Preliminary areal extensive non-invasive tunnel construction site probing

The planned B 427 tunnel by-passing the city of Bad Bergzabern (Rhineland-Palatinate) is located in the northern foothills of the Vosges Mountains, on the western edge of the Upper Rhine Graben.

Several exploratory drillings show a homogeneous lithology of the variegated sandstone (*grès rose des Vosges)* down to the tunnel level, whose outcrops on the surface are weathered into loose sand.

Areal extensive information on the expected rock quality and on tectonic features of the subsurface along the approximately 1.75 km long tunnel L1 is practically unavailable from five borehole locations. The results of a hybrid seismic preliminary investigation led to an updated state of knowledge with regard to the type of excavation techniques to be decided on.

The data from 12 hybrid seismic profiles with a total length of about 5.4 km were recorded, subjected to EDP and interpreted (see map of Fig. 1).

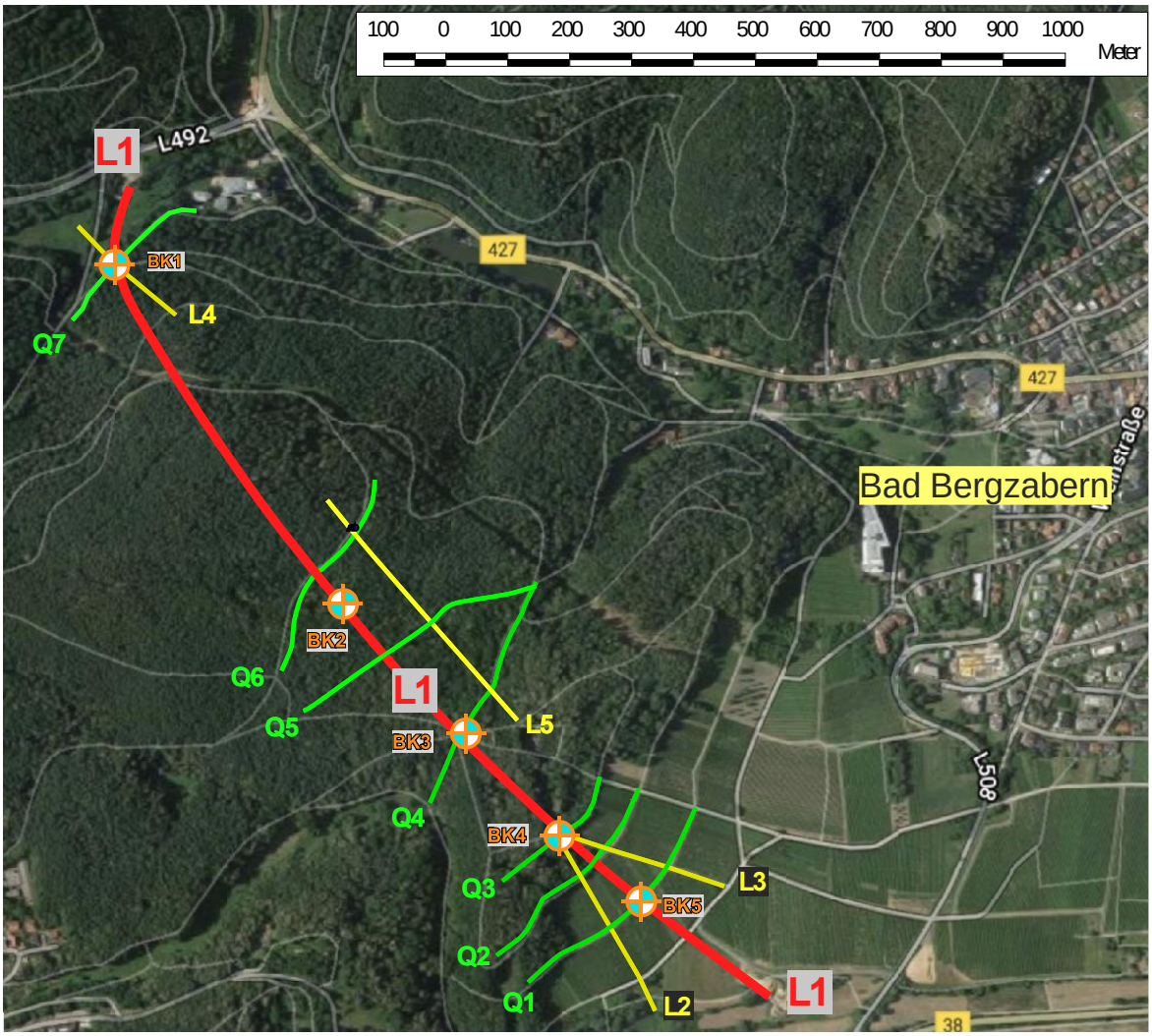

Fig. 1 Situation map of the twelve seismic lines along the planned route of the road bypass tunnel.

