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Geological Setting and Petrography of some Greywackes and Associated Rocks of Dharwar, Karnataka

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Abstract: A petrographic analysis of Archaean greywackes from the Northern part of Dharwar region Dharwar Supegroup indicates that much of the matrix are distinctly immature rocks wit poorly-sorted angular to sub-angular grains, comprising largely quartz, feldspar and lithic fragments. They are characterised by 37.26% quartz, 8.81% feldspar, 38.61% rock fragments, 3.45% carbonates and others 1.88% average of fifteen samples. Detrital quartz, feldspar and rock fragments are observed to contribute the matrix, feldspar and rock fragments principally sericitisation. The coarse grain greywacke shows decreasing in matrix content through the succession corresponding to an increase in detrital quartz, feldspar and rock fragments content. In the investigated area phyllites, metavolcanics and bif's are also studied. More importantly puckering structures is commonly noticed in phyllites of the region.

Keywords: Dharwar, Greywackes, Detrital, Fragments, Sericitisation.

I. INTRODUCTION

Greywacke is a variety of sandstone generally characterized by its hardness, dark colour, and poorly sorted angular grains of quartz, feldspar, and small rock fragments or lithic fragments set in a compact, clay-fine matrix. Fine grained clastic sediments like greywackes constitute the most abundant rocks of the Archaean sedimentation. Such a type of rocks are the extensively studied clastic metasediments of the greenstone belts all over the world [1, 5, 7, 11, 13, 14 and 17]. The overall abundance of any clastic sedimentary component in the greenstone belts is of considerable significance.

For example, the occurrence of detrital sediments like greywackes has a clear significance in terms of the then prevailing exogenic processes and environment. Such sediments contain important information about the source compositions, weathering conditions, nature of provenance and geodynamic settings of the depositional basins. In the Neo-archaean Dharwar-Shimoga green-stone belt of the western Dharwar craton greywackes are the most abundant clastic metasediments. Greywacke composition is least affected by sorting process and diagenesis therefore they nearly reflect the composition of early crust [12]. In particular, greywackes from younger greenstone belts are affected by alteration process and metamorphic effect. Hence they are potential in understanding the composition of the early crust [5, 8 and 11]. It is on the premises that these greywackes are least affected during chemical weathering and rapidly deposited.

II. GEOLOGICAL SETTING

A. Geology of the Western Dharwar Craton

The Dharwar craton in south India is one of the best geologically documented terrains with voluminous gneisses, granitoids and several volcano sedimentary supracrustal belts for understanding the nature of the Archaean geology, tectonics, crustal evolution and metallogeny. The craton has been divided into two distinct tectonic regions, the Western Dharwar Craton (WDC) and the Eastern Dharwar Craton (EDC), separated by the Chitradurga Shear Zone, close to the linear Closepet Granite. The contact between WDC and EDC is not sharp, and there is a transition zone between the Chitradurga Shear Zone and Closepet Granite.

The grey gneissic complex covering the entire craton was formerly known by the term the “Peninsular Gneiss”. However, in age, composition, mutual relation with the associated supracrustal rocks and geographic distribution in separate tectonic blocks, the term “Peninsular Gneiss” (>3000 M.a.) is proposed to be restricted to the gneisses of WDC, while the granites and gneissic terrain of EDC is collectively called as the “Dharwar Batholith” of 2.7 to 2.5 M.a age [3]. The greenstone belts/schist belts of the Dharwar Craton are divided into three groups on the basis of their stratigraphy and age [15, 16].

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In the WDC, the greenstone belts of 3.1 to 3.3 M.a. of Sargur Group are deformed together with the Peninsular Gneiss and are unconformably overlaid by the younger (2.6-2.8 M.a), moderately deformed greenstone belts of Dharwad Supergroup. Greenstone belts of the Kolar Group from the EDC are coeval with the greenstone belts of the Dharwad Supergroup. In the Dharwad Supergroup, two main divisions are recognized [15] (Table. 1). The sediments of Dharwar Supergroup were laid on elongate protogeosyneline over a basement of the Sargur Schist and Pyritiferous orthoquartzites.

