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PETROLOGY AND PHYSICO-MECHANICAL PROPERTIES OF WADI ALLAQI ORNAMENTAL STONES, SOUTHERN EASTERN DESERT, EGYPT

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ABSTRACT

The present paper deals with the suitability of igneous and metamorphic rocks outcropping at Wadi Umm Ashira and Wadi Tilal Al-Qulieb northwest Wadi Allaqi, Southern Eastern Desert, Egypt, to be used as ornamental stones. The igneous rocks are represented by granites and rhyolites. Meanwhile, the metamorphic rocks include white marble and colored or dolomitic marbles. The applied basic tests include petrography, physical and mechanical (apparent density, real density, volume of open pores, open porosity, water absorption and compression strength). All of these tests were carried out according to the requirements of the European Standard **(**EN) standards. Based on petrography and chemical analyses, the present study discusses the effect of the chemical and mineralogical compositions as well as the crystal sizes on the physical and mechanical properties of the studied rock units. The present work recommends quarrying the igneous rocks and marbles at the northwest Wadi Allaqi, as these rocks exhibit physical and mechanical properties similar to the requirements of the standards specification for ornamental stones.

Keywords: Ornamental stones, petrographic characteristics, geotechnical characterization, mechanical and physical properties.

INTRODUCTION

The term ornamental stones are namely used commercially as a result of its resistance to external factors, strength, and texture diversity and aesthetic appearance in additional to their physical and mechanical properties. The ornamental stone industry is considered as a one of the important industrial activities around the world, it is expected to grow annually to satisfy the continuous increase in the construction building industries.

In Egypt, the ornamental stone industry grows progressively as a result of the increasing demand on the Egyptian dimension stones, either on the local or the international scale. This had led to a continuous increasing of the production rates. There are many enterprises and workshops working in the dimensional stone industries in Egypt. Seventy percent of them are located in Shaq Al-Thoaban area (South Cairo) concerning quarrying production. The Egyptian production of ornamental stones sharing about 4.5% of the world markets and occupy the fourth world rank. The overall export reaches up to 1.5 million tons per year, 0.9 million ton as raw materials and 0.6 million tons as processed products, this means that Egypt considered the 7th dimension stone exporter in the world (Hamza *et al*., 2011).

The present work report an investigation of the physical and mechanical properties of some Egyptian ornamental stones in the northwest Wadi Allaqi, Southern Eastern Desert, Egypt as new site for granites and marbles quarries. The results of this study will be used to predict the engineering properties of these rocks based on mineralogical and physio-mechanical characteristics.

The investigated rock specimens were collected from Wadi Tilal Al-Qulieb and Wadi Umm Ashira between (latitudes 22° 40"- 23° 00"N and longitudes 33° 15" - 33° 30E) nearby the east bank of the Nasser Lake (Fig. 1).

The basement complex cropping out around Wadi Tilal Al-Qulieb and Wadi Umm Ashira areas comprises ultramafic rocks, arc volcanoclastic metasediments, island arc metagabbro-diorite complex, and late to post granite (Noweir et al, 2000, Ahmed, 2002).

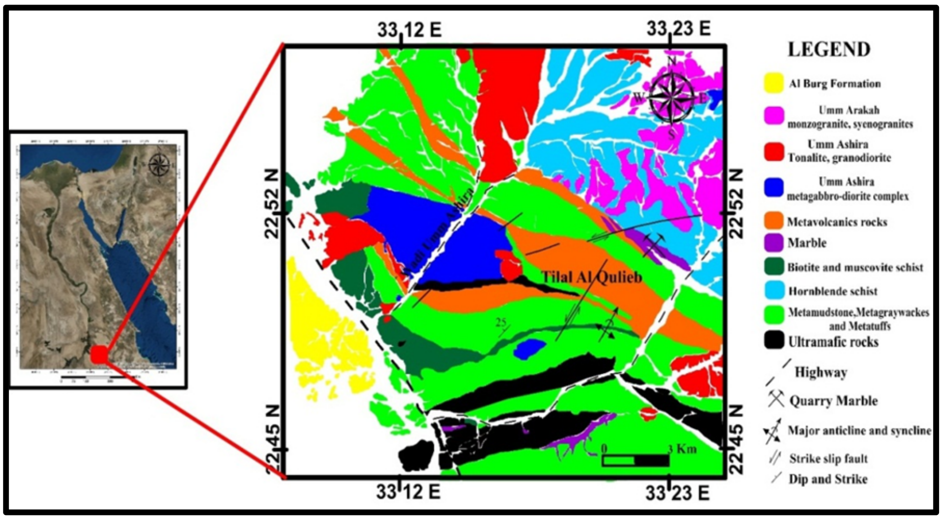

Fig. 1: Location and geological map of the studied area after (Noweir et al, 2000).

The marbles are distributed in the east of Tilal Al-Qulieb area as blocks or inverted layers (vertical level) of variable thicknesses concentrated with in schists (Fig. 2). The pink granite occurs in the western part of wadi Umm Ashira and north wadi Shikayat. They occur in leucocratic (buff), massive, medium- to coarse-grained (Fig. 3). Biotite granite is occurring usually grey in color, fine to medium-grained represented by separated masses in wadi Umm Ashira. The rhyolite rocks occupy a low hills area and exhibit sharp structural contact with the metagabbro in the western part of Wadi Umm Ashira. Rhyolites in Umm Ashira area are characterized by phenocrysts of quartz and orthoclase. These rocks are massive, fine-grained, light brown in color (Fig. 4).

