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# Petrography, Geochemistry and Tectonic Settings of Granitic Gneisses from Swarnagadde Plateau of Western Ghats, Karnataka

**Rajendrakumar Y. Budihal[1]*, Manjunatha. S[2], Swanand A. Ajgaonkar[3]**

Associate Professor, Department of Geology, Karnatak Science College, Dharwad-580 001, India [1, 2]

Research Scholar, Department of Geology, Karnatak Science College, Dharwad-580 001, India[3]

*Corresponding Author: Dr. Rajendrakumar Y. Budiha[1]

**Abstract:** The granitic gneisses of the Swarnagadde plateau located on the southwestern margin of Uttar Kannada district forming a basement complex of peninsular gneiss, have been examined in the field, mapped and interpreted on the basis of petrological and geochemical data. This was meant to categorize the rocks and to understand the tectonic setting in order to evaluate the crustal evolution. The chemical analyses were done using inductively-coupled plasma mass spectrometer. From the results obtained, the major element contents of granitic gneisses reflect their fairly homogeneous composition. Mineralogy of rock is dominated by plagioclase (49-62%), quartz (29-42%), K-feldspar (1-5%) and /or hornblende is in decreasing order. The granitic gneisses formed from medium to low grade metamorphism of granite and granodiorite witnessed at a late stage in the Precambrian records of the area. Tectonically most of the rock samples plotted in the field of volcanic arc granite+Syn-collisional granite rocks, which indicated that the protolith granite and granodiorite are volcanic arc magmas predominantly post orogenic development in island-arc to continental and collision zone.

**Keywords:** Granitic gneiss, Swarnagadde, tectonic setting, tonalitic, collision zone.

## I. INTRODUCTION

The Peninsular Gneisses covers major part of the southwest coast consisting of migmatitic grey gneisses which falls within tonalite-trondhjemite-granodiorite composition [1, 2]. The general trend of gneisses is NNE-SSW in the northern parts whereas in the southern part the gneisses and other associate rock types show east westerly trend.These granitic gneisses are about 3200 Ma old [3]. Whereas younger Kanara batholith of granitoid composition (granite, granodiorite to quartz monzonite with diorite border) is dated at 2600 Ma by Rb/Sr method. The major part of the study area is granitic gneiss which occurs as subterranean rocks and comprising nearly 80 percent protolith of the investigated area. The granitic gneisses form a part of the Kanara gneisses [3] or north western/coastal continuation of peninsular gneisses [6] and occur as the most abundant rock formations of the Swarnagadde plateau [3, 4]. These rocks are principally of tonalitic to granodioritic in nature [5].

Formation of these granitic gneisses are the result of influx of tonalitic, trondhjemitic to granodioritic matter into the crust around 3000 Ma ago [6]. Excellent exposures of these rocks are found to occur at North-Western part of the Horbagh village and some outcrops are well exposed in quarry section, railway cuttings and also in recent road cuttings of the study area. Granitic gneisses are medium to coarse grained, moderate to highly foliated and dark to light grey in colour. The extent of the study of gneisses is well within the wide range covered by the peninsular gneiss and presumably has the same genetic history as the peninsular gneiss.

## II. GEOLOGICAL BACKGROUND

The granitic gneisses comprise nearly 70 to 80 per cent of the bed rocks of the study area. These are exposed at the base and along the northern and eastern scarp regions of the plateau that lies within Latitude 74° 24´ to 74° 30´ E and Longitude 14° 18´ to 14° 24´ N at the south western margin of the Peninsular region as in Fig 1. Nevertheless, excellent exposures occur about 5 km south and south-east of Chandavara village. On the other hand, exfoliation or scaling is the most common and prominent feature noticed in the relatively large exposed outcrops of granitic gneisses. These granitic gneisses appear in various shades of grey to pink, are fine to medium grained and possess a gneissic to massive texture. Locally there are coarse-grained, mineralogically similar bodies with sharp to gradational contacts. In part, the gneiss exhibits a salt and pepper texture and is mesocratic. The leucocratic variety is light grey to pink and locally possesses mafic lenses, pods and streaks as inclusions. Quartzo-feldspathic pegmatite veins and irregular bodies are common in the

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leucocratic granitic gneiss. In the study area, the mafic to felsic constituents differs considerably from out crop to out crop. The lighter leucocratic varieties have some potash feldspars and may locally be more abundant than plagioclase.
This quartzo-feldspathic pegmatite veins vary in colour from grey to white and in grain size coarse to fine. The grain size variation is seen both amongst the different bodies and within the individual body. Within the individual body, the variation may be irregular or include fine grained (aplitic) core and coarse grained borders or vice versa. There perhaps exist two or more generations of quartzo-feldspathic infusions and appear to be both magmatic and metamorphic/metasomatic. Orientation of quartzo-feldspathic pegmatite veins particularly of syntectonic metamorphic/metasomatic ones, parallel to banding/foliation is a common feature; the post-tectonic pegmatitic infusions may, however, show discordant relation. A random thin section examination of the quartzo-feldspathic infusions reveals the large mineralogical variations among them; generally the coarse and pinkish varieties are K-feldspar bearing, while the whitish/leucocratic and finer grained ones are plagioclasic.