Table.1 Generalised Lithostratigraphy of Dharwar Supergroup [15]

Group	Formation	Litho-Assemblage (as in the type area)
Chitradurga Group	Hiriyur	Predominantly greywacke with Fe-Mn chert; polymict conglomerate
	Ingaldhal	Quartz-chlorite schist, argillite with Fe-Mn chert and metabasalt
	Vanivilas	Fe-Mn formations, carbonates, phyllite and quartzite with conglomerate at the base
	------- Unconformity -------	
Dharwar Super group	Mulaingeri	Fine clastics, predominantly with chemical sedimentation
Bababudan Group	Santaveri	Bimodal volcanics, **of** quartzite in subordinate amounts
Bababudan belt	Allampur	Quartzite with basic igneous rocks
	Kalasapura	Basic volcanics with quartzite and conglomerate at the base

B. Geology of the Area

The investigated area comprises a thick sequence of metasediments with greywackes, polymict conglomerate and banded iron formations, with occasional metavolcanic sequences (Fig. 1). In general, the foliation and schistosity of these rocks strike NNW-SSE and their dip varies from 75o to sub-vertical, due east as well as west.

The conglomerate, overlying the metavolcanics, occurs as a prominent litho-unit in the eastern margin of the belt in the study area. Based on the lithological association and petrographic characters in the investigated area, greywackes occurring in and around the Dharwad have been considered (Fig. 1). Greywacke and intercalated phyllite in the study area constituting Ranebennur formation of Dharwar super group [6, 15]. Greywackes of Dharwar are fine grained and occurrence of BIF within greywackes is a rare feature. Acid volcanic is frequent in the region to the north of the Dharwad. Platformal sediments like BIF's and carbonates are seen in the region of Nagalavi and intercalation of phyllites with greywackes is a common feature.

The study of greywackes comprises the northern part of the Dharwar region are best exposed in the quarries at Varavanagalavi, Kittur, Kalagahatagi, Inam Hongal, Haliyal, Mandihal, Alnavar and Ramapur. The rocks found in the area under study are light to dark grey in colour, under microscope they exhibit angular to sub angular consisting of detrital Quartzo-feldspathic material and rock fragments. The matrix is fine grained in nature and material finer than 0.03 mm are included in the matrix.

