From Palmström A.: RMi – a rock mass characterization system for rock engineering purposes.
PhD thesis, Oslo University, Norway, 1995, 400 p.

Chapter 1

INTRODUCTION

> *"The corner-stone of any practical rock mechanics analysis or rock engineering is the geological data base upon which the definition of rock types, structural discontinuities and material properties is based. Even the most sophisticated analysis can become a meaningless exercise if the geological information upon which it is based is inadequate or inaccurate."*
> Evert Hoek, 1986.

The statement above clearly indicates the importance and need for good quality rock mass characterization for use in rock engineering, design and construction. Proctor (1971) has shown that the estimated cost of an underground excavation depends more upon geological data than does any other type of civil engineering work. Any work that can contribute to better knowledge and documentation of rock masses should therefore be of common interest. The importance and need for improved geo-data has also later been stressed by Einstein et al. (1979) and Einstein and Baecher (1983). Bieniawski (1984) stresses that
"it is extremely important that the quality of the input data matches the design requirements. Obviously, it must be realized that if incorrect input parameters are employed, incorrect design information will result. Speaking in computer jargon, the following expression would be appropriate: 'garbage in, garbage out'."

In the report "Definition of the most promising lines of research " presented by ISRM (1971) the highest priority research subjects were defined as:
1. Determination of strength and deformability of fissured and massive rock masses as a function of time.
2. Correlation between the mechanical properties of rocks and geological and petrographic data.

In the same report it was also stated that: *"At present time most geologic and petrographic descriptions of specimens or bodies of rock are qualitative, whereas rock mechanics determination of mechanical properties of rock are quantitative.*
Because many engineering decisions are based on a combination of geologic and rock mechanics data, it is important that a more systematic means of combining and correlating this information should be developed.
There is a need for better documentation and correlation of geological and petrographic data, and corresponding mechanical property data obtained from both laboratory specimens and/or rock masses, together with operating experience in the same rock mass, or the subsequent performance of structure in the rock mass created by excavation."

Thus, already early in the development of rock mechanics the importance of establishing general methods and systems for improved characterization of rock masses together with a common language for those engaged in engineering and construction in rock was clearly expressed. This request has to some extent, been met by some of the classification systems which are presented later, but few of them are of a general character as they are mainly directed towards a specific engineering function or design.
From the obvious need and interest for better geo-data mentioned above one should expect that people involved in rock engineering and construction should have made significant efforts in

working out methods to arrive at better quality geo-data. However, in the early days in rock mechanics and engineering geology, people paid surprisingly little interest in the geological aspects. Karl Terzaghi, in his later years, when he had changed much of his attention from soil to rock mechanics, wrote in his diary in 1961 about rock mechanics. *"I am more and more amazed about the blind optimism with which the younger generation invades this field, without paying attention to the inevitable uncertainties in the data on which their theoretical reasoning is based and without making serious attempts to evaluate the resulting errors."*

Later, Poisel (1990) points out that the same trends have continued also during the last 10 years: *"A look at rock mechanics papers shows that at present it is only important to perfect mathematical procedures and to investigate rock-like materials. Rock mechanics, however, still needs investigations in the field - not only testing to get its parameters - geomechanical models, and intuition.*
Regretfully we do not ask ourselves often enough if the results we reach by mathematical calculations really apply to nature. Rock mechanical models should be determined by what nature shows, not by what can be done within mechanical-mathematical limits. Thus it should first be attempted to find out what is going on in nature, which procedures or which mechanisms take place in the structure, and only then it should be considered how to model them by mechanical-mathematical means."

From the foregoing it is clear that there has been continuous need also to establish a common language to characterize rock mass parameters of importance for engineering for construction and treatment of rock.

1.1 Outline of this work

The opinions presented above largely explain the purpose of this work. A main goal has been to improve the quality of geological input data, which consequently will lead to better design and rock engineering to be applied in rock construction. No attempt has been made to analyze the science of either geology or rock mechanics, but rather, only to use and relate geological knowledge to the characteristics of the material called *rock mass*. Fig. 1-1 shows the main structure of the work and its main applications.

The first step outlined in this figure is the collection of data representative of the rock mass composition, based on observations and measurements.

The second step includes characterization of these data into a general rock mass index (RMi). This index and the definitions of its input parameters can be used in communication as well as for input in existing and possible future engineering systems.

In a third step, the RMi can be adjusted for parameters or features of importance for the actual utility or construction to assess the quality of the ground. By combining this with input from the actual excavation or construction requirements, the system can be used in a fourth step for design and engineering.

