

# Study of Hungarian Rocks Regarding Potential Reactivity to Alkalis

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## Abstract

The durability of concrete can be affected due to internal reactions between the alkalis of the cement paste and certain forms of silica present in the aggregates. Petrographic examination provides a useful tool to assess the alkali reactivity of aggregates. In the present work Hungarian stones that are used as aggregates were analyzed for alkali reactivity. Sandstone, two granitic rocks, one andesite and one diabase were studied using petrographic microscopy in order to identify the presence of potentially reactive forms of silica and to classify these rocks accordingly. Complementary methods such as scanning electron microscopy were also applied. Our results confirm that all studied rocks, except diabase, contain silica that has a potential of alkali reaction. Hence analyzed rocks are classified to Class II from the alkali reactivity point of view, while diabase is in Class I.

## Keywords

Alkali-silica reactions • Aggregates • Silica • Petrography • SEM

## 1 Introduction

Concrete can be affected by internal reactions between the alkalis of the cement paste and certain forms of silica present in the aggregates, reducing the durability of the concrete and

the service life of the structures. The aggregates can therefore be classified as innocuous, of reactivity uncertain or potentially alkali-reactive, depending on the forms of silica they contain. The alkali-silica reaction can occur just a few years or some decades after the construction and the potentially reactive aggregates are accordingly named fast reactive (e.g. when opal is present) or slow reactive (e.g. aggregates containing deformed quartz or volcanic glass).

The potential alkali reactivity of aggregates can be studied with the petrographic examination; mineralogical and textural description of the samples. The reactivity of some rocks containing silica, such as sandstone, greywacke and gneiss (Fernandes et al. 2016) is well known but there are other rocks, such as the carbonate and some volcanic rocks that need to be further studied. In fact, the reaction between the cement paste and the carbonate rocks is not yet well understood and lately it has been considered that deterioration of concrete with these rocks was due to the presence of cryptocrystalline quartz spread in the rocks (Katayama 2010; Sanchez et al. 2012). The deleterious behavior of some under-saturated volcanic rocks has been attributed to the chemical composition of the volcanic glass they contain. Some authors consider a threshold of 65% SiO<sub>2</sub> for the composition of the volcanic glass (Wakizaka 2000).

In Hungary most of the aggregates are exploited from alluvial deposits of sand and gravel, which are considered as non-potentially reactive. Crushed aggregates are composed of igneous rocks and sedimentary carbonates. From igneous rocks Eocene-Miocene andesite, and late-Miocene basalt are common, while granite is found in smaller areas (Török 2007). Andesite and basalt have been used for prestressed prefabricated elements, wherever the tensile strength is of importance, but andesite has shown to be potentially reactive.

The present work summarizes the results of the petrographic characterization of seven selected samples, four of sedimentary rocks and three under-saturated igneous rocks.

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## 2 Materials and Methods

For this study one sandstone, two granitic rocks, one andesite and a diabase were studied. These lithotypes occur at various locations in Hungary representing wide geographic range (Fig. 1). The granitic rocks, the andesite and the diabase are used as aggregate (Török 2015). The andesite has excellent aggregate properties with mean Los Angeles abrasion values of 13 (Török and Czinder 2017), while diabase performs even better with a Los Angeles abrasion value of 11, which is much lower than that of the granite (Török 2007).

Petrographic microscope using plane polarized (PPL) and crossed polarized light (XPL) were used in order to identify the presence of potentially reactive forms of silica and to classify these rocks accordingly. When necessary, complementary methods such as scanning electron microscope with energy dispersive spectrometry (SEM/EDS) were also applied.

## 3 Results and Discussion

The studied samples represent wide-ranges of lithologies with various micro-fabric (Fig. 2) containing different forms of silica that can be potentially reactive to alkalis. The sandstone is composed of angular clasts of quartz, quartzite and chert. The interstitial spaces are filled with micro- to cryptocrystalline quartz, abundant feather-like clay minerals, some mica and ferruginous cement.

The monzogranite contains quartz, perthitic K-feldspar, zoned plagioclase, biotite and hornblende, with minor epidote, chlorite and calcite. The rock is deformed, showing undulatory extinction in the larger crystals of quartz and

subgraining with formation of microcrystalline strained quartz. The altered granitic rock is intensely tectonized and is composed of quartz with abundant subgraining, perthitic K-feldspar and plagioclase. Abundant secondary calcite is present in the borders of the larger crystals of the main constituents.