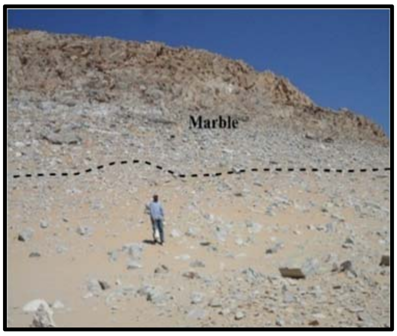

Fig. 2: Photograph showing large thick of marble outcrops in east Wadi Tilal Al –Qulieb.

Fig. 3: Photograph showing the pink granite mass exposed at Wadi Umm Ashira.

Fig. 4: Photograph showing the massive rhyolite of Wadi Umm Ashira.

METHODOLOGY

A total of 31 rock blocks (granite, rhyolite and marble), which were large and homogeneous enough to provide test specimens free from fractures, joints or partings, were collected and tested for this study.

Chemical Analyses

Representative twelve rock samples (two rhyolite, four grey granite, two pink granite, two white marble and two dolomitic or coloured marble) were chemically analyzed for major elements and the averages of their chemical composition are listed in Tables (1 & 2). The analyses were performed using inductive coupled plasma (ICP) by lithium metaborate ($LiBO_2$) flux fusion at Acme Analytical Laboratories, Vancouver, BC Canada. To detect major oxides, samples were prepared as powder bellets then one gram was used to know the loss on ignition (LOI) by heating the powder at 105°C for 24 hour, then heating it for one hour. ICP analysis is performed at computer-controlled spectrometers on solid and liquid samples. Solid samples must be converted to liquid form before testing by dissolving the sample in a solvent (typically acid) to produce a solution. The sample solution is introduced into the ICP as a fine aerosol of droplets.

Table 1: Average chemical analyses (Wt%) and the calculated normative color index (NCI) of Wadi Allaqi igneous rocks.

Major Oxides	Grey Granite Average	Pink Granite Average	Rhyolite Average
SiO_2	68.03	72.2	70.32
TiO_2	0.46	0.41	0.42
Al_2O_3	14.02	13.66	14.42
$Fe_2O_3^t$	3.75	2.06	2.33
MnO	0.08	0.03	0.04
MgO	0.36	0.66	0.68
CaO	1.41	1.53	1.79
Na_2O	5.46	3.72	3.82
K_2O	3.13	4.44	4.29
P_2O_5	0.1	0.09	0.09
LOI	3.2	1.2	1.8
Total	100	100	100
NCI	4.11	2.72	3.01

Table 2: Average chemical analyses (wt.%) of marble rocks.

Rocks / Oxides	White marble Average (No. 3 samples)	Colored marble Average (No. 4 samples)
SiO_2	4.17	5.15
TiO_2	0.01	0
Al_2O_3	0.25	0.07
$Fe_2O_3^t$	0.17	0.22
MnO	0.09	0.03
MgO	0.48	20.14
CaO	52.61	29.25
Na_2O	0.03	0.01
K_2O	0.01	0.01
P_2O_5	0.18	0.12
LOI	42	45
Total	100	100

Determination of water absorption at atmospheric pressure according to the European Standard BS EN- 13755 (2008)

Water absorption is the proportion of water able to be absorbed by cubic samples under specific immersion conditions (Fig. 5). It was carried out in the Marble and Granite Laboratory, National Research Centre, Cairo. The water absorption at atmospheric pressure (Ab) of each specimen is calculated by the equation: -

Ab = (ms-md / md) x 100
Ab: water absorption
ms: mass of the saturated specimen, in grams
md: mass of the dry specimen, in grams

Determination of compressive strength according to European Standard BS EN-1926 (1999)

The studied ornamental stones were tested under uniaxial compression according to European Standard BS EN-1926 (z1999). These samples were in the form of cubic samples with dimensions of 3 x 3 x 3 cm^3 (ASTM, 2008 & ISRM, 2007).

The uniaxial compressive strength (UCS) is one of the key properties for characterization of rock materials in engineering practices. The uniaxial compression test was carried out by using a computerized compression machine. Figure 6 and 7 shows the laboratory testing for uniaxial compressive strength on cubic specimen. Compressive strength is the maximum force divided by area.

Fig. 5: Photograph showing the studied specimens (granite, rhyolite and marble) immersed by tap water at 20±10°Cup half the height of the specimens.

Fig.6: Photograph showing uniaxial compression strength (UCS) test under compression testing machine.

Fig. 7: Photograph showing marble sample after compression stage.

$$\mathbf{Cs = F / A}$$

Where: **Cs** = Compressive strength
F = Force load, in Newton
A = Cross sectional area of the specimen

Determining the "apparent density" regular-shaped objects according to BS EN-1936 (1999)

Apparent density (in kilograms per cubic meter) is the ratio of the mass of the dry specimen and its apparent volume. It is expressed by equation: -

$$\mathbf{Pb = (md / ms\text{-}mh) \times \rho rh}$$

Pb: Apparent density
md: mass of the dry specimen, in grams
ms: mass of the saturated specimen, in grams
mh: mass of the specimen immersed in water, in grams
ρrh: density of water, in kilograms per cubic meter

Determination of the real density of fine powder by Pycnometer and open porosity according to BS EN-1936 (1999)

Real density defined as the ratio of the dry specimen mass to the volume of its solid part. It is therefore measured in kg/m^3. It affected by two factors the mass of the component and the packing or the amount of the open porosity. According to table 3, the real density ranged from 2.64% to 2.92%. The content of Fe, Mg and Ti strongly affect the rock density.

The open porosity according to BS EN-1936 (1999) is the percentage of the volume of the open pores and the apparent volume of the specimen. It is expressed by the equation:

$$\text{Open pores (PO \%)} = (ms - md / ms - mh) \times 100$$

Table 3. Mechanical and physical properties of the studied igneous rocks.

