POTENTIAL ALKALI-SILICA REACTIVITY OF SUDANESE AGGREGATES

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This is the first systematic study of potential alkali-aggregate reactivity for the Sudan. Aggregate samples were obtained from a number of active or potential rock quarries or gravel workings. Gel-pat, ASTM C227 and NBRI tests were carried out on selected siliceous samples. Petrographic studies were also made of aggregate samples and test pieces. Reactivity was assessed in the gel-pat test between 20° C and 60° C, temperatures appropriate to Sudan; gel formation showed a large increase at higher temperatures. Most aggregates were found to be innocuous whereas two samples proved slowly expansive in NBRI tests.

INTRODUCTION

Sudan is the largest country in Africa, with an area of 2.5 M km^2. It is bisected by the River Nile, the longest river system in the world, and north to south encompasses about 18 degrees of latitude, from arid Wadi Halfa, in the north to equatorial Juba in the south (Figure 1). The arid inland western margin borders countries such as Libya and Chad whilst the eastern border is formed by the Red Sea and Ethiopia. Much of the population and industrial activity are centred on the Red Sea coast or the main river valleys, particularly that of the River Nile; the use and transport of water is a major preoccupation. Large dams have been built, often in concrete, throughout the country and the findings at the Kamburu Scheme in Kenya described by Sims and Evans (1) heightened awareness of potential alkali-silica reaction in Africa.

The country's major cement industry is centred on Atbara north of Khartoum. There is considerable variability in the cement used as some of it is imported.

GEOLOGY OF THE SUDAN

A summary of the main units is presented in Figure 2.

The first modern and easily available account of the geology of the Sudan was provided by Whiteman (2) in 1971 and this book remains a useful introduction to the rock types in the country. Other authors have provided access to a substantial volume of past work, including Vail (3) and Vail and Duggua (4).

The 'Solid' Formations. Four major subdivisions of this broad group may be recognized:

1 The Basement Complex - characterized by vast areas of structurally disturbed and metamorphosed gneisses and schists with associated granites and gabbros. The Complex outcrop probably underlies half of the surface area of the country.

2 Igneous rock complexes - of differing rock type and age of intrusion; also distinctive ring complexes of particular scientific interest.

3 A subsequent sedimentary cover of relatively undeformed deposits - sandstones are typical but cherts also occur.

4 Basaltic igneous centres - associated with rifting in this part of Africa.

Crushed rock aggregates have been derived from most of the units described above.

The Unconsolidated Formations. The Solid Formations have provided material for the subsequent sand and gravel deposits encountered in relict or in the modern wadi form. The unconsolidated cover includes alluvial deposits of channel, terrace and fan type with associated colluvial deposits, including footslope and hillwash materials. Residual soils rich in iron bearing compounds occur and extensive drifts of windblown Qoz sand cover substantial areas.

Sand and gravel workings exploit these deposits throughout Sudan.

SOURCES OF AGGREGATE

Aggregates for testing and examination were obtained by El Tilib (5) from a number of locations in Sudan (Figure 2). Twenty four materials were chosen, the majority from the margins of the River Nile north of Khartoum. An engineering geological map of this area, at a scale of 1:80,000, was also prepared from aerial photographs.

Six samples of natural sand (Nos 1-6) from seasonal water courses, named wadis or khors, were obtained; 3 samples of gravel (Nos 7-9) from existing gravel workings were also collected.

Four samples, identified as rhyolite from the Sabaloka ring complex (Nos 10 and 11), Jebel es Sufur northeast of Khartoum (No 14) and Jebel Seluwib (No 24), in the Red Sea Hills, were obtained.

Two samples of granite were selected from an operating quarry at Jebel Sileitat northeast of Khartoum (No 16) and an undeveloped quarry at Sabaloka (No 13). A sample of basalt (No 15) was obtained from an operation at Jebel et Toriya west of Khartoum. Sandstones were obtained from 3 locations: an undeveloped quarry at Jebel Rauwiyan at Sabaloka (No 12) and from operating quarries at Merkhiyat Jebels west of Khartoum (No 17) and Jebel Aulia in

Khartoum Province (No 18).