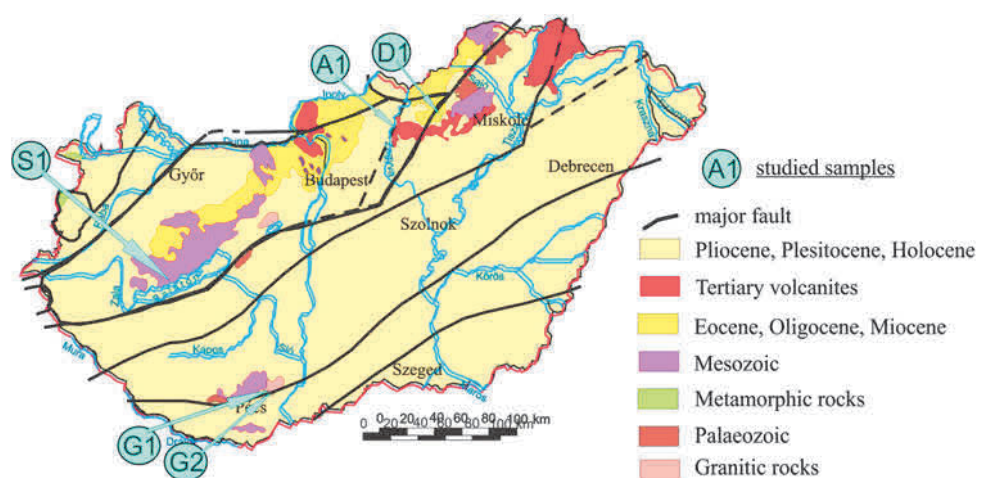
The andesitic rock is a porphyric igneous rock of intermediate composition with phenocrysts of zoned plagioclase, ortho- and clinopyroxene. Some crystals are partially altered to clay minerals and carbonates. The fine-grained groundmass shows small laths of plagioclase. SEM/EDS analyses were carried out in order to identify the components of the groundmass. The spectra and element mapping obtained show the presence of quartz intergrowths with feldspars (Fig. 3).

The greenish grey diabase/dolerite sample is composed of phenocrysts of plagioclase and pyroxene. The groundmass is very fine grained, with laths of plagioclase and abundant fibrous greenish mineral which resulted from the alteration of a primary mineral. According to SEM/EDS analyses chlorite is the main mineral in the groundmass (Fig. 4). This mineral is responsible for the greenish colour of the rock. No free silica was detected in this rock.


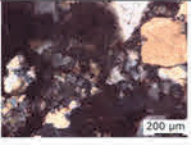

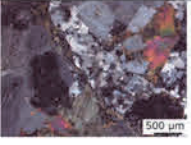

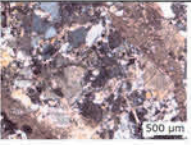



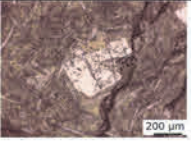
## 4 Conclusions

Sedimentary and igneous rocks from Hungary were studied by petrographic methods to assess the potential reactivity to alkalis. The sandstone contains micro- to cryptocrystalline quartz, besides the clasts of chert and is Class II. From the igneous rocks, the diabase is the only one that does not contain free silica minerals and is therefore Class I. All the other rocks contain cryptocrystalline quartz and deformed, subgrained quartz and are classified as Class II.

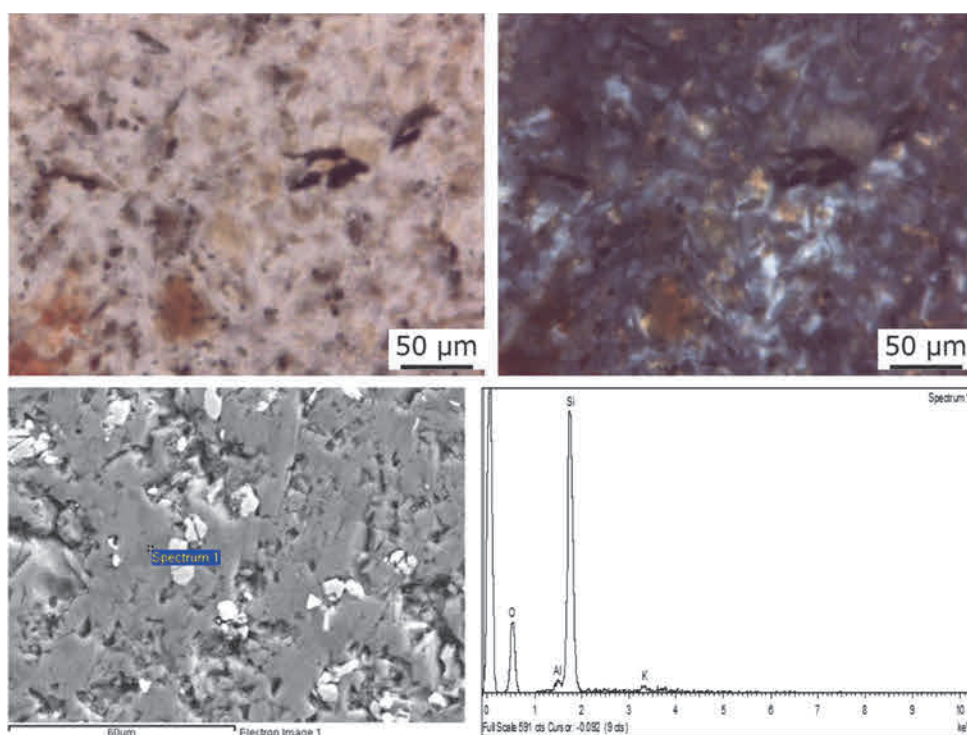
**Fig. 1** Simplified geological map of Hungary (modified after Haas 2001 and Török 2015) showing the sample sites (S1-sandstone, A1-andesite, D1-diabase, G1 and G2 granite, see Fig. 2 for details)