	S. No.	Water Absorption %	Open Porosity %	Apparent Density Kg/m³	Volume of Open Pores (mm)	Apparent Volume mm³	Compressive Strength MPa	Real Density g/cm³
Biotite Granite	G1	0.39	1.02	2637.87	0.51	50.01	110.09	2.7
	G2	0.37	0.98	2646.26	0.48	49.32	85.60	2.7
	G3	0.37	0.99	2643.35	0.49	49.68	104.42	2.7
	G4	0.38	1.00	2640.55	0.50	49.88	115.57	2.7
	G5	0.35	0.93	2632.82	0.46	49.34	75.61	2.67
	G6	0.34	0.91	2631.40	0.45	49.78	90.58	2.72
	G7	0.46	1.24	2718.63	0.62	49.97	46.15	2.8
	G8	0.43	1.18	2718.99	0.59	50.18	129.61	2.81
	Average	0.39	1.03	2658.74	0.51	49.77	94.7	2.73
Alkali feldspar Granite	P1	0.40	1.04	2614.99	0.52	50.13	159.24	2.67
	P2	0.35	0.92	2611.92	0.45	49.18	91.76	2.67
	P3	0.39	1.02	2617.76	0.50	49.12	103.45	2.74
	Average	0.38	0.99	2614.89	0.49	49.48	118.15	2.69
Rhyolite	R1	0.33	0.87	2628.89	0.41	47.05	178.18	2.64
	R2	0.33	0.86	2629.99	0.41	47.86	165.79	2.68
	R3	0.34	0.89	2628.20	0.42	47.48	164.26	2.68
	Average	0.33	0.87	2629.03	0.41	47.46	169.41	2.66

RESULTS AND DISCUSSION

Igneous Rocks (Granites and Rhyolites)

The studied igneous rocks were classified into the followings types: biotite granites (grey granite), alkali feldspar granites (pink granite) and rhyolite.

Petrography

Biotite granites (Grey granite)

Biotite granites are composed essentially of plagioclase, quartz, potash feldspar (microcline and orthoclase) and biotite (Fig. 8 A, B & C). Hornblende, muscovite and sphene are the accessory minerals. Chlorite and sericite occur as an alteration product. These range from 2.5 to 4mm in length and from 1.4 to 3mm in width. Quartz is subhedral to euhedral crystals up to1.8mm in length and 0.6mm in width. It characterized by invariably the quartz display and undulatory extinction due to stress. Quartz is represented by two generations; a primary generation is mostly which formed of subhedral to euhedral crystals (Fig. 8A). While, the secondary generation forms small fresh crystal filling the interstitial spaces. Plagioclase (An_{10-16}) occurs as medium to coarse-grained, subhedral to euhedral crystals. The large plagioclase crystals are observed showing zonation, percline and Carlsbad twinning (Fig. 8B). Microcline is medium to coarse-grained and subhedral to euhedral crystals (Fig. 8A). Orthoclase is coarse-grained, exhibits perthitic texture and represented by albite and potash feldspar. Hornblende occurs as brown color, medium-grained, euhedral to subhedral crystals with pleochroism from yellowish green to brown (Fig. 8C).

Alkali feldspar granites (Pink granite)

Alkali feldspar granites are composed mainly of potash feldspars, quartz, plagioclase, biotite and muscovite. The dominant minerals are quartz, plagioclase, potash feldspar and biotite. Muscovite, chlorite and sericite occur as an alteration minerals. Quartz is represented by medium- to coarse-grained, anhedral crystals and characterized by strong undulose extinction, polygonal porphyritic crystals. Plagioclase (An_{1-10}) mostly sodic plagioclase (oligoclase) and appears as medium-grained subhedral crystals and uncommonly saussuritized. These crystals have slightly displacement due to deformation and saussuritized (Fig. 8D). Orthoclase is coarse-grained, subhedral to euhedral crystals and slightly altered to sericite.

Rhyolites

Rhyolite are characterized by spherulitic and porphyritic textures with essential components of quartz, potash feldspar (sanidine) and plagioclase phenocrysts set in a fine-grained groundmass (Fig. 8E & F). Quartz is the predominant mineral constituent and occurs as anhedral grains or as euhedral phenocryst that range from 4.3 to 6.3mm in length and from 2.3 to 3.4mm in width. Two generations of euhedral and anhedral quartz crystals can be distinguished; euhedral quartz crystals occur as inclusions within the fine-grained groundmass, whereas the anhedral quartz crystals occur as anhedral small crystals filling the interstitial spaces between the other minerals. In these rocks, radiate intergrowths of quartz and alkali feldspar are arranged about euhedral and form granophyric texture (Fig. 8F). Plagioclase (An_{2-12}) occurs as medium- to coarse-grained subhedral to euhedral crystals represented by albite to oligoclase. The primary plagioclase is up to 2 mm in width and 4 mm in length, deformed crystals partially altered to sericite (Fig. 8E). Potash feldspars occur as phenocrysts and commonly present as sanidine. They are small subhedral crystals usually characterized by still preserved simple twinning.

