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# Low Cost Ceramic Product Based on Mixing Granodiorite and Talc from Eastern Desert, Egypt

**Said H. Abd El Rahim[1,*], Nahla I. Abd El Ghaffar[1], Zeinab A. Abd El-Shakour[1] and Esmat M. A. Hamzawy[2]**

*[1] Geological Sciences Department, [2]Glass Research Department, National Research Centre, 12622, Dokki, Giza, Egypt.*

**Abstract**

The Abu Ziran area is easily accessible following the Quseir-Qift asphaltic road in the Central Eastern Desert of Egypt. Microscopically and geochemically, the granodiorite rock represents a good source for the major oxides that are contained in its mineral components: quartz, oligoclase, orthoclase, microcline, biotite and hornblende as its essential minerals constituents; besides sphene, zircon, apatite and magnetite as its accessory minerals constituents. These minerals represent suitable raw materials in the formulation of the low cost ceramic product.

The low cost ceramic materials were prepared from mixing wastes of granodiorite and talc quaries in the Eastern Desert, Egypt. Four samples were prepared in the 70:30, 60:40, 50:50 and 40:60 ratios of granodiorite:talc. After sintering process of the green ceramic samples up to 1300 $^{o}$C, aluminum enstatite, kyanite, pyrope and cristobalite were developed. The microstructure of the sintered samples show rod-like crystals in micron and submicron size oriented or disoriented in glassy matrix. The samples enjoy good densities between 1.65 and 2.21 g/cm$^3$ and porosity ratio between 18.01 and 39.27 %. This low cost ceramic product can be used in insulation for heat and sound.

**Keywords:** Abu Ziran area, Egypt, Granodiorite, Talc**,** Ceramic Product, Insulation

## 1.Introduction

The Abu Ziran area is a part of the Central Eastern Desert of Egypt. The area is easily accessible from the east following the Red Sea highway along the coast to Quseir city (Fig. 1). The easy accessibility and the fact that granodiorite rock is to be found there may encourage the construction of ceramic product factories as well as the sustainable development and civilization in the Central Eastern Desert of Egypt.

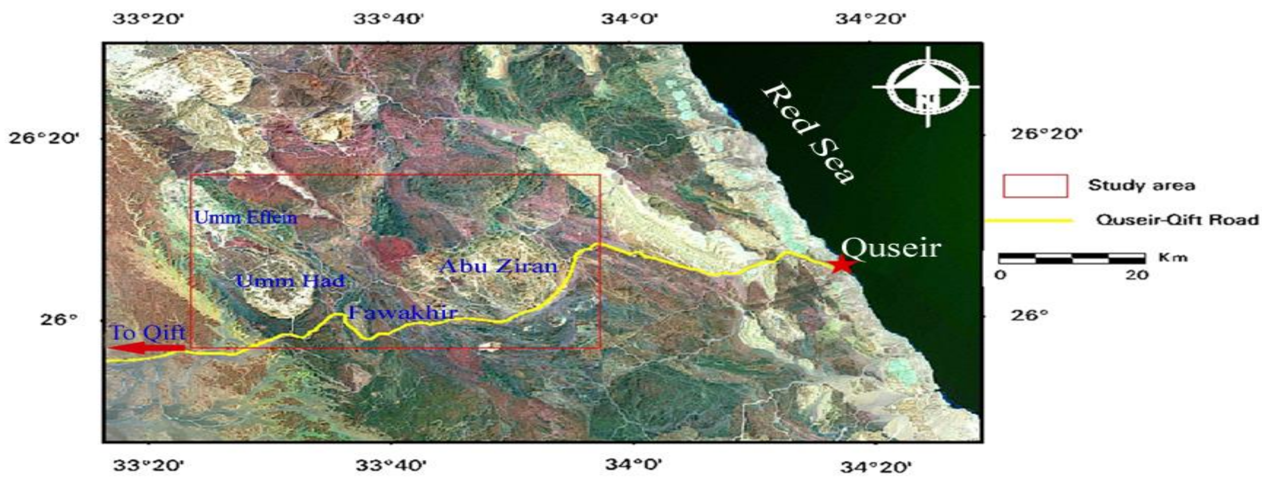


Fig. 1. Landsat image showing the location of the study area.

