nagra

Arbeitsbericht NAB 19-05

Quaternary Borehole QBO Neuhausen (QNEU)

Data Report

December 2019

M. W. Buechi, A. M. Kuster, M. Huber, D. Amschwand, H. Madritsch & G. Deplazes

National Cooperative for the Disposal of Radioactive Waste

Hardstrasse 73
P.O. Box 280
5430 Wettingen
Switzerland
Tel. +41 56 437 11 11

www.nagra.ch

nagra

Arbeitsbericht NAB 19-05

Quaternary Borehole QBO Neuhausen (QNEU)

Data Report

December 2019

M. W. Buechi[1)], A. M. Kuster[1)], M. Huber[1)], D. Amschwand[1)], H. Madritsch[2)] & G. Deplazes[2)]

[1)] Quaternary Geology & Paleoclimatology Research Group
University of Bern
[2)] Nagra, Wettingen

KEYWORDS

SGT-E3, HAA, SMA, Field investigations, Quartärbohrung, Quaternary Drilling, QBO, QNEU, Drilling technology, Geophysical logging, Petrophysical logging, Neuhausen, Neuhauserwald Channel, Quaternary, Geology

National Cooperative for the Disposal of Radioactive Waste

Hardstrasse 73
P.O. Box 280
5430 Wettingen
Switzerland
Tel. +41 56 437 11 11

www.nagra.ch

Nagra Arbeitsberichte ("Working Reports") present the results of work in progress that have not necessarily been subject to a comprehensive review. They are intended to provide rapid dissemination of current information.

Table of Contents

List of Tables

List of Figures

List of Appendices

(Annotation: The appendices E to I can be found in the digital version of this report (PDF).

1 Introduction

In the context of the sectoral plan "Sachplan geologische Tiefenlager" (SGT) Nagra is currently investigating three sites (Jura Ost, Nördlich Lägern, Zürich Nordost) in northern Switzerland to potentially host repositories for radioactive waste. The field exploration project "Quartär-untersuchungen" (QAU) is dedicated to the characterisation of Quaternary deposits within and around these siting regions to further constrain scenarios of their geological long-term evolution. The investigations support the reconstruction of Quaternary landscape evolution.

The borehole (Quartärbohrung, QBO) at Neuhausen (QBO Neuhausen / QNEU, Tab. 1) is part of Nagra's Quaternary investigation program (QAU; compare Nagra 2017). The QNEU drill site (Fig. 1 and 2) is located very close to a previous destructive drilling (11-NS-AZ-34; Dr. Heinrich Jäckli AG 2012; Fig. 2) and was chosen to further characterize and sample the valley fill of the Neuhauserwald Channel (Neuhauserwald-Rinne) as well as verify its reported depth. The borehole QNEU was conducted from 21.11.2018-01.02.2019 using a combination of Düsterloh hammer drilling and wire-line drilling with a triple-tube core-barrel, i.e. with a plastic core liner.

This report covers the request for a documentation of the authorized works on-site (UVEK 2018, Dispositiv 5.11) and documents also the core description and first lab analyses (UVEK 2018, Dispositiv 5.12). The work has been carried out according to the work program (Arbeitsprogramm, Nagra 2018) and this report corresponds to the data report announced there.