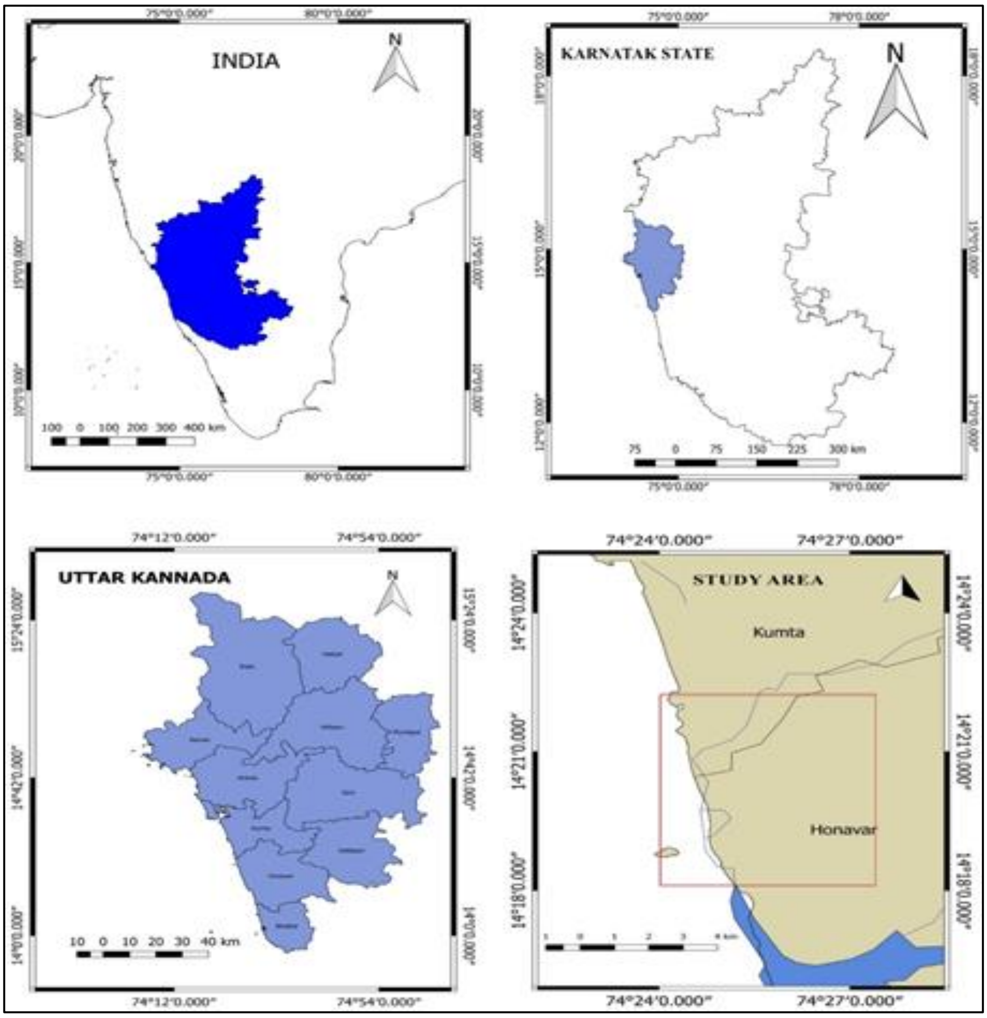


**Fig 1:** Geological map of the study area. Inset: Maps of the study area showing the distribution of granitic gneisses.

## III. PETROGRAPHY

The equigranular light/ash grey coloured granitic gneisses which outcrops at the study area are strong gneissic banding/foliated to massive, and medium to coarse grained. These rocks display imprint of well-developed gneissosity, manifested in terms of alternate dark (mafic minerals) and light coloured (quartzo-feldspathic) bands. Microscopically the granitic gneisses exhibit xenomorphic granular texture. Mineralogically granitic gneisses are considerably plagioclasic in character. Quartz is only next in importance and K-feldspar is a minor mineral phase. Biotite, hornblende, epidote and muscovite are the common mafic minerals. Chlorite, calcite, apatite, zircon and Fe-Ti oxides are the common accessories of the granitic gneisses of the study area.

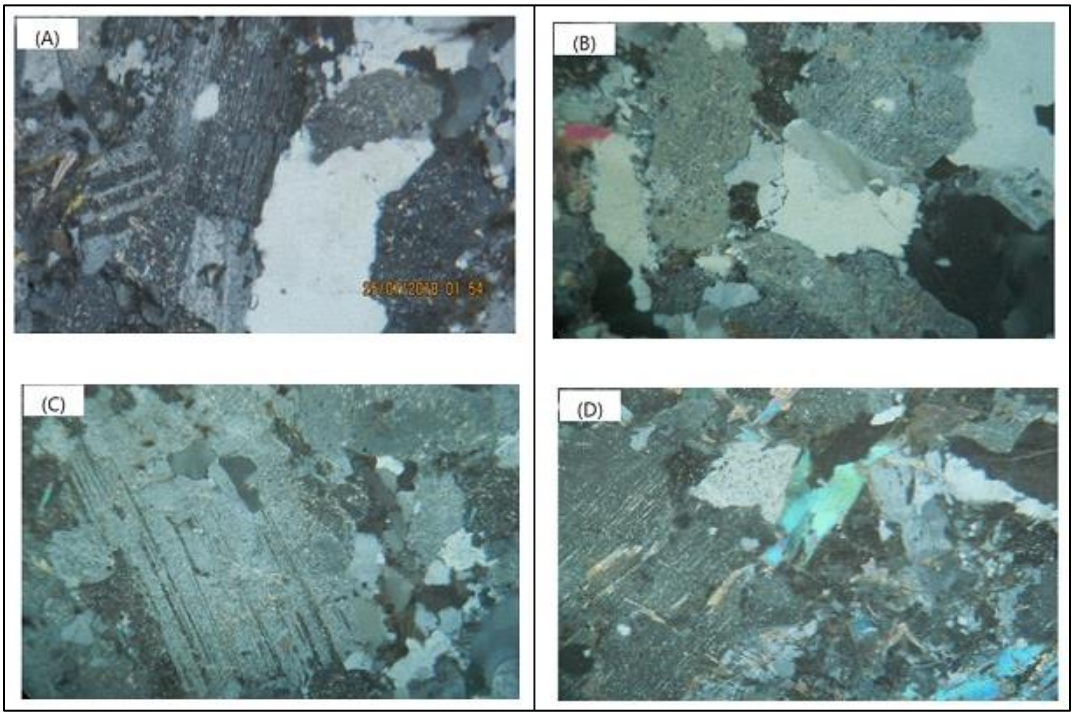


**Fig 2 (A-D): (A)** Photomicrograph of Granitic gneiss shows evidences of K-feldspar and quartz.
**(B)** Photomicrographs shows anhedral grains of quartz occupying the grain boundaries of feldspar grains.
**(C)** Photomicrograph of granitic gneiss shows hypidiomorphic texture with strong sericitisation of plagioclase.
**(D)** Photomicrograph of granitic gneiss exhibits alteration of biotite to chlorite.