*Corresponding author e-mail: said_abdelrahim@yahoo.com ORCID iD: https://orcid.org/0000-0002-1456-7783
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The geological, petrological, geochemical, geochronological " age dating" and geotectonics studies; assessment of ornamental stones and the remote sensing at the Abu Ziran area have attracted the attention of many authors, e.g. [1-24]; whereas there is no any attention for granodiorite rock utilization in the formulation of ceramic. Therefore, the aim of this work is mainly represents the first attempt for utilizing the granodiorite in the preparation of ceramic that can be used in insulation for heat and sound. The primary raw materials considered wealth for any country when used well. The igneous or metamorphic rocks subjected to weathering usually changed with the time into sedimentary ones. Recently, [25] metioned that many igneous, metamorphic rocks are used as fluxes in cermaic industries. Researchers used many residues of qurries or mines and solid industrial wastes in ceramic manufactures. However many researchers prefer aluminosilicate containing rocks, that can used either in refractories, composites or ceramics materials. Clays are famous in the later materials and widely used in ceramics. Also residues of granites or basalts quarries are very useful in ceramic, glaze, …etc. Residue of steatite and kaolin were used in preparation of ceramic composites, their sintering up to 1300 $^oC$, gave enstatite, mullite, periclase, hematite and both clino-and protoenstatite as well [26]. The later material have good strength that reach 78 MPa. Ceramic material, from glassy matrix with enstatite and forsterite, were prepared from dust of harful serpentine asbestos (45-70 wt%) with clay-sand mix (30-50%) and glass waste (0-5%). Such ceramic material help in reducing the hazardus asbestos and it have a bending strength between 2.85-56.97 MPa [27]. Mixture of cordierite and andalusite containing with little enstatite mullite and cristobalite ceramic was prepared from admixed andalusite and clay sintered up to 1350 $^oC$ [28]. Ceramic tiles like commercial ones were prepared from granodiorite and clay [29]. Egyptian nepheline syenite (0, 5, 10, 15 %) was used in the usual ceramic batch (kaoline-sand) and the resultant fired samples up to 1260 °C gave mullite in glassy matrix [30]. The binary wastes of metamorphic slate (10 to 60 %) with ulexite were used as a glaze raw material and its firining up to 1160 $^oC$, produce glaze in honey and buff to reddish brown colour [31]. Residue of limestione with silica fume and glass waste were used in produce composite ceramic of wollastonite and pseudowollastonite which have considerable properties [32]. In the present work, granodiorite and talc were used in preparation ceramic composite material. The sintered composite samples were charctarized both the developed phase and their microstructures. Also densities and porosities of the sintered ceramic samples were measured too.

## 2.Geological setting

The Abu Ziran area is located in the Central Eastern Desert of Egypt between latitudes 26º 00' 00”- 26º 03' 12” N and longitudes 33º 45' 24”- 33º 53' 12” E (Fig. 2). The study area covered by the following rock varieties: orthogneisses, psammitic gneiss, myllonite, amphibolites, serpentinite, metagabbro, Abu Ziran granitoids (diorite, tonalite, granodiorite, monzogranite) and Arieki monzogranite. The granodiorite (Figs. 3a,b and c) is the subject of the present paper. The use of granite as a building material is continuously increasing around the world [21]. Granite, as a natural rock with important construction characters. The quality of granite as ornamental stone depends on various factors such as grain size, color, and weathering [18]. It is found that the granodiorite rock of Abu Ziran pluton (Figs. 3a,b and c) is promising for exploitation and suitable to be quarried as ornamental stones [23]. Besides, granite can be beneficially used in the preparation of stoneware ceramic bodies to produce ceramic floor tiles [33].

## 3.Materials and methods

Geological field trips were done for studying the geologic setting and collecting some representative rock samples of the granodiorite from the area under study. Thin sections and polished surfaces were prepared for each sample. The thin sections and polished surfaces of the granodiorite were studied in detail using Transmitted Light and Reflected Light Nikon Research Polarizing Ore Microscope (Model Optiphot 2-PoL, attached with Nikon Digital Camera, Model DS-Fi2, made in Japan). Chemical analyses of the granodiorite rock were done by XRF device at the National Research Centre in Egypt.

### *3.1. Processing*

The starting material in preparation the present ceramic materials are granodiorite (Abu Ziran area) and talc (Hamata area) from quarries wastes in the Eastern Desert, Egypt (Table 1). Four samples were prepared with the ratios 70:30, 60:40, 50:50 and 40:60 of granodiorite: talc (Table 2). Both samples were subjected to pulverizing, quartering and get a representative sample of 0.037 mm grain size. Green mixtures were prepared from the mixtures using PVA solution (7%) as binder, The green discs were prepared by shaping the samples using uniaxial pressure (20 KN). The green samples were subjected to drying at 200 °C to evaporate the PVA solution then sintered up to 1300 °C from some samples.

Identification of the developed phases, after sintering process, was by X Ray Diffraction analysis (XRD-model-Bruker AXS D8 advance using Cu Kα-radiation). For examination the microstructures, Scanning Electron Microscopy (SEM, model FEJ quanta 250 Fei, Holland) was used on fresh fracture surface. The later samples were subjected to etching using 1%$HNO_3$ + 1% HF solution for 30 seconds before check-up in the SEM.

