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Mechanical quality of bedrock with increasing ductile deformation

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Abstract

Most of the rocks in Precambrian shield areas have experienced a complex structural and metamorphic evolution, processes which have a strong influence on bedrock quality. The properties vary on both a local and a regional scale. It is highly beneficial to know the variations in detail when exploiting the rocks for industrial purposes. The main objective of the investigation was to study the variation of rock mechanical properties in an originally more or less isotropic rock at various stages of ductile deformation. The rocks investigated were Paleoproterozoic and with ages of ca. 1.80–1.88 Ga, and the areas chosen for sampling were situated north-east of Lake Vänern (Kristinehamn; 10 samples), south of the city of Eskilstuna, South Central Sweden (5 samples) and south of Ödeshög, near Lake Vättern in southern Sweden (7 samples). The 12 samples from the latter two areas are described in this investigation, while the 10 samples from Kristinehamn have been published earlier (Göransson et al., 2004). A comprehensive study of various parameters of importance for bedrock quality has been performed on all samples, e.g. studded tyre test (STT) and Los Angeles test (LA), uniaxial compressive strength (UCS), ultrasonic velocity, perimeter measurements of mineral phases, and petrographic and chemical analyses. The weakly deformed and massive (more or less isotropic) rocks show a tendency towards better properties of abrasion (STT) than the strongly deformed rocks and this can also be said for UCS, reflecting the greater ability of rocks to split along foliation planes. This is not entirely unambiguous, as the more deformed rocks, such as the mylonites, may have varying properties. This depends on the combined effects of, e.g. grain size, recrystallisation and foliation. However, the brittleness (LA) shows somewhat better values with increased deformation. This may depend on higher amounts of dark minerals, as their existence does not affect this test as much as in the case of abrasion tests. The perimeter values of the mineral phases display generally higher values, i.e. grain boundaries for the more strongly deformed rocks are more complicated. However, the values for the investigated mylonites may vary between low and high. The lower value may be due to dynamic recrystallisation and the creation of triple points (static recrystallisation) making the rock weaker. Besides, the development of a strong foliation may decrease rock strength despite the usually finer grain size. The results show that it is extremely important to consider all possible variations of bedrock before classification and exploitation, as the bedrock material in fact is highly heterogeneous.

Keywords: Granite; Granodiorite; Tonalite; Foliation; Deformation; Precambrian; Aggregates; Chemical analyses; Thin sections; Engineering properties; Eskilstuna; Ödeshög; Sweden

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1. Introduction

Most of the crystalline rocks in Precambrian shield areas have experienced a complex structural and metamorphic evolution. The interplay between deformational and metamorphic processes is crucial for parameters, such as mineralogical composition, texture, structure, grain size, grain boundary relation etc. (Göransson et al., 2004). Schistosity, gneissosity and lineation are important ductile planar and linear structures, which make bedrock heterogeneous. In addition, the bedrock is intersected by brittle structures such as joints and sets of joints, fracture zones and faults and even microcracks. Ductile deformation may both improve and deteriorate the bedrock quality whereas brittle deformation, on the other hand, is mainly a "destructive" process even if the resulting block size may be favourable for quarrying (Bedrock Quality map Partille-Lerum, M. Göransson, SGU, in prep.). These processes have a strong influence on the bedrock properties, which are important to know when classifying the material and exploiting or using it for construction purposes. The Geological Survey of Sweden (SGU), following the methodology by Persson and Schouenborg (1995, 1996), regularly performs Bedrock Quality investigations, mainly in the densely populated areas of Sweden (Persson, 1998a,b, 2000; Persson et al., 2003). The information presented on how to use the bedrock material for different purposes is continuously discussed with the users, leading to better products. Research and development projects have been carried out and have begun to improve the quality of the information provided (Göransson et al., 2004). In actual investigation road cuts were selected where several varieties of rocks in stages between isotropic or weakly deformed and strongly deformed (mylonitic) could be studied.

2. Geological setting

The three areas chosen for this study are 1) situated near the city of Kristinehamn north-east of Lake Vänern in south-central Sweden, 2) south of the city of Eskilstuna in the eastern parts of South Central Sweden, and 3) around the city of Ödeshög, which is near the eastern coast of Lake Vättern in southern Sweden (Fig. 1). The results from the area near Kristinehamn have been published earlier (Göransson et al., 2004), whereas this paper considers the two latter areas. The Kristinehamn area and the Ödeshög area are dominated by c. 1.67 Ga intrusive rocks belonging to the c. 1.85–1.65 Ga Transscandinavian Igneous Belt (TIB; Fig. 1). The rocks of the Ödeshög area are slightly older than those of the Kristinehamn area but are of the same kind. During the c. 1.1–0.9 Ga Sveconorwegian orogeny, which strongly affected the already existing crust in south-western Sweden, all rocks in the area northeast of Lake Vänern were more or less strongly deformed and metamorphosed. Granites, gneissic in some places, dominate these areas, and the bedrock is post-tectonic in relation to the Palaeoproterozoic Svecokarelian structures in the eastern part of south-central Sweden. The rocks of the Eskilstuna area are crystalline Precambrian rocks (Svecokarelian) that are mainly 1.9 to 1.7 Ga old. In this region sedimentary veined gneisses predominate and vary in composition, especially regarding their mica, quartz and feldspar content. Gneissic granitoids are common, varying compositionally from granite to granodiorite and tonalite. The latter rock types were sampled in this investigation.

3. Methodology

During sampling, a sledgehammer and an iron-bar lever were used to extract the rock material. First, the material was crushed in a gyratory crusher (Svedala Arbrå R 5026–64, 30 mm exit aperture) and then in a laboratory jaw crusher (Morgårdshammar A23, 16 mm exit aperture). To receive a suitable ballast fraction for the analysis, two screen sorting sieves series (Gilson TS-1FX and Pascall Inclyno) were used. To supply the geophysical and the compressive strength tests, rock cores with a diameter of 45 mm were taken out parallel and perpendicular to the foliation from two to three boulders.

A comprehensive study of various parameters of importance for bedrock quality was performed on all samples, e.g., studded tyre (STT) and Los Angeles Impact (LA) tests, uniaxial compressive strength (UCS), ultrasonic velocity (UPV), length/thickness index (LT (3) and LT (5) indicating the shape of the grains, perimeter measurements as well as petrographic and chemical analyses. Methods in accor-