One sample was obtained of quartz porphyry (No 19) from an undeveloped quarry about 14 km west of Omdurman and a chert (No 20) from a deposit about 14 km northeast of Shendi, Nile Province. Other remaining samples were a chalcedony (No 21) from a type location in the Red Sea Hills, a granite gneiss (No 22) from Jebel Nyala in Southern Darfur Province and a metaquartzite (No 23) from a quarry about 15 km southwest of ed Damazin, Blue Nile Province.

POTENTIAL REACTIVITY TESTING

Gel-pat, ASTM C227 and NBRI tests were carried out on most samples. Where gel-pat tests proved positive, with detection of gel, then mortar bars were made up from these aggregates for further study. In general the ASTM C227 tests proved inconclusive and the most useful test proved to be the NBRI test (6). Expansion criteria summarized by Grattan-Bellew (7) were used in examining results of the NBRI tests. Gel and microcracks typical of ASR were observed in all cases. The results are presented in Table 1. NBRI expansion results are presented in Figure 3.

Expansions which were suspected to arise from ASR were confirmed by petrographic analysis of thin sections and uranyl acetate testing of sliced test pieces using the ultra violet light technique suggested by Natesaiyer and Hover (8).

CONCLUSIONS

This investigation was carried out using aggregates with suspected reactivity potential from various parts of Sudan. Most samples, based on this study, appeared to be innocuous although petrographic work revealed known potentially reactive constituents were present. Substantial gel was observed in the gel-pat test, particuarly at higher temperatures. This suggests that aggregates which may be innocuous in moderate climates could be reactive in areas such as the Sudan. Two igneous rock samples were shown to be potentially reactive and slowly expansive with expansion continuing beyond 50 days with the NBRI test; this expansion was shown to be a direct result of ASR.

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TABLE 1 Summary of Test Results

Reference number, type of aggregate, petrography of aggregate/Potentially reactive components found	Gel-Pat % particles with gel			Expansion Test	
	20° C	40° C	60° C	ASTM C227	NBRI (6,7)
1 Sand. Microcrystalline quartz; highly strained quartz. Colloidal silica within limonite coating	3	10	22	0.00	0.03
6 Sand. Microcrystalline quartz. Highly strained quartz	2	3	Not tested	0.00	0.02
7 Gravel. Microcrystalline quartz. Strained quartz with deformation lamellae	2	4	10	0.00	Not tested
10 Rhyolite. Crypto-crystalline quartz	2	13	30	0.01	Not tested
13 Microgranite. Micro-crystalline to crypto-crystalline quartz	2	Not tested	Not tested	Not tested	Not tested
14 Rhyolite. Glass and devitrified glass. Crypto-crystalline veining	4	16	41	0.01	0.10*
15 Basalt. No reactive veining appears to be present	0	0	Not tested	Not tested	Not tested
16 Granite. Micro-crystalline quartz intergrown with micrographic texture	2	3	Not tested	Not tested	Not tested
18 Sandstone. Micro-crystalline quartz. Strained quartz. Silica veining.	3	8	23	0.01	0.04
19 Quartz Porphyry. Micro/ cryptocrystalline ground mass. Veinlets of tridymite (?)	4	16	43	0.01	0.10*
20 Chert. Micro/ cryptocrystalline quartz	2	5	20	0.01	Not tested
22 Granite gneiss. Some fractured quartz, microcracks filled with silica, may be opal	3	8	25	0.01	Not tested
23 Metaquartzite. Highly strained quartz. Micro-crystalline quartz. Sutured grain outlines	0	2	10	0.00	Not tested

* Continuing to expand after 50 days.