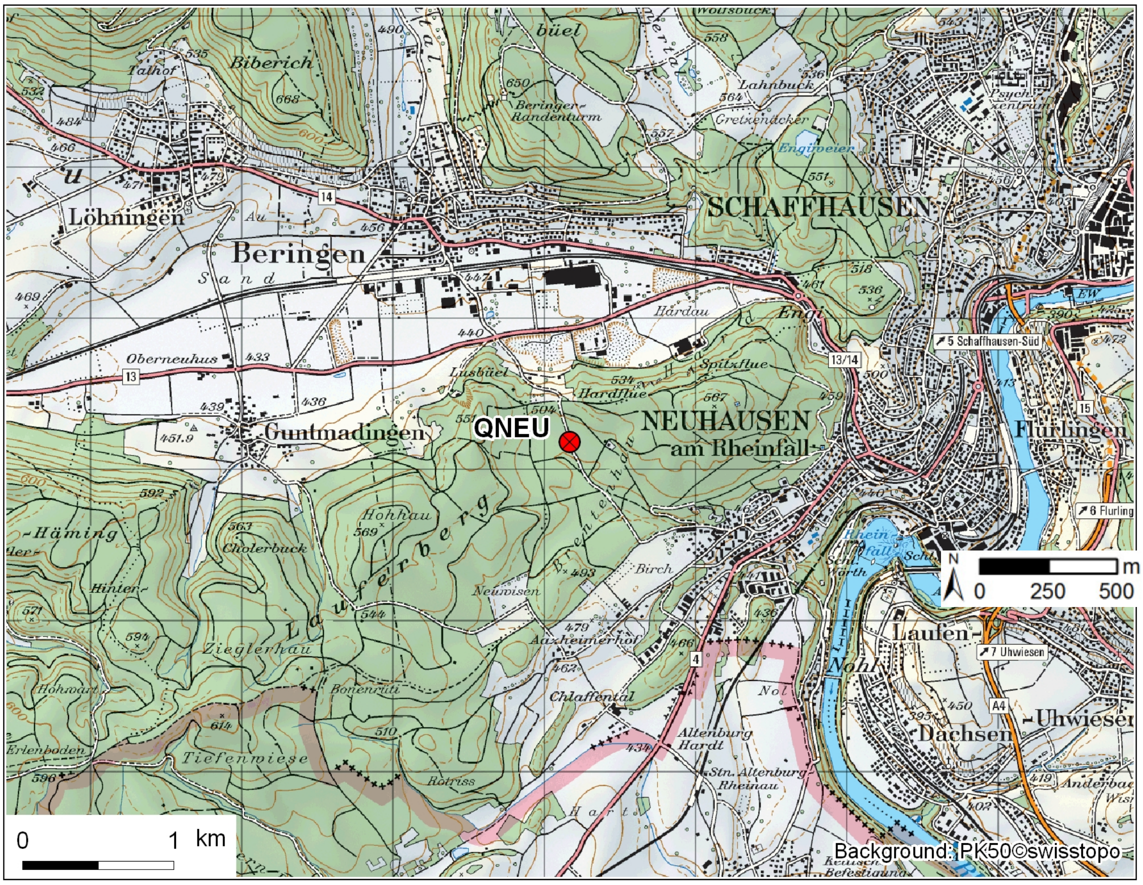

Fig. 1: Location of the Quaternary borehole Neuhausen (QNEU).

In this report, we present core images, sedimentological descriptions, and geophysical measurements of the cores, all of which were acquired at the University of Bern. Additionally, a report on geophysical borehole logging by BLM Gesellschaft für Bohrlochmessungen mbH and L. Keller (roXplore gmbh; responsible for quality control) and a technical drilling report by Fretus AG edited by P. Hinterholzer-Reisegger (Nagra) are presented in appendices H and I, respectively. This report is the basis for planning further core analysis and later interpretation in the larger geological context.