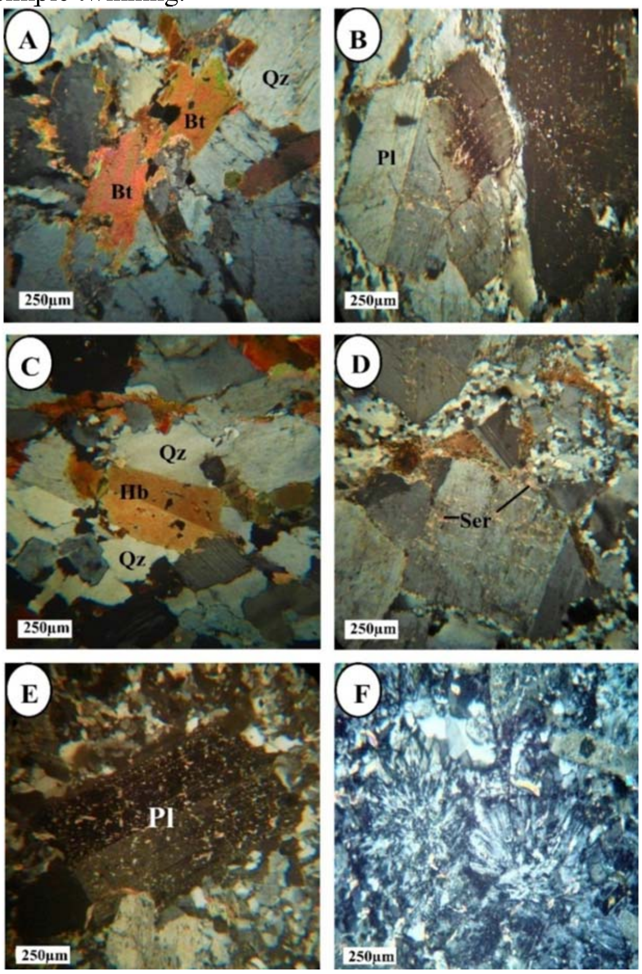

Fig. 8: Microphotographs showing petrographic features of the studied igneous rocks: - A. Large biotite (Bt) crystal altered to sericite (Ser) and muscovite in biotite granite. C.N.B. Carlsbad twinning and deformed planes of plagioclase (Pl) filled with sericite in biotite granite. C.N. C. Baveno twinning of hornblende (Hb) in biotite granite. C.N. D. Highly altered plagioclase to sericite (Ser) and epidote (Epi) in alkali feldspar granite. C.N. E. Porphyritic texture exhibit within rhyolite rocks. C.N. F. Spherulitic texture of rhyolite rocks. C.N.

Chemical Characteristics of the Igneous Rocks

The chemical analyses of the present acidic igneous rocks (Table 1), reveals that, the grey granite, pink granite and rhyolite exhibit, more or less, a narrow range of chemical variations. The highest SiO_2% value in pink granite is 72.20 %, while the lowest is 68.03% encountered in grey granite. Rhyolite is more enriched in MgO and CaO (0.68 and 1.79% respectively) than the other two granitic types. Grey granite is more enriched in total iron as Fe_2O_3 and Na_2O (3.75% and 5.46% respectively) than pink granite and rhyolite. The mafic constituents in the present acidic igneous rock are measured by using the normative color index (NCI) that was proposed by Irvine and Baragar (1971). The highest NCI value is encountered in the grey granite (4.11), and decreases to 3.01 and 2.72 in rhyolite and pink granite respectively.

Mechanical and Physical Properties of the Igneous Rocks

Relations between unixial compressive strength of rocks and their physical properties were studied by Scott and Nielson (1991) and Palchik and Hatzor (2000). The maximum compressive strength values are recorded in the rhyolite samples (Table 3), as it varies from 164.26 to 178.18MPa with an average of 169.41 MPa. The granitic rocks exhibit lower compressive strength values 118.15 MPa and 94.70 MPa for pink granite and grey granite respectively. It is argued that, the chemical as well as the mineralogical variations between rhyolite and granites are, to a great extent, very narrow; hence the main factor affecting the compression strength values are the crystallinity as well as the crystal sizes.It is obvious that the compressive strength increases with the decrease of the crystal size from granites to rhyolite, (Fig. 9). It is also noticed that, the high content of total iron decreases the compressive strength values (Fig. 10). This may be due to the presence of Fe-rich minerals, mainly phyllosilicates and double chain silicates (biotite and hornblende respectively). Both silicate types are characterized by weak bonding between the alternating silica tetrahedron sheets and chains resulting in one or two perfect sets of cleavage. According to Deer and Miller (1966), the present acidic igneous rocks are classified as high to medium strength rocks. The maximum water absorption values are encountered in granitic rocks, 0.38% pink granites and 0.39% grey granites, while the lowest value is 0.33% rhyolites. This indicates that, the water absorption decreases with the grain size decreases from granite to rhyolite (Fig. 11). The open porosity varies from 1.03% grey granite to 0.99% both pink granite and rhyolite, (Table 3). The relation between the open porosity and water absorption shows that the water absorption increases with the increasing of the open porosity from rhyolite, pink granite to grey granite (Fig. 12).

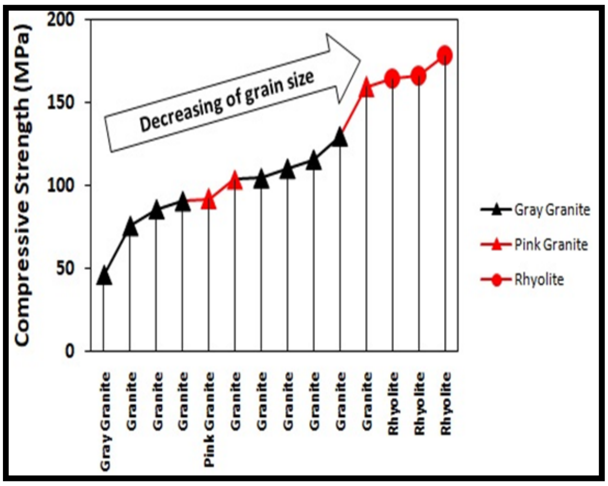

Fig. 9: Diagram showing the compressive strength of the studied rocks increases with the decrease of the grain size.