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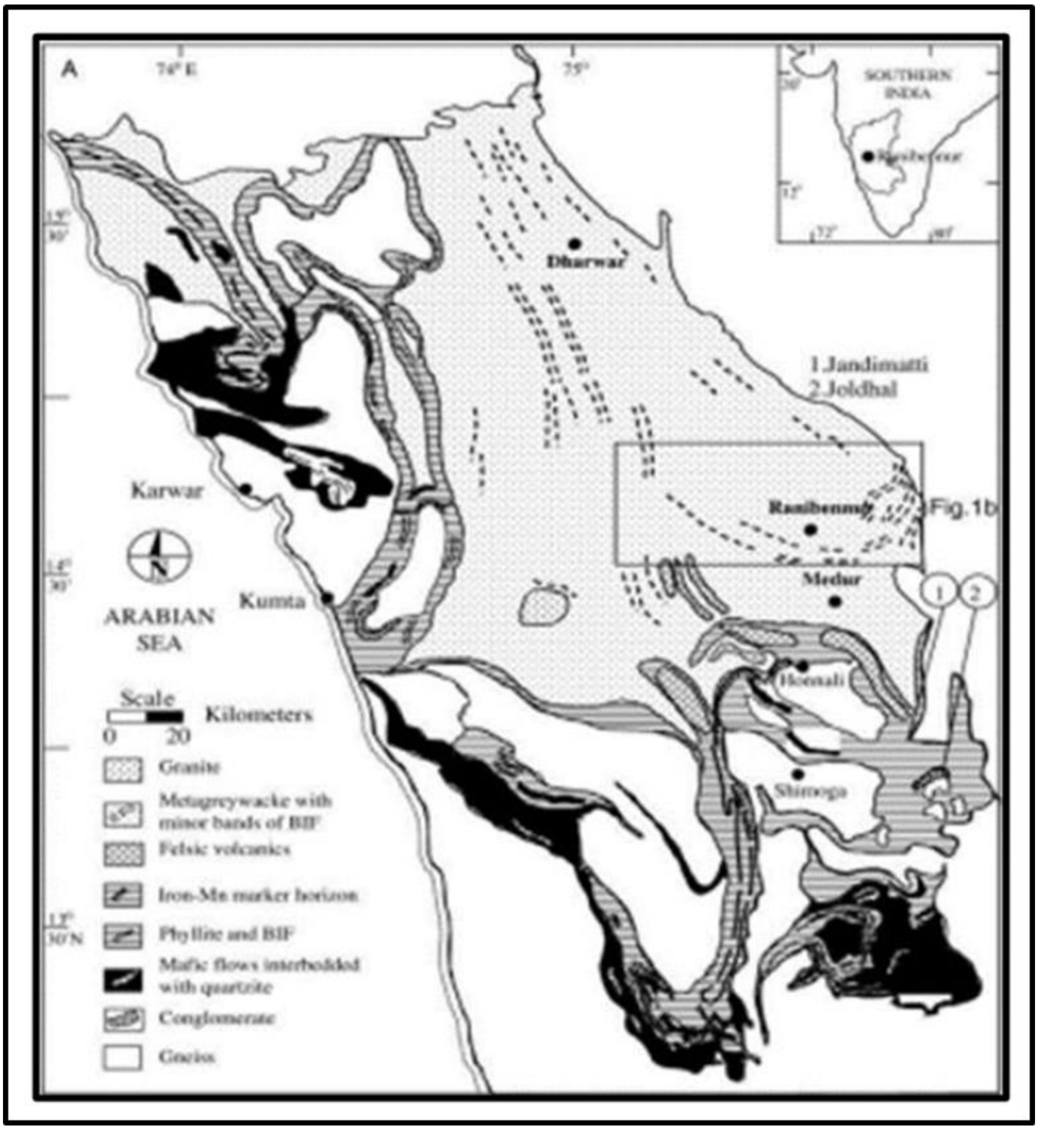

Fig. 1 Geological Map of the Study Area.

III. MATERIALS AND METHODS

Field and Laboratory Investigations

A Geological map of the area on a scale of 10 cm = 1.6 km is prepared. This contains a lithological map with only basic structural elements with dip and strike. The fresh samples of various litho-units were collected which were associated with the greywackes avoiding the collection in weathered areas for various laboratory studies. For the areas subjected to intensive weathering fresh samples were collected in the nearby quarries.

The selected rock samples have been subjected to thin section studies for mineral composition, petrographic characters, and chemical analysis. The petrographic characters lead to the presence of lithounits like greywacke, phyllites, metavolcanics, banded iron formations and dykes of doleritic composition.

For modal composition of the sample (This is carried out only for the greywacke samples). For this work, thin sections of the area 3-4 Sq.cms have been used with an average of 1,000 grains per rock and the work was carried out with the Leitz Counter Machine in the Department of Geology, Karnatak University, Dharwad.All paragraphs must be indented.

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IV. RESULTS AND DISCUSSION

A. Field and Petrographic Features

Around Dharwad greywackes are medium to fine grained fresh and show intercalations of phyllite, at places mafic flows occur up to the thickness of 15-20 meters. In addition to rhythmic intercalation of phyllite, oxide facies, BIF's occur, which constitute ridges of the hills around Mugad and Aravatagi. Greywackes show the effect of metamorphism and rude schistocity can be observed with pocket lens. Representative Greywacke and intercalated phyllite samples are selected for the petrographic studies. The selected fresh rock samples of greywacke and phyllite have been subjected to thin section studies for mineral composition and petrographic characters.