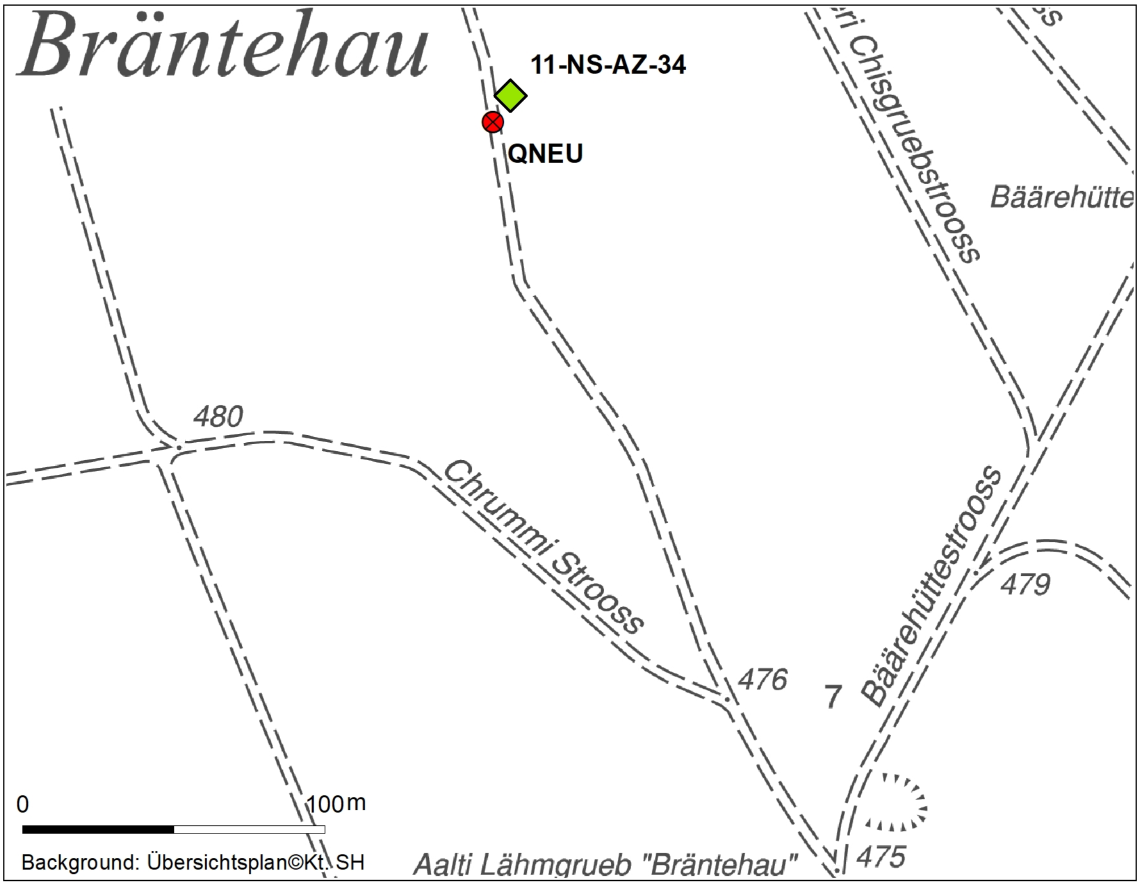

Fig. 2: Detailed location of Quaternary borehole Neuhausen (QNEU) and adjacent borehole 11-NS-AZ-34 (Dr. Heinrich Jäckli AG 2012).

Tab. 1: Key data of the Quaternary borehole Neuhausen (QNEU).

Coordinates	2'686'170.37 E / 1'282'180.94 N
Elevation (m a.s.l.)	487.83
Depth (m b. ground)	137.2

2 Methods

2.1 Drill-site core handling

After pull-out, the cores (in orange plastic liners with 10.4 cm inner diameter, usually in 1 m-core runs) were taken out of the core barrel, closed with plastic caps, sealed with tape and labeled with the core name (QNEU plus driller's depth). The core direction was labelled on the end caps ("O" for "oben" or "U" for "unten"), on the plastic liner itself ("Kopf" at the top, "Krone" (drill bit) at the bottom), and also on the wooden boxes used for storage of the individual cores. Labelling generally was performed by the drilling supervisor, who also weighed the individual core pieces for a first assessment of core recovery.

The cores were stored on site until the next transport to the cool storage facility in Bern, which typically occurred within two to three working days. At the drill site, the cores were protected from freezing, excessive heating and extended exposure to daylight.

2.2 Core lab workflow

2.2.1 Petrophysical logging

The whole cores were first analyzed with a Geotek multi-sensor core logger (MSCL) within one to few days after drilling. The MSCL recorded bulk density (by gamma attenuation), p-wave velocity and magnetic susceptibility in a 5 mm depth-resolution (Geotek 2016, Schultheiss and Weaver 1992). The results of the measurements are given in appendix F. Data points related to strongly disturbed core material or gaps within the core, as indicated on the individual section logs, were discarded. Apart from that, the data were not revised (e.g. no smoothing of the data at core ends). The remaining data points were vertically positioned according to chapter 2.3.2 (composite depth).