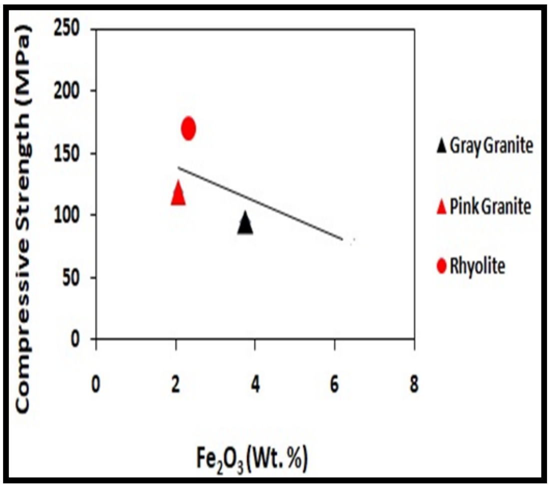

Fig.10: Diagram showing the compressive strength of the studied rocks decreases with increase of iron content.

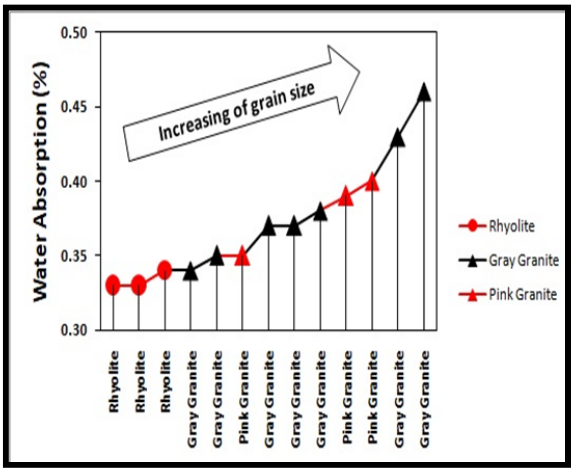

Fig.11: Diagram showing the water absorption of the studied rocks increases with increase of the grain size.

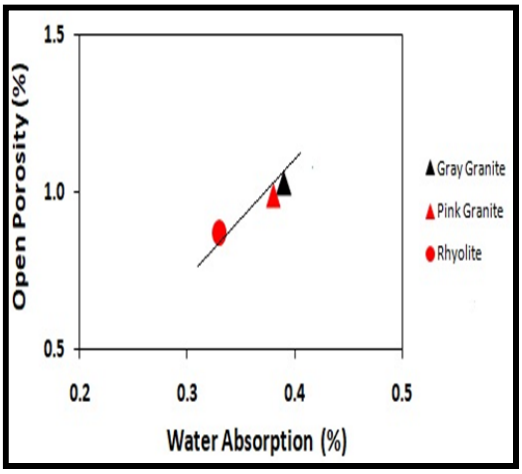

Fig.12: Diagram showing the water absorption and open porosity increase from rhyolite, pink granite to grey granite.

The averages of apparent densities of the tested rhyolite, pink granite and grey granite are 2629.03, 2614.89 and 2658.74 kg/m^3 respectively. The averages of real densities are 2.66, 2.69, 2.73 g/cm^3 rhyolite, pink granite and grey granites respectively. Such variation in densities is closely related to the chemical composition of the solid component of the rocks. The apparent density increases with the increase of the Fe-Mg rich minerals (Fig. 13). On the other words the increase of SiO_2 content results in decrease of density either real density or apparent density (Fig. 14).

Apparent density of the rock is defined as the mass of the rock per unit of its apparent volume, while the real density is expressed by the ratio between the mass of dry specimen and volume of its solid part. It is clear from these definitions that, both types of densities are closely related to the density of the solid volume of the material, however, the apparent density may include the volume of non-solid parts (e.g., air in the open pores), and hence the real density values are higher than that of the apparent density, unless the tested material contains non-open spaces.

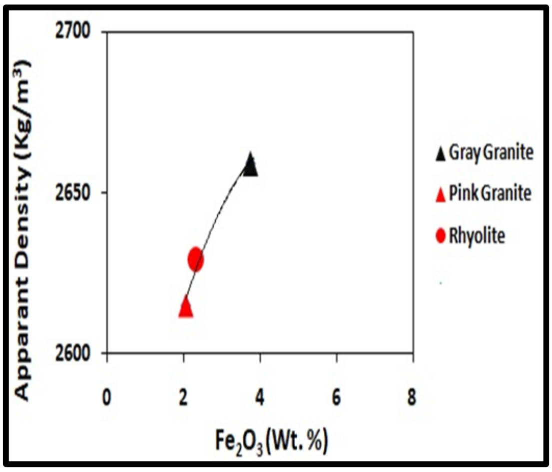

Fig. 13: The Apparent density of increase with increase total iron content.

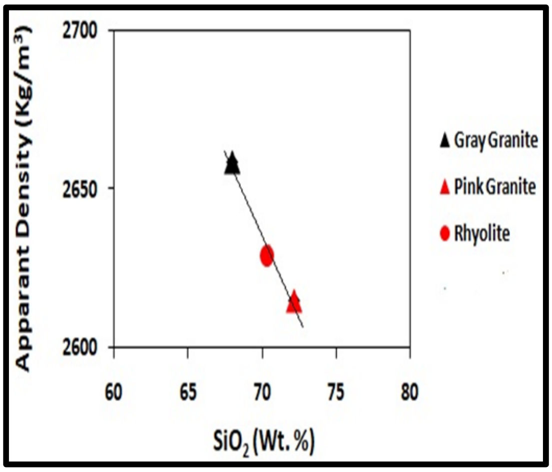

Fig. 14: The Apparent density deceases with the increase of silica content.