Seismic refraction diving wave tomography inversion is used to derive the detailed distribution of seismic propagation velocities in the subsurface. These are directly proportional to mechanical rock strength (Fig. 2a). As can be seen from the two legends, the **i**so-**v**elocity **c**ontour **l**ine of 2'500 m/s (IVCL2500) on the main profile L1 points to the boundary between unstable and stable Buntsandstein rock. The planned tunnel transect is situated over the entire length of the profile at shallower depths than the IVCL2500, that is in mechanically unstable, not self-supporting bedrock.

In analogy to an X-ray image, the reflection seismic section in Fig. 2b portrays the structural composition of the subsurface. Tectonic features such as fracture zones and layer folds are readily identified.

A deepening of the red IVCL2000 on the approximately 500 m long profile section between 850 m and 1350 m as well as a prominent decompaction zone enclosed by the dark blue IVCL1500 at the intersection with the profile Q4 at the borehole BK3 are very much in evidence (see Fig. 2c) below.

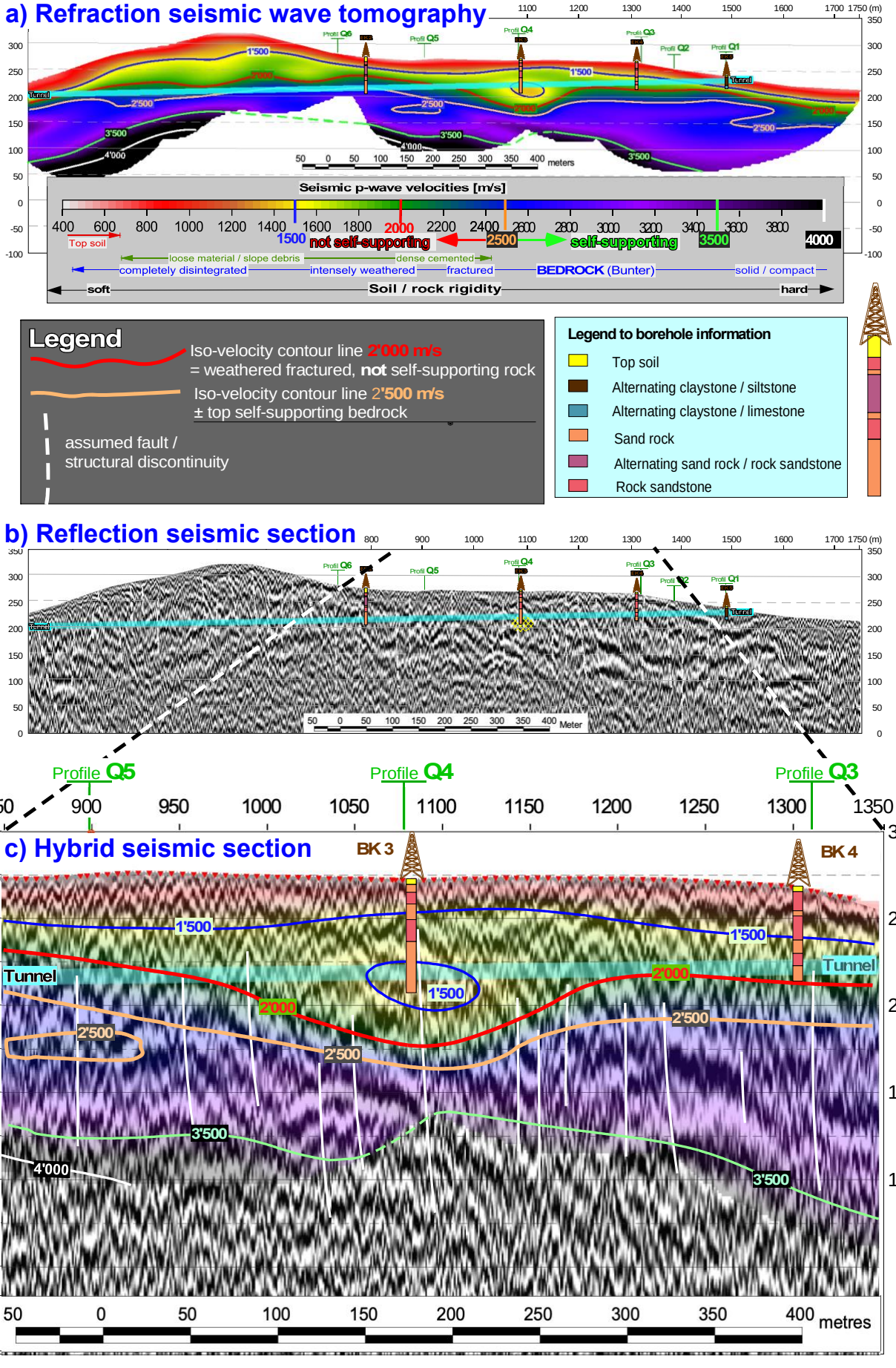

Fig. 2 Depth of the planned tunnel along the entire main profile across zones of different rock strengths in a) and across the tectonic structures in b). The geological situation of the enlarged central section is represented in c).