Note also:

- Low p-wave velocity values (below the value for water of ~1500 m/s) are measurement artefacts and generally result of missing mechanical coupling due to a gap between the plastic liner and the core material.
- Exceptionally high peaks in magnetic susceptibility may be the result of metal shards broken off the core catcher or drill bit (as observed in QNEU-126.5-127.0 at 19 cm section depth).

2.2.2 Core opening and description

Core opening was then performed in two steps: After labelling the plastic liner on both sides, the length of it was sliced with a buzz-saw on opposite sides. Then, the core was split into half. In case of sand, silt or clay, this was done by pushing two pieces of sheet metal in the slit between the liner halves. Gravelly sections had to be split by levering with a spatula. All cores were opened under subdued red light to allow for later luminescence dating (see section 2.5). One core half (B-half) was then packed into two layers of stretch foil and wrapped in opaque tubular foil to prevent desiccation and light exposure.

The freshly opened surface of the other core half (A-half) was then prepared for core imaging and sedimentological logging. This included evening out the surface and cleaning some surficial clasts. High-resolution core photos were recorded with a line-scan camera mounted on the MSCL.

Following this, the sedimentology was logged for each core section (see appendix E). Additionally, smear slides were prepared from intervals of interest, bulk sediment samples for later analysis were taken (ca. 1 sample per meter considered to be representative for the lithology), and shear strength measurements were taken using an Eijkelkamp pocket suited for max. 250 kPa (Eijkelkamp 2012, see appendix G). For later clast petrographic studies samples of ca. 200 clasts of the 2-6 cm fraction were taken from the core (see appendix G, A- and B-half sampled to narrow sampling depth interval). For storage, the A-half was also sealed with two layers of stretch foil and wrapped in tubular foil.

For description of bedrock cores, a different approach was used. After splitting the liners, one liner half was lifted off the core, and the photos and descriptions were made based on the whole core. H.R. Bläsi helped with the description of the bedrock cores.

2.2.3 Core storage

At the time of completion of this report, all processed cores are being kept refrigerated, either at the University of Bern or the cold storage of Emmi in Ostermundigen. Later, the cores are planned to be stored in the core repository of Nagra in Mellingen.

2.3 Preliminary data integration

2.3.1 Core recovery

After an initial estimation at the drill site using core weight (see appendix I), the recovery was determined based on the initial description of the cores including the MSCL data. The core recovery was in general between 83-100%. This recovery value is defined here as the ratio between the length of recovered core and length of the drilled interval. Sediment that could be clearly identified as strongly disturbed (i.e., original sedimentary context could not be reconstructed) or infall/recore material was excluded and does not add to the recovered core length. In addition, feedback on the coring process from the drill crew and the drilling supervisor was included. The core-lab recovery is given in Appendix D.

2.3.2 Composite depth

To construct a composite depth:

- The top of the recovered cores was aligned with the top depth of the driller's depth. All other core material was placed below that top. The non-recovered intervals were placed at the bottom of the cored interval (IODP-MI 2011). As mentioned above, material that could be clearly identified as infall/recore material or strongly disturbed was excluded and does not add to the recovered core depth.
- The length of the recovered cores may exceed the cored length. In an overlength case the cores were scaled linearly to match the drilled length.

2.3.3 Core section documentation

All relevant observations were summarized on section logs (Fig. 3, see appendix E). These are specifically:

- **Composite depth**: see chapter 2.3.2
- **Core image**
- **Section depth**
- **Lithology:** General core lithology represented by graphic patterns (legend provided in appendix A)
- **Structures and sampling**: Sedimentary structures and contacts (legend provided in appendix A) and sampling points. The depth is given in section depth. Note: All samples taken until the date of this report are indicated (see also appendix G). Not all the samples taken will necessarily be analyzed. During the upcoming detailed analysis, additional samples may be taken.
- **Description** of the respective unit: Grain size and composition (principal and secondary fractions), sedimentary structures, color (using a Munsell Rock Color Book, 2014 production, munsell.com), clast properties, additional free comments

2.3.4 Overview and condensed core profiles

Individual section logs were summarized and preliminarily interpreted in overview geological profiles for the borehole Neuhausen (appendix B). A second profile plots the petrophysical MSCL measurements together with borehole geophysical data (see appendix C).