Normative color index is used to express the content of Fe – Mg rich minerals in the present rhyolite and granites. The normative color index (NCI) expressed by olivine + pyroxene + magnetite + hematite + ilmenite (CIPW norm calculations according to (Hutchison, 1974), and the data are listed in Table (1). The Apparent density increases as the NCI increases (Fig. 15). Figure (16) illustrates the relation between the compressive strength and the real density; it is clear from the diagram that the compressive strength decreases with the real density increases from rhyolite, pink to grey granite. Although the grey granite has the highest real density (2718.99 kg/m^3), its compressive strength is the lowest (46.15 MPa), this is due to the high contents of Fe-Mg rich minerals reflected by high NCI values.

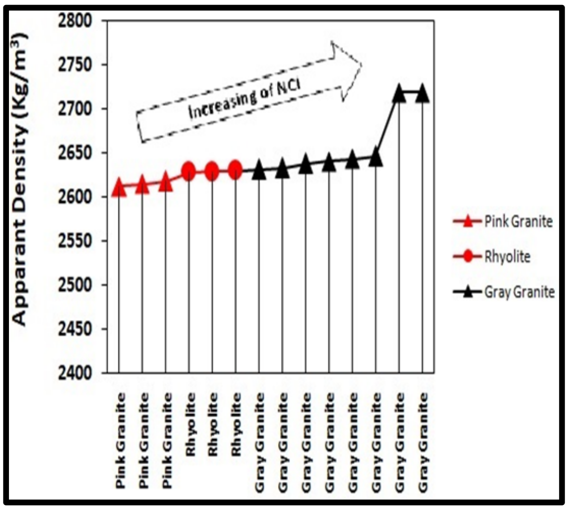

Fig.15: The Apparent density of increases with increasing normative color index (NCI).

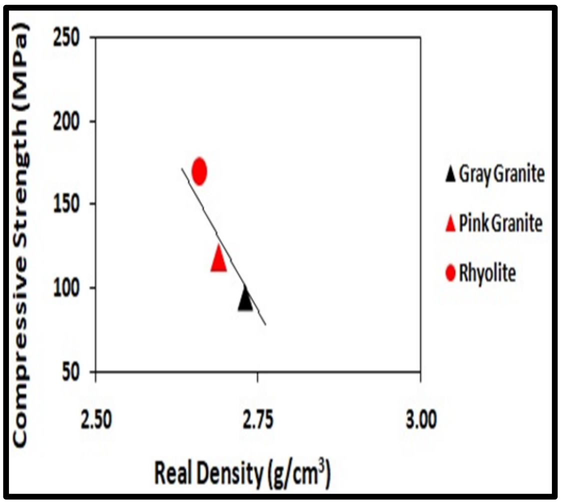

Fig.16: The compressive strength decreases with the increase of the real density.

Metamorphic Rocks

The studied metamorphic rocks were classified into the followings types: white marble and colored dolomitic marble.

Petrography

A. Marbles

The studied marbles exhibit various colors ranging from banded milky white, grey to black (Fig. 17A & B). The hand specimen samples may contain veinlets of quartz. Petrographically, the marbles could be classified into two types; white marble and colored (dolomitic) marble.

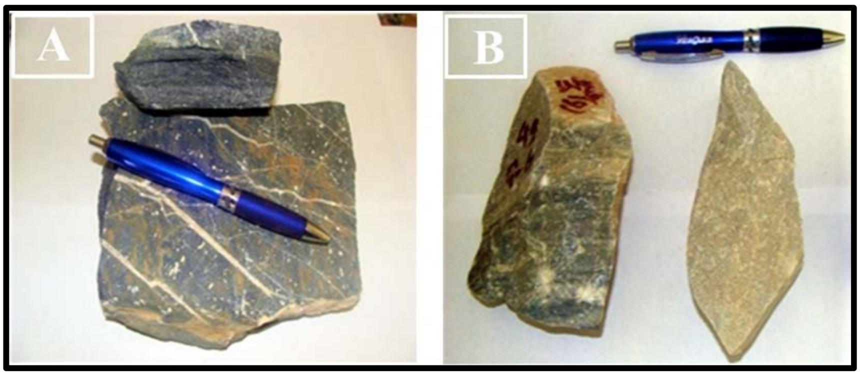

Fig.17: A & B: Hand specimens showing the different colors of marble (black, grey and white).

The first type of marble (white marble) is composed of calcite as major constituent associated with traces of talc and quartz. Calcite is colorless with distinct cleavage, twinkling and ranged from medium- to very coarse-grained. It is characterized by the presence of well-developed crystals granoblastic texture (Fig.18A & B). Quartz appears as lenses and anhedral to subhedral crystals with undulose extinction (Fig.18A). Talc occurs as colorless microcrystalline to medium crystalline plates (Fig. 18B).

The second type of marbles (colored dolomitic marble) is formed of dolomite, graphite, antigorite and talc (Fig.18C & D). These rocks range in size from fine-grained to very coarse-grained patches. Carbonate minerals composed of calcite and dolomite are observed with a mosaic texture in which the individual carbonate grains are approximately equant. The orientation of carbonate crystals is as indicator on the effect of pressure (Fig. 19C). Carbonates occur in two phases. The first phase is represented by coarse-grained aggregates (Fig. 18D). While, the second phase of the carbonates has suffered different degrees of deformation which appear in the form of carbonate lenses, kink banding and subsequent fragmentation and recrystallization into fine-grained aggregates. These marbles are commonly stained with reddish material (most probably iron oxides). Graphite appears as fine-grained streaks impregnated with fine-grained carbonates (Fig. 18C). Antigorite occurs as anhedral to subhedral crystals within carbonate minerals (Fig. 18C). Talc occurs as a secondary mineral formed by alteration of magnesium carbonates (magnesite and dolomite).

Chemical Characteristics of Marbles

The chemical composition of the two marble types is listed in Table (2). It is clear that, the white and colored marbles are very close in composition except CaO% and MgO%. The white marble is mainly calcite marble CaO% = 52.61, while MgO% = 0.48). The colored marble is dolomitic (MgO = 20.14% and CaO = 26.25%). Such variation reflected on the mechanical and physical properties.

