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# Petrography and Geochemistry of the Neoarchaean Greywackes from Central Part of the Dharwar-Shimoga Greenstone Belt, Western Dharwar Craton

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**Abstract:** *Greywackes are the most dominant of litho units in the central part of the Dharwar-Shimoga greenstone belt of the Western Dharwar Craton. They are texturally immature with angular to subangular detrital sand grains with 25 to 60 % matrix. Quartz forms the main detrital component and is mostly monocrystalline with distinct undulatory extinction. Amongst feldspars, plagioclase feldspar exceeds K-feldspar. Micas occur as large and small flakes that are oriented. Biotite is the main mica mineral. The phyllite, chert, quartzite and felsic volcanic rock fragments are common. The matrix is generally made up of chlorite, sericite, clay to silt-sized quartz and feldspar. In Q-F-L classification diagram, these rocks plot in the fields of quartz wackes and quartzose wackes. The silica content varies between 60.93 and 68.07 wt% and alkalies between 3.69 and 5.21 (Table 2), and compositionally they are comparable to andesite and dacite. Moderately higher values of $Fe_2O_3$ (av. 8.16 wt%), MgO (av. 7.89 wt%) and $K_2O/Na_2O$ (av. 1.65) indicate a matrix with an abundance of chlorite, biotite, clays and iron oxides. The petrographic and geochemical evidence suggests that these greywackes were derived from the source which had felsic to intermediate composition, with a moderate relief exposed to arid and dry palaeoclimatic conditions. As compared to greywackes of the northern part of the Dharwar-Shimoga greenstone belt, the greywackes of the present study area (central part) have higher values of MgO, $Fe_2O_3$+MgO, $K_2O/Na_2O$, $Al_2O_3/Na_2O$ and lower values of $Al_2O_3$, $Na_2O$, and $SiO_2/MgO$.*

***Keywords:*** *Greywacke, Petrography, Geochemistry, Provenance, Dharwar-Shimoga greenstone belt*

## 1. Introduction

The Dharwar-Shimoga greenstone belt of the Western Dharwar Craton is the largest greenstone belt composed of vast volcano-sedimentary sequences. The rocks have witnessed different phases of deformation and greenschist facies metamorphism [1-3]. Greywackes are the most dominant lithounits of this belt [1,2]. Studies have been carried out on different parts of this belt on various aspects such as the provenance, tectonic settings and palaeoclimatic conditions of the clastic sedimentary rocks [2,4-6]. Recently, Ugarkar et al. [7] have carried out detailed studies on the greywackes of the northern part of this belt to understand their provenance, geodynamics and crustal evolution based on their petrographic and geochemical characters. The present paper deals with the preliminary study related to field, petrography and major oxide geochemistry of metagreywackes of the central part of the Dharwar-Shimoga greenstone belt

## 2. Geological setting

The Dharwar-Shimoga greenstone belt of the Western Dharwar Craton comprises volcano-sedimentary sequences with the dominance of clastic sediments than volcanic. According to Swaminath and Ramakrishnan [1] and Harinadha Babu et al. [8], the Dharwar-Shimoga belt is divided into different formations namely Jandhimatti, Joldhal, Medur and Ranibennur formations. The Jandhimatti Formation consists of polymict conglomerate, lithic arenite, chlorite-quartz schist, quartzite and sericite schist that are underlain by the older basement gneissic complex. The Joldhal Formation has limestone, dolomites ferruginous and manganiferous cherts and carbonaceous phyllite, which are made by chemical processes. The Medur Formation is made up of acidic and basic intermediate rocks with chemogenic and detrital sediments. The younger Ranibennur Formation is dominated by greywackes interbedded with finely grained argillites. The greywackes of present study area belong to the Medur and Ranibennur formations in the central part of Dharwar-Shimoga greenstone belt. The study area consists of vast volcano-sedimentary sequences, predominantly basic to felsic volcanic flows, with chemical and detrital sedimentary rocks. The volcanic rocks predominate southern part of the study area, while the sedimentary rocks, main greywackes with bands of banded ferruginous cherts/quartzites dominate the northern part (Fig.1). The volcanic rocks form antiform, trending E-W and plunging towards WNW at a moderate angle. The sedimentary rocks, like greywackes and banded ferruginous cherts, follow the general Dharwarian trend (NNW-SSE), dipping 70-$75^0$ due to NE as well as SW.