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**Table 1.** Chemical composition of the starting raw materials.

| Raw material | Constituents in oxide wt.% | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | FeO | $MnO_2$ | MgO | CaO | $Na_2O$ | $K_2O$ | $P_2O_5$ | IL |
| Granodiorite | 62.83 | 1.06 | 15.48 | 1.23 | 6.99 | 0.09 | 2.09 | 4.34 | 3.72 | 1.79 | 0.37 | 0.88 |
| Talc | 65.17 | nd | 1.68 | 0.42 | 0.00 | nd | 31.85 | 0.42 | 0.34 | 0.12 | 0.17 | |

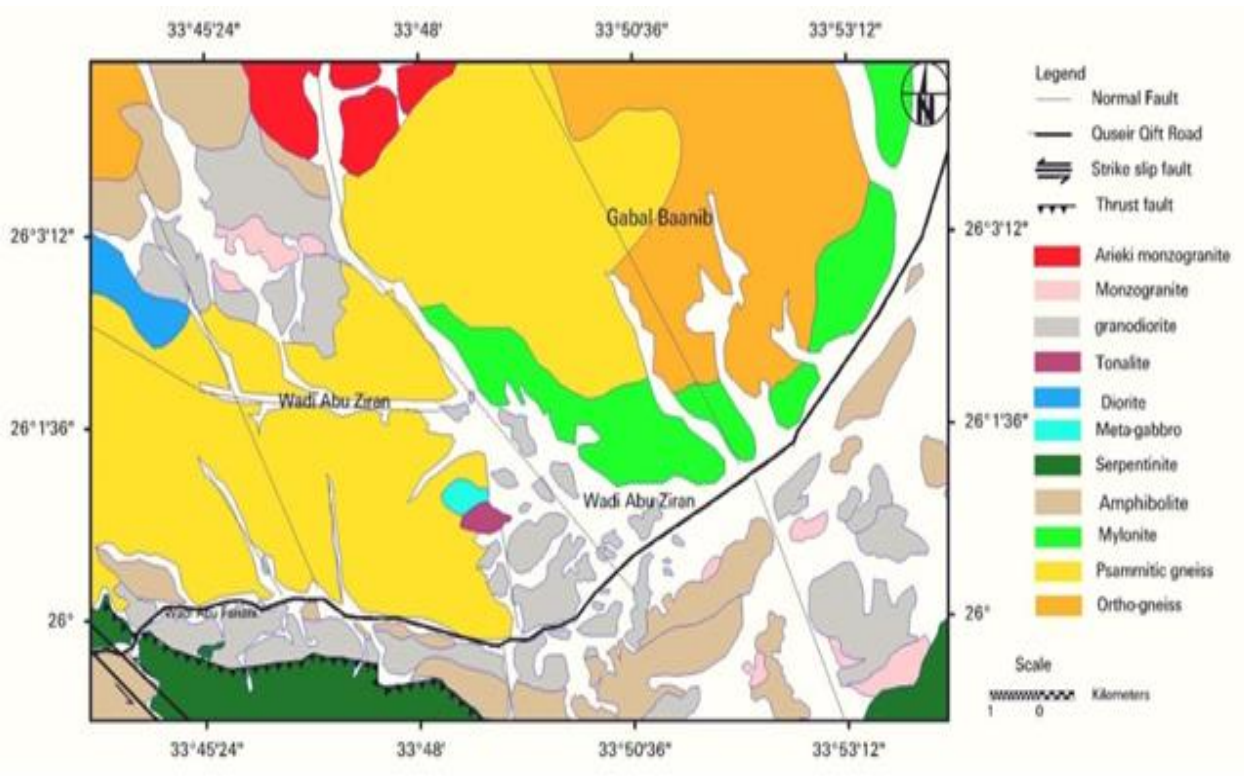



Fig. 2. Geologic map of Abu Ziran area (Khyamy et al., [20] and is modified by Abd El Ghaffar [23]).