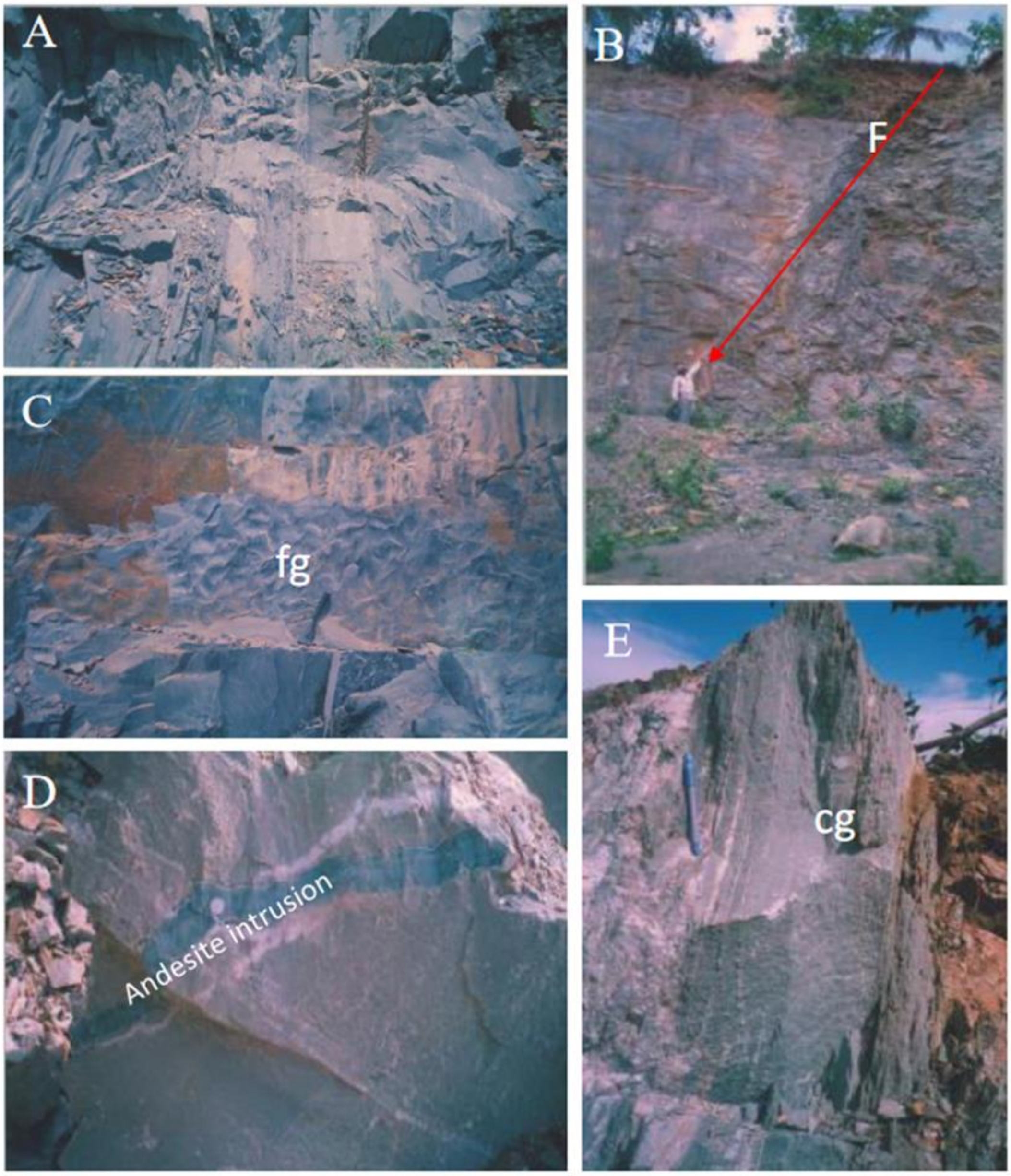

Fig. 2: (A) Field photographs shows occurrences of greywackes in working quarry at Mandihal. **(B)** A fault is noticed in the greywackes. **(C)** Fine grained greywackes. **(D)** Intrusion of andesite in greywackes near Ramapur. **(E)** Coarse grained greywackes.

