

Petrographical Significance of Some Geotechnical Parameters of Quartzites in the Togo Series at Aburi Area, Ghana

George M. Tetteh¹, Samuel Kwafo²

^{1,2}Department of Geological Engineering, University of Mines and Technology, P. O. Box 237, Tarkwa, Ghana.

Abstract - Quartzites in the Togo Series at the Aburi area in Ghana range from less metamorphosed quartzitic sandstone to sheared, recrystallised and flaggy quartzites generally, fractured, folded and faulted. While the quartz grains, particularly in the quartzitic sandstone, preserve some primary rounded to subrounded sedimentary textures, sheared quartzite varieties are elongated and recrystallised into fine to medium grained sugary, glassy and smoky quartz which are fractured and partially recrystallised. Porosity is highest for sheared quartzite (1.93 %) moderate in chloritic quartzite, flaggy quartzite, recrystallised quartzite; and lowest in quartzitic sandstone (0.71 %). Quartz composition is slightly lower in the deformed quartzite such that the average porosity negatively correlates with quartz modal percentage. Again the more deformed rocks have higher flaky minerals (chlorite, sericite and muscovite) than quartzitic sandstone and show strong negative correlation with modal percentage of platy minerals which also mark crenulated foliations. Generally, flaggy quartzite has the highest average uniaxial compressive strength (140.80 MPa), reduced in quartzitic sandstone, recrystallised quartzite, chloritic quartzite and sheared quartzite. The lower negative correlation of uniaxial compressive strength (UCS) for both modal percentages of quartz and platy minerals might be a reflection of extensive joints and cleavages which affect the strength of the rock as quartz is brittle and the platy minerals were introduced during deformation and metamorphism.

Key Words: Petrography, Geotechnical, Quartzites, Togo Series, Porosity, Uniaxial compressive strength

1. INTRODUCTION

The Dahomeyan System borders the Togo Series to the east and the Birimian Supergroup overlain by the Voltaian formation to the west (Fig. 1). The Togo Series form a range of mountains and hills which trend northeast, from the Volta River between Kpong and Anum to the Ghana-Togo border near Palime. The rocks originally consisted of alternating arenaceous and argillaceous sediments converted into phyllites, schists and quartzites except in few localities where original shales and sandstones are undeformed [1]. The rocks, mainly quartzites, schists, phyllites and sandstones are deformed into recumbent and isoclinal folds and faulted especially at the western and eastern contacts with the Dahomeyan rocks metamorphosed from greenschist to amphibolite facies [2]. The quartzites of the Togo Series are deformed into two major folds, thrust faulted foliated, quartz-veined, and fractured [1]. The strength of the Togo quartzites classified as metasandstone; thin layered quartzite and metaquartzite have rock force values (load) of 110, 200 and 260 kN respectively [3]. This paper describes the petrography of some quartzites at Aburi area, and the relationship of their textures with the geotechnical characteristics.

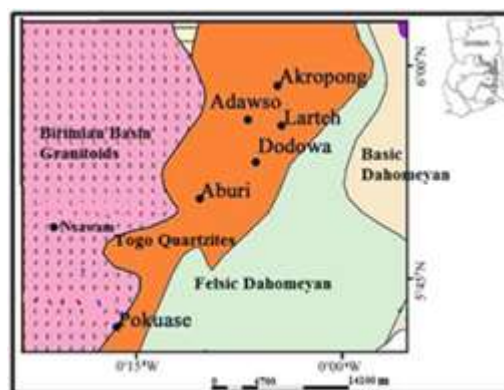


Fig 1: Geological map of an area which encloses Aburi area after [2]

2. METHODS USED

Rock samples were collected from outcrops at different localities in Aburi and surrounding areas including Larteh, Peduase Lodge, Ayi Mensah and a quarry at Amanhyia (Fig. 1), and thin sections prepared for petrographic studies. Geotechnical analysis of uniaxial compressive strength, bulk density and porosity were done at the University of Mines

and Technology, Tarkwa. The samples were also moulded into cubes and left to stand for 24 hours using cementing materials, loaded into a machine and the weight on the rock was increased until it fractured. The uniaxial compressive strength (UCS) of the specimen was calculated by dividing the maximum load borne by the specimen by the average cross-sectional area of the mould [4].