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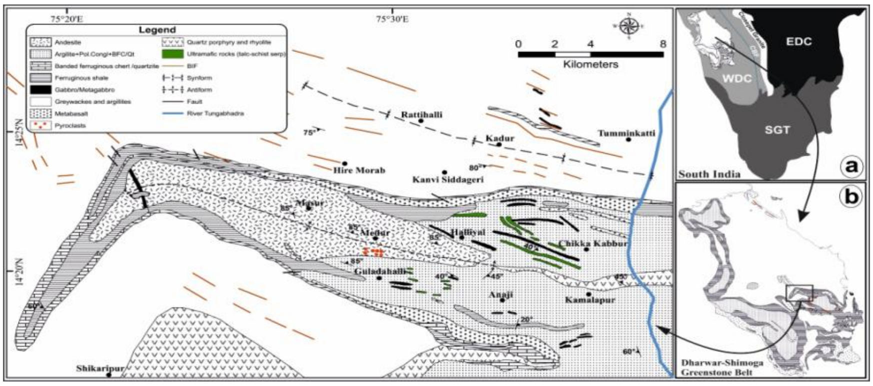


**Fig.1:** *Geological map of the study area (Modified after Ziauddin et al., 1978)*

### 3. Petrography

The immature light to grey colored greywackes of the study area show poorly sorted angular to subangular clasts. Texturally, these rocks are wackes with 25-60% matrix (Fig.2a to d). The matrix is generally made up of chlorite, sericite, clay to silt-sized quartz and feldspar. Quartz forms the main detrital component and is mostly monocrystalline with distinct undulatory extinction. Amongst feldspars, plagioclase feldspar exceeds K-feldspar. Micas occur as large and small flakes that are oriented. Biotite is the main mica mineral. The phyllite, chert, quartzite and felsic volcanic rock fragments are common (Fig.2a, c). The carbonates occur as small vein fillings and patches. Carbonates commonly replace detrital grains along their grain boundaries. The euhedral pyrites and iron oxides are common opaque minerals in the rocks (Fig. 2a, d).

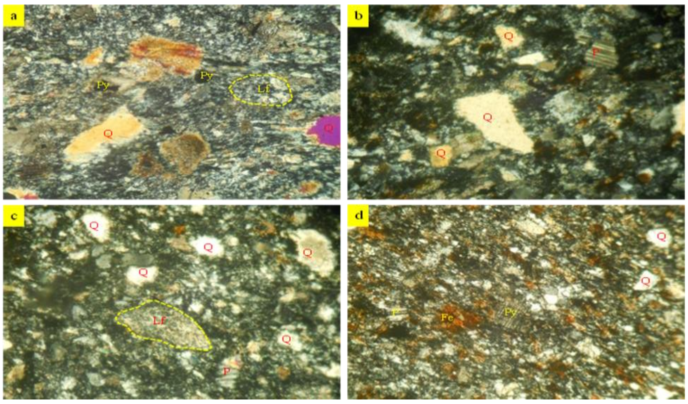

***Fig.2 a to d:*** *Photomicrograph of greywacke of the study area (Q-quartz, P-plagioclase, Lf- lithic fragments, Fe-iron oxide, Py-pyroxene; Magnification: 100X)*

These greywackes have an average modal composition of 43% quartz, 6.11% feldspars (plagioclase dominates), 1.33% lithic fragments (cherts + quartzites + volcanic) and 36.44% matrix (Table 1). The lithic fragments are comparatively larger than mineral clasts (Fig. 2a–d). In Q-F-L classification diagram, these rocks plot in the fields of quartz wackes and quartzose wackes (Fig.3).

