Arbeitsbericht NAB 20-01

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Data Report

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KEYWORDS

SGT-E3, HAA, SMA, Field investigations, Quartärbohrung, Quaternary Drilling, QBO, QTRU, Drilling technology, Geophysical logging, Petrophysical logging, Trüllikon-Rudolfingen, 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 siting regions (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 Trüllikon-Rudolfingen (QBO Trüllikon-Rudolfingen / QTRU, Tab. 1) is part of Nagra's Quaternary investigation programme (QAU; Nagra 2018a). The drill site was chosen to constrain the bedrock geometry and the valley fill of the Rudolfingen Trough (Fig. 1 and 2) together with borehole QBO Marthalen-Oobist (QMOB, Kuster et al. 2019). The borehole QTRU was positioned in the centre of the Rudolfingen Trough based on recently acquired reflection seismic line 16-QAU-11 (Nagra 2018b). The borehole QTRU was conducted in the period 15.02.2019 – 05.04.2019 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 authorised works on-site (UVEK 2019, Dispositiv 5.29) and documents also the core description and first lab analyses (UVEK 2019, Dispositiv 5.30). The work has been carried out according to the work program (Arbeitsprogramm, Nagra 2019) and this report corresponds to the data report announced there.

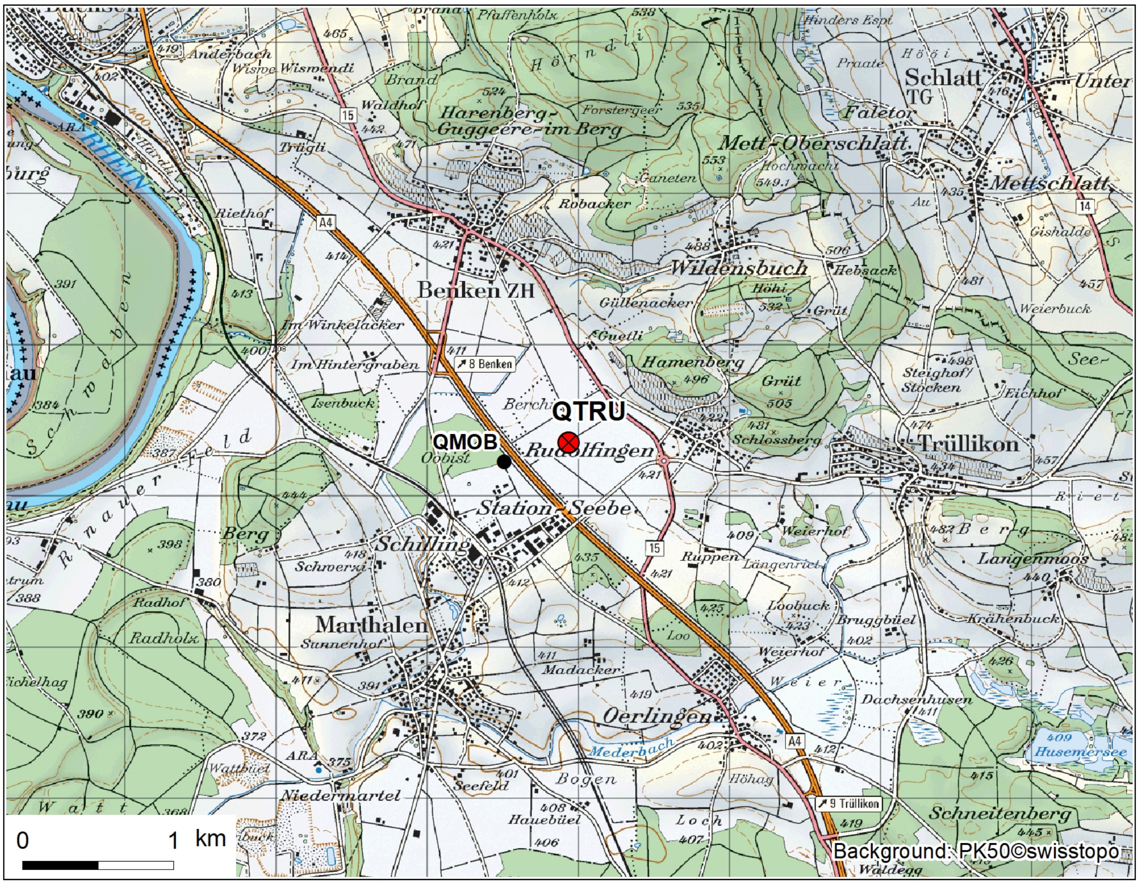

Fig. 1: Location of the Quaternary borehole Trüllikon-Rudolfingen (QTRU) and adjacent Quaternary borehole QMOB (Kuster et al. 2019).

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.