In Fig. 2c) of this enlarged profile section, a hybrid seismic profile (refraction tomography velocity field in combination with high-resolution reflection seismic section) is shown. The planned tunnel's position is here more than 60 m *above* the upper limit of solid, self-supporting rock (IVCL2500).

The hybrid seismic cross line Q4 as shown in Fig. 3, crosses a trough fault structure whose neighbourhood is typically characterized by numerous minor faults. At the intersection with the main profile L1, the borehole BK3 and the tunnel crossing in unstable rock formations are directly above the prominent fault **A** marking the steeply dipping southwestern flank of the trough fault structure.

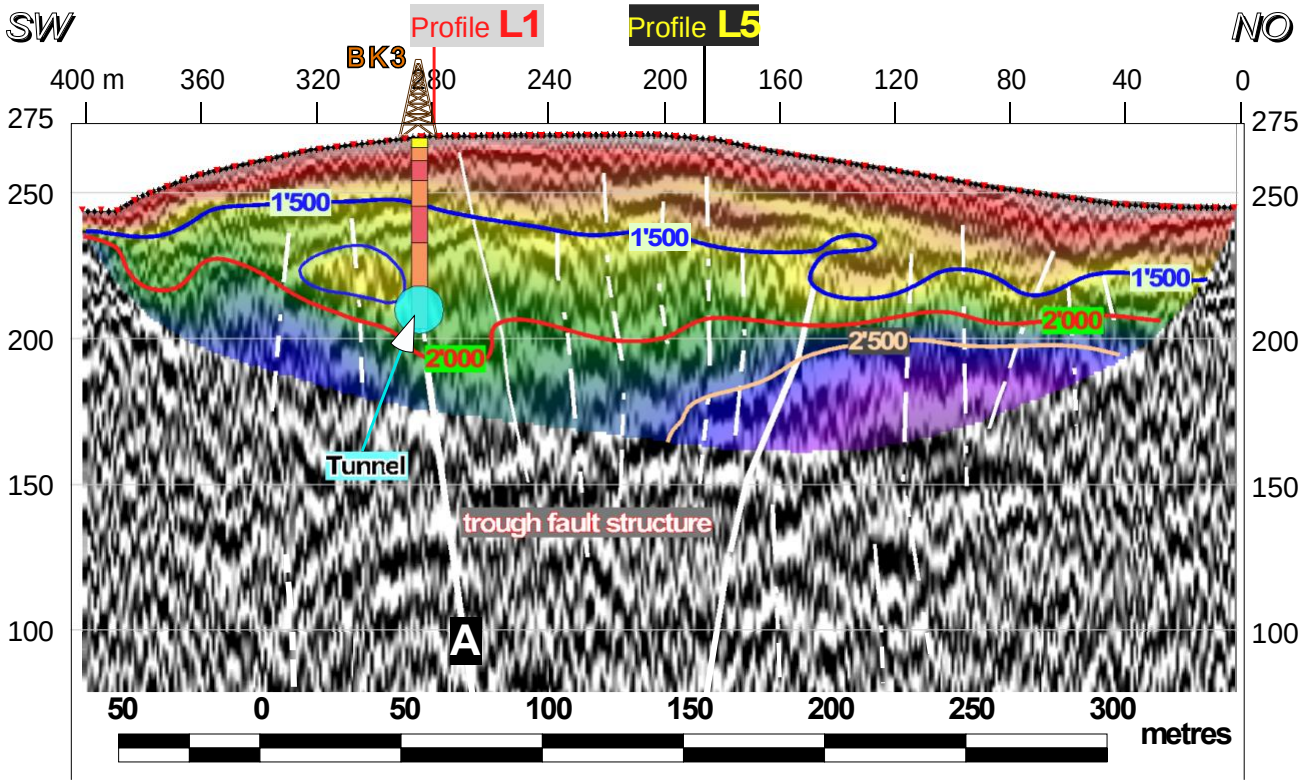

Fig. 3 The hybrid seismic profile of the cross section Q4 shows the vivid tectonic structures as well as the unfavourable position of the planned tunnel in unstable, not self-supporting rock in the distinctive trough fault structure.

Cost / benefit ratio of preliminary seismic construction site characterizations

The costs of this seismic survey with the twelve seismic lines totalling 5.4 km are lower than those for a single exploratory drilling to a depth of 70 - 80 m.

As in the petroleum exploration industry, the main task of seismic surveying is to define meaningful borehole locations, from which rock samples and wire line logging results are geologically representative of an area being as large as possible.

Generally, it is recommended that decisions with regard to invasive construction site investigation programmes, such as boreholes, are to be based on an updated state of knowledge by using cost-effective seismic prospection methods.

Seismic methods – here the *hybrid seismic technique, a combination of seismic refraction tomography inversion with high resolution seismic reflection profiling* – combined with information from boreholes thus provide an optimal cost / benefit ratio in any exploratory project of this kind.

by Walter Frei
GeoExpert AG
info@geoexpert.ch
Tel. +41 71 652 60 70

November 2019