Under microscope greywackes exhibit poorly sorted texture consisting of quartz, feldspar and rock fragments. Both monocrystalline and polycrystalline quartz are common. Replacement of feldspars by secondary carbonate is least in greywackes of Dharwad, rock fragments like cherty, phyllitic and BIF's are also common in Dharwad. These rock

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fragments suggest recycled and granitic provenance for them. Matrix is dominated by chlorite of green variety. Pyrite is a common secondary mineral its diagrammatic origin is indicated by (cubic) well developed crystal faces and replacement of other minerals. Biotite and other minerals are less than 5% in matrix of the greywackes, secondary carbonate replace both matrix as well as clastic grains. The embayment of clastic grains by matrix minerals suggests the role of diagenesis. The metamorphic of low grade green schist facies has not affected the original fabric of the greywackes.

B. Field Occurrence

Greywackes in the study area, occur at many places Varavanagalavi, Kittur, Kalagahatagi, Inam Hongal, Haliyal, Mandihal, Alnavar and Ramapur (Fig. 2A-E)etc., are among the important places. The exposures are mainly as outcrops, on the road sides, on the hills, road cutting, mounds, railway cuttings, nalla cuttings and in quarries. At places where it was difficult to find fresh samples due to weathering samples were collected in quarries representing the area. The greywackes in the investigated area occur in both thick and thin sedimentary sequence interbedded with Phyllites, Metavolcanics Banded Iron Formations, etc.

The greywackes are megascopically hard and compact and grey in colour (Fig. 2A-D). For the reason that they are easily available in abundance, and being strong and tough they are used as building stones, road metal, floorings, etc., in this part. They are strongly indurated; variation in grain size is easily noticeable. The rude schistocity, which is the indication of metamorphism on these rocks, is also observed. Generally metaphoric fabric is not easily noticeable in the hand specimen of sample of the study area that are metamorphosed to low grade green-schist facies. These samples when subjected to the petrographic observations show pyrites and at times even with well-developed faces and large grains of pyrites are also noticed. Greywackes are studded with pyrite grains, which are as big as 1 Sq.cms.

C. Petrography of greywackes

The petrographic observations reveal that the greywackes of the area under investigation in general exhibit poorly sorted texture (Fig. 3C) consisting mainly of quartz, feldspars, biotite (Fig. 3D) along with rock fragments which are both metasedimentary and metamorphic in frame work. Muscovite, Pyrite and Carbonates found embedded in the fine-grained matrix. Occasionally Orthoclase is also noticed in some samples of the greywackes (Fig. 2E), carbonate occurs as the secondary minerals. The greywackes are metamorphosed to low grade green-schist facies and rude schistosity in some sections exhibits effect of metamorphism, indicating amphibolites facies of metamorphism. Sometimes also observe the igneous rock fragments in thin section of greywackes (Fig. 3F).

Quartz:

Quartz and Chert together compose 35% to 43% of the rock volumetrically. They exhibit variation in size and are angular in shape. Quartz occurs in the form of mono crystalline and polycrystalline (Fig. 2G).They show undulose extinction and corroded margin.

The important texture observed in greywackes is “Chevaux-de-frise”, which is formed by penetration of fine-grained crystals of chlorite into quartz. As a result, the original water worn boundaries have disappeared and given rise to a boundary composed of “Chevaux-de-frise’’ which is hazy the margin formed due to authegenic chlorite. The same feature is also noticed in some other crystals of the greywackes, a case of attacking a plagioclase crystal is noticed in (Fig. 2H). Chert (Fig. 4A) occurs as the rock fragments, which is composed of the microcrystalline mosaic of intergrowth of quartz.