**A. Modal composition**

Mineral (modal) and Chemical compositions are the two most used numerical and effective parameters in classifying and describing granitoid rocks [7, 8, 9, 10]. These properties have relatively close relationships, but the mineral composition does not strictly correlate with the chemical composition of the granitoids. For example, the A/CNK values that are used to discriminate I- and S-type granitoids have no direct relationship to the modal composition of the rock. The chemical and modal composition of granitoid rocks are related to a large number of factors, such as variable magmatic source and differentiation processes [11]. In addition, regional or contact metamorphism can later change the mineral modes of granitoid rocks. Modal analyses of nine granitic gneiss samples have been presented in the Table 1 for petrographic classification. The mineralogy of the rock is dominated by plagioclase (49-62%), quartz (29-42%), K-feldspar (1-5%), biotite (1-4%) and/or hornblende in decreasing order of abundance. As per the IUGS-Streckeisen [7, 12] classification, the plot of the granitic gneisses of the study area lies in the field of trondhjemites of the Q-A-P diagram (Fig 3).

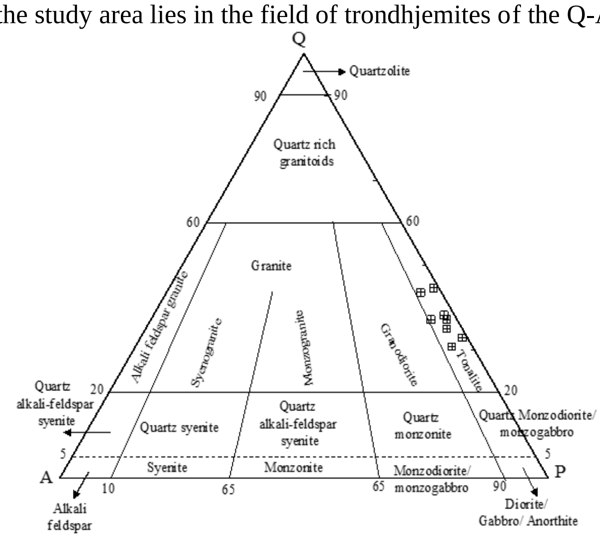


**Figure 3.** Q-A-P ternary plots of modal analyses of granitic gneisses of the Swarnagadde plateau after Streckeisen, [7].

  

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**Table 1.** Modal composition of Granitic gneisses of the Swarnagadde Plateau.

| Minerals | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Av |
|---|---|---|---|---|---|---|---|---|---|---|
| Quartz | 35 | 36 | 35 | 29 | 41 | 31 | 33 | 35 | 42 | 35.22 |
| K-feldspar (Alkali) | 5 | 2 | 2 | 4 | 4 | 1 | 3 | 2 | 1 | 2.67 |
| Plagioclase | 54 | 56 | 57 | 61 | 49 | 62 | 58 | 57 | 51 | 56.11 |
| Q+A+P | 94 | 94 | 94 | 94 | 94 | 94 | 94 | 94 | 94 | 94.00 |
| Biotite | 1 | 2 | 3 | 3 | 4 | 2 | 1 | 2 | 2 | 2.22 |
| Hornblende | 2 | 0 | - | 1 | - | 1 | - | 3 | - | 1.40 |
| Epidote | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 1.56 |
| Muscovite | 0 | - | - | - | 0 | - | 2 | - | 1 | 0.75 |
| Calcite | 0 | - | 1 | - | - | - | - | - | - | 0.50 |
| Accessories/ Opaque's | 1 | 2 | 0 | 1 | 1 | 1 | 1 | 0 | 2 | 1.00 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.00 |
| Q | 37.23 | 38.30 | 37.23 | 30.85 | 43.62 | 32.98 | 35.11 | 37.23 | 44.68 | 37.47 |
| A | 5.32 | 2.13 | 2.13 | 4.26 | 4.26 | 1.06 | 3.19 | 2.13 | 1.06 | 2.84 |
| P | 57.45 | 59.57 | 60.64 | 64.89 | 52.13 | 65.96 | 61.70 | 60.64 | 54.26 | 59.69 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

## IV. MATERIAL AND METHODS

In order to understand the broad geochemical characteristics of granitic gneisses of the study area, 12 samples have been chemically analysed for major, minor and trace elements by using inductively coupled plasma optical emission spectroscopy (ICP-OES for major and minor oxides) and inductively coupled plasma mass spectroscopy (ICP-MS for trace elements) with fusion opening (lithium borate) and, with 4-acid digestion. A software package GCD kit 4.1 in R programming language was used to plot all the classification and geotectonic setting diagrams employed for this study. The chemical whole rock analytical data obtained for the different granitic gneisses of the study area are presented in Table 2.

### A. Results

### A.1 Geochemistry

The results of chemical whole rock major and minor oxides (in %) and some trace elements (in ppm) analyses of 12 rock samples (Table 2) have been used to classify the granitic-gneiss rocks and to understand the geotectonic setting in order to evaluate the crustal evolution in the study area. Geochemically the granitic gneiss has a composition with the range of silica content between 71.71% and 73.26%. The content of $TiO_2$ is more or less consistent, 0.34 to 0.65%.