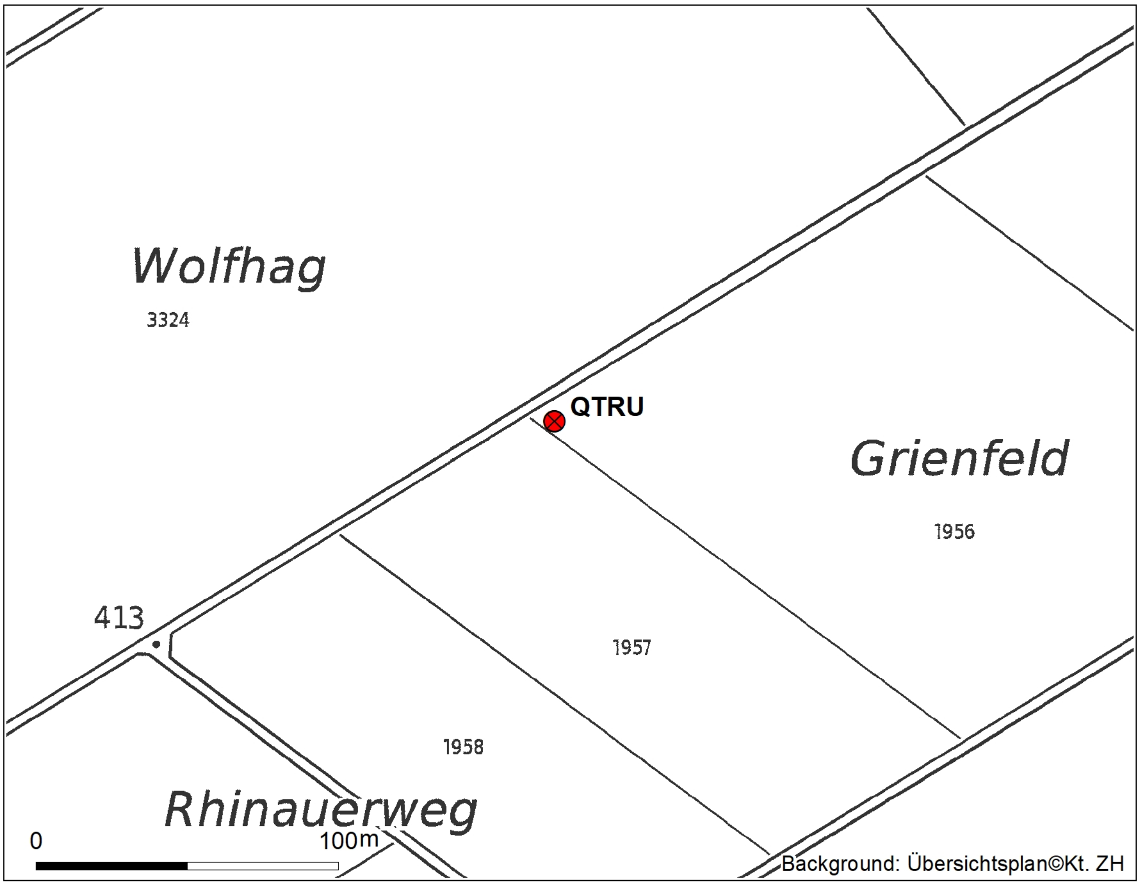

Fig. 2: Detailed location of Quaternary borehole Trüllikon-Rudolfingen (QTRU).

Tab. 1: Key data of the Quaternary borehole Trüllikon-Rudolfingen (QTRU).

Coordinates	2'691'937.45 E / 1'277'352.65 N
Elevation (m a.s.l.)	412.83
Final depth (m b. ground)	99.0

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 core name (QTRU 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 analysed 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 & 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 section 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 the 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 (examples visible in core images at 24.5 m and 39.40 – 39.50 m).

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 2.4). 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 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.

2.2.3 Core storage

At the time of completion of this report, all processed cores are being kept refrigerated at 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 high (see Appendix D). This recovery value is defined here as the ratio between the length of recovered core (section length) 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 recovery. In addition, feedback on the coring process from the drill crew and the drilling supervisor was included.

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 composite 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 summarised on section logs (Fig. 3, see Appendix E2). These are specifically:

- **Composite depth**: see section 2.3.2
- **Core image**
- **Section depth**
- **Lithology:** General core lithology represented by graphic patterns (legend provided in Appendix A2)
- **Structures and sampling**: Sedimentary structures and contacts (legend provided in Appendix A1) 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 analysed. 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, colour (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 summarised and preliminarily interpreted in overview geological profiles for the borehole Trüllikon-Rudolfingen (Appendix B1 and B2). 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.