Mechanical and Physical Properties of Marbles

The results of mechanical and physical properties are listed in Table (4). The compressive strength varies from 62.62 MPa in white marble to 87.67 MPa in colored marble, the high values of compressive strength in colored marble is may be due to the high content of dolomite as the MgO reaches up to 21.18% while in white marble the average MgO% is 0.48%.

The water absorption varies from 0.34% to 0.37% in white marble and dolomitic marble respectively, while the open porosity varies from 0.93% to 1.05% in white and colored marble respectively. The two parameters are closely related to each other's as the water absorption increase as the porosity increases (Fig. 18).

The apparent density varies from 2683.27kg/m^3 to 2820.91kg/m^3 in white and colored marble respectively. The real density varies from2.69 g/cm^2 to 2.86g/cm^2 in white and colored marble respectively. The high densities in the colored marble (apparent and true) are closely related to the content of MgO% and in turn the dolomite content. The high MgO% strengthens the colored marble resulting in higher compressive strength values (Fig. 19).

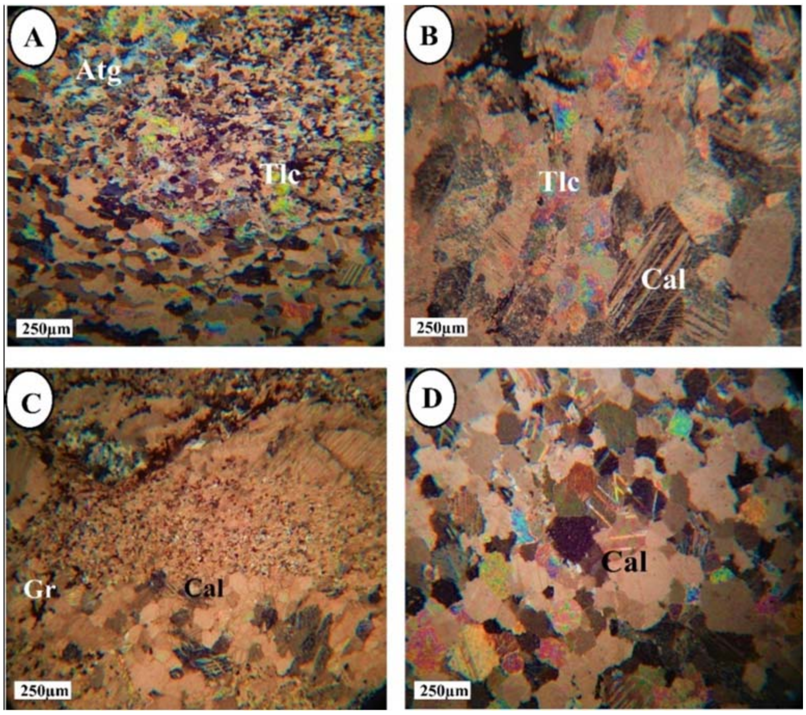

Fig. 18: Microphotographs showing the petrographic features: A & B. Medium grains of calcite and talc (Tlc) crystals showing good twinkling of white marble. C.N., X 4 /10. C. Kink bands of calcite grains, graphite (Gr) and antigorite (Atg) of colored (dolomitic) marble. C.N., X 4 /10. D. Mosaic texture in colored (dolomitic) marble. C.N.

Table 4. Mechanical and physical properties of the tested marbles.

		Water Absorption %	Open Porosity %	Apparent density Kg/m3	Volume of open porosity (mm)	Apparent Vol Mm3	Compressive Strength MPa	Real Density g/cm3
Colored Marble	CM1	0.37	1.03	2820.55	0.50	48.49	103.83	2.85
	CM2	0.36	1.01	2827.13	0.50	49.80	91.92	2.92
	CM3	0.41	1.16	2816.14	0.45	38.74	77.90	2.83
	CM4	0.34	0.96	2819.81	0.49	51.09	77.02	2.86
	Average	0.37	1.05	2820.91	0.49	47.03	87.67	2.86
White Marble	WM1	0.35	0.93	2682.86	0.46	49.56	62.59	2.68
	WM2	0.36	0.96	2682.32	0.47	49.25	50.95	2.69
	WM3	0.34	0.91	2684.65	0.46	50.75	74.30	2.71
	Average	0.34	0.93	2683.27	0.465	49.85	62.62	2.69

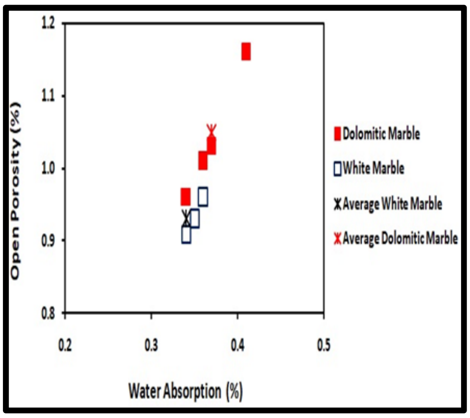

Fig.18. The water absorption increases with increase of the open porosity.

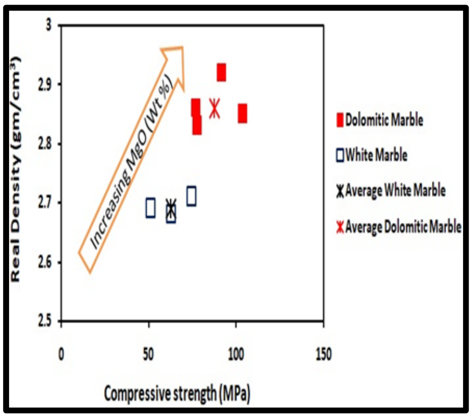

Fig. 19. The compressive strength increases with increase of the real density as the MgO content is increase.