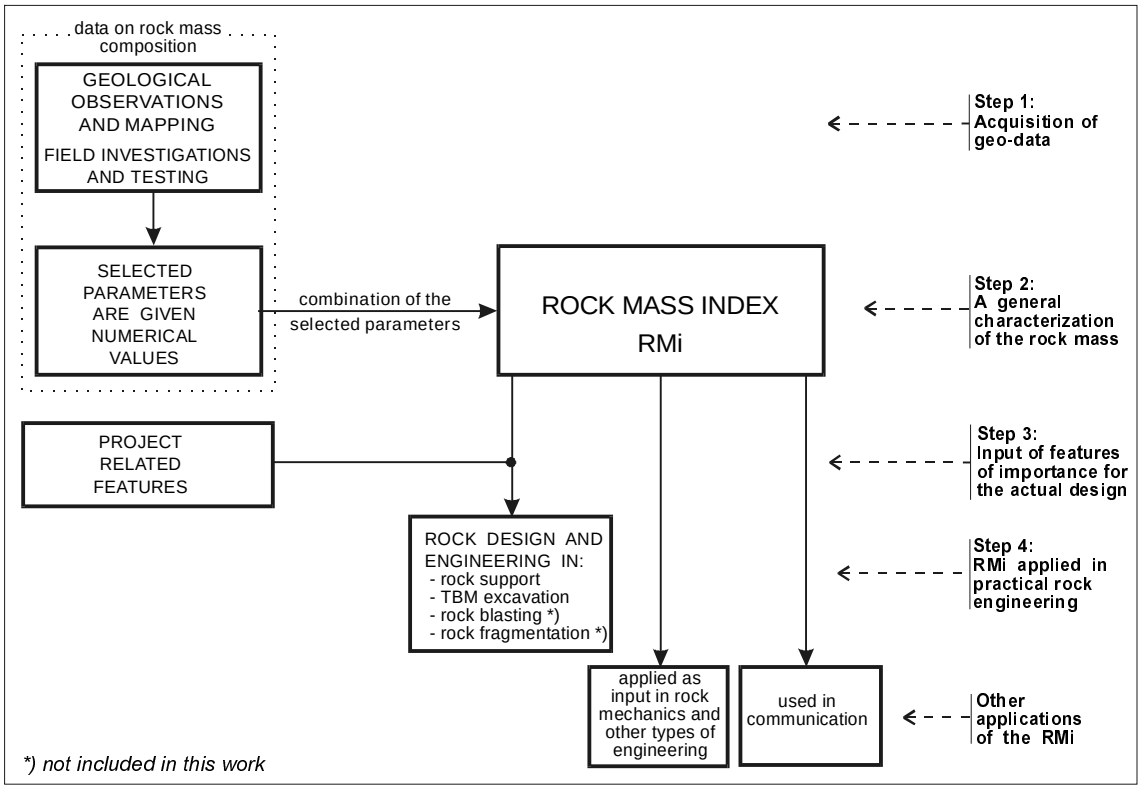

Fig. 1-1 Main principles of the system presented.

The work has been structured into the following main fields:

1. Collection and characterization of geological and material data (geo-data) described in Chapters 2 - 3 and in Appendices 1 - 5.
2. Combination of geo-data in RMi outlined in Chapters 4 - 5 and in Appendix 6.
3. Application of RMi in practical rock engineering. Chapters 6 - 8 and Appendix 7 describe the direct use of RMi in rock support and in full face tunnel boring (TBM) capacity assessments.

The main part of this contribution has been to develop a general system for characterizing rock masses in which individual parameters representative of a rock mass are combined. The selection and combination of these parameters are based on a comprehensive study of available literature and communication with experienced people. The system is calibrated against documented large scale and in situ test results from real rock masses. The following features have been important during the development of the work:

- The system should be simple and meaningful in terms, i.e. only few input data have been selected to arrive at understandable expressions.
- Where possible, existing methods for finding the characteristics of the geo-data required should be utilized; i.e. simple and practical methods for collecting the input values have been described.
- The system should have a general form; i.e. constitute a platform which can be applied in rock engineering; it should be possible to apply it as input in existing engineering systems or methods.

With reference to the above statements by Terzaghi and by Poisel and also to statements by Müller (1982) it is a prerequisite that the limitations and uncertainties in geo-data are always considered when applied in calculations, design and engineering.

In addition to its contribution to improvements in practical rock engineering, it is hoped that this work may lead to more systematic use of rock mass descriptions. Together with well defined expressions for important geological features this may improve

- the quality of rock mass descriptions,
- the use of geo-data from field investigations, and
- the language between geologists and rock engineers involved in rock engineering and construction.

The basis and goal of this work has, in fact, already long ago been formulated by John (1969):
"Rock mechanics has to provide methods of analysis which are realistic compromises between the best representation of the actual ground conditions and pragmatic engineering. The rock mechanics practitioner has to face the fact that many geological engineering and rock mechanics problems may be too complex to allow rigorous analysis but at the same time are deemed satisfactory for the construction of major structures. Qualitative evaluations, quantitative descriptions of geologic features as such, and comparisons of specific test results are always of interest but may not suffice as basis for engineering decisions and designs.
Neither a purely geological nor a completely technical classification of rock masses will answer its intended purpose but suitable parameters of rock masses should be defined and quantified in rock engineering terms."

Before going further, some terms which are commonly used in this work, may need to be clarified:

Describe is to tell or write about, give a detailed account of; to picture in words. In a description, although all the complicated technical terms are recorded, essentially the individual puts down whatever she feels is important. Thus, in describing a rock material or rock mass it is only by chance that a system or order is followed. Seldom can the record be compared to that of another investigator.

Characterize is to report the particular qualities, features, or traits of. Rock mass *characterization* is the designation of rock mass quality based on numbers and descriptive terms of certain features in the rock mass. Such characterization can include one or more parameters.

Classify is to arrange or group in classes according to some system or principle. Rock mass *classification* is the process of combining certain features of a rock mass into classes or groups. It follows a system and order with information being recorded in a prescribed manner. By this it is possible to combine different features using mathematical expressions. Classification enables useful comparisons to be made between the work of two or more investigators.

In this work the term *characterize* has been selected for the process of indicating the structure, composition and strength of rock masses. In practice there is, however, often not much difference between the process of classification and characterization a rock mass. A main difference may be that characterization also contains descriptive terms.