Understanding the geological and geotechnical drill core logging process – key to success

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ABSTRACT: The preparation of a consistent ground model in mining and civil construction requires a clear understanding of the geological and geotechnical data collected during the different investigation phases. Drill core logging data may be collected during distinct steps in the drill core logging process. A meaningful interpretation of the drill core logging data is often difficult due to inconsistencies in the logging process and shortcomings in the data management. Such errors and deficiencies can significantly influence the interpretation of the ground conditions. Common sources of error in the drill core logging process include careless drill core handling, inconsistencies in the logging criteria, and the lack of a well-structured data management system. These difficulties can be mitigated or even avoided by identifying the source of error, implementing measures to correct the inconsistencies and by establishing a clear documentation system for the drill core logging process.

Keywords: diamond drilling, drill core logging, quality control, data management.

1 INTRODUCTION

The understanding of geological and geotechnical drill core logging data is fundamental for the preparation of a consistent ground model in civil construction and mining. At large-scale mining and infrastructure projects with thousands to several hundred thousand meters of exploration drilling and, as a result, the acquisition of millions of data require a systematic concept of the drill core logging process and a clear understanding of possible sources of error (e.g. Seery et al. 2013 and Kramer Bernhard et al. 2020). The quality and validity of any analysis and interpretation of geological and geotechnical drill core logging data depends on the knowledge of how these data were collected, by which assumptions, and for which goal. Although standard procedures and workflows for data geological and geotechnical data collection exist (e.g. ISRM 1978, Read et al. 2009 and Dempers et al. 2010), a meaningful interpretation of the data, including 3D modelling, is often difficult due to inconsistencies and misunderstandings in the drill core logging process and shortcomings in the drill core data management (e.g. Ureel et al. 2013 and Orpen & Orpen 2020). Such errors and deficiencies can significantly impact the interpretation of the geological and geotechnical conditions, leading to decisions which may critically influence the technical and economic viability of a project.

2 PROJECT INVESTIGATION PHASES

Many projects in the civil engineering and mining sector go through a long history of geological and geotechnical investigation. Periods with extensive field and laboratory testing often alternate with phases of little or no investigation.

The evolution of a project from the initial ground investigation to the definitive design stage may be characterized by changes in the acting parties (owner, consultants, contractors), responsible teams managing and executing the investigation and may also result in changes in the process of how and by which means geological and geotechnical data are collected, analyzed, and interpreted. As a result, changes in the format, terminology, and mapping and drill core logging methods are common.

3 STEPS IN THE DRILL CORE LOGGING PROCESS

During the past few years, the transformation from analogue (field books, drill core logging sheets) to digital data acquisition (tablets, PCs, smartphones) has seen significant developments (e.g. Horner et al. 2016 and Seery et al 2018) in reducing mapping and drill core logging time and also narrowing potential errors in the data acquisition process. However, even the application of sophisticated data acquisition and data management tools in drill core logging require a profound understanding of the drill core logging process itself and the possible sources of error in each logging step.

The drill core logging process may involve one single step in small-scale projects but may also include five or even more different steps in the case of complex mining projects (see Figure 1).