**Table 2.** Chemical composition of the ceramic batches.

| Sample No. | Constituent Ratio | | Chemical composition in wt % | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | G | T | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | FeO | $MnO_2$ | MgO | CaO | $Na_2O$ | $K_2O$ | $P_2O_5$ |
| G10 | 10 | 00 | 62.83 | 1.06 | 15.48 | 1.23 | 6.99 | 0.09 | 2.09 | 4.34 | 3.72 | 1.79 | 0.37 |
| GT73 | 7 | 3 | 63.53 | 0.74 | 11.34 | 0.99 | 4.89 | 0.06 | 11.02 | 3.16 | 2.71 | 1.29 | 0.26 |
| GT64 | 6 | 4 | 63.77 | 0.64 | 9.96 | 0.91 | 4.19 | 0.05 | 14.00 | 2.77 | 2.37 | 1.12 | 0.22 |
| GT55 | 5 | 5 | 64.00 | 0.53 | 8.58 | 0.83 | 3.49 | 0.05 | 16.97 | 2.38 | 2.03 | 0.95 | 0.19 |
| GT46 | 4 | 6 | 64.23 | 0.42 | 7.20 | 0.75 | 2.80 | 0.04 | 19.95 | 1.99 | 1.69 | 0.79 | 0.15 |

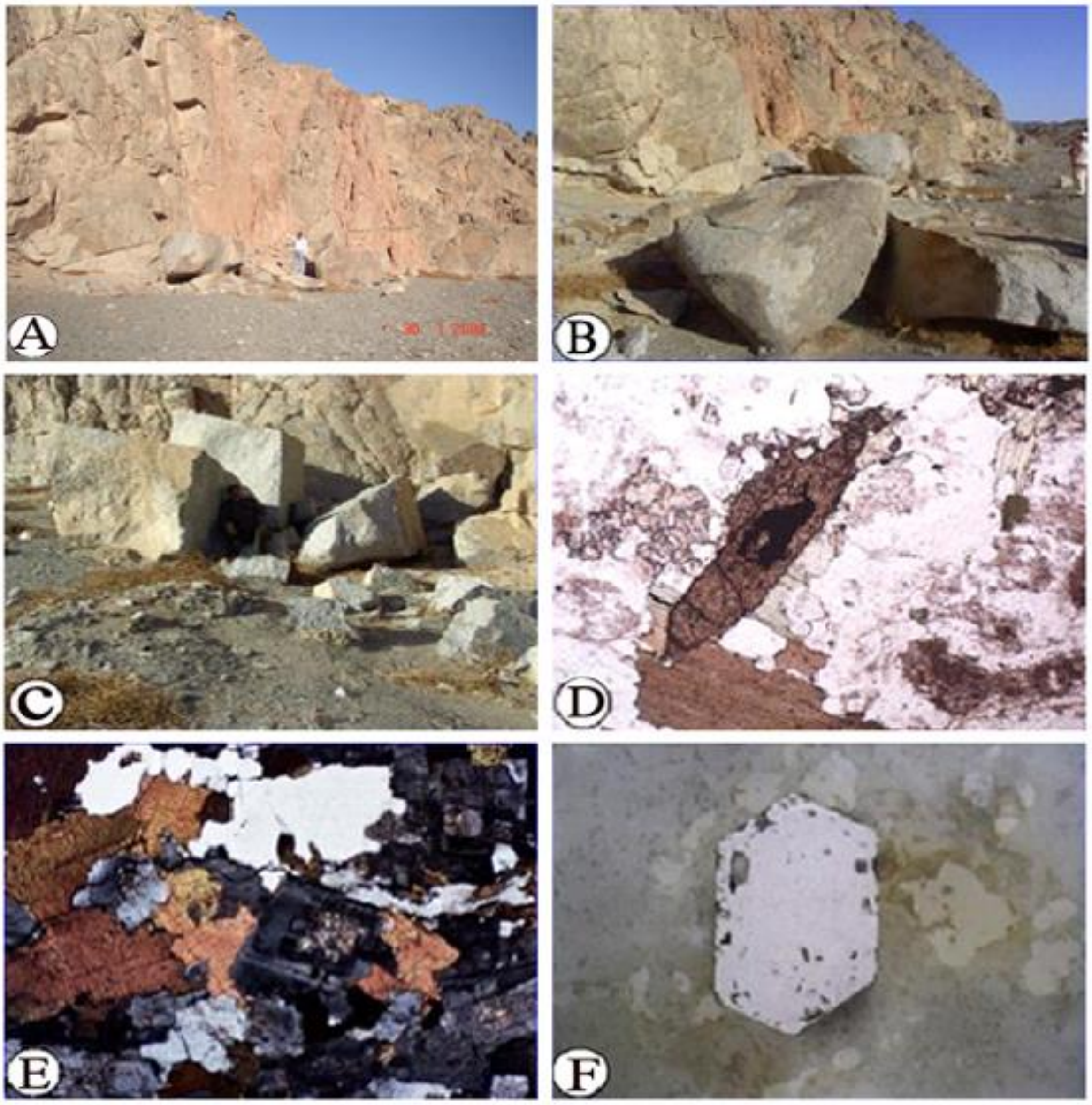



**Fig. 3.** (A) Low lying masses of the granodiorite. (B) Close up view showing jointed granodiorite. (C) Old workings of the granodiorite ornamental stones quarry. (D) Photomicrograph of wedge shaped sphene crystal enclosed opaques. PPL, 40X. (E) Photomicrograph showing association of oligoclase, quartz, potash feldspars, biotite, hornblende and opaques. C.N, 40X. (F) Photomicrograph showing magnetite pseudomorphs after euhedral cross section of hornblende. RPL, 200X

