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Hydraulic conductivity variability of the Boom Clay in north-east Belgium based on four core drilled boreholes

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ABSTRACT

The hydraulic conductivity of the Boom Clay is investigated since many years in Belgium in the framework of the site characterisation programme supporting the performance assessment of potential geological disposal of high-level radioactive waste in this formation. In this paper, the variability of the hydraulic conductivity is assessed in a large part (1100 km^2) of the deposition area of the Boom Clay. It is based on numerous vertical and horizontal hydraulic conductivity measurements (K_v and K_h) performed with permeameter-type experiments on clay cores from four distant boreholes, i.e. Doel-2b, Zoersel, Mol-1 and Weelde-1. A thorough analysis of the results of the grain-size measurements is performed and its relationship with the hydraulic conductivities is examined through multiple regressions. This approach allows deriving site-specific empirical relationships to predict vertical hydraulic conductivities from the grain-sizes used as soft data. This increases our confidence in the global value of the vertical hydraulic conductivity at the scale of the formation and enhances the overall assessment of the variability of this parameter at the regional scale. Further efforts should be done to evaluate the variability of the hydraulic conductivity with relationships that are suitable for the whole depositional area. This would make the method more attractive for the overall assessment of a potential host-formation for geological disposal.

1. Introduction

1.1. Foreword and objectives

In Belgium, geological disposal in the Boom Clay is considered as a potential solution for the disposal of high-level and long-lived radioactive waste. This formation, extending in north-east Belgium and situated between about 186 m and 289 m depth at the Mol site, presents various favourable properties such as, a.o., a very low hydraulic conductivity (about 10^{-12} m/s), strong sorption capacity for many radionuclides and self-sealing properties.

In this framework, the various possible transport processes in this potential host-formation are evaluated. A very low hydraulic conductivity in combination with limited hydraulic gradients over the host-formation makes that water flow in the clay formation is negligible and that diffusion is the main transport mechanism (where diffusion is dominant). In the safety assessment of this geological disposal, migration of radionuclides through the host clay formation and the subsequent transport within the surrounding aquifer system are simulated (Marivoet et al., 2002).

A large investigation programme has been running since more than 30 years to characterise this formation. Although most of the Boom Clay characterisation has been carried out in the underground research laboratory (URL), at the Mol site, many efforts have been done, since 1996, to determine the hydraulic and transport properties in the Boom Clay over its deposition area in north-east Belgium.

This paper presents the results of numerous measurements of hydraulic conductivity values (K) determined in the laboratory, on clay cores from four distant boreholes and it proposes a simple but detailed and methodical approach to evaluate the distribution of this parameter over the deposition area.

1.2. Location of the boreholes in the investigation area

The four investigated boreholes are the Doel-2b, Zoersel, Mol-1 and Weelde-1 boreholes spread over the depositional area of the Boom Clay, where its top is ranging from 50 to 260 m below the ground surface (m bgs) or from −44 m to −230 m above sea level (m asl) (see Fig. 1). Information about the four boreholes is provided in Table 1.

1.3. Geological and hydrogeological context of the Boom Clay

The Boom Clay is a Tertiary argillaceous formation extending in north-east Belgium. It crops out in a small west-east band from the Scheldt estuary area in the west (south of Antwerpen), along the