The $Fe_2O_3$ varies between 1.69 and 2.89%. These granitic gneisses have higher $Na_2O$ content rages from 4.24 to 5.40 wt% with most of the samples showing around 4.5 wt%, whereas $K_2O$ content ranges from 0.90-1.26 wt%. The observable $N_2O/K_2O$ ratios are in the range of 3.33 to 5.62 wt% with majority of the values between 3 and 4, the rock is fairly sodic. On the other hand the ratios of $K_2O/Na_2O$ are ranges from 0.18 to 0.30 wt% which is typical of tonalites and trondhjemites. They are also commonly rich in alumina, and almost all the samples show $Al_2O_3$ more than 14.26 and less than 15.10 in wt%. The granitic gneisses of the study area are relatively poor in ferromagnesian elements ($Fe_2O_3$+MgO+MnO+$TiO_2$ = 2.61 to 4.42 wt %) and majority of the samples show 3.4 to 4.2 wt%.

The major element compositions along with differentiation index (D.I) of granitic gneisses are available and those are furnished in Table 2 and it is evident that granite gneisses are quartz normative, with variable amount of normative quartz. The D.I. values of normative quartz ranges from 33.61 to 39.88. The differentiation index (D.I) for granitic gneisses varies from 82.55 to 86.44 [13].

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**Table 2.** Chemical compositions of major, minor (in %) and trace (in ppm) of the Granitic gneisses of the study area.