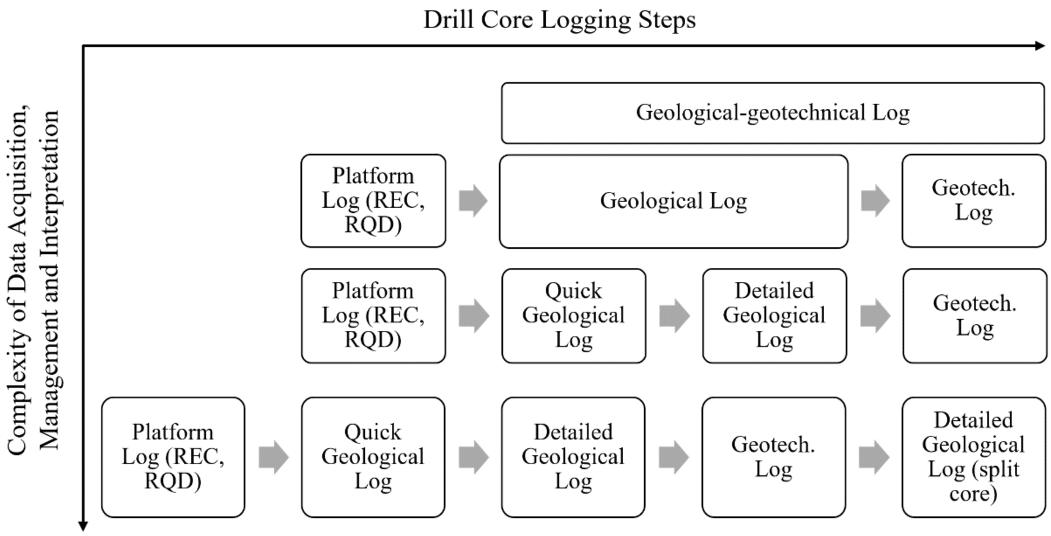

Figure 1. Diagram illustrating the increase of drill core logging complexity with the increase in drill core logging steps.

In the civil engineering environment, a single geological-geotechnical drill core log is common. In such cases, only one team of geologists and/or geotechnical personnel is performing the geological-geotechnical drill core logging process. Occasionally, recovery (REC %) and RQD (%) data are registered directly at the drilling platform, either by the on-site geologist or by the drilling team.

However, in the minerals exploration and mining environment the process of drill core logging can substantially differ, for example, the various cycles of drill core logging which are characterized by a distinct focus and objective (Stenhouse et al. 2020). Usually, a geological and a geotechnical drill core log are prepared separately. In general, the geological team focuses on lithology, (hydrothermal) alteration types and intensities, mineralogy and textures, whereas the geotechnical team concentrates on strength parameters and the types and characteristics of discontinuities. A register of the drill core recovery (REC) and the RQD may be prepared by the drilling staff or geologists at the platform and, additionally, during the geotechnical drill core logging stage. In many cases, the geological drill core log is prepared first, followed by the geotechnical drill core logging transferring, and using distinct parameters of the geological drill core log such as lithology, alteration, and texture.

On occasion, it may be necessary to separate the geological drill core logging in two stages, a quick and a detailed geological drill core log. This can be meaningful when the drilling program is strongly dependent on short-term decisions. A detailed geological log on cut drill core may be implemented at specific projects or project stages to enable the analysis of specific mineralogical and textural characteristics. In such cases, only half of the drill core is available for this detailed logging. The other half of the drill core is sent to the laboratory for analysis or testing.

If oriented drilling is performed, structural drill core logging may be conducted either as part of the geological or geotechnical logging stage or a specific structural logging stage may be implemented focusing on the distribution and characterization of structures (Ureel et al. 2013, Bright et al. 2014, HCOV 2017, Kramer Bernhard et al. 2020 and Stenhouse et al. 2020).

In addition to the drill core logging performed by the geology and/or geotechnical team on site, semi-automated (e.g. portable devices such as XRF spectrometer or structural scans) and automated (e.g. hyperspectral scanning) logging technologies may be applied (Harraden et al. 2019 and Kramer Bernhard et al. 2020). These technologies are now increasingly used in the mining industry, in order to gain additional information on the occurrence and distribution of specific minerals. Geotechnical parameters, including the frequency, spacing, and roughness of discontinuities, can also be registered using automated technologies facilitating the estimation of the rock mass quality (RQD, RMR, Q).

Drill core photos are often taken from wet and dry core. In the mining industry, it is also common to take photos from entire and cut (split) drill core. The point of time when the photos are taken differs from one project to the other. Frequently, drill core photos are taken at a specific place in the drill core shack after completion of the geological and geotechnical drill core logging and before sampling and testing (e.g. geochemistry, rock/soil mechanics, geometallurgy).

