Arbeitsbericht NAB 19-04

Quaternary Borehole QBO Marthalen-Oobist (QMOB)

Data Report

December 2019

National Cooperative
for the Disposal of
Radioactive Waste

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SGT-E3, HAA, SMA, Field investigations, Quartärbohrung, Quaternary Drilling, QBO, QMOB, Drilling technology, Geophysical logging, Petrophysical logging, Marthalen-Oobist, Rudolfingen Trough, Quaternary, Geology

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(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 "Quartäruntersuchungen" (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 Marthalen-Oobist (QBO Marthalen-Oobist / QMOB, Tab. 1) is part of Nagra's Quaternary investigation program (QAU; compare Nagra 2018a). The drill site was chosen to constrain the bedrock geometry and the valley fill of the Rudolfingen Trough together with borehole QBO Trüllikon-Rudolfingen (QTRU, Huber et al. 2020 in prep.) (Fig. 1, 2). The borehole QMOB was positioned at the southern margin of the Rudolfingen Trough, where the previous drilling AZ 97-11 indicated the possibility that at this site an older and a younger basin fill separated by till are preserved (Frey & Günther 1997, Graf 2009, Nagra 2018a, b). The locality of QMOB and QTRU was defined based on the findings of AZ 97-11 and on the recently acquired reflection seismic line 16-QAU-11 (Nagra 2018b).

The borehole QMOB was conducted between 29.10 and 16.11.2018 by a combination of Düsterloh Hammer drilling and wire-line drilling with a triple-tube core-barrel, i.e. with a plastic core liner.

