61 Scanline Sampling Techniques for Rock Engineering Surveys: Insights from Intrinsic Geologic Variability and Uncertainty

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Abstract

Discontinuity surveys are based on collecting rock data from fieldwork and are an essential component of rock-mass quality estimation in rock engineering. Strength, deformability and permeability characteristics of a rock-mass are strongly influenced by its discontinuities. Scanline surveys are a reliably technique in which a line is drawn over an outcropped rock surface and all the discontinuities intersecting it are measured and described. The discontinuity geometry for a rock-mass is characterised by the number of discontinuity sets, mean density and the distributions for location, orientation, size and spacing/fracture intercept. Rock site investigation deals with several key elements that need to be addressed, namely the information required to characterise the rock system and the intrinsic uncertainty associated with this information. This way, quantifying the information content of the on-site measurements and creation a database is vital to be used for decision making processes and risk assessment on rock engineering design projects. In addition, a clear geology framework plays a key-role to support the investigation of all rock engineering projects. Nevertheless, the intrinsic variability of geological, petrophysical and geotechnical properties must be quantified for reliability-based design and to decrease the geological uncertainty. All geologists and engineers' practitioners must have the aim to contribute to the correct study of the ground behaviour of soil and rock, their applications in sustainable design with nature and environment and to satisfy the society's needs.

Keywords

Scanline techniques • Rock-mass • Engineering geosciences • Rock engineering • Uncertainty

61.1 Introduction

Barton (2012) argues the *"Discontinuous behaviour provides rich experiences for those who value reality, even when reality has to be simplified by some empiricism"*. This impressive quotation describes the general framework of the complexity of the heterogeneous rock-mass behaviour. The lessons learned on several geoengineering projects stress the importance of the accuracy of the basic geological and geotechnical data information related to the rock masses characterization and assessment.

Linear or circular sampling or sampling within windows along a scanline are accurate approaches to the systematic record of discontinuities (joints, fractures, faults, veins, etc.).

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In several geologic and geotechnical frameworks this is, moreover, the easiest and fastest way to collect discontinuities data (e.g., Priest and Hudson 1981; Hudson and Priest 1983; Priest 1993; Mauldon et al. 2001; Rohrbaugh et al. 2002; Priest 2004; Peacock 2006; Chaminé et al. 2010, 2013; Pinheiro et al. 2014). Scanline surveys will provide an amount of reliable information concerning structural geology, petrophysical and geotechnical features of rock masses, either in boreholes or exposed rock surfaces (Fig. 61.1). However, some procedures must be fulfilled to avoid systematic or random errors (Terzaghi 1965; ISRM 1981; CFCFF 1996; Hudson and Cosgrove 1997). Collecting data for the basic geotechnical description of rock masses is of considerable importance for the prediction of scale effects in rock mechanical behaviour (Cunha and Muralha 1990).

The characteristics of discontinuities can be estimated using scanline sampling techniques (Fig. 61.2), but the accuracy is subject to bias (e.g., Priest and Hudson 1981; Priest 1993; Park and West 2002; Rohrbaugh et al. 2002). According to Mauldon et al. (2001) the circular sampling tools and estimators (such as fracture trace intensity, trace density and mean trace length) eliminate most sampling biases, due to orientation and also correct many errors owing to censoring and length bias. Conversely, Wu et al. (2011) argue the predictions based on the rectangular window methods were found to be more accurate than that based on the circular window methods.

In this work, we highlight the importance of an integrative approach for geoengineering purposes of field surveys performed with scanline techniques on free rock-mass faces in diverse contexts, such as quarrying, underground excavations and hard-rock hydrogeotechnical studies. All studies should be developed in a GIS platform by using the following tools: field mapping, morphotectonic analysis, structural geology, rock geotechnics and hydrogeomechanics. This approach led us to a better understanding of the relevance of rock masses heterogeneity for geoengineering purposes at different scales and to reduce the intrinsic variability and uncertainty in collecting geologic and geotechnical data.

61.2 Rock Scanline Surveys: A Reliable Tool to Unbiased Sampling

Discontinuity features play a major role in controlling the mechanical behaviour of a rock-mass (Priest and Hudson 1981). Discontinuities are generally characterised in terms of the following properties (e.g., ISRM 1981; Priest 1993, 2004): orientation, frequency or spacing, size and shape, aperture, conductivity, surface geometry, strength and stiffness. Describing only the discontinuities which seem to be important can be considered as a subjective method of fracturing surveying. From a statistical perspective, it is important to set up a rigorous unbiased sampling regime at the rock face such as (Priest 2004): sampling all traces of discontinuities within a defined area (window sampling), all that intersect a circle (circle sampling) or all that intersect a straight line (scanline sampling). ISRM (1981) stated that a scanline survey is an objective method for recording and describing rock fracturing on a rock-mass exposure (Fig. 61.3).