The Procedures for determining the bulk density commenced with measurement of the mass of wet specimen using an electronic balance. The specimen was immersed into water hanging from a thread to determine its volume which is equal to the volume of water displaced, then waxed and its mass measured. The waxed specimen was immersed in water to determine the volume of the waxed specimen then the mass and volume of the sample determined by subtracting the mass and volume of the wet specimen from that of the waxed specimen. The bulk density was calculated by dividing the mass of the specimen by the volume. The specimen was immersing into a beaker of water to determine volume displaced, then saturated for 24 hours for the mass of the saturated specimen to be measured, and then oven dried for a couple of hours for the mass of the dried specimen to be determined. The porosity of the sample was obtained by dividing the volume of voids by the total volume.

3. RESULTS

Quartzitic Sandstone (QSS) is light brown, sugary with glassy texture with quartz veins across and parallel to foliations. The main foliation is crenulated and shows intersection lineations. In thin section, the rock is medium grained, subrounded, and moderately sorted, with chlorite and opaque oxide fillings at grain boundaries. Quartz which is iron oxide stained shows undulose extinction and is weakly fractured (Fig. 2).

Chloritic Quartzite (CLQ) is massive, medium-grained, moderately sorted and has a sugary texture and cut by quartz veinlets and jointed (Fig. 3). In thin section, quartz is drawn out, folded with some fold hinges refolded. Quartz showed deformation lamellae, undulose extinction and recrystallised into fine grains.

Sheared Quartzite (SHQ) (Fig. 4) is light grey, thinly foliated with grains recrystallised into sugary to glassy textures that is sheared and partially recrystallised with fractures parallel to foliations and marked by intersection lineations. Sheared quartzite shows elongated quartz marked by chlorites which exhibit microfolds. Elongated quartz grains which show undulose extinction together with muscovite and chlorites mark different generations of cleavages (Fig. 5).

Flaggy quartzite (FGQ) is dark grey, glassy, foliated (2cm thickness) with quartz elongated, partially recrystallised and marked by muscovite (Fig. 6).

Recrystallised quartzite (RCQ) is massive, light grey, medium-grained, recrystallised and contains glassy, fractured quartz with opaque minerals along fractures (Fig. 7). In thin section, the foliations are folded, microfaulted and occupied by chlorite and rare drawn out quartz. The quartz grains are also bent and show fractures across elongated direction. The quartzites are interbedded with schists and cut by quartz veins; opaque oxide inclusions are common. Table 1 shows the modal percentage – quartz ranges from 75 % in flaggy quartzite to 90 % in quartzitic sandstone, chlorite 2 % to 15 %, sericite and muscovite up to 6 %; Table 2 shows uniaxial compressive strength (UCS) results and Table 3 the bulk density and porosity measurement on representative quartzites.



Fig 2: Photograph of quartzitic sandstone outcrop - massive with glassy texture



Fig 3: Photograph of chloritic quartzite showing quartz veinlets and joints



Fig 4: Photograph of sheared quartzite outcrop sections being light grey; the rock is fractured with some foliations marked by intersecting lineations

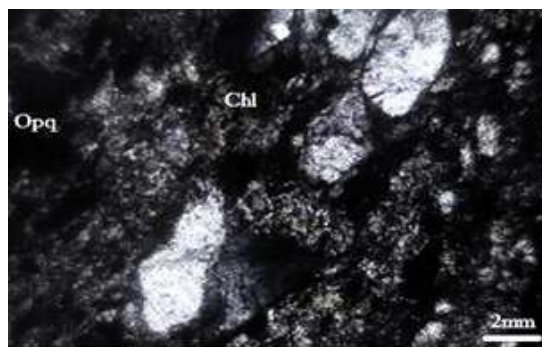


Fig 5: Photomicrograph of sheared quartzite under cross polarised light showing elongated quartz grains (Opq = opaque mineral; Chl = chlorite)