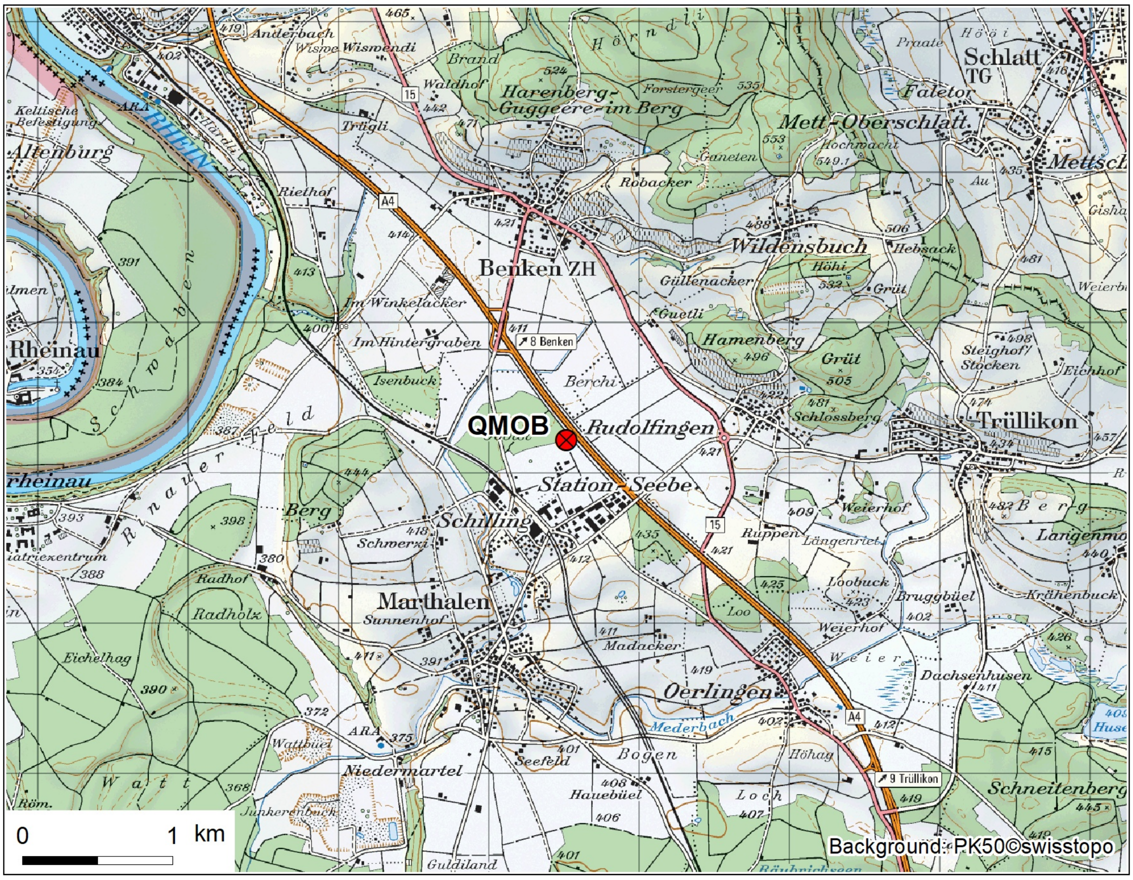

Fig. 1: Location of the Quaternary borehole Marthalen-Oobist (QMOB).

This report covers the request for a documentation of the authorized work on-site (UVEK 2018, Dispositiv 5.29) and documents also the core description and first lab analyses (UVEK 2018, Dispositiv 5.30). The work has been carried out according to the work program (Arbeits-programm, Nagra 2018c) and this report corresponds to the data report announced there.

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 terratec Geophysical Services GmbH & CO KG and L. Keller (roXplore gmbh; responsible for quality control) and a technical drilling report by Blétry 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.