## 4.Results and Discussion

*4.1. Characterization of the raw materials*

*4.1.1. Microscopical investigations*

The granodiorite is the dominant rock among the exposed granitoids and it is the subject of the present paper. The granodiorite exhibits equigranular, myrmektic and perthitic textures (Figs. 3d and e). The essential minerals are plagioclase "oligoclase", quartz, potash feldspars, biotite and hornblende. The accessory minerals include sphene, zircon, apatite and opaques "magnetite" (Fig. 3f). The secondary minerals are represented by epidote, allanite, sericite and muscovite.

*4.1.2 Chemical and mineralogical analyses*

The chemical composition of the present ceramic material show that it is rich in $SiO_2$, MgO, $Al_2O_3$, FeO, CaO, ..which can restrict the possible crystalline phases may be within $SiO_2$-MgO, $SiO_2$-$Al_2O_3$ and $SiO_2$-MgO-$Al_2O_3$. However the samples were sintered at different temperatures between 1200 ºC and 1300 °C (Figs. 4-6). The sintering process of G10, GT73, GT64, GT55 and GT46 samples between 1200 ºC and 1300 °C, show the crystallization of enstatite aluminum [$Mg_{0.961}Al_{0.027}SiO_3$ - ICDD 76-2428], kyanite [$Al_2SiO_5$ - ICDD 74-2217], pyrope [$Mg_3Al_2(SiO_4)$ - ICDD 72-0124] and little cristobalite [$SiO_2$ - ICDD 82-1403]. Sintering process at 1200 °C of G10 sample or granodiorite alone, kyenite was developed as the major phase with little enstatite aluminium and cristobalite whereas incorporation of 30% (GT73) or 50% (GT55) talc enhanced the crystallization of enstatite aluminium as the major phase (Fig. 4). However the later phase became the major phase with very little cristobalite at 1250 °C in the GT64, GT55 and GT46 samples (Fig. 5). Increase the sintering temperature of GT46 sample up to 1300 °C led to appearance of pyrop in addition to the major enstatite aluminium and little cristobalite (Fig. 6). Generally kyanite was developed at low temperature 1200 °C in G10 sample of the highest alumina and silica, however, it became the second phase after the major aluminum enstatite with incorporation of talc in the GT73 and GT55 samples. Increase of talc over grandiorite led to formation of pyrope with the later major aluminum enstatite.

The microstructure of the sintered ceramic samples show particle sizes between micron and submicron. The sintered granodiorite G10 sample shows oriented and randomly oriented crystals scattered in glassy matrix and pores. It also shows directed parallal rod-like crystal of kyanite in submicron size and also some scattered tetragonal crystal of cristobalite (Fig. 7). Other GT73, GT64, GT55 and GT46

Samples show similar crystal shape. Euhedral crystals were spread in four and six sides in GT64 samples, also some quadrant twin crystals were also developed in GT55 sample (Fig. 7). The present ceramic samples show total porosity and bulk density ranges from 39.27 to 18.01 % and from 1.65 to 2.21 g/cm3 respectively (Table 3). It is clear that increase of talc ratio concomitant with decrease of density and increase of porosity. Incorporation of talc [$Mg_3SiO_4(OH)_2$] mean an increase of OH group which liberate at high temperature and causes the pores in the ceramic body.

The present results show that, we can get ceramic materials can resist the temperature up to 1000 ºC and have good properties. These refractoriness materials have good density (average 1.97g/cm$^3$) and porosity (average 27.52 %). This cheap materials can be used in insulation for sound and temperature (up to 1000 °C) and building materials.