Downhole geophysical surveys, including televiewing techniques (acoustic, optical), are not discussed here as these methods deal with the data acquisition at the borehole wall and not with the drill core itself (Ureel et al. 2013).

4 COMMON SHORTCOMINGS IN THE DRILL CORE LOGGING PROCESS

Potential errors and uncertainties in drill core logging may include systematic errors (e.g. inadequate equipment calibration, incorrect data transfer), random errors (e.g. inconsistent or erroneous data collection, careless handling of the drill core), and human errors (e.g. lack of experience and training of the logging personnel, lack of communication) which need to be considered during subsequent data review and analysis (e.g. Ureel et al. 2013, Kramer Bernhard et al. 2020 and Orpen & Orpen 2022). Some selected examples of common shortcomings in the drill core logging process are shown below, which may cause misinterpretations during subsequent data analysis, interpretation and, in consequence, pose a risk to the technical and/or economic viability of a project.

4.1 Careless transportation and handling of drill core

Careful drill core handling starts at the drill core platform when the core is extracted from the tube and is laid out on the tray and the drill core box. During this initial step, the core run, recovery, and the RQD are measured. A quick geological log may also be prepared directly at the drilling site.

For many projects, the drilling platform is at a distance, sometimes several kilometers (often dirt roads, difficult topographic conditions) from the drill core shack where all or most of the other drill core logging steps are performed. In consequence, long-distance transportation of the drill core boxes (by mule, truck, helicopter, people) without a proper protection of the drill core may have a significant impact on the quality of the drill core due to additional mechanical breakage and decomposition. In addition, during the later steps of drill core logging the drill core boxes may be moved multiple times. A long storage time and repeated handling of the drill core boxes (in/out of the shack) affects the drill core and its integrity, altering its original appearance by decomposition, higher fracturing, drying, and hardening (Ureel et al. 2013).

In consequence, geological and geotechnical drill core logging must consider any possible negative effect of improper handling and transportation of the drill core as this may result in erroneous interpretations which may negatively impact further analysis, such as the design of pit walls or the geometry and layout of underground structures (tunnels, caverns).

4.2 Inconsistent drill core logging criteria

Occasionally, the drill core logging teams are decoupled from each other. This may happen, for example, during the transition from a greenfield to a brownfield exploration stage, or at projects with separate teams in the exploration and mining departments, or where resource geology is disconnected from the geotechnical team. Such a decoupling may also occur due to a lack of communication between shifts or even within a single logging team.

In general, the focus and objective of each drill core logging step is distinct and involves the collection of specific data sets. However, inconsistencies in the drill core logging criteria have a significant impact on the subsequent analysis and interpretation of information.

A very common issue between drill core logging teams is the identification and determination of zones of increased fracturing, faults, and shear zones. Resource geology teams and geotechnical teams may have a different understanding of where a fault intersection starts and ends in the drill core, of where the fault core zone is, or where the limits of a fault damage zone are (e.g. Ben-Zion & Sammis 2003 and Faulkner et al. 2010). As a result, different drill core intersection lengths may be recorded for the same drill core but by the different logging teams.

Although drill core logging manuals (geological, geotechnical, structural) may exist for each logging step, the criteria for logging may substantially differ, if the manuals were prepared without interchange of information and joint coordination. Additionally, the introduction of new terms or concepts due to changes in the project (e.g. boundary conditions, acting parties, geological models) may interfere with existing practices and methodologies applied in the drill core logging process.

4.3 Lack of well-structured data management

Many projects lack a well-structured data management system for data capture, QA/QC and data storage. Common errors during the data capture occur when the information is collected by analogue methods and transcribed into MS-Excel or MS-Access, or specific database software.

The absence of standardized codes (for lithology, alteration and texture types, structure types, etc.) is a potential source of error, as it may cause typing errors and inconsistent abbreviations. In such a situation, the cleaning-up of information may require substantial time and resources.