| Oxide | BSG-71 | BSG-74 | BSG-57 | BSG-59 | BSG-75 | BSG-76 | BS-78 | BS-83 | BS-84 | BS-85 | BS-87 | BS-89 | Av |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ (wt. %) | 71.71 | 72.25 | 72.06 | 73.11 | 73.26 | 72.04 | 72.42 | 71.87 | 72.56 | 72.06 | 72.83 | 72.27 | 72.38 |
| $TiO_2$ | 0.46 | 0.65 | 0.34 | 0.52 | 0.45 | 0.65 | 0.44 | 0.56 | 0.50 | 0.48 | 0.57 | 0.46 | 0.51 |
| $Al_2O_3$ | 14.91 | 14.73 | 14.87 | 14.97 | 14.26 | 15.10 | 14.77 | 15.00 | 14.63 | 14.85 | 14.95 | 14.60 | 14.79 |
| $Fe_2O_3$ | 2.89 | 2.54 | 2.48 | 1.69 | 2.45 | 2.43 | 2.38 | 2.66 | 2.56 | 2.85 | 2.35 | 2.17 | 2.43 |
| MnO | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| MgO | 1.02 | 0.51 | 1.01 | 0.39 | 0.97 | 0.77 | 0.76 | 0.89 | 0.93 | 0.90 | 0.80 | 0.64 | 0.78 |
| CaO | 0.45 | 2.08 | 0.70 | 1.18 | 0.79 | 0.97 | 1.09 | 0.71 | 0.75 | 0.74 | 1.56 | 1.00 | 1.04 |
| $Na_2O$ | 4.24 | 5.06 | 5.21 | 5.40 | 5.03 | 5.09 | 4.96 | 4.66 | 4.85 | 4.62 | 4.20 | 4.72 | 4.83 |
| $K_2O$ | 1.26 | 0.90 | 1.20 | 1.00 | 1.12 | 1.13 | 1.10 | 1.40 | 1.16 | 1.07 | 0.85 | 1.04 | 1.10 |
| $P_2O_5$ | 0.05 | 0.09 | 0.07 | <0.05 | 0.08 | 0.07 | 0.07 | 0.06 | 0.07 | 0.06 | 0.08 | 0.06 | 0.07 |
| $Cr_2O_3$ | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| LOI | 2.69 | 1.06 | 1.63 | 1.50 | 1.28 | 1.63 | 1.69 | 2.16 | 1.72 | 1.74 | 1.07 | 1.61 | 1.68 |
| Total | 99.80 | 99.85 | 99.58 | 99.75 | 99.68 | 99.88 | 99.69 | 99.98 | 99.73 | 99.37 | 99.25 | 98.58 | 99.63 |
| D.I | 83.21 | 82.55 | 85.54 | 86.44 | 85.99 | 84.84 | 84.57 | 84.44 | 85.02 | 83.76 | 81.41 | 84.00 | |
| $K_2O/Al_2O_3$ | 0.08 | 0.06 | 0.08 | 0.07 | 0.08 | 0.07 | 0.07 | 0.09 | 0.08 | 0.07 | 0.06 | 0.07 | 0.07 |
| $Na_2O$ $Al_2O_3$ | 0.28 | 0.34 | 0.35 | 0.36 | 0.35 | 0.34 | 0.34 | 0.31 | 0.33 | 0.31 | 0.28 | 0.32 | 0.33 |
| $K_2O/Na_2O$ | 0.30 | 0.18 | 0.23 | 0.19 | 0.22 | 0.22 | 0.22 | 0.30 | 0.24 | 0.23 | 0.20 | 0.22 | 0.23 |
| $Na_2O/K_2O$ | 3.37 | 5.62 | 4.34 | 5.40 | 4.49 | 4.50 | 4.51 | 3.33 | 4.18 | 4.32 | 4.94 | 4.54 | 4.46 |
| K/Na | 0.17 | 0.10 | 0.13 | 0.10 | 0.12 | 0.12 | 0.12 | 0.17 | 0.13 | 0.13 | 0.11 | 0.12 | 0.13 |
| Ti | 0.28 | 0.39 | 0.20 | 0.31 | 0.27 | 0.39 | 0.27 | 0.33 | 0.30 | 0.29 | 0.34 | 0.27 | 0.30 |
| Fe | 2.02 | 1.78 | 1.73 | 1.18 | 1.71 | 1.70 | 1.67 | 1.86 | 1.79 | 1.99 | 1.64 | 1.52 | 1.70 |
| Mg | 0.61 | 0.30 | 0.61 | 0.23 | 0.58 | 0.47 | 0.46 | 0.54 | 0.56 | 0.54 | 0.48 | 0.39 | 0.47 |
| Ca | 0.32 | 1.49 | 0.50 | 0.85 | 0.56 | 0.70 | 0.78 | 0.51 | 0.54 | 0.53 | 1.11 | 0.72 | 0.74 |
| Na | 3.14 | 3.75 | 3.87 | 4.00 | 3.73 | 3.77 | 3.68 | 3.46 | 3.59 | 3.42 | 3.11 | 3.50 | 3.58 |
| K | 1.05 | 0.74 | 1.00 | 0.83 | 0.93 | 0.94 | 0.91 | 1.16 | 0.96 | 0.89 | 0.71 | 0.86 | 0.92 |
| Trace Be | 0.84 | 0.88 | 0.78 | 1.18 | 0.70 | 0.97 | 0.81 | 0.91 | 0.71 | 0.87 | 1.04 | 0.88 | 0.89 |
| Co | 4.86 | 3.46 | 3.43 | 1.67 | 2.68 | 3.01 | 3.21 | 3.94 | 3.31 | 4.73 | 4.03 | 2.85 | 3.41 |
| Cs | 0.47 | 0.31 | 0.40 | 0.26 | 0.35 | 0.37 | 0.36 | 0.42 | 0.38 | 0.61 | 0.56 | 0.33 | 0.41 |
| Cu | 6.70 | 6.83 | 4.87 | 10.88 | 4.18 | 7.20 | 6.97 | 6.95 | 5.57 | 6.75 | 8.84 | 6.51 | 6.95 |
| Ga | 23.15 | 21.61 | 20.43 | 21.69 | 16.52 | 21.25 | 20.54 | 22.20 | 19.36 | 24.95 | 21.83 | 19.23 | 21.02 |
| Hf | 1.40 | 1.22 | 1.14 | 1.09 | 1.05 | 1.19 | 1.19 | 1.29 | 1.17 | 1.02 | 1.25 | 1.10 | 1.18 |
| Li | 12.04 | 6.42 | 10.36 | 5.97 | 8.30 | 8.58 | 8.71 | 10.31 | 9.31 | 10.71 | 10.55 | 8.15 | 9.10 |
| Mo | 0.85 | 0.86 | 0.78 | 0.84 | 0.00 | 1.06 | 0.89 | 0.96 | 0.48 | 0.87 | 0.97 | 0.48 | 0.72 |
| Nb | 2.52 | 2.14 | 1.90 | 1.97 | 1.71 | 2.07 | 2.07 | 2.30 | 2.01 | 2.29 | 2.56 | 2.00 | 2.13 |
| Ni | 9.72 | 4.93 | 3.18 | 2.95 | 2.78 | 4.60 | 5.08 | 7.16 | 4.97 | 7.55 | 7.23 | 5.01 | 5.55 |
| Pb | 10.31 | 14.49 | 7.85 | 11.60 | 7.38 | 11.10 | 10.58 | 10.71 | 9.05 | 10.39 | 12.48 | 9.93 | 10.55 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rb | 43.68 | 31.35 | 38.97 | 31.53 | 33.38 | 37.03 | 36.37 | 40.35 | 36.87 | 39.86 | 39.17 | 35.61 | 37.09 |
| Sc | 2.17 | 1.74 | 1.57 | 1.52 | 1.33 | 1.68 | 1.69 | 1.92 | 1.62 | 1.92 | 1.43 | 1.62 | 1.69 |
| Sr | 255.37 | 1293.38 | 325.34 | 1145.55 | 275.37 | 663.74 | 688.44 | 659.59 | 367.46 | 459.63 | 978.63 | 617.00 | 662.73 |
| Th | 3.20 | 2.84 | 2.90 | 2.94 | 2.72 | 2.91 | 2.93 | 3.06 | 2.89 | 3.06 | 3.61 | 2.89 | 3.02 |
| Y | 2.87 | 4.18 | 3.96 | 4.55 | 3.65 | 4.36 | 3.87 | 3.62 | 3.63 | 3.40 | 4.24 | 3.55 | 3.81 |
| Zn | 67.99 | 67.25 | 79.64 | 65.19 | 47.17 | 66.42 | 65.06 | 67.20 | 57.19 | 66.76 | 72.58 | 59.88 | 64.94 |
| Zr | 63.36 | 54.39 | 52.21 | 49.41 | 44.28 | 53.44 | 53.09 | 58.40 | 51.34 | 58.12 | 78.24 | 51.20 | 56.43 |