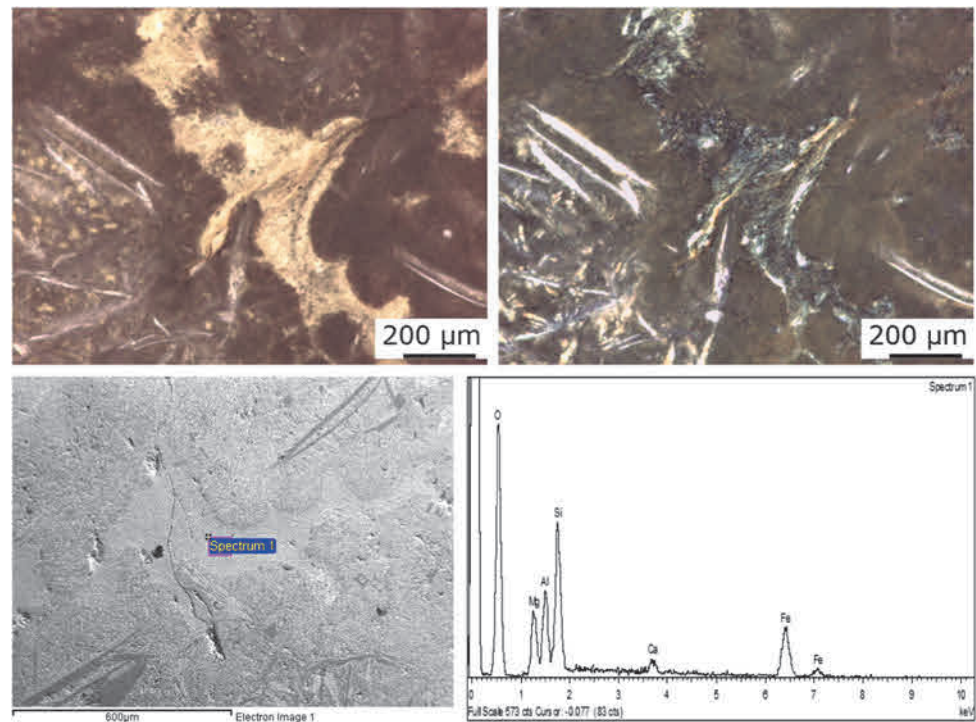
**Fig. 2** Studied lithologies and their microscopic image (XPL) (see location of sampling sites on Fig. 1)

	Location/Age	Hand sample	Thin section
S1	Red sandstone Balatonrendes/Permian  Potentially reactive		
G1	Granitic rock (Monzogranite) Bátaapáti/Carboniferous  Potentially reactive		
G2	Altered granite Bátaapáti/Carboniferous  Potentially reactive		
A1	Andesite Gyöngyössolymos  Potentially reactive		
D1	Diabase Egerbakta  Non-reactive		

**Fig. 3** Groundmass of the andesite, composed of microcrystalline quartz and feldspar. Photomicrographs under PPL (left) and XPL (right), image obtained by SEM and EDS spectrum



**Fig. 4** Diabase with intense alteration to chlorite. Photomicrographs under PPL (left) and XPL (right), image obtained by SEM and EDS spectrum



**Acknowledgements** This publication is supported by FCT-project UID/GEO/50019/2013—IDL (IF) and Hungarian National Research, Development and Innovation Fund (K 116532) (ÁT).

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