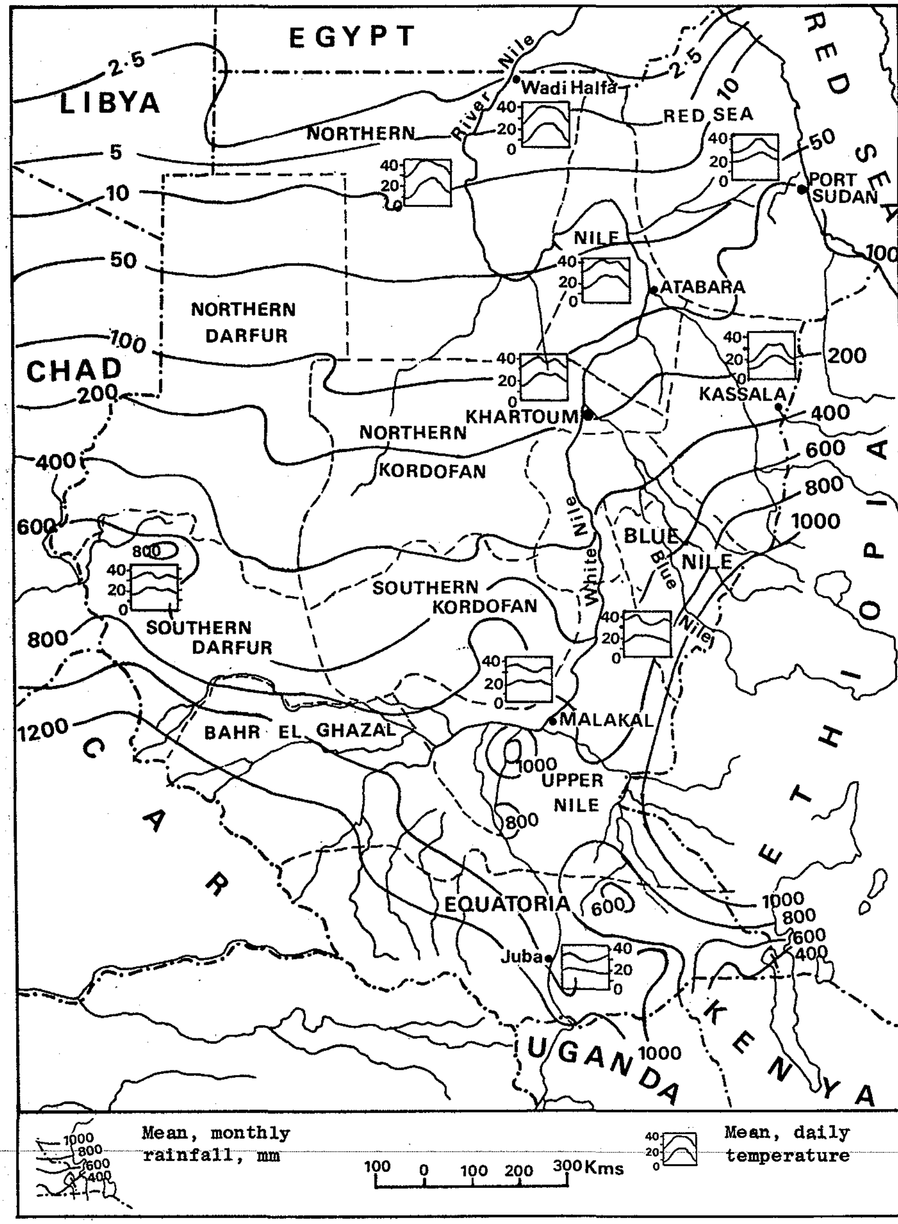

Figure 1 Climatic Map

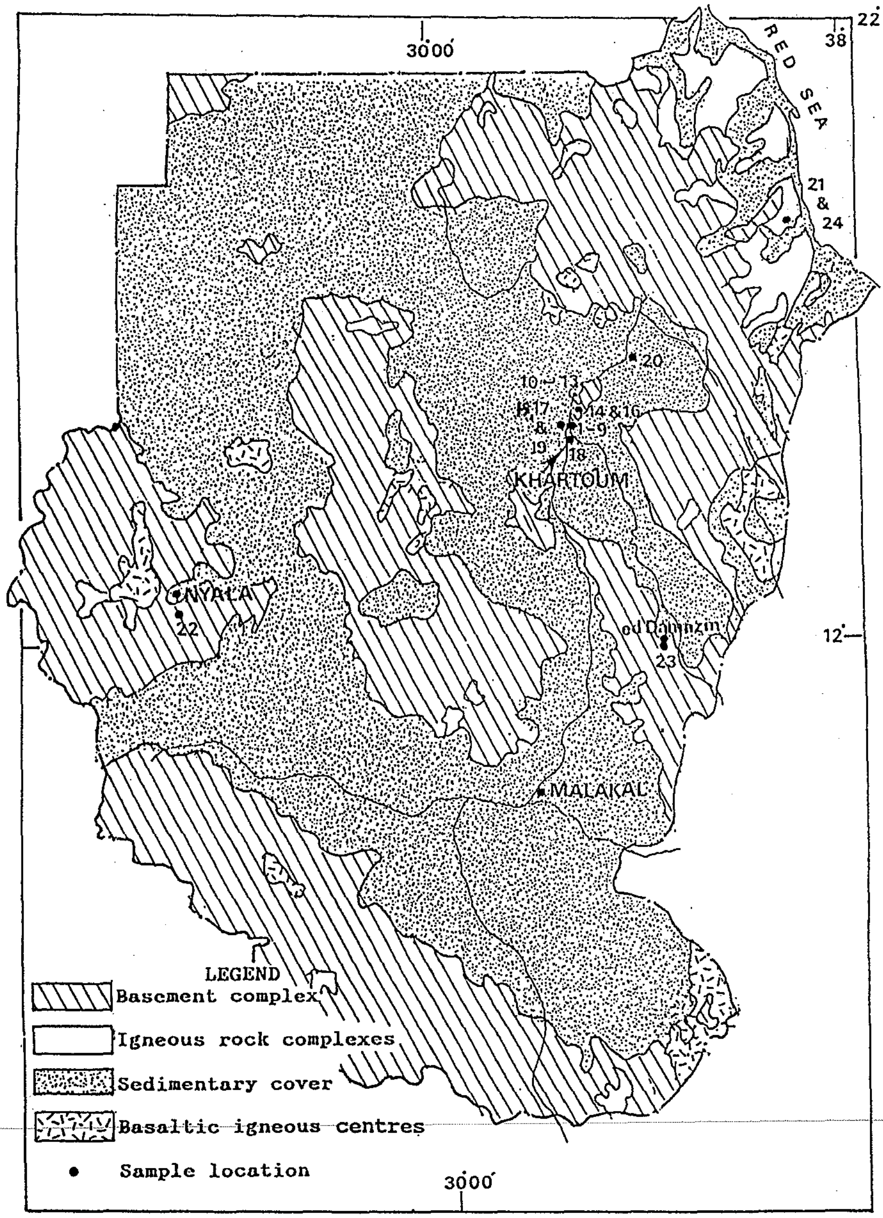