Fig 6: Photograph of flaggy quartzite outcrop showing glassy texture (foliations are about 3 cm thick)



Fig -7: Photograph of recrystallised quartzite outcrop showing light grey rock with fractures

Table 1: Modal analysis of representative quartzites in the Aburi area

Minerals (%)/ Sample ID	RCQ	QSS	SHQ	FGQ	CLQ
Quartz	80	90	80	75	78
Chlorite	7	2	10	10	15
Opaque Mins.	7	9	3	13	2
Sericite	6	-	5	2	-
Muscovite	-	-	2	-	5
Total	100	100	100	100	100

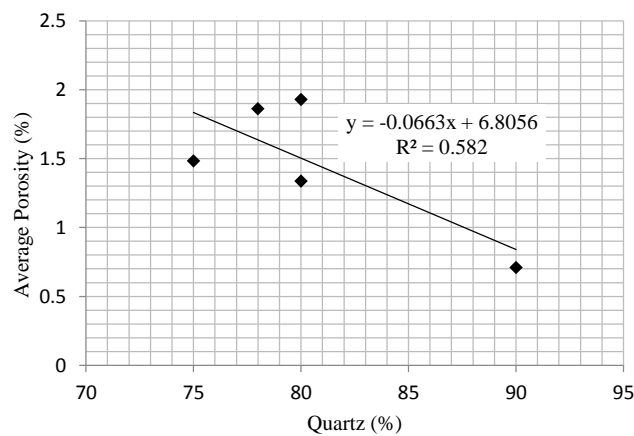


Fig 8: Graph of porosity against quartz % for selected quartzites

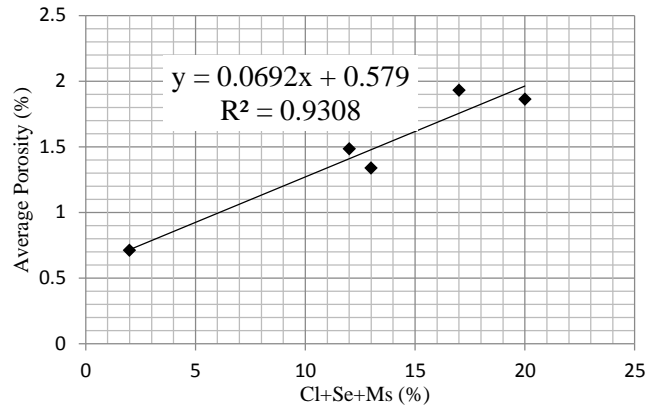


Fig 9: Graph of porosity against (Chlorite+Sericite+Muscovite) % for selected quartzites