2.4 Provisions for luminescence dating

In anticipation of later luminescence dating, the drill cores were protected against exposure to daylight with the following measures:

- **Opaque liners**: The cores were drilled in opaque liners.
- **Core opening**: The cores were opened under subdued red light.
- **Core storage**: The B-halves were wrapped in two layers of stretch foil and opaque tubular foil and stored in wooden storage boxes. This setup ensures protection against light and rapid desiccation.

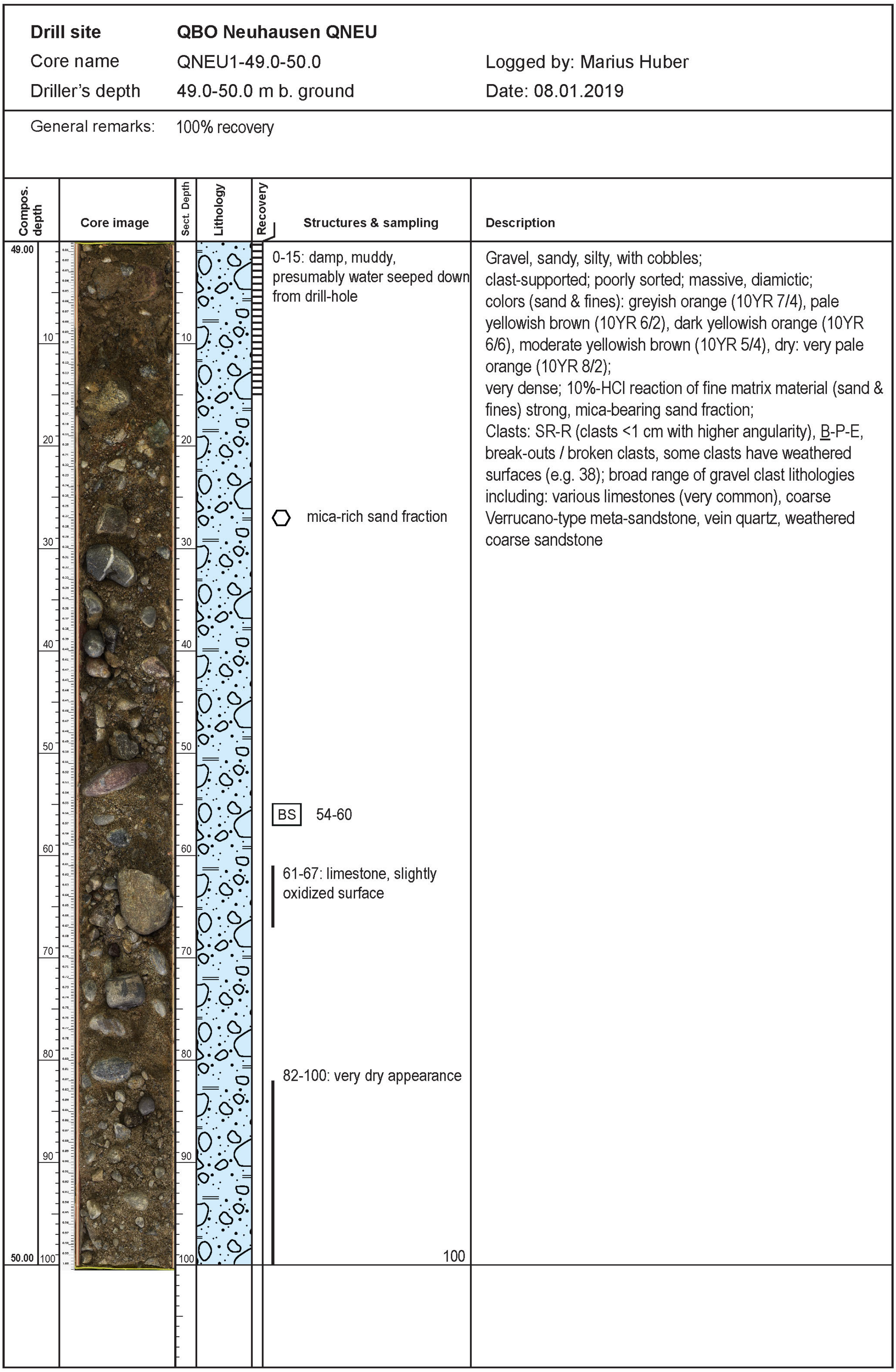

Fig. 3: Example for section log.

2.5 Porewater and geotechnical samples

Porewater sampling requires squeezing of fresh and unopened full cores of fine-grained units (Tomonaga et al. 2011, 2014) and is generally performed on the drill site without prior MSCL scanning. However, the prevailing coarse-grained lithologies in QNEU largely inhibited the application of this conventional squeezing method. Only one sample could be squeezed. This sample was taken from the top of a ~25-cm-long section cut from the bottom end of core 22-23 m. This squeezed section was later split open and described as all other core material; squeezing apparently caused only minor disturbance of the core material. Note: The MSCL data were recorded from the squeezed and potentially disturbed core pieces.

The conventional technique used to collect pore water samples for noble-gas analysis is known to work well for fine-grained unconsolidated lacustrine sediments. This method, however, did not allow collection of samples from coarse or well-compacted sediments recovered in QNEU. For this reason, an alternative sampling approach was tested for the cores from QNEU in parallel to the conventional sampling (ref. appendix G, "AM"). After core recovery, sediment chunks were transferred from core 112-113 m into an airtight bottle using a metal spoon. The bottle was not filled completely in order to leave a headspace volume where at a later stage the concentrations of gases emitted from the sediments could be determined.