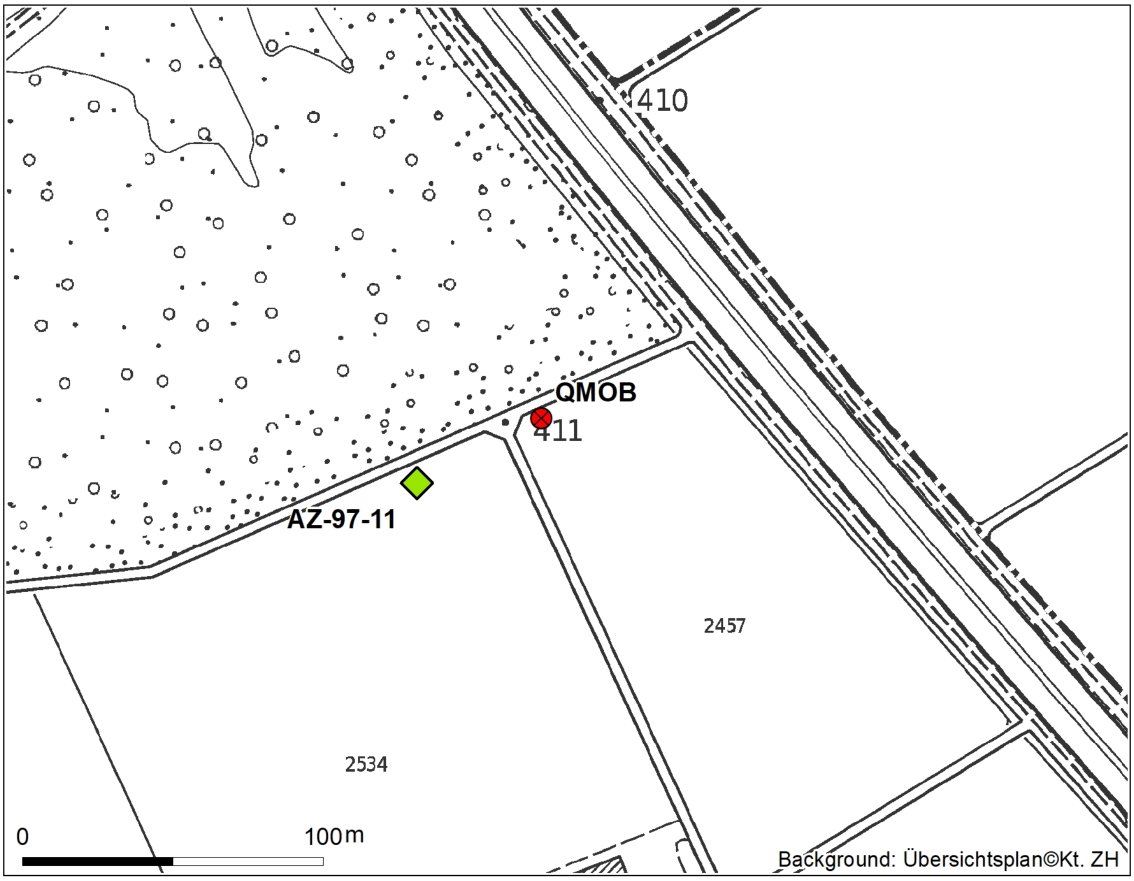

Fig. 2: Detailed location of Quaternary borehole Marthalen-Oobist (QMOB) and adjacent borehole AZ 97-11 (Frey & Günther 1997).

Tab. 1: Key data of the Quaternary borehole Marthalen-Oobist (QMOB).

Coordinates	2'691'509.52 E / 1'277'226.47 N
Elevation (m a.s.l.)	411.09
Depth (m b. ground)	48.0

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 labelled with the preliminary core name (“MOB” 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 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 excessive heating, freezing 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 QMOB1-29.0-30.0 at 63 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 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 storage, the A-half was also sealed with two layers of stretch foil and wrapped in tubular foil.

For description of lithified 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.

2.2.3 Core storage

At the time of completion of this report, the processed cores are being 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 80-100 %. 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 geological profiles for the borehole Marthalen-Oobist (appendix B). An additional profile plots the petrophysical MSCL measurements together with borehole geophysical data (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.

