and that it is crossed by the CPT at 100 m. Another small scale fault is situated between 30 and 60m and displaces the same compact layer by about 1m but does not continue up to the surface. The local geology is poorly known at this location which makes interpretation of the CPT profile difficult but we think that the compact layer corresponds to the Hukkelberg gravel on top of the Pliocene Mol formation (Gullentops & Vandenberghe, 1995). Gullentops et al. 1974 report 15 m offset for the peaty De Maat Bed of the Mol formation in the nearby Mol Donk quarry. This would mean that about 8m of fault displacement occurred between the formation of the De Maat Bed and the Hukkelberg gravel.

Because the anomalies close to the surface and in the topography at site 19 correspond to a clear fault at depth on the CPT profile we chose this site for future trenching to study the most recent fault displacement.

Conclusions

CPT profiles have been successfully applied for fault localisation and imaging. At site 19 along the Rauw fault the CPT profile was part of the preliminary geophysical investigation but at site 4 along the Bree fault scarp it was done while the trench was already opened to improve our depth view and the interpretation of the long-term activity.

CPT profiles are a relatively fast technique that provides good depth penetration and vertical resolution but a rather poor horizontal resolution. Fault displacements can thus be clearly observed but horizontal localisation of a fault is more difficult. A combination of different geophysical, geological and geomorphologic techniques is recommended for the study of recent fault activity.

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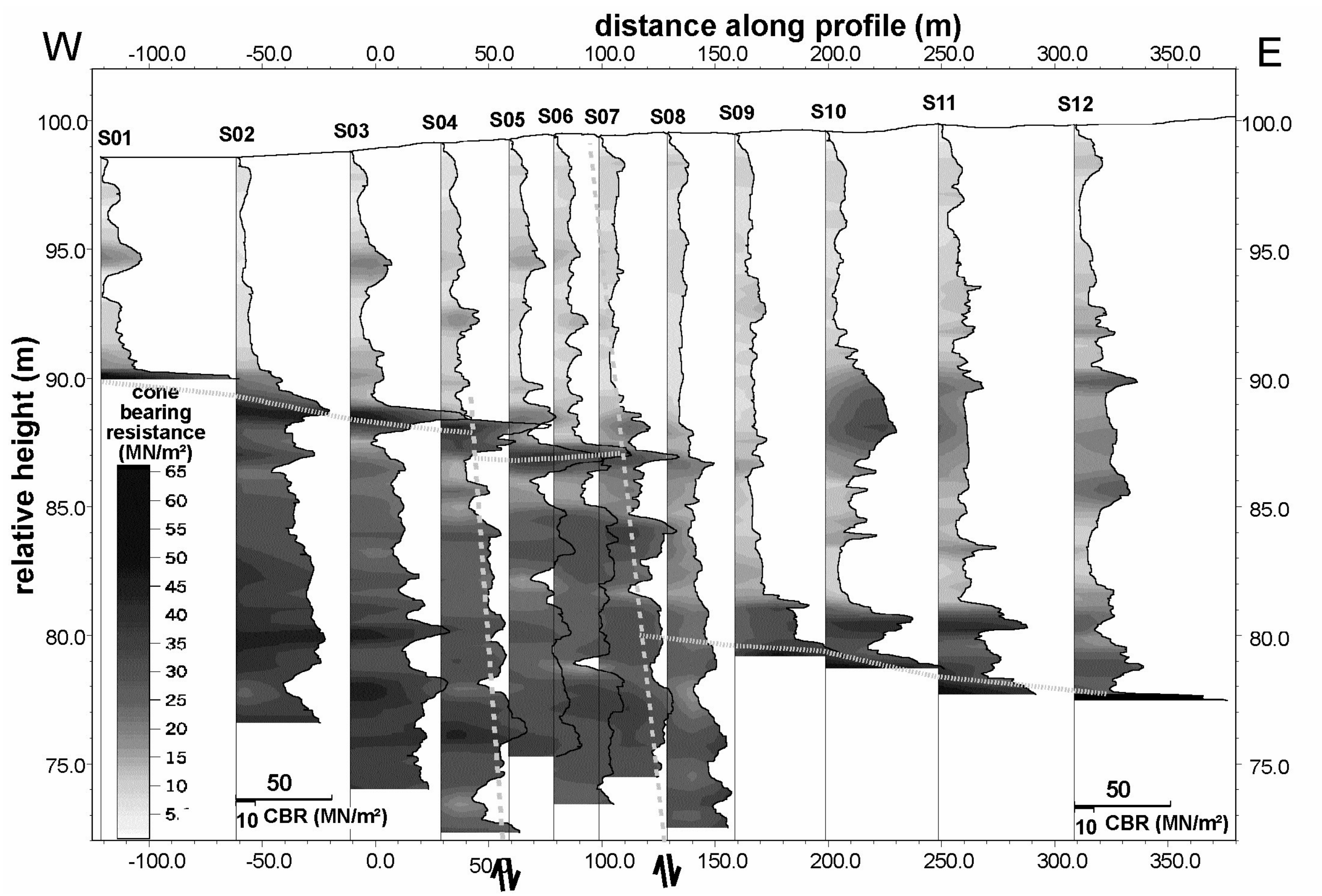

Figure 4. CPT profile at site 19 along the Rauw Fault with CBR both as greyscale and as graphs.