Groundwater samples for noble-gas analysis were acquired using plastic bottles inserted into a liner that was dropped into the saturated zone in a depth ranging from 102 m to 112 m. These samples were sealed in copper tubes (see e.g. Beyerle et al. 2000).

At the stage of reporting, no geotechnical samples from QNEU were taken.

3 Preliminary geological overview

The QBO Neuhausen (QNEU) recovered the 127 m thick sedimentary infill of the Neuhauserwald Channel. Bedrock at the base of the borehole consists of interbedded limestones and marls of the Villigen Formation; the sponge-rich facies between 133.8 m and the end of the borehole at 137.2 m likely belongs to the Hornbuck Member (Gygi 2000).

The overlying Quaternary sediments forming the infill of the Neuhauserwald Channel consist of 100 m gravels (127-27 m depth). These gravels often contain a sandy and silty matrix and are moderately to poorly sorted. They are preliminarily interpreted as fluvial, possibly fluvioglacial, gravels. The proposed subdivision of these gravels currently mainly relies on their overall lithofacies, the occurrence of units rich in cobbles to boulders, and the observation of intervals with oxidized "rusty" gravels (especially ca. 30-40 m). At the given core scale, the transitions between these units appear however gradual and may be worth to be investigated further (e.g. based on provenance).

The gravelly main infill is overlain by sands (27-1.6 m) which are interbedded with gravel (0.5 to few m thick beds) and silt/clay (dm-thick beds). These sands are rich in secondary carbonate concretions (isolated nodules and layers). This facies is interrupted at 9-11 m where gravels and diamicts containing clasts shaped by glacial transport (facetted and bullet shapes, broken clasts, break-outs and striated surfaces) indicate the proximity to a former glacier front. Overall the sediments between 27 and 1.6 m are therefore interpreted to reflect everchanging hydrological conditions with deposition in a shallow lake with currents and/or fluvial sands and gravels. This succession is covered by 1.6 m of soil and colluvial cover sediment.