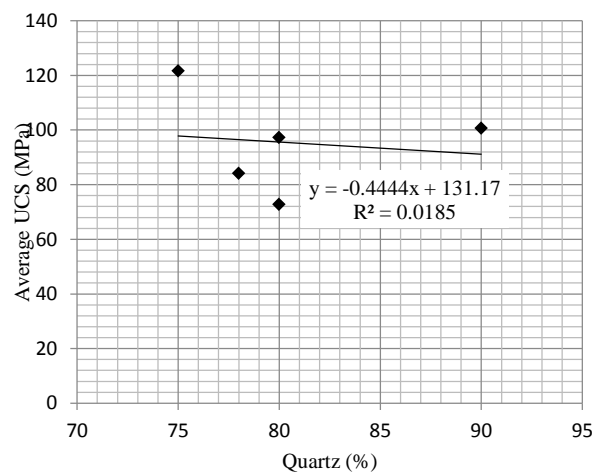


Fig 10: Graph of UCS against quartz % for selected quartzites

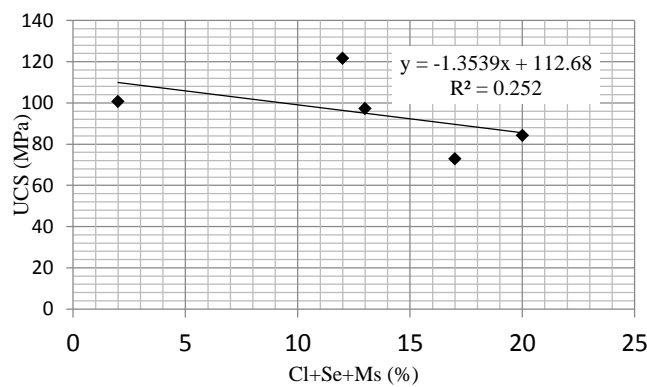


Fig 11. Graph of UCS against platy minerals (Chlorite+Sericite+Muscovite) % in quartzites

Table 2: Uniaxial compressive strength (UCS) results on selected quartzites

Sample No.	RCQ-A	RCQ-B	RCQ-C	QSS-A	QSS-B	QSS-C	SHQ-A	SHQ-B	SHQ-C	FGQ-A	FGQ-B	FGQ-C	CLQ-A	CLQ-B	CLQ-C
Mass of Specimen (g)	126.59	97.578	95.307	108.771	124.637	113.894	92.541	106.366	82.036	54.312	53.421	95.884	135.881	122.099	62.686
Mass of Saturated Specimen	127.127	97.923	95.786	109.001	124.882	114.174	93.049	106.965	82.674	54.785	53.578	95.081	136.801	122.492	63.188

(g)															
Mass of Dry Specimen (g)	126.533	97.537	95.264	108.742	124.598	113.856	92.476	106.292	81.993	54.284	53.379	94.852	135.793	122.024	62.674
Volume of Displaced Water (cm ³)	48.000	34.000	32.000	38.000	43.000	40.000	32.000	39.000	30.000	19.000	19.000	30.000	50.000	42.000	21.000
Volume of Voids (cm ³)	0.594	0.386	0.522	0.259	0.284	0.318	0.573	0.673	0.681	0.501	0.199	0.229	1.008	0.468	0.514
Porosity	0.012	0.011	0.016	0.007	0.007	0.008	0.018	0.017	0.023	0.026	0.011	0.008	0.020	0.011	0.025
Average Porosity (%)	1.337			0.710			1.930			1.483	1.861				

Table 3: Bulk density and porosity measurement on selected quartzites

Sample No.	RCQ-A	RCQ-B	RCQ-C	QSS-A	QSS-B	SHQ-A	SHQ-C	FGQ-B	CLQ-A	CLQ-C
Bulk Density (g/cm ³)	3.00	3.15	2.91	3.46	3.54	1.73	3.05	3.92	3.92	3.75
Mass of Specimen (g)	126.59	97.58	95.31	108.77	124.64	92.54	82.04	54.31	135.88	62.69
Mass of Saturated Specimen (g)	127.13	97.92	95.79	109.00	124.88	93.05	82.67	54.78	136.80	63.19
Mass of Dry Specimen (g)	126.53	97.54	95.26	108.74	124.60	92.48	81.99	54.28	135.79	62.67
Volume of Displaced Water (cm ³)	48.00	34.00	32.00	38.00	43.00	32.00	30.00	19.00	50.00	21.00
Volume of Voids (cm ³)	0.59	0.39	0.52	0.26	0.28	0.57	0.68	0.50	1.01	0.51
Porosity	0.012	0.011	0.016	0.007	0.007	0.018	0.023	0.026	0.020	0.0245

DISCUSSION

The types of quartzites in the Togo Series at the Aburi area include; quartzitic sandstone, chloritic quartzites, sheared-, recrystallised- and flaggy quartzites. Generally, the rocks are fractured, folded and faulted with quartz grains particularly in the quartzitic sandstone being rounded to subrounded, but sheared varieties in more deformed rocks are elongated and recrystallised into fine to medium grains. The composition of quartz is low in the flaggy quartzite and chloritic quartzite, moderate in both recrystallised and sheared quartzites and high in the quartzitic sandstone. Chlorite is moderate in chloritic quartzite, low in both flaggy and sheared quartzites and very low in recrystallised quartzite and quartzitic sandstone respectively (Table 1).