***Table.1:*** *Modal analysis of greywacke of central part of Dharwar-Shimoga greenstone belt*

| Samples | TM36 | TM29 | TM40 | TM39 | TM14 | TM37 | TM34 | TM28 | TM30 | Av. |
|---|---|---|---|---|---|---|---|---|---|---|
| Quartz | 50 | 48 | 30 | 50 | 59 | 30 | 31 | 46 | 43 | 43 |
| Plagioclase | 8 | 4 | 5 | 5 | 10 | 5 | 5 | 3 | 8 | 5.89 |
| K-feldspar | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0.22 |
| Chert/quartzite | 1 | 0.5 | 1 | 2 | 3 | 1 | 0 | 0.5 | 0 | 1 |
| Volcanic clasts | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0.33 |
| Matrix | 35 | 25 | 40 | 30 | 25 | 50 | 45 | 40 | 38 | 36.44 |
| Carbonates | 5 | 2 | 20 | 10 | 3 | 15 | 18 | 10 | 15 | 10.89 |
| Biotite | 0 | 20 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 2.56 |
| Opaque minerals | 0.5 | 0.5 | 0.5 | 0.3 | 0.2 | 0.5 | 0.2 | 0.2 | 0.2 | 0.34 |
| Total | 99.5 | 100 | 101.5 | 99.3 | 100.2 | 101.5 | 100.2 | 99.7 | 104.2 | 100.68 |

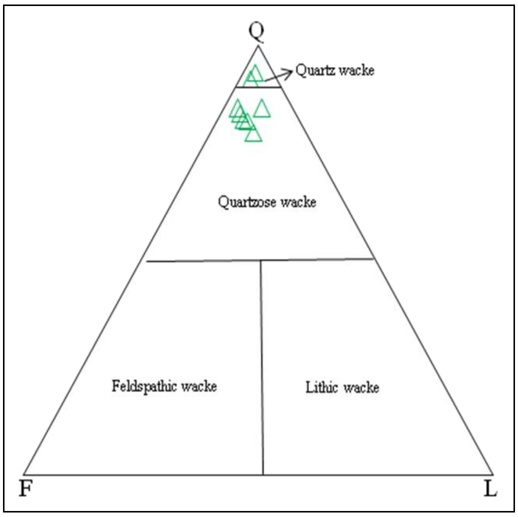


*Fig.3: QFL diagram of greywackes of the study area*

## 4. Geochemistry

Nine representative and least altered fresh greywacke samples have been collected from the surface, trenches, quarries and road cuttings. These rock samples were powdered to -200# mesh size manually to avoid contamination. The instrument X-Ray Fluorescence (XRF: Philips MAGIX PRO Model 2440), at the CSIR-NGRI, Hyderabad, and NCESS, Trivandrum were used to analyze the major oxides.

In greywackes of the study area, the silica content varies between 60.93 and 68.07 wt% and alkalies between 3.69 and 5.21 wt% (Table2), and compositionally they are comparable to andesite and dacite (Fig. 4). Moderately higher values of $Fe_2O_3$ (av. 8.16 wt%), MgO (av. 7.89 wt%) and $K_2O/Na_2O$ (av. 1.65) indicate a matrix with an abundance of chlorite, biotite, clays and iron oxides. As compared to greywackes of the northern part of the Dharwar-Shimoga greenstone belt [7] the greywackes of the present study area (central part) have higher values of MgO, $Fe_2O_3$+MgO, $K_2O/Na_2O$, $Al_2O_3/Na_2O$ and lower values of $Al_2O_3$, $Na_2O$, and $SiO_2$/MgO.

