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Petrographic features as an effective indicator for the variation in strength of granites

Muhammad Sajid [a,*], John Coggan [a], Mohammad Arif [b], Jens Andersen [a], Gavyn Rollinson [a]

[a] Camborne School of Mines, University of Exeter, Penryn Campus, Cornwall TR10 9EZ, UK
[b] Department of Earth Sciences, COMSATS Institute of Information Technology, Abbottabad, Pakistan

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ABSTRACT

The textural characteristics of four different granites from the lower Himalayan regime in north-western Pakistan have been examined in relation to their effect on the mechanical nature of rock. Detailed petrographic examination and subsequent quantitative QEMSCAN analysis provide better understanding of the difference between their textures. Three of the granite types are slightly altered (Grade-II) whereas the other has a higher degree of alteration and corresponds to alteration Grade-III. The mechanical properties determined for each granite type include: unconfined compressive and tensile strength, elastic modulus, P-wave velocity, Schmidt hardness and dry density. Statistical analyses, combined with post-test petrography, demonstrate textural control on mechanical properties. The important petrographic characteristics influencing mechanical behaviour include modal concentration and grain size of individual minerals, mean grain size of rock and distribution of grain size within a rock. Recrystallization of minerals along boundaries has a pronounced effect on increased strength of granites. Texture, however, has a significant influence on the variation of strength of granites with similar alteration grade.

1. Introduction

Evaluation of the physical and mechanical characteristics of granites is essential when considering their industrial use and/or application e.g. for use as dimension stone or building material. Alteration of granites can have a detrimental effect on engineering behaviour and significantly change the behaviour of granites in different environments/conditions e.g. exposure to moisture/temperature, mechanical load etc. A number of researchers have previously described the cataloguing of granites based on their weathering and alteration (Brown, 1981; Hencher et al., 1990; Hencher and McNicholl, 1995; Anon, 1995; Irfan, 1996; Momeni et al., 2015). Several researchers have shown an inverse relationship between the strength of granite and increasing degree of alteration. Coggan et al. (2013) presented increasing kaolinization/alteration and associated changes in mineralogy to be responsible for a marked reduction in strength of granites from south-west England. Sousa (2013) evaluated the effect of mineral characteristics on the behaviour of different Portuguese granites including mineral weakening, quartz fissuration and type of contact between quartz with quartz and other mineral groups. He showed that evaluation of textural characteristics of quartz were vital for understanding the mechanical behaviour of granites. The influence of mineralogical composition and water content on the mechanical behaviour of argillite is described by Hu et al. (2014). The strength and elastic moduli were found to be significantly affected by increasing clay and water content. Rigopoulos et al. (2014) investigated ultrabasic and basic rocks from Greece to establish the relationship between mechanical and petrographic features. They revealed that strength tended to improve as the ratio between soft and hard minerals, ratio between secondary and primary phases and the degree of serpentinization decreased. Basu et al. (2009) assessed the engineering characteristics of altered granites from Brazil. They noticed that several alteration features, including mineralogical reform, disruption of existing textures and initiation of new cracks caused a reduction of strength of granites. The effect of weathering/alteration on porosity and compressive strength of various rock types from Turkey was presented by Tugrul (2004). He proposed that microtextures in relation to weathering of rocks were the controlling factors that influenced their physical and mechanical properties. Sajid and Arif (2014) investigated the effect of textural varieties on the mechanical behaviour of Utla granites from north-west Pakistan. They found that increased porosity and water absorption due to extensive recrystallization and associated mineralogical changes to be responsible for reduced strength of fine grained granites.

From the literature, researchers have observed a change in the mechanical behaviour with increased alteration grade; however, significant variation in strength is also observed in granites with similar alteration grade. The major objective of the current study is to describe the possible factors related to textural differences that are responsible for this mechanical variation in granites with analogous alteration. Pre- and post-test petrographic characteristics are compared to examine the influence of textural parameters (grain size, grain boundary recrystallization,

* Corresponding author.
E-mail address: ms575@exeter.ac.uk (M. Sajid).