Hence different varieties of quartz occur - sugary, glassy and smoky quartz, fractured and partially recrystallised. Quartz also shows undulose extinction, recrystallised, and cut by quartz veins. Chlorite and muscovite/sericite mark the foliations which are crenulated with intersection lineations. Average porosity ranges from 0.71 to 1.93 % with highly deformed rocks showing higher values: sheared quartzite being highest, followed by chloritic quartzite (1.86 %), flaggy quartzite, recrystallised quartzite; quartzitic sandstone is least (0.71 %). Quartz composition is slightly lower in the deformed quartzite, hence the graph of average porosity against quartz modal percentage is negatively correlated with a correlation coefficient of 0.763 (Fig. 8). The more deformed rocks have higher flaky minerals than quartzitic sandstone. The relationship between these minerals and higher porosity which shows strong negative correlation with a correlation coefficient of 0.9308 may not be due to composition of platy minerals (chlorite, sericite and muscovite) occupying grain contacts or pores but at foliations [5] (Fig. 9, Table 3). Uniaxial compressive strength ranges from the minimum in sheared quartzite (28.57 MPa) to flaggy quartzite (140.80 MPa). Generally, flaggy quartzite has the highest average uniaxial compressive strength followed by quartzitic sandstone, recrystallised quartzite, chloritic quartzite with the minimum being sheared quartzite (Table 2). These values have a low negative correlation with both modal percentages of quartz and platy minerals having correlation coefficients of 0.136 and 0.502 respectively (Figs. 10 and 11). Joints and cleavages have many roles in affecting the strength of the rock. Such structures may appear on microscopic scale to affect the rock

strength. Reduction of uniaxial compressive strength with the intensity of platy minerals shows the stronger effect of microstructures and textures rather than modal percentage on geotechnical parameters.

4. CONCLUSION

Quartzites in the Togo Series at the Aburi area range from less metamorphosed quartzitic sandstone to sheared, recrystallised and flaggy quartzites. Generally, these rocks are fractured, folded and faulted with quartz grains, particularly in the quartzitic sandstone, showing primary sedimentary textures of rounded to subrounded while sheared quartzite varieties are elongated and recrystallised into fine to medium grains of quartz which give rise to sugary, glassy and smoky quartz types, also fractured and partially recrystallised. Chlorite and muscovite/sericite mark foliations which are crenulated. Porosity is highest in more deformed rocks in the area such that sheared quartzite has the highest values (1.93 %), moderate in chloritic quartzite, flaggy quartzite, recrystallised quartzite; and lowest in quartzitic sandstone (0.71 %). Quartz composition is slightly lower in the deformed quartzite such that the average porosity negatively correlates with quartz modal percentage. The more deformed rocks have higher flaky minerals than quartzitic sandstone and show strong negative correlation with modal percentage of platy minerals (chlorite, sericite and muscovite). Generally, flaggy quartzite has the highest average uniaxial compressive strength (140.80 MPa) with a reduction through quartzitic sandstone, recrystallised quartzite, chloritic quartzite and sheared quartzite. Lower negative correlation with both modal percentages of quartz and platy minerals might be a reflection of extensive joints and cleavages on the uniaxial compressive strength of the rock. The relative effect of quartz which is brittle and platy minerals introduced during different stages of deformation may occupy or microstructural planes of weakness in the rocks.

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BIOGRAPHY



Lecturer at University of Mines and Technology, Tarkwa, Ghana. Fields of interest include Structural Geology, Petrology Geochemistry and Mineral Exploration. Holds PhD (University of Ghana).