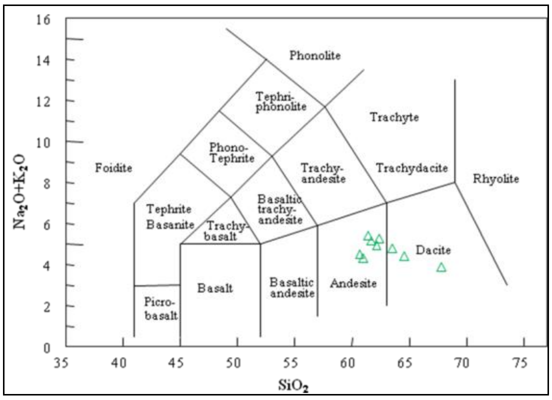


*Fig.4: Total alkali silica plot (after Le Bas et al., 1986)*

***Table.2:*** *Major oxide geochemistry of greywacke of central part of the Dharwar-Shimoga greenstone belt*

| Samples | TM28 | TM29 | TM30 | TM33 | TM34 | TM35 | TM36 | TM39 | TM40 | Av. | Av. NDSB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 68.07 | 62.65 | 63.76 | 62.42 | 60.93 | 61.24 | 64.81 | 61.7 | 61.97 | 63.06 | 62.58 |
| $TiO_2$ | 0.48 | 0.7 | 0.7 | 0.7 | 0.57 | 0.62 | 0.62 | 0.62 | 0.62 | 0.63 | 0.59 |
| $Al_2O_3$ | 10.83 | 10.64 | 10.59 | 13.38 | 12.51 | 12.32 | 11.49 | 11.97 | 12.44 | 11.80 | 14.38 |
| MnO | 0.11 | 0.12 | 0.1 | 0.1 | 0.08 | 0.12 | 0.1 | 0.09 | 0.08 | 0.10 | 0.12 |
| $Fe_2O_3$ | 7.5 | 8.32 | 9.6 | 8.08 | 9.33 | 8.27 | 7.61 | 7.44 | 7.27 | 8.16 | 7.72 |
| CaO | 2.61 | 2.94 | 1.92 | 2.87 | 2.25 | 3.5 | 3.53 | 2.73 | 3.14 | 2.83 | 3.23 |
| MgO | 6.14 | 8.68 | 8.1 | 6.93 | 8.75 | 7.9 | 7.16 | 8.45 | 8.87 | 7.89 | 4.54 |
| $Na_2O$ | 0.77 | 2.11 | 1.85 | 2.28 | 0.96 | 1.83 | 2.78 | 2.49 | 2.75 | 1.98 | 3.3 |
| $K_2O$ | 2.92 | 2.94 | 2.75 | 2.45 | 3.35 | 2.29 | 1.42 | 2.72 | 2.2 | 2.56 | 2.11 |
| $P_2O_5$ | 0.12 | 0.12 | 0.11 | 0.12 | 0.11 | 0.12 | 0.11 | 0.12 | 0.13 | 0.12 | 0.16 |
| Total | 99.55 | 99.22 | 99.48 | 99.33 | 98.84 | 98.21 | 99.63 | 98.33 | 99.47 | 99.12 | 98.73 |
| $Na_2O+K_2O$ | 3.69 | 5.05 | 4.6 | 4.73 | 4.31 | 4.12 | 4.2 | 5.21 | 4.95 | 4.54 | 5.41 |
| $K_2O/Na_2O$ | 3.79 | 1.39 | 1.49 | 1.07 | 3.49 | 1.25 | 0.51 | 1.09 | 0.8 | 1.65 | 0.64 |
| $SiO_2$/MgO | 11.09 | 7.22 | 7.87 | 9.01 | 6.96 | 7.75 | 9.05 | 7.3 | 6.99 | 8.14 | 14.52 |
| $Al_2O_3/Na_2O$ | 14.06 | 5.04 | 5.72 | 5.87 | 13.03 | 6.73 | 4.13 | 4.81 | 4.52 | 7.1 | 4.36 |
| $Fe_2O_3$+MgO | 13.64 | 17 | 17.7 | 15.01 | 18.08 | 16.17 | 14.77 | 15.89 | 16.14 | 16.04 | 12.26 |
| CIA | 63.22 | 57.11 | 61.89 | 63.78 | 65.60 | 61.79 | 59.78 | 60.12 | 60.59 | 61.54 | 61.45 |

*Av. NDSB- Average value of greywacke from the northern part of Dharwar-Shimoga greenstone belt.*

## 5. Provenance

The mineralogy and chemical composition of the sedimentary rocks are controlled by the composition of the source rocks and also weathering, the rate of transportation and their depositional environment [11,12]. Climatic conditions of the source region play an important role in causing weathering and maturity of sediment product. The increase of degree of chemical weathering reflects the change of climate towards warm and humid conditions, which are more favorable for chemical weathering in the source region [13]. In the $SiO_2$-($Al_2O_3$+$K_2O$+$Na_2O$) diagram (Fig.5) of Suttner and Dutta [14] for the chemical maturity of clastic sediments and their palaeoclimatic environment, the plots of greywackes of present study area indicate a source with arid climatic conditions. The CIA values of the studied sediments range between 57.11and 65.60 with an average value of 61.54, indicating a low to moderate degree of weathering [15,16].