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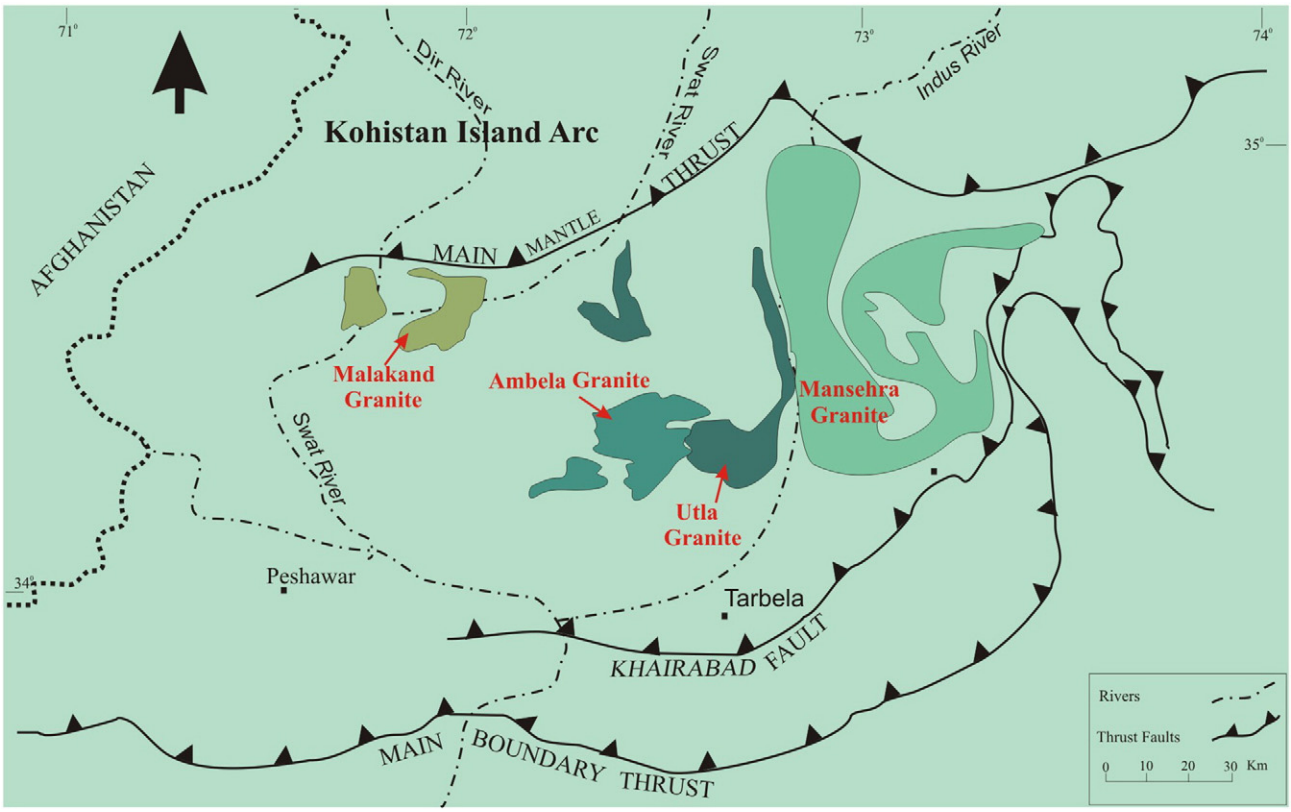

Fig. 1. Geological map of north-west Pakistan showing location of studied granites

modal concentration) on fracture propagation and engineering behaviour. Four texturally different granite types (Mansehra granite: MG, Malakand granite: SG, Utla granite: UG, Ambela granite: AG) from the lower Himalayan regime of north western Pakistan (Fig. 1) have been used to investigate this phenomenon.

2. Geology of studied granites

The Kohistan Island arc is separated from the Indian plate in north Pakistan by a regional fault known as the Main Mantle Thrust (Burg, 2011) (Fig. 1). The Khairabad fault divides the Indian plate into the northern internal metamorphosed zone and the southern external unmetamorphosed or low-grade metamorphic zone (Treloar et al., 1989) (Fig. 1). All the granitic bodies in this study (MG, SG, UG and AG) lie towards the north of the Khairabad fault, but represent different magmatic episodes. UG and MG exhibit similar mineralogical and chemical characteristics (Sajid et al., 2014) but texturally different varieties can be found in both of these plutons. MG yields whole-rock Rb–Sr age of 516 ± 16 Ma and intrudes Pre-cambrian Tanawal quartzite (Le Fort et al., 1980). AG has an alkaline signature and can be related to Permian

Fig. 2. Representative cylindrical core samples of studied granites