Feldspar

Feldspar the next abundant mineral in the greywackes forms nearly 7.82 to 12.62 of the rock. It occurs as clastic grains. Characteristically among feldspars, plagioclase (Fig. 4B) predominates over potash feldspars. Plagioclase occurs as lath shaped, however among potash feldspar microcline is also seen and is abundant which exhibits “cross hatched twinning” (Fig. 4C) at times plagioclase and K-feldspar are altered to sericite, chlorite. The feature of sausoritisation of plagioclase feldspar is noticed in the some greywackes (Fig. 4D).

Matrix is mostly composed of grains less than <0.03 mm and mostly of chlorite and therefore the matrix appears green in colour. Carbonates minerals (Fig. 4E) are important secondary minerals. At some places it shows tendency for replacement of plagioclase. It replaces matrix and such samples matrix is rich in carbonate minerals. Iron oxides, pyrite and Zircon are the important opaque minerals. Pyrite appears as the specks and also as well developed crystal faces and appears to replace all other minerals. Such a texture suggests late diagenetic origin.

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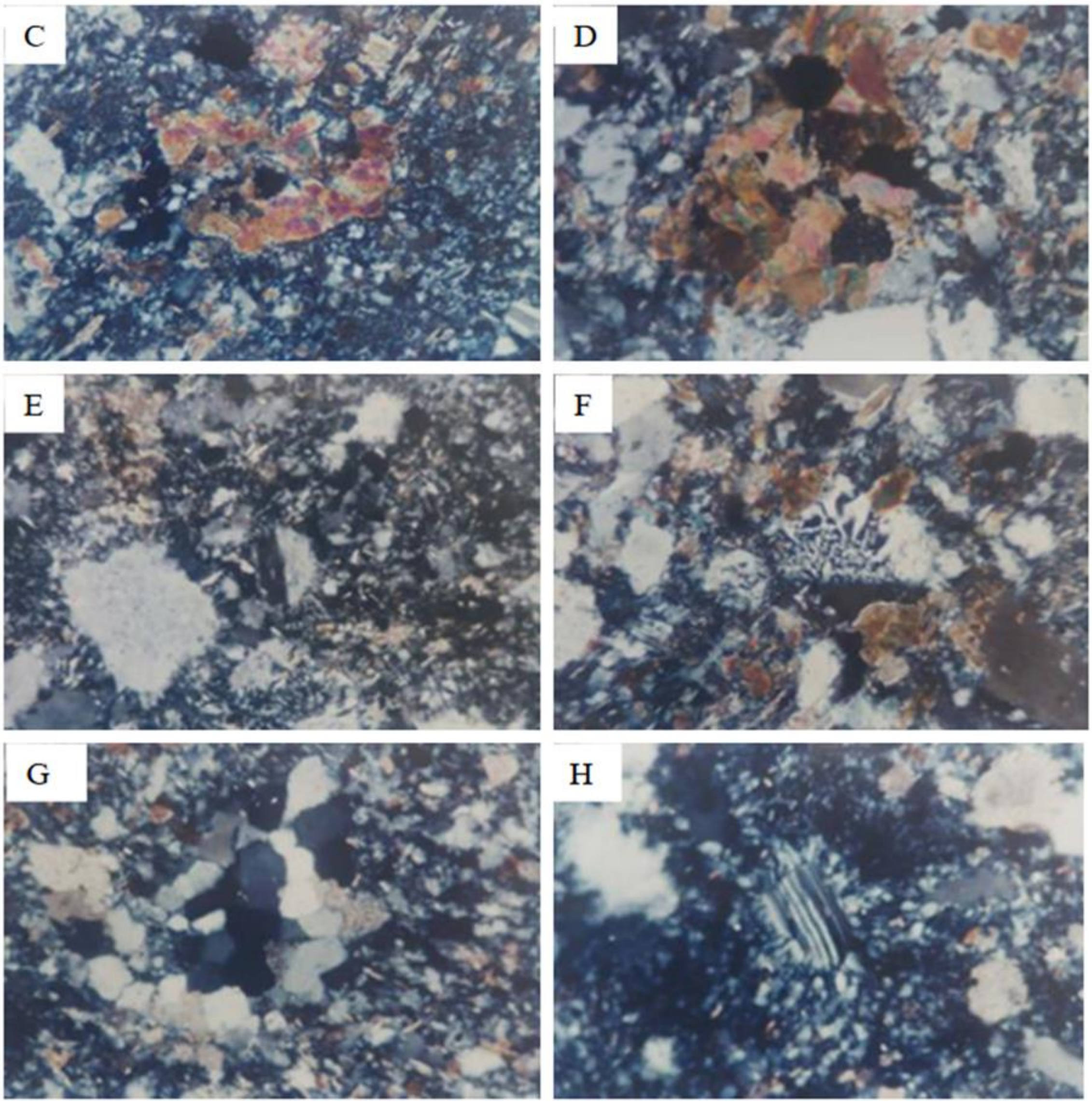