Figure 2 Geological Map

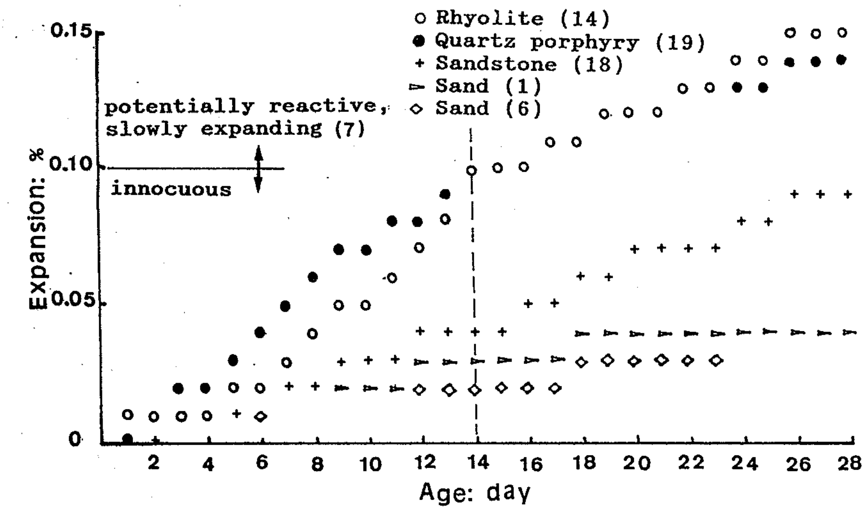

Figure 3 Expansion-age relationship from NBRI tests