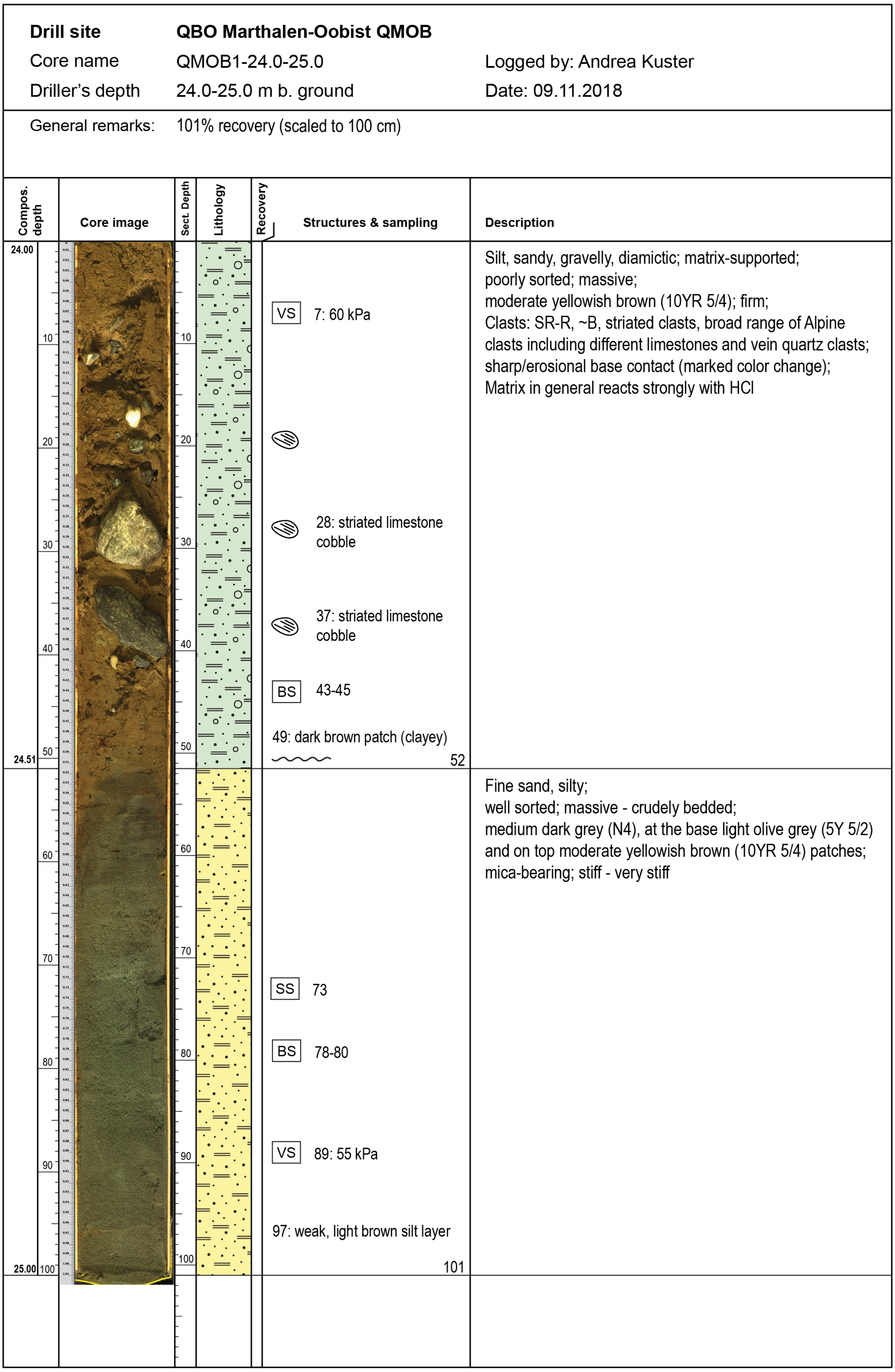

Fig. 3: Example for section log.

2.5 Porewater and geotechnical samples

Porewater sampling required squeezing of fresh and unopened full cores (Tomonaga et al. 2011, 2014) and was performed directly on the drill site without prior MSCL scanning. The squeezed samples were ~25 cm long and taken from the bottom ends of the respective cores. The samples targeted by pore-water sampling were later split open and described as all other cores; squeezing apparently caused only minor disturbance of the core material. Note: The MSCL data were recorded from the squeezed and potentially disturbed core pieces.

It should be noted that 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, might not allow collection of samples from coarse or well-compacted sediments. Thus, at the borehole Marthalen-Oobist an alternative sampling approach was tested in parallel to the conventional sampling (ref. appendix G, "Headspace"). After core recovery, sediment chunks were transferred from a selected core 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.

From the borehole in Marthalen-Oobist no geotechnical samples were taken so far.

3 Preliminary geological overview

At the drill site in Marthalen-Oobist, the Quaternary sediments above the Lower Freshwater Molasse (USM, Keller et al. 1990) are 24.5 m thick. The Molasse sediments consist of mudstones and sandstones and intervals of unconsolidated sands. The overlaying Quaternary sediments comprise some 5.3 m of matrix-supported, massive diamicts with a lot of reworked Molasse sediments at the base and some 8.1 m of massive or crudely bedded, fine-grained diamicts. These basal diamicts are preliminarily interpreted as tills and glacier-proximal glaciolacustrine sediments. They are overlain by 7.5 m of lacustrine sediment (or possibly a distal glaciolacustrine facies) and 3.6 m of deltaic to fluvial sands and gravels.

The bedrock at Marthalen-Oobist is ca. 35 m higher as was expected from the adjacent destructive drilling AZ 97-11 suggesting that the initial bedrock identification in the latter hole is incorrect. The shallower bedrock depth found at Marthalen-Oobist is in very good agreement with the reflection seismic image of Nagra section 16-QAU-11 whose preliminary interpretation (Nagra 2018b) was strongly driven by the now questionable interpretation of AZ 97-11. The seismic interpretation now needs revision according to the findings at Marthalen-Oobist.

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

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