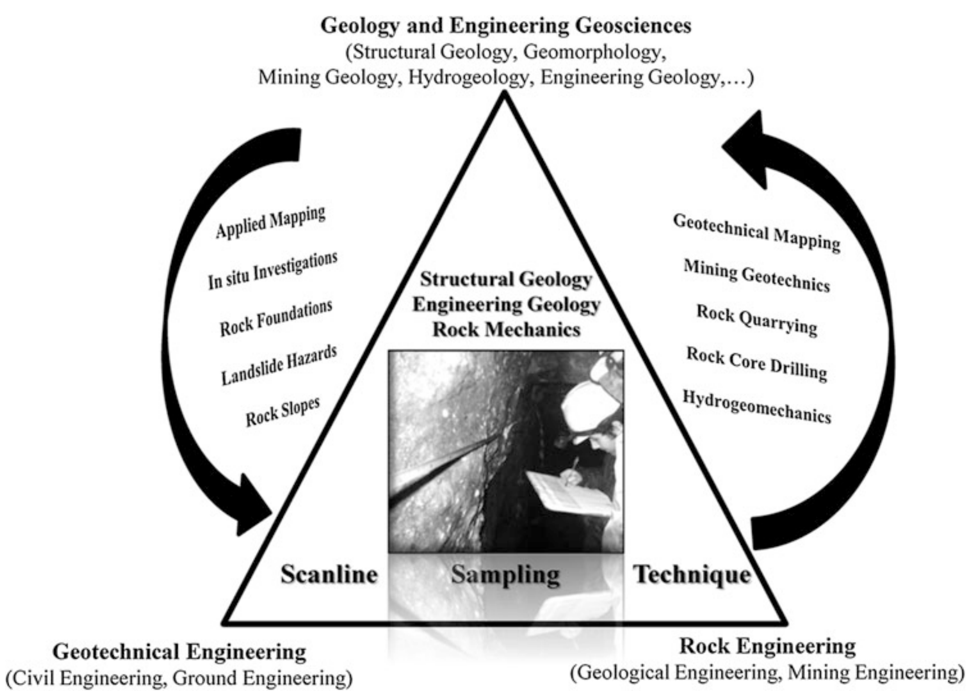

Fig. 61.1 The main scientific and technical fields of applications of scanline sampling technique surveys related to engineering geosciences, rock engineering and geotechnical engineering

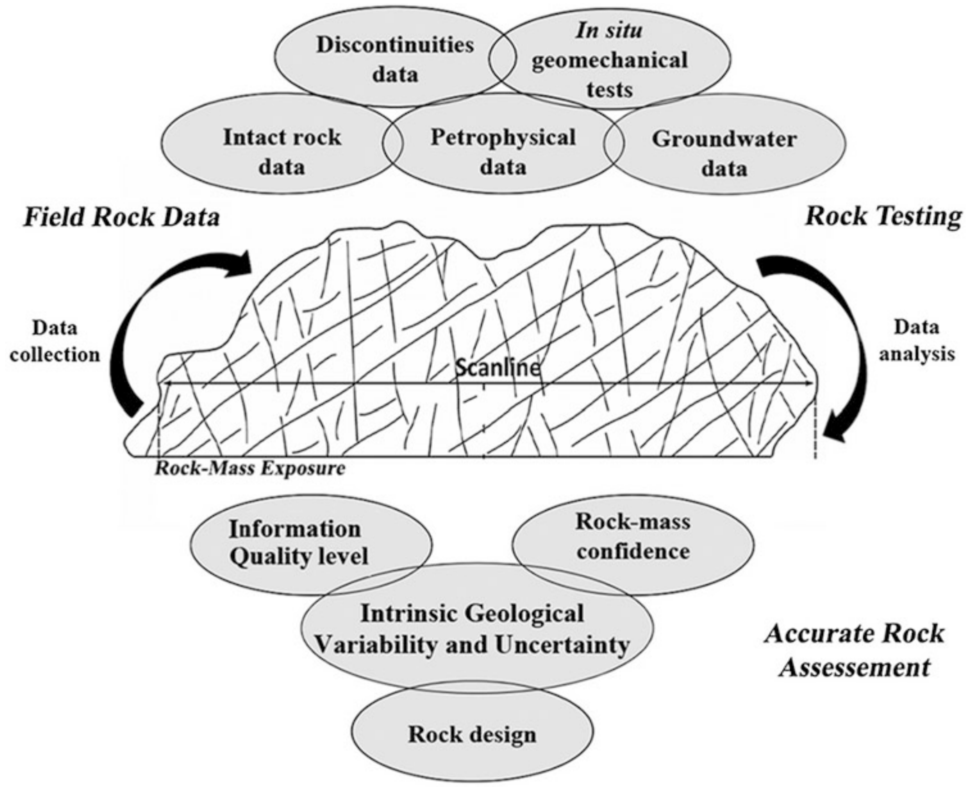

Fig. 61.2 Rock scanline surveys framework to rock design (slope, tunnel, quarry and cavern): a reliable tool to reduce the intrinsic geologic variability and uncertainty