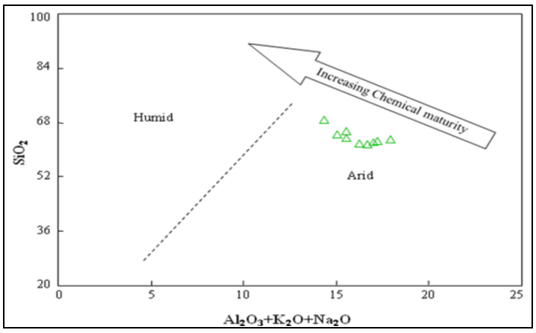


***Fig.5:*** *$SiO_2$ vs $Al_2O_3$+$K_2O$+$Na_2O$ binary plot (after Suttner and Dutta, 1986)*

The source rocks for greywackes available in and surrounding the study area were Peninsular Gneisses, Closepet Granites, banded ferruginous quartzites, ultramafic, mafic and felsic volcanic. Amongst volcanic, the felsic rocks dominate. $K_2O$ values greater than 1 wt% (av. 2.39 wt%), indicate that these sediments were derived from acid-intermediate source [17,18]. The initial composition of the source rock can also be obtained from the weathering trend line at the feldspar join in the A-CN-K diagram (Fig. 6). Present greywacke samples plot between the andesite and granodiorite fields, indicating felsic to intermediate source rock composition. Also in the $TiO_2$ vs. $Al_2O_3$ discrimination diagram of provenance characters, plots of these sediments indicate intermediate to felsic provenance (Fig. 7).

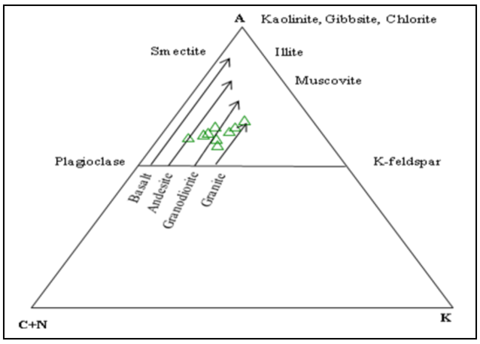


***Fig.6:*** *A-C+N-K triangular plot of greywacke sample from the study area (A-$Al_2O_3$, C-CaO, N-$Na_2O$, K-$K_2O$) (after Nesbitt and Young, 1984, 1989)*

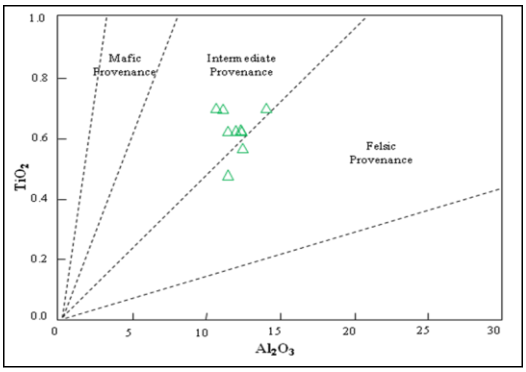


***Fig.7:*** *Discrimination diagram of $Al_2O_3$ vs $TiO_2$ of studied greywacke (after, Potter et al., 2005; Lamaskin et al., 2008)*

The mineralogical assemblage and geochemical characteristics of greywackes of study area support that the source region had a moderate relief and tectonically active terrain exposed to arid and dry palaeoclimate during weathering.

## 6. Conclusions

The greywackes**,** which form the most abundant lithology in the central part of the Dharwar-Shimoga greenstone belt, are texturally immature with angular to subangular detrital sand grains with 25 to 60 % matrix. Monocrystalline quartz forms the main detrital component. Amongst feldspars, plagioclase feldspar exceeds K-feldspar. The phyllite, chert, quartzite and felsic volcanic rock fragments are common. The matrix is generally made up of chlorite, sericite, clay to silt-sized quartz and feldspar. Based on the proportions of detrital components, these greywackes are classified as quartz and quartzose wackes. Chemical compositionally they are comparable to andesite and dacite. The petrographic and geochemical evidence suggests that these greywackes were derived from the source which had felsic to intermediate composition, with a moderate relief exposed to arid and dry palaeoclimatic conditions. As compared to greywackes of the northern part of the Dharwar-Shimoga greenstone belt, the greywackes of the present study area (central part) have higher values of MgO, $Fe_2O_3$+MgO, $K_2O/Na_2O$, $Al_2O_3/Na_2O$ and lower values of $Al_2O_3$, $Na_2O$, and $SiO_2$/MgO.

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