Fig. 3: (C) Photomicrograph shows poorly sorted nature of grains. **(D)** Photomicrograph shows a cluster of Biotite grains in greywackes. **(E)** Photomicrograph shows presence of Orthoclase. **(F)** Photomicrograph shows presence of igneous rock fragments. **(G)** Photomicrograph shows polycrystalline quartz. **(H)** Photomicrograph shows "Chevaux-de-frise" plagioclase feldspar.

D. Heavy mineral suite:

Heavy minerals found in the greywackes of the study area are pyrite, zircon, sphene, apatite and epidote. Though heavy mineral separation has not been undertaken in the study area, these minerals are evident in the thin sections of the rocks and occur in the order of abundance as mentioned above. The above mentioned heavy minerals are represented in the microphotos as follows, Zircon, (Fig. 4F), Sphene (Fig. 4G), Apatite (Fig. 4H), Epidote (Fig. 4I).

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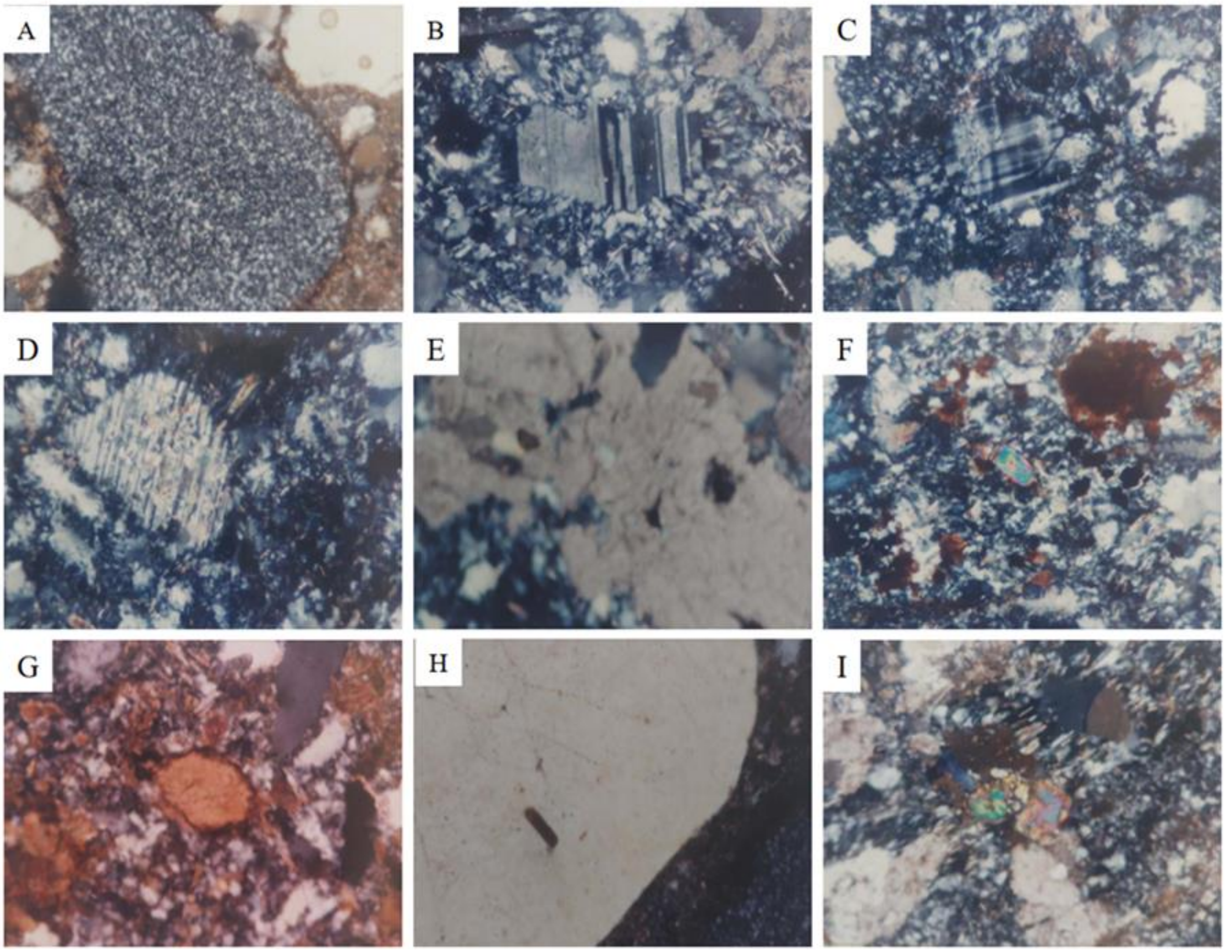

Fig. 4: (A) Photomicrographs of Chert grain in greywackes. **(B)** Plagioclase feldspar in greywackes. **(C)** Microcline Feldspar. **(D)** Plagioclase grain undergone sausoritisation. **(E)** Carbonates in greywackes. **(F)** Zircon in greywackes. **(G)** Sphene in greywackes. **(H)** Zircon and Apatite. **(I)** Epidote in greywackes.

E. Modal composition of Greywackes