SUMMARY AND CONCLUSION

The studied Wadi Allaqi rocks are represented by biotite granites, alkali feldspar granites and rhyolites of acidic igneous rocks, in addition to white and colored (dolomitic) marbles.

Petrographically, the biotite (grey) granite is composed essentially of coarse-grained plagioclase, quartz, with fewer amounts of potash feldspars (orthoclase) and biotite is the main mafic constituent. Hornblende, chlorite and muscovite are sometimes observed as accessory minerals. The alkali feldspar (pink) granite composed mainly of orthoclase, quartz, plagioclase, and biotite. Muscovite and sericite usually exist as secondary minerals. Rhyolites are composed of quartz, potash feldspar and plagioclase as phenocrysts set in fine-grained groundmass built up of very fine-grained quartz, potash feldspar and plagioclase.

The physical and mechanical properties of the acidic rocks revealed that, the maximum compressive strength values are recorded in rhyolite, with an average of 169.41 MPa. The granitic rocks exhibit lower compressive strength values 118.15 MPa and 94.70 MPa for pink granite and grey granite respectively. The maximum water absorption values are encountered in the granitic rocks, (0.38 %) and (0.39 %) in pink and grey granites respectively. Meanwhile, the lowest value is recorded in rhyolites (0.33 %). The apparent densities of rhyolite, pink and grey granites are 2629.03, 2614.89 and 2658.74 kg/m^3 respectively, while the real density varies from 2.66 to 2.69 to 2.73 g/cm^3 in rhyolite, pink and grey granites respectively.

The white marble is composed essentially of calcite, sometimes associated with traces of talc and quartz. Meanwhile, the colored (dolomitic) marble is formed mainly of dolomite with fewer amounts of calcite, graphite and antigorite.

In marble, the compressive strength varies from 62.62 MPa in white marble to 87.67 MPa in colored marble; the water absorption varies from (0.34%) to (0.37%) while the open porosity varies from 0.93% to 1.05% in white marble and dolomitic marble respectively.

The present work also discussed the effect of the chemical and mineralogical composition as well as the crystal sizes on the physical and mechanical properties of the studied rocks. In the acidic igneous rocks, the content of mafic minerals such as biotite and hornblende expressed by the normative color index, clearly affects their physical and chemical properties. The high NCI value increases the porosity, water absorption and real density and decreases the compressive strength values. On the other hand, the crystal size affects the water absorption contents as the later increase with the increase the grain sizes, while the compressive strength decreases with the increasing of the grain size.

In marbles, the physical and mechanical properties are closely affected by contents of MgO, mainly related to dolomite, as the compressive strength and real density increase with increasing of the amount of MgO%.

The present work recommends quarrying of the acidic igneous rocks and marbles at the northwest of Wadi Allaqi. These rocks exhibit physical and mechanical properties exceeding the requirements of the international standards for dimension stones. The acidic igneous rocks, especially rhyolites, are fit for tiling in heavy duty traffic areas such as rail stations, airports, etc. The colored marbles are fit for tiling in medium duty traffic areas such as hotels, museums, and indoor buildings, while the white marble is fit for indoor cladding.

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Petrology and physico-mechanical properties of Wadi Allaqi

الخواص البتروجرافية والفيزيقوميكانيكية لأحجار الزينة بوادي العلاقي– جنوب الصحراء الشرقية –مصر

باسل شلبي و حاتم الدسوقي و محمد هيكل و أحمد مصطفي

الخلاصة

تتناول هذه الدراسة مدى ملاءمة الصخور النارية والمتحولة في وادي أم عشيرة ووادي تلال القليب شمال غرب وادي العلاقي ، جنوب الصحراء الشرقية ، مصر ، لاستخدامها كأحجار زينة.

تشمل الاختبارات الأساسية التطبيقية لصخور الدراسة: الخواص البتروجرافية والفيزيقوميكانيكية (الكثافة الظاهرية والكثافة الحقيقية وحجم المسام المفتوحة والمسامية المفتوحة وامتصاص الماء وقوة الانضغاط). كما ناقش هذا البحث تأثير التركيب الكيميائي والمعدني على الخواص الفيزيائية والميكانيكية للصخور المدروسة.

اتضح من الدراسة البتروجرافية للصخور المجمعة من وادي أم عشيرة ووادي تلال القليب شمال غرب وادي العلاقي أنها تتكون من الصخور النارية الحامضية مثل الجرانيت البيوتايتي والغرانيت الفلسبار القلوي و الرايوليت، بالإضافة إلى الصخور المتحولة المتمثلة في الرخام الأبيض والملون (الدولوميت).

أظهرت الخصائص الفيزيائية والميكانيكية أن صخر الرايوليت له أعلي قيمة ضغط بمتوسط ١٦٩.٤١ ميجا باسكال ويليه صخر الجرانيت الوردي بمتوسط ١١٨.١٥ وعليه يمكن استخدامهما في أحجار الزينة. بينما سُجلت أقل قيمة ضغط في كلاً من صخور الجرانيت الرمادي ٩٤.٧٠ ميجا باسكال والرخام بنوعيه (الابيض ميجا باسكال 62.62 والملون 87.67 ميجا باسكال).

تعتبر خاصية امتصاص الماء أحد العوامل المهمة في قياس متانة الصخور فكلما قلت النسبة عن ٢% كلما دل علي قوة الصخر وهذا متوفر في صخور هذه الدراسة . لذا نوصي باستخدام هذه الصخور النارية والمتحولة في الشمال الغربي من وادي العلاقي في صناعة أحجار الزينة.