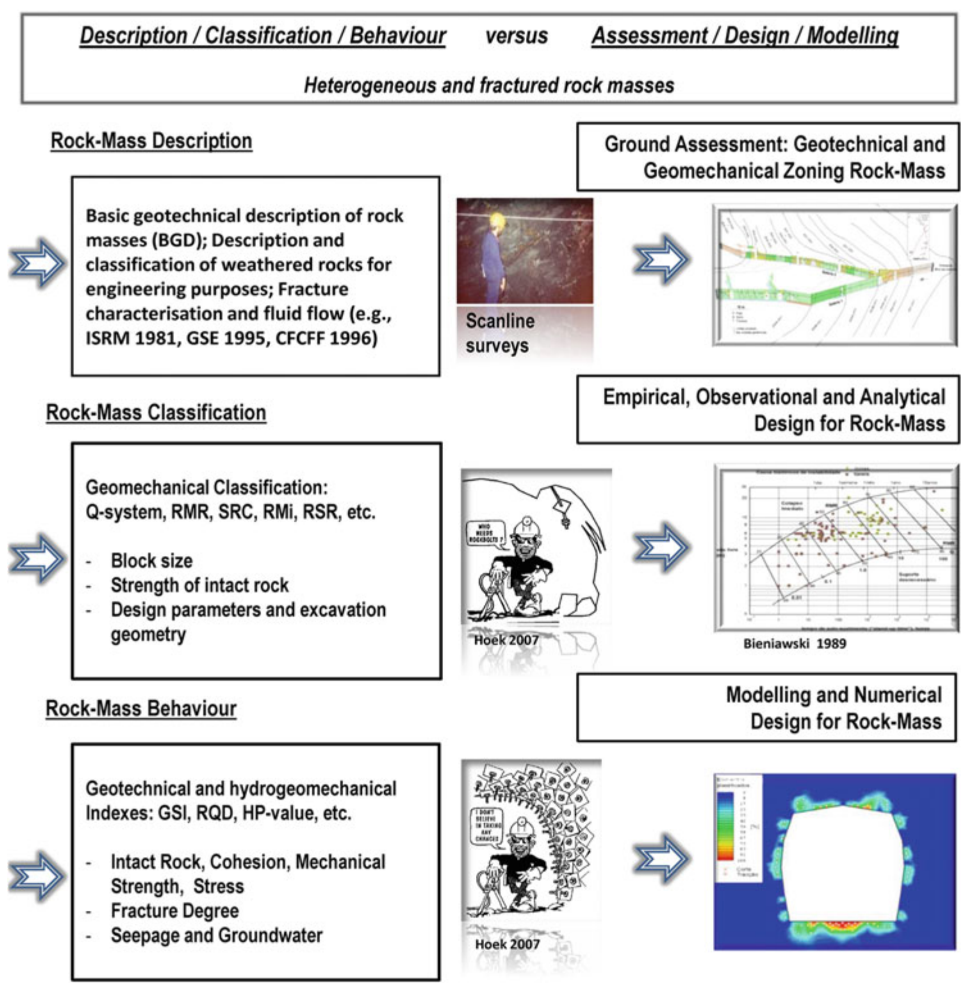

Fig. 61.3 The description/classification/behaviour *versus* assessment/design/modelling of heterogeneous and fractured rock masses

61.3 Concluding Remarks

A clear geology and structural geology framework plays a key-role to support the investigation of all rock engineering projects (Hudson and Cosgrove 1997; Hoek 2007; De Freitas 2009; Chaminé et al. 2013; Shipley et al. 2013). The heterogeneity of the geological properties of rock masses is very significant in geoengineering issues (Hudson and Cosgrove 1997). Particularly, the assessment of in situ block size plays a key-role in rock engineering design projects, such as mining, quarrying and highway cutting operations (e.g., Lu and Latham 1999; Haneberg 2009; Chaminé et al. 2013). In addition, the evaluation based on engineering geosciences, geohydraulic and geotechnical features of rock masses involve combining parameters to derive quantitative geomechanical classifications for geoengineering design (e.g., Bieniawski 1989; Gates 1997; Smith 2004; Barton 2006, 2012; Hoek et al. 2013). In short, good rock engineering must be based in good engineering geosciences, and the big issue raised by Pells (2008), "*what happened to the mechanics in rock mechanics and the geology in engineering geology*", is still valid. However, the intrinsic variability of geological, petrophysical and geotechnical properties must be quantified for reliability-based design and to decrease the uncertainty (e.g., Mazzoccola et al. 1997; Hoek 1999; Keaton 2013). In addition, Mazzoccola et al. (1997) stated an important issue: "*Is there enough information available for design?*".

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