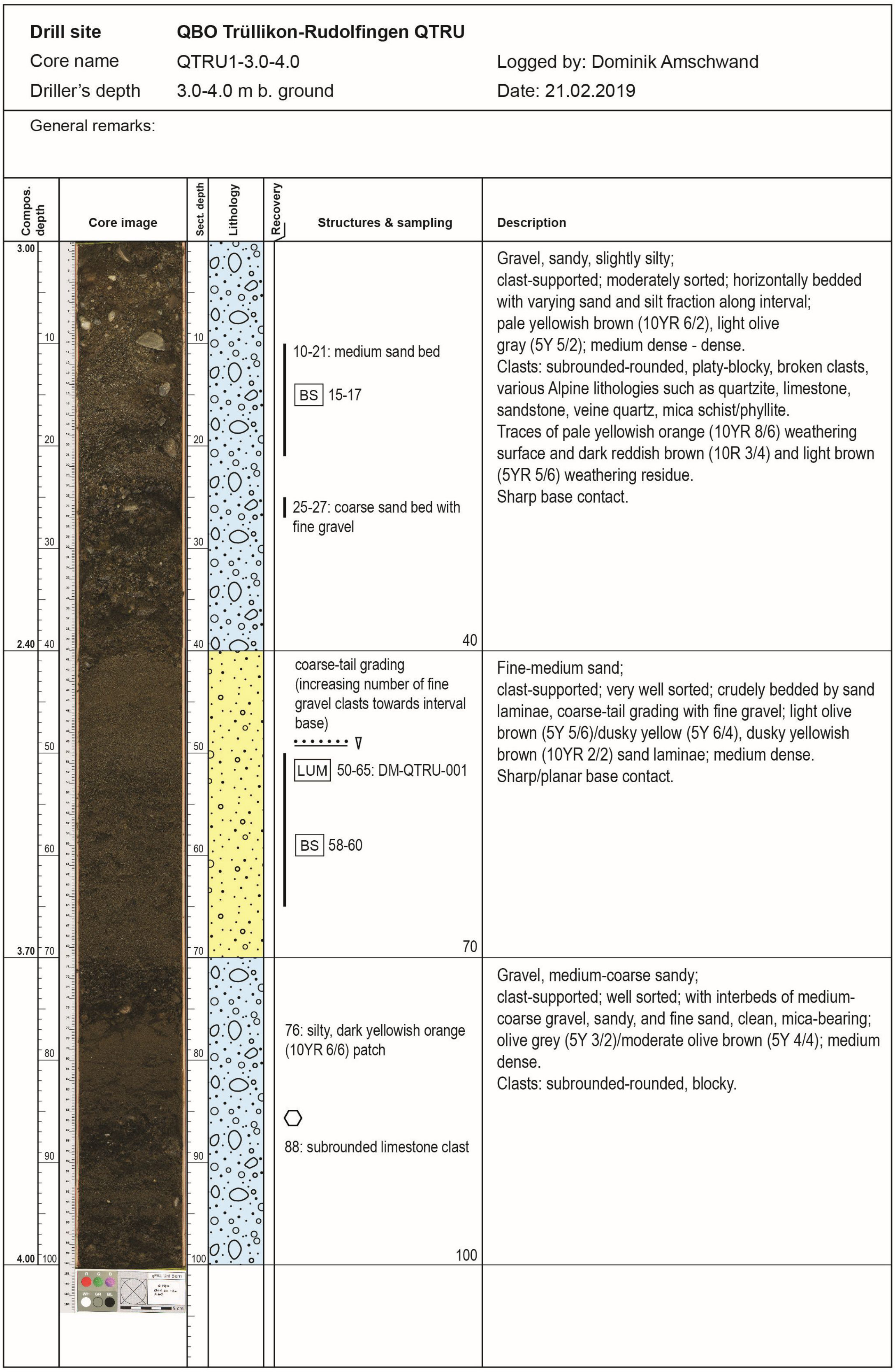

Fig. 3: Example for section log.

2.5 Pore water and geotechnical samples

Pore water sampling using the conventional squeezing method (see Appendix G, "squeezing") required fresh and unopened full cores (Tomonaga et al. 2011, 2014) and was performed directly on the drill site without prior MSCL scanning. The squeezed sections were ~ 25 cm long and taken from the bottom ends of the respective cores. The sections targeted by pore water sampling were later split 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.

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 from the lowermost part of QTRU. For this reason, an alternative sampling approach was applied on one core from QTRU (*see* Appendix G, "AM"). After core recovery, sediment chunks were transferred from the bottom of core 83.0 – 83.5 m into an airtight stainless-steel 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.

One groundwater sample for noble-gas analysis was acquired from a depth of ca. 4 – 5 m (Appendix G) using plastic bottles inserted in a liner within the core recovery tool. This sample was sealed in a copper tube (see e.g. Beyerle et al. 2000).

At the stage of this report, no geotechnical samples from QTRU were taken.