**Table 2 Contd:** CIPW norms and Nigli values of the granitic gneisses of the study area

| Sample | BSG-71 | BSG-74 | BSG-57 | BSG-59 | BSG-75 | BSG-76 | BS-78 | BS-83 | BS-84 | BS-85 | BS-87 | BS-89 | Av |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CIPW | | | | | | | | | | | | | |
| Q | 39.89 | 34.42 | 34.36 | 34.84 | 36.81 | 35.09 | 36.10 | 36.74 | 37.12 | 38.34 | 40.85 | 37.92 | 36.98 |
| C | 5.87 | 1.87 | 3.90 | 2.92 | 3.53 | 3.91 | 3.61 | 4.67 | 4.20 | 4.89 | 4.48 | 4.03 | 3.97 |
| Or | 7.45 | 5.32 | 7.09 | 5.91 | 6.62 | 6.68 | 6.50 | 8.27 | 6.86 | 6.32 | 5.02 | 6.15 | 6.53 |
| Ab | 35.88 | 42.82 | 44.09 | 45.69 | 42.56 | 43.07 | 41.97 | 39.43 | 41.04 | 39.09 | 35.54 | 39.94 | 40.88 |
| An | 1.91 | 9.73 | 3.02 | 5.69 | 3.40 | 4.36 | 4.95 | 3.13 | 3.26 | 3.28 | 7.22 | 4.57 | 4.72 |
| Hy | 2.54 | 1.27 | 2.52 | 0.97 | 2.42 | 1.92 | 1.89 | 2.22 | 2.32 | 2.24 | 1.99 | 1.59 | 1.96 |
| Il | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| Hm | 2.89 | 2.54 | 2.48 | 1.69 | 2.45 | 2.43 | 2.38 | 2.66 | 2.56 | 2.85 | 2.35 | 2.17 | 2.43 |
| Ru | 0.40 | 0.65 | 0.34 | 0.52 | 0.45 | 0.65 | 0.44 | 0.56 | 0.50 | 0.48 | 0.57 | 0.46 | 0.50 |
| Ap | 0.12 | 0.21 | 0.17 | 0.06 | 0.19 | 0.17 | 0.17 | 0.14 | 0.17 | 0.14 | 0.19 | 0.14 | 0.15 |
| Sum | 97.05 | 98.82 | 97.95 | 98.30 | 98.42 | 98.26 | 98.00 | 97.82 | 98.02 | 97.64 | 98.20 | 96.97 | 97.95 |
| NIGLI | | | | | | | | | | | | | |
| Si | 400.20 | 379.10 | 385.36 | 410.50 | 404.12 | 387.99 | 395.65 | 391.93 | 399.17 | 396.15 | 403.39 | 412.98 | 397.04 |
| Al | 49.03 | 45.54 | 46.86 | 49.53 | 46.35 | 47.92 | 47.55 | 48.20 | 47.42 | 48.10 | 48.79 | 49.16 | 47.82 |
| Fm | 20.86 | 14.02 | 18.03 | 10.40 | 18.15 | 16.03 | 15.97 | 18.15 | 18.22 | 19.17 | 16.40 | 14.78 | 16.53 |
| C | 2.69 | 11.69 | 4.01 | 7.10 | 4.67 | 5.60 | 6.38 | 4.15 | 4.42 | 4.36 | 9.26 | 6.12 | 6.06 |
| Alk | 27.42 | 28.75 | 31.10 | 32.97 | 30.84 | 30.45 | 30.10 | 29.50 | 29.93 | 28.37 | 25.55 | 29.94 | 29.53 |
| K | 0.16 | 0.10 | 0.13 | 0.11 | 0.13 | 0.13 | 0.13 | 0.17 | 0.14 | 0.13 | 0.12 | 0.13 | 0.13 |
| Mg | 0.41 | 0.28 | 0.45 | 0.31 | 0.44 | 0.39 | 0.39 | 0.40 | 0.42 | 0.38 | 0.40 | 0.37 | 0.38 |
| C/fm | 1.93 | 2.57 | 1.37 | 2.20 | 1.87 | 2.63 | 1.81 | 2.30 | 2.07 | 1.99 | 2.37 | 1.98 | 2.08 |
| Ti | 0.12 | 0.20 | 0.16 | 0.06 | 0.19 | 0.16 | 0.16 | 0.14 | 0.16 | 0.14 | 0.19 | 0.15 | 0.15 |
| P | 0.13 | 0.83 | 0.22 | 0.68 | 0.26 | 0.35 | 0.40 | 0.23 | 0.24 | 0.23 | 0.56 | 0.41 | 0.39 |
| Qz | 190.51 | 164.11 | 160.96 | 178.61 | 180.77 | 166.17 | 175.25 | 173.92 | 179.44 | 182.67 | 201.18 | 193.24 | 179.21 |

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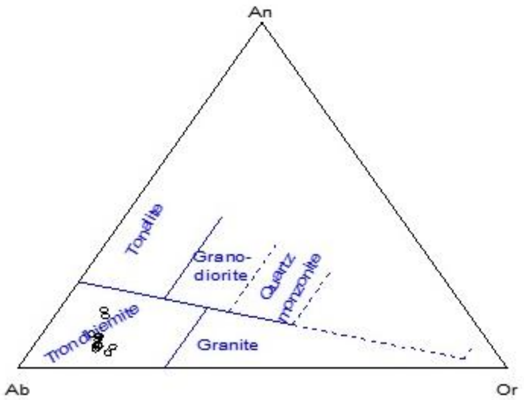


**Fig 4:** Normative Ab-An-Or ternary plot for granitic gneiss after O' Connor, with the fields after Barker [14, 15] showing trondhjemitic trend.

The normative compositions of the granitic gneiss when compared to in An-Ab-Or triangular diagram of O'Connor [14] modified by Barker [15], their composition plot in the trondhjemite field (Fig 4). The normative Q-Ab-Or ternary diagram (Fig 5-A) shows strong trondhjemitic trend indicating predominantly sodic character, which is also archetypical of Archaean rocks. When the ionic weight percentage of K-Na-Ca are plotted in triangular diagram (Fig B) most of the granitic gneisses of the study area are more alkaline than the normal calc-alkaline and show characteristic of Na- and K-enrichment trends [16]. Cao-$Na_2O$-$K_2O$ (Fig C) and $Na_2O$-$K_2O$ (Fig D) contents corresponding to tonalite to trondhjemitic trends which are so typical of the Precambrian shield areas of the world [17, 18].