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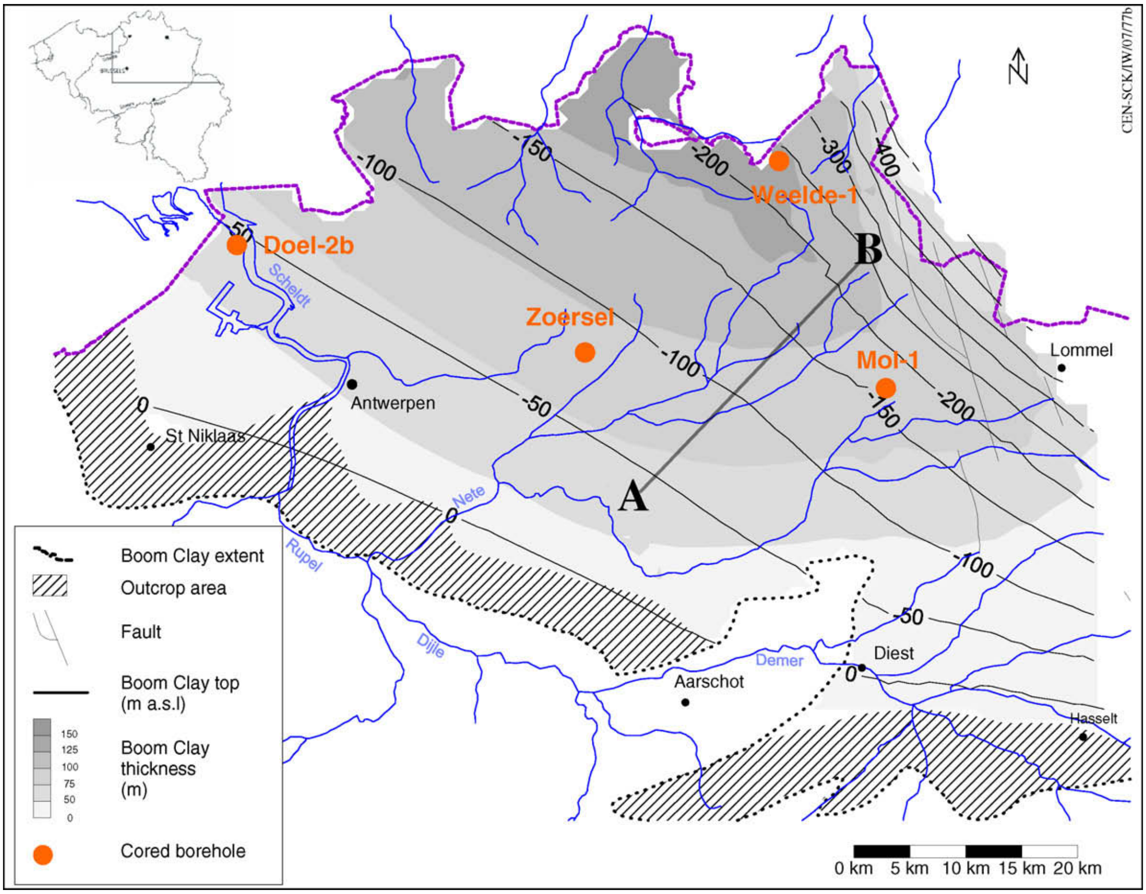

Fig. 1. Extent of the Boom Clay and location of the investigation boreholes and A–B profile.

Table 1
General information about the boreholes.

Name of the borehole	Doel-2b	Zoersel	Mol-1	Weelde-1
X lambert coordinate (m)	142,228	173,320	200,191	190,649
Y lambert coordinate (m)	224,452	214,840	211,652	231,963
Z ground surface (m asl)	7.7	13.1	24.9	30.9
Z drilling table (m asl)	8.1	13.9	29.7	31.8
Total depth (m)	173.5	300.0	572.5	528.2
Drilling year	1998	1996	1997	1997
Ref number at GSB	14E242	29E348	31E314	8E159

asl: Above sea level; GSB: geological survey of Belgium.

Rupel river and the Demer river to the Meuse river in the east (south of Hasselt). It is slightly dipping into the north–north-eastern direction with a slope of about 1–2% and increasing thickness (see Fig. 1). At the Mol site, the Boom Clay has a thickness of a little more than 100 m, whereas its top is located at about 186 m depth.

It is covered by sandy layers of Quaternary, Neogene and late Paleogene ages belonging to a large aquifer system called the Neogene Aquifer. The Boom Clay, overlays the two deeper aquifers of Lower Rupelian (sand and clay layers) and Lede-Brussel (sand), which are separated by the Asse Clay (see Fig. 2).

Besides quartz, K-feldspar, Na-plagioclase, pyrite and carbonates, the Boom Clay comprises essentially (mostly about 60%) clay minerals dominated by illite, mixed layered illite–smectite, kaolinite and traces of chlorite (Van Keer et al., 2001). Its composition is relatively homogeneous over its depositional area. However, it is characterised by a banded structure essentially found in the alternation of siltier and more clayey beds of thicknesses ranging from 10 cm to 2 m. This fine sequence of "clayey/silty beds" is enhanced by the presence of more bituminous organic matter in the dark clay beds and by horizons with calcareous concretions called septaria, spread over the whole formation (Vandenberghe, 1978; Vandenberghe and Van Echelpoel, 1987). This typical clayey/silty beds sequence has the particularity that it can be recognised over large distances allowing detailed correlation as far as the delimitation of the beds can be accurately determined.

The Boom Formation can also be subdivided into three main stratigraphic units (Vandenberghe et al., 2001). They are, from the basis to the top, the Belsele-Waas Member, which is the siltiest part of the Boom Clay, the Terhagen Member, characterised by pale grey clay and comprising the lowest proportion of coarser particles (sand or silt) and only two dark bituminous zones, and finally the Putte Member, characterised by dark clay and the systematic presence of organic matter. The Putte Member comprises one of the key horizons called the "double band" (db), situated in its lower part and which consists of two relatively coarse layers separated by a thin clay layer (Vandenberghe and Van Echelpoel, 1987). The upper part of the Boom Formation is siltier, and called the "Transition zone" (Vandenberghe et al., 2001).

2. Materials and methods

2.1. Drilling, coring technique and sample preparation

The boreholes were drilled within different drilling programmes, commissioned by ONDRAF/NIRAS (the Belgian radioactive waste management agency) from 1996 to 1998. The four boreholes were cored in the whole Boom Clay interval and the