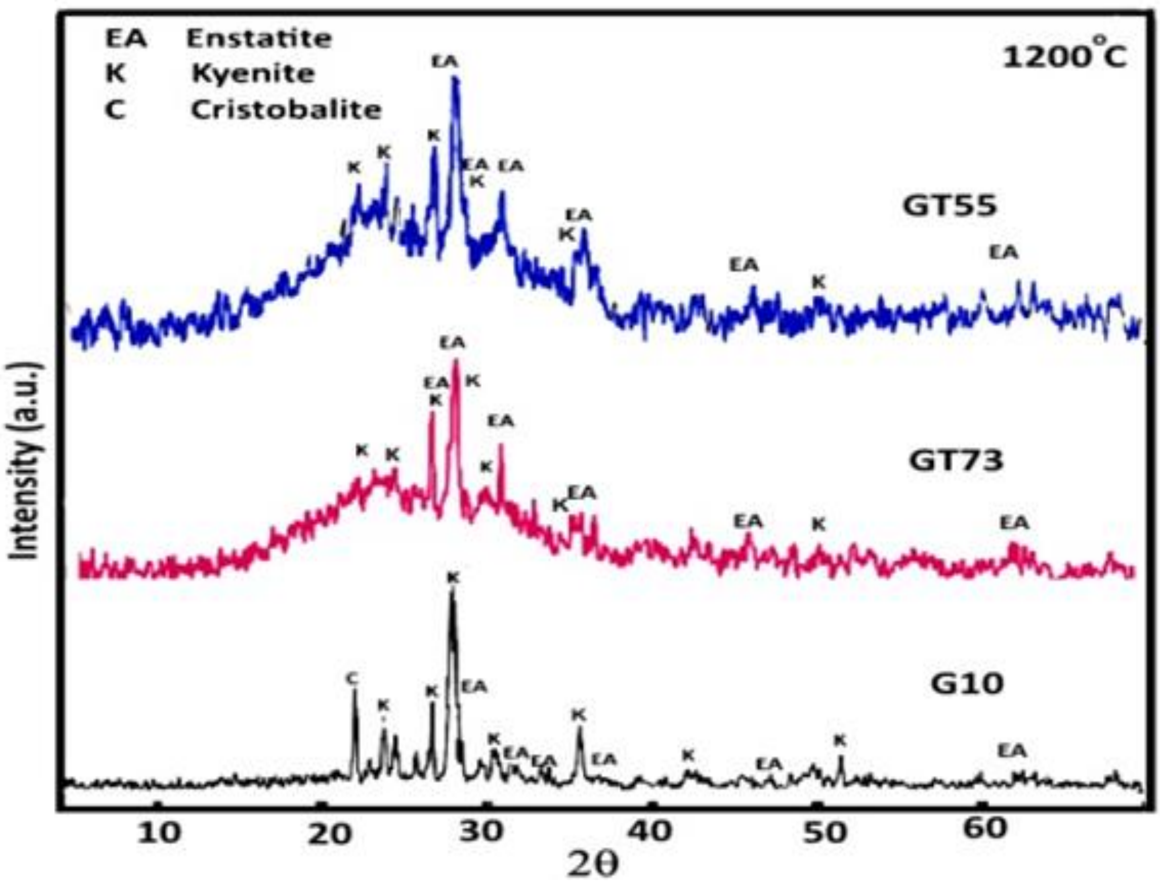



**Fig. 4.** X ray diffraction patte-rns of G10, GT73 and GT55 sintered at 1200 °C for 2h.

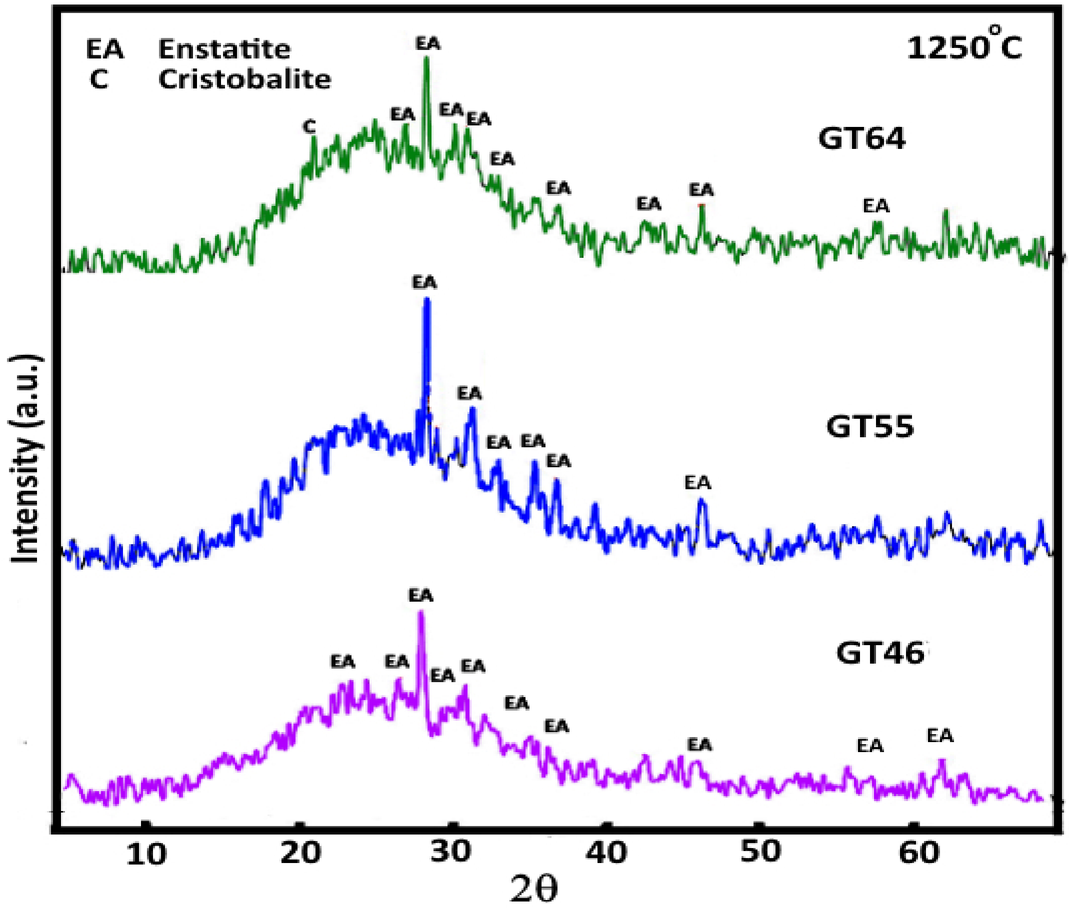
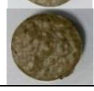