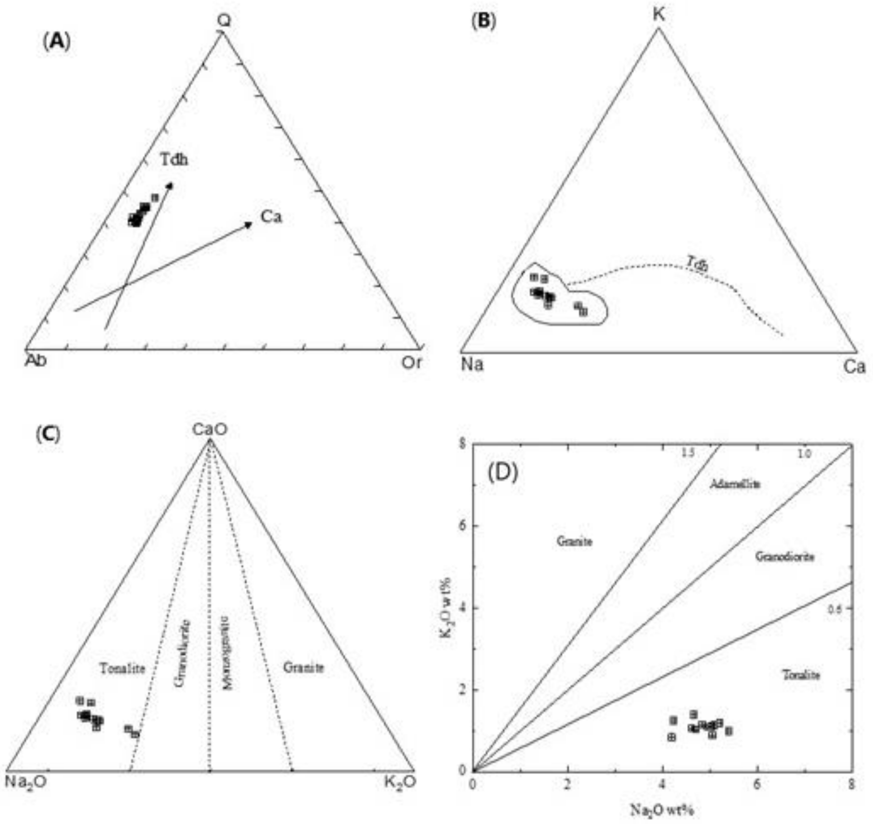


**Fig 5 (A-D): (A).** Q-Ab-Or ternary plots for Swarnagadde granitic gneiss after Barker and Arth, [17].
**(B)**. K-Na-Ca ternary diagram showing calc-alkaline and trondhjemite (Tdh) trends after Barker and Arth, [16].
**(C).** CaO-$Na_2O$-$K_2O$ ternary plot for the granitic gneisses of the study are after Condie and Hunter, [17].
**(D)**. $K_2O$ vs $Na_2O$ binary plot of granitic gneisses of the study area with fields of Tonalite, Granodiorite, Adamellite and Granite after Chappell et al, [18].

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Barker [15] has classified the occurrences of granite trondhjemitic-tonalitic suites which are as follows:

**a)** Archaean Grey gneiss terraines.
**b)** Peripheries of Archaean greenstone belts.
**c)** Proterozoic and Palaeozoic continental margins.
**d)** Mesozoic and Cainozoic continental margins.
**e)** Sub-volcanic regions of island arc and
**f)** Ophiolites.

Me Gregor [19] studied the Archaean grey gneiss of the Godthab region, and reviewed the possibilities of several models responsible for the origin of these rocks.

These models include:
a) remelting of older sialic material
b) contamination of basic magmas with sialic crustal material
c) fractional crystallization of basaltic magmas
d) partial melting of basaltic rocks.

From the study of chemistry of these grey gneisses, he proposed a model of origin by partial melting of basaltic rocks, but precludes an origin by remelting of sialic rocks. Tarney et al. [20] put forward for the granite trondhjemitic and tonalitic gneisses from Scotland and East Greenland, a model of partial melting of garnet amphibolite. Tarney et al. [20] were of the opinion that the deeper part of the batholith inverted to dry granulite facies assemblages during or shortly after the phase of crustal generation; probably in response to changing $CO_2$- rich fluid composition. Expulsion of hydrous fluid was accompanied by loss of K, Rb and Th thus enhancing the tonalitic/trondhjemitic characters of the gneiss complex.

**A.2 Tectonic Setting**

A comparison of major and trace element characteristics of the granitic gneisses of the present research area through various discrimination diagrams has helped to constrain the possible tectonic environment in which these samples have crystallized. According to Pearce et al. [9] application of discriminant diagrams should be done very carefully especially for very old rocks. Thus discrimination especially those based on the major oxide contents, should be used very carefully, as in these rocks the effects of the older enriched mantle source/ lithosphere must also be accounted for along with the effects of the later modifications in the rock chemistry due to metamorphism or alterations which may alter the actual tectonic signatures.

In Fig 12 (A) to (D) tectonic discrimination plots based on trace element compositions are shown. The variation plots of Y (ppm) with Nb (ppm) and that of Nb+Y with respect to Rb (ppm) are shown in Fig 12 (A) and Fig (B) respectively. Fields for volcanic arc granite (VAG) within plate granite (WPG), ocean ridge granite (ORG) and syn-collision granite (Syn-COLG) are from Pearce et al., [9].

The diagrams are based on the well-established behaviour of fluid immobile element viz. Rb and fluid immobile high field strength elements viz. Y and Nb, during the magma generation and crystallization. In Fig 12 (A), the samples have almost same concentration for both Nb and Y.

The fields marked after Pearce et al. [9], classifies these samples are within volcanic arc granite + syn-collision. In Figure (B) Nb+Y vs Rb are also lying in the field of the within volcanic arc granite + syn-collision. Reconstruction of tectonic regime of formation of granitic gneisses has also been attempted using the R1-R2 plot (Fig C) as suggested by Bachelor and Bowden [21] showed the granitic gneiss formed from metamorphism of Orogenic granitoids.

Log Rb vs Sr (Fig D) discrimination diagram for granitic gneisses showing affinity to continental trondhjemite and quartz diorite [22, 23]. All the parameters mentioned have indicated essentially the same tectonic setting of formation of granitic gneisses of the study area viz, predominantly post orogenic development in island arc to continental arc regime and collision zone.