A common difficulty is the misuse of the “comment” or “observation” column in the drill core logging database. In this column, very different observations may be registered, which include words, word fragments, numbers, and symbols, often in different languages, if the project uses international coding and terms. In such a “comment” column information and data are dumped that (a) do not fit into the predefined logging columns, (b) have not been observed in the project so far, or (c) have been observed, but cannot be explained or characterized adequately. Important information may be lost, if it is registered in such an observation column, as this information is rarely systematically analyzed during further data process and analysis.

The lack of a clear QA/QC system of the information raises the potential of systematic errors. As more time passes, it will be more difficult to perform any verification on the drill core in its original state. Finally, the storage of the information in separate spreadsheets increases the time required to integrate all the information in a unique standardized file.

5 MITIGATION AND AVOIDANCE OF INCONSISTENCIES

5.1 Drill core handling

Several aspects of drill core handling are important to maintain the physical conditions of the drill core and to document any possible alterations during transportation and handling:

- Preparation of a guideline for drill core and drill core box handling and transportation, where the procedures and materials for packing, wrapping, and storing of drill core and the transportation and handling of the boxes is described.
- Implementation of a high-quality procedure for recovery and RQD measurement at the drilling platform (performed by well-trained staff).
- Comparison of the drill core logs prepared at the drilling platform and the core shack regarding fracturing and RQD, determine the difference of these parameters and implement measures for careful drill core handling and transportation.

5.2 Relogging of drill core

If specific logged parameters differ significantly from one drill core database to the other (e.g. length of fault intersections, zones of increased fracturing), relogging of drill core may be necessary to overcome such inconsistencies. Regarding relogging the following should be considered:

- Relogging of drill core should cover a certain percentage of the total drilled meters in the project. The percentage is a function of the complexity of the geological and geotechnical conditions at the project as it should cover a variety of different geological conditions, including non-tectonized, fractured, faulted, altered, fresh, and weathered material.
- If the physical drill core is not available for relogging or heavily disturbed due to later mechanical or chemical deterioration, drill core photos can be used. However, it is important that the photos are taken under standardized conditions (e.g. lighting camera settings, scale, color table, markings of core runs) to guarantee good quality of the photos.
- Although expensive, automated scanning of the drill core can provide important additional information in order to understand and correct any observed differences.

5.3 Data management

Drill core logging data needs to be managed in a well-structured system facilitating a clear, easy, and logical access to the data for further processing. The following should be considered:

- The drill core logging workflow and the data management system for storing and processing the data need to be clear and understandable to all involved parties (Weil 2019 and Kratz et al. 2021). The data management system must cover all steps in the drill core logging process, from data capture to QA/QC and data storage.
- The data management system should include internal validation routines advising users in case of any erroneous data entry and should enable the processing of all data acquired from different investigation campaigns and different sources (Seery et al. 2018).
- Individual steps in the collection of the various data types should be reviewed and cross-checked on a regular basis to recognize any potential inconsistency that may arise during the drill core logging process or during later data handling and data transfer.
- If inconsistencies exist in the drill core database, a tailor-made solution may be necessary to extract the information which is required for further analysis. It may be useful to establish unique criteria which combine information from different logged parameters and different logging steps. Such a process helps to narrow down the information of very specific conditions for subsequent analysis and 3D modelling (e.g. identifying intersections of fault material and the distinction of fault core zones and damage zones).

6 COMMUNICATION IS THE KEY

Communication is the key to understand the drill core logging process and to be aware of any potential weakness. A clear documentation of each individual step in the drill core logging process, jointly elaborated by all involved parties (logging teams, data management staff), significantly helps to generate a common understanding of the logging parameters and the objectives of each drill core logging step. Drill core logging manuals should be updated on a regular basis. Any changes in the drill core logging and drill core logging process need to be documented and communicated to all the involved parties, in order to be considered in further analysis and interpretation, including 3D geological and geotechnical modelling. Specialized databases that include internal validations can be very useful, as they allow users to be advised if there are any errors.

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