**Fig. 5.** X ray diffraction patterns of GT46, GT55 and GT64 sintered at 1250 °C for 2h.

**Table 3.** Densties, porosities and shape of the samples after sintering process.

| Sample Code | Sintered at °C/2h | Bulk density g/cm$^3$ | Ratio of total Porosity % | Ratio of closed pore % | Sample shape |
|---|---|---|---|---|---|
| **G10** | 1200 | 2.21 | 18.01 | 10.86 |  |
| **GT73** | 1200 | 2.16 | 20.26 | 12.63 |  |
| **GT64** | 1250 | 1.65 | 39.27 | 31.45 |  |
| **GT55** | 1250 | 2.00 | 26.51 | 23.57 |  |
| **GT46** | 1300 | 1.81 | 33.54 | 27.10 |  |

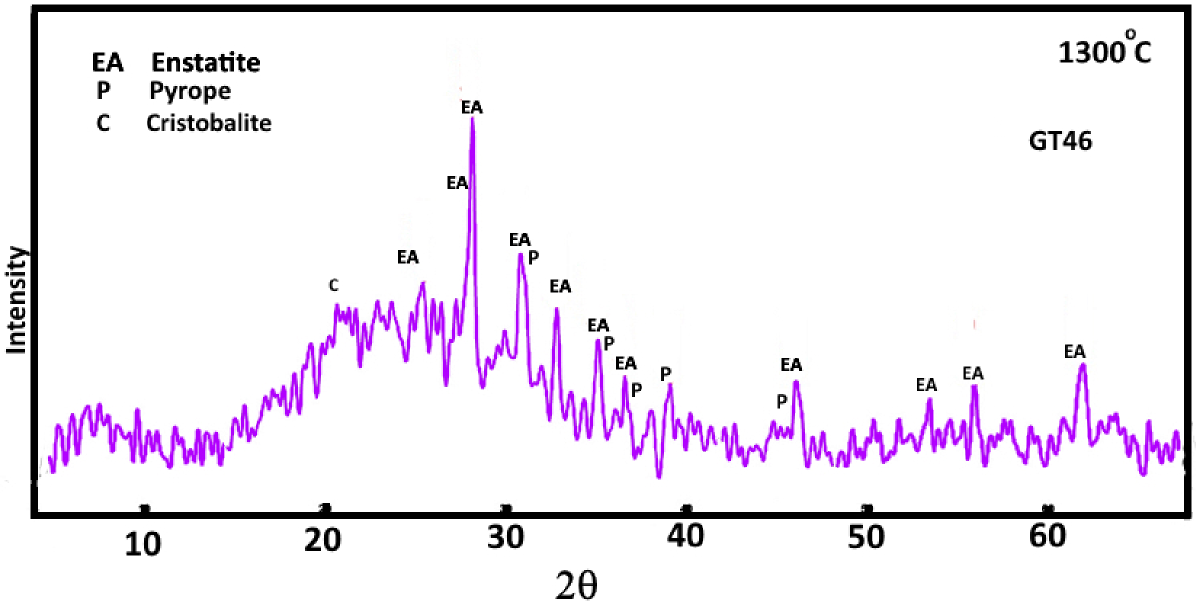



**Fig. 6.** X ray diffraction patterns of GT46 sintered at 1300 °C for 2h.

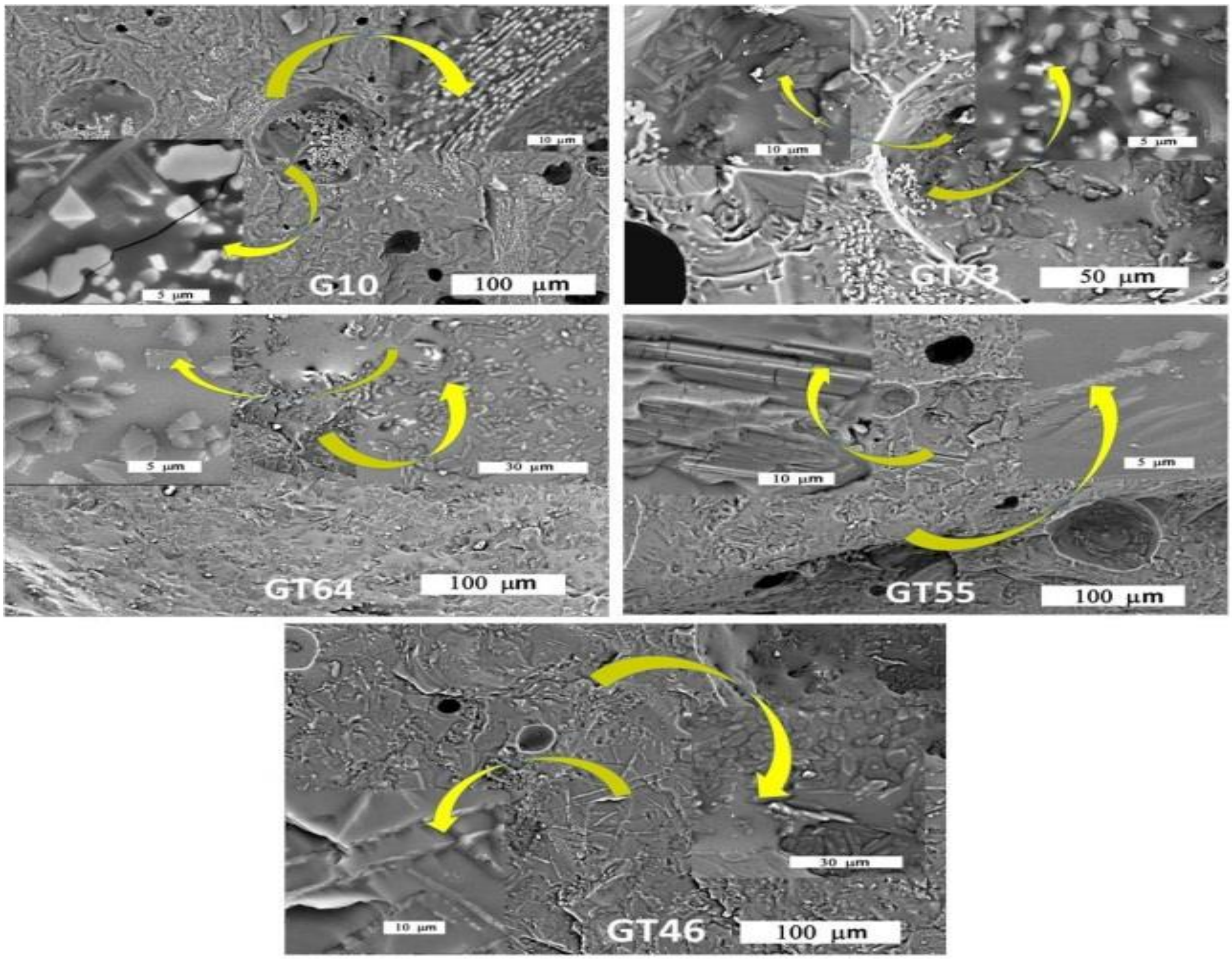



**Fig. 7.** SEM micrographs of G10, GT73, GT64, GT55 and GT46 samples sintered at different temperatures

## 5. Conclusions

Microscopically, the Abu Ziran granodiorite is essentially composed of oligoclase, quartz, orthoclase, microcline, biotite and hornblende. The accessory minerals include sphene, zircon, apatite and magnetite. According to its characteristics, granodiorite can be used in the production of the low cost ceramic product**.**

The sintered admixed mixtures of granodiorite and talc between 1200 ºC and 1300 ºC, shown the crystallization of aluminum enstatite, kyanite, pyrope and cristobalite. The microstructures of the composite ceramic sintered samples was modified into rod-like crystals in micron and submicron size which spread in glassy groundmass. This ceramic samples were enjoyed good density (between 1.81 and 2.21g/cm$^3$) and porosity (between 18.01 and 39.27 %). The present ceramic materials can be used in building materials as insulation process up to 1000 ºC.

## Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. "There are no conflicts to declare".

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