 

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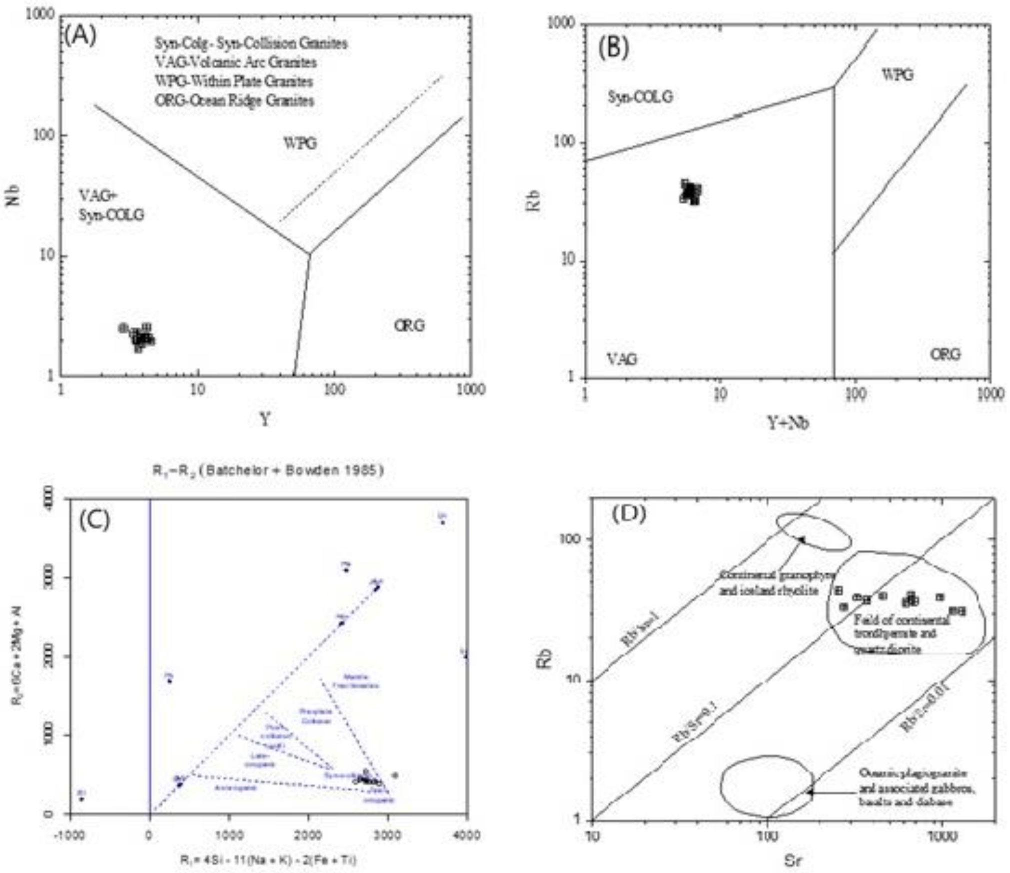


**Fig 6 (A-D): (A)** Binary discrimination plots of Log Y vs Log Nb after Pearce et al 1984 [9] to understand possible tectonic settings of the Swarnagadde Granitic gneiss.

**(B).** Binary discrimination plots of Log Rb vs Log Y+Nb fields after Pearce et al [9] to understand possible plate tectonics of the study area.

**(C).** Binary discrimination diagram of R1 (4Si-11(Na+K)-2F (Fe+Ti) vs R2 (6Ca+2Mg+Al) fields after Bachelor and Bowden, [21].

**(D).** Log Rb vs Sr discrimination diagram for Granitic gneisses showing affinity to continental trondhjemite and quartz diorite. Granophyre, trondhjemite and oceanic plagiogranite fields after Coleman and Peterman, Coleman and Donato, [22, 23].

## V. DISCUSSION AND CONCLUSIONS

The major part of the study area is granitic gneiss which occurs as subterranean rocks and comprising nearly 80 percent bedrock of the investigated area. Granitic gneisses are medium to coarse grained, dark to light grey in colour. The leucocratic granitic gneiss is grey to pink and locally exhibits mafic veins, quartzo-feldspathic pegmatite veins and irregular bodies are common in this variety. Orientation of quartzo-feldspathic pegmatite veins particularly of syntectonic metamorphic/metasomatic ones. A thin section examination of these varieties reveals the large mineralogical variations among them. Generally the coarse and pinkish verities are K-feldspar bearing, while the whitish/leucocratic and finer grained ones are plagioclasic in nature. Mineralogically granitic gneisses are significantly plagioclasic in nature. Quartz is only next in importance and K-feldspar is a minor mineral phase. Biotite, hornblende, epidote and muscovite are the common mafic minerals. Chlorite, calcite, apatite, zircon and Fe-Ti oxides are the common accessories of the granitic gneisses of the study area. Chemically the granitic gneisses of the study area are very largely in the range of tonalite-trondhjemites and are comparable to similar Precambrian granitic gneisses of other well-known shield areas of the world. There is a considerable uniformity, or only a constrained variation in the contents of the major element oxides and the trace elements. The protolith granite and granodiorite of granitic gneisses of this area are orogenic in nature (Fig C). They plotted largely in the fields of volcanic arc and Syn-collisional granites (Fig A). The granite geotectonic discrimination plots (Nb+Y vs Rb) of Pearce et al. [9] reveals that the granitic gneiss formed from volcanic arc granite + Syn-collisional granitic rocks. All these parameters suggests they form like volcanic-arc magmas predominantly post orogenic development in island-arc to continental and collision zone.

 

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## VI. CONCLUSIONS

The granitic gneisses of the study area showed, from their overall geochemical and petrographical features, that they were most likely derived from primary magmatic differentiation of the granitic magma and partly associated to the medium-low grade metamorphism witnessed at a late stage in the Precambrian records of the area. These protoliths were formed from mantle magma mixed with partial melting of crustal materials in an arc related orogenic (syn-collisional) tectonic setting.

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