In the neighbouring, previous destructive drilling 11-NS-AZ-34 glacigenic lakes sediments (with pieces of white soft lacustrine chalk) have been described in a depth of 88-128 m (Dr. Heinrich Jäckli AG 2012). In the new cored drilling QNEU no such lake sediments could be found. As the two drilling are very close to each other (ca. 10 m) it is likely that these differences reflect the uncertainties introduced by destructive drilling, sampling and cutting description and that no lake sediments occur at the borehole 11-NS-AZ-34.

Water occurrences in QNEU are reported in the upper sandy sediments (between approximately 15 and 23 m) and much deeper at around 102-103 m (see appendix I). The latter occurrence is in approximate agreement with the inferred groundwater table in the neighbouring Klettgau valley (von Moos & Nänny, 1970).

Detailed core documentation and supplementary data are organized in the appendices as listed on page II.

4 References

Benn, D. I. (2004): Clast morphology. – In: Evans, D. J. A. & Benn, D. I., eds., A practical guide to the study of glacial sediments. Edward Arnold, London, 78-92.

Beyerle, U., Aeschbach-Hertig, W., Imboden, D. M., Baur, H., Graf, T. & Kipfer, R. (2000): A mass spectrometric system for the analysis of noble gases and tritium from water samples. Environ. Sci. Technol. 34, 2042–2050.

Dr. Heinrich Jäckli AG (2012): 2D-Seismik Nordschweiz 2011/12: Geologische Aufnahme der Aufzeitbohrungen (Teil 1). Nagra Arbeitsbericht NAB 12-22.

Eijkelkamp (2012): Pocket vane tester operating instructions. URL (accessed 21.8.2018): https://www.eijkelkamp.com/download.php?file=M11410e_Pocket_vane_test_5306.pdf

Geotek Ltd (2016): Multi-Sensor Core Logger MSCL – Manual version Nov 1, 2016. URL (accessed 21.8.2018): http://www.geotek.co.uk/wp-content/uploads/2016/04/MSCL-manual-1-Nov-16.pdf

Gygi, R. A. (2000): Annotated index of lithostratigraphic units currently used in the Upper Jurassic of northern Switzerland. Eclogae Geologicae Helvetiae 93/1, 125-146.

IODP-MI (2011): IODP Depth Scales Terminology. Definitions and guidelines for depth scales in the Integrated Ocean Drilling Program. Version 2.0. URL: www.iodp.org/policies-and-guidelines/142-iodp-depth-scales-terminology-april-2011/file

Naef, H., Büchi, M., Bläsi, H.R., Deplazes, G. and Gysi, M. (2019): Lithology Manual, Lithological description of drill cores and cuttings in Northern Switzerland. Nagra Arbeitsbericht, NAB 19-11.

Nagra (2017): Quartärbohrung Neuhausen, Gesuch um Erteilung einer Bewilligung für erdwissenschaftliche Untersuchungen. Sondiergesuch NSG-Q 17-02.

Nagra (2018): Arbeitsprogramm NSG-Q 17-02 AP, Quartärbohrung Neuhausen.

Powers, M. C. (1953): A new roundness scale for sedimentary particles. – In: Journal of Sedimentary Petrology 23, 117-119.

Schultheiss, P. and P. Weaver (1992). Multi-sensor core logging for science and industry. OCEANS'92. Mastering the Oceans Through Technology. Proceedings., IEEE.

Tomonaga, Y., et al. (2011). An improved method for the analysis of dissolved noble gases in the porewater of unconsolidated sediments. Limnology and oceanography: methods 9. 42-49.

Tomonaga, Y., Brennwald, M.S., Meydan, A.F. & Kipfer, R. (2014). Noble gases in the sediments of Lake Van–solute transport and palaeoenvironmental reconstruction. Quaternary Science Reviews 104, 117-126.

UVEK (2018): Verfügung vom 8. Februar 2018 betreffend Gesuch vom 4. August 2017 um Erteilung einer Bewilligung für erdwissenschaftliche Untersuchungen (Sondiergesuch NSG-Q 17-02), Quartärbohrung Neuhausen.

von Moos, A. & Nänny, P. (1970): Grundwasservorkommen im Klettgau, Kanton Schaffhausen. Eclogae Geologicae Helvetiae 63/2, 467-481.