3 Preliminary geological overview

At the drill site in Trüllikon-Rudolfingen the Quaternary sediments above the Lower Freshwater Molasse (USM; Keller et al. 1990) are 88 m thick (Appendix B1 and B2). The Molasse bedrock mainly consists of alternating silt- and sandstones which are often colourfully mottled. The directly overlaying Quaternary sediments between 88.0 and 75.8 m depth comprise massive or crudely bedded, fine-grained and gravelly diamicts. Below ca. 80.5 m depth these diamicts are rich in Molasse-derived components, i.e. sand and fines in the matrix and occasional clasts/slabs. The basal diamicts are preliminarily interpreted as till or glacigenic diamicts (e.g. subaqueous debris flows) emplaced in a subglacial, submarginal or proglacial glacilaustrine setting. Between 75.8 and 51.6 m depth follows a succession of fining-upward glacilacustrine sediments. At its base, this unit contains beds of gravels and diamicts that are likely emplaced in a glacier-proximal glacilacustrine or glacideltaic environment. Above ca. 70 m depth these coarse-grained beds are absent, and the sediments are fining from sand to silt and clay but remain rich in dropstones. Between 51.6 and 34.0 m depth the core is mainly composed of laminated fines which are likely emplaced in a distal glacilacustrine to lacustrine environment. At 34.0 – 30.8 m the fine-grained sediments continue but show increased shear strengths and contain again outsized clasts that likely represent dropstones. Between 30.8 and 6.8 m the lacustrine sediments continue with an upward coarsening trend from silt with interbedded sand to sand with silty interbeds. At 17 – 14.5 m the sands contain organic material. From 6.8 to 0.9 m gravel and sand indicate a change to coarse-grained deltaic or fluvial deposition. The upper 0.9 m represent cover sediments with soil formation.

The bedrock depth of 88.0 m is in good agreement with the reflection seismic image of Nagra section 16-QAU-11 (Nagra 2018b).

Detailed core documentation and supplementary data are organised in the Appendices as listed on page II.

4 References

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.

Eijkelkamp (2012): Pocket vane tester operating instructions. Eijkelkamp Agrisearch Equipment. URL (accessed 21.08.2018): https://www.eijkelkamp.com/download.php?file=M11410e_Pocket_vane_test_5306.pdf

Evans, D. J. A. & Benn, D.I. (2004): A practical guide to the study of glacial sediments. Edward Arnold, London.

Geotek Ltd (2016): Multi-Sensor Core Logger MSCL – Manual version Nov 1, 2016. URL (accessed 21.08.2018): http://www.geotek.co.uk/wp-content/uploads/2016/04/MSCL-manual-1-Nov-16.pdf

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

Keller, B., Bläsi, H.-R., Platt, N.H., Mozley, P.S. & Matter, A. (1990): Sedimentäre Architektur der distalen Unteren Süsswassermolasse und ihre Beziehung zur Diagenese und der Petrophysik. Eigenschaften am Beispiel der Bohrungen Langenthal. Nagra Technischer Bericht NTB 90-41.

Kuster, A.M., Huber, M., Amschwand, D., Deplazes, G., Madritsch, H. & Buechi, M.W. (2019): Quaternary Borehole QBO Marthalen-Oobist (QMOB) Data Report. Nagra Arbeitsbericht NAB 19-04.

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

Nagra (2018a): Gesuch um Erteilung einer Bewilligung für erdwissenschaftliche Untersuchungen Quartärbohrung Trüllikon-Rudolfingen. Nagra Sondiergesuch. NSG-Q 18-02.

Nagra (2018b): 2D Reflection Seismic Exploration and Provisory Interpretation of Overdeepened Quaternary Valleys around the Nagra Siting Regions Zürich Nordost and Nördlich Lägern. Arbeitsbericht NAB 18-22.

Nagra (2019): Arbeitsprogramm: Quartärbohrung Trüllikon-Rudolfingen. Nagra Sondiergesuch. NSG-Q 18-02 AP.

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

Schultheiss, P. & Weaver, P. (1992): Multi-sensor core logging for science and industry. OCEANS'92. Mastering the Oceans Through Technology. *In:* Dorman, C.E. (ed.): Proceedings of the IEEE OCEANS 92 Conference: Mastering the Oceans through Technology, Newport, Rhode Island, October 26-29, 1992, Vol. 2, 608-613. Central New England Engineering Council of IEEE, The New England Section of the Marine Technology Society, IEEE Catalogue No. 92CH3217-7.

Tomonaga, Y., Brennwald, M.S. & Kipfer, R. (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 (2019): Verfügung des UVEK betreffend Gesuch vom 16. April 2018 um Erteilung einer Bewilligung für erdwissenschaftliche Untersuchungen (Sondiergesuch NSG-Q 18-02), Quartärbohrung Trüllikon-Rudolfingen. Verfügung Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation, Bern.