Quantitative volumetric analysis of minerals has been determined for fifteen samples of the area taking into consideration the variation they exhibit and to cover the entire area. Generally the greywackes consists of Quartz (37.26%), Feldspars (10.32%), Matrix (38.61%), Rock fragments (3.45%), Carbonates (8.58%) and others (1.88%) average of the fifteen samples presented in Table. 2. It is recognised that development of secondary matrix causes problems in determination of QFL percentage and also in the interpretation of provenance based on QFL scheme.

Volumetrically the quartz range between 33.46% to 40.19% and average is 37.26%. The modal composition shows that the quartz content is 33.46% to 40.19% fall in the range of quartz intermediate type of Crook [4] and agree with the observation of McLennan [9] that, most Archaean greywackes belong to the class of quartz intermediate type. Detrital quartz, feldspar and rock fragments are observed to contribute the matrix, feldspar and rock fragments principally sericitisation.

The rock fragments in the greywackes of the area constitute volumetrically less than 5% (average of fifteen samples for rock fragments is 3.45). These are metasedimentary in nature and include fine to medium grained quartzite and Chert. Low-grade metamorphic rock fragments of phyllite and chlorite schist are also seen. The matrix is fine grained as mentioned previously and consisting of chlorites, quartz, feldspars, sericite and pyrite, among these chlorite is abundant.

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Table. 2: Modal analysis for the greywackes samples of the study area.

Minerals	D-1	D-2	D-6	D-8	D-9	D-11	D-15	D-17	D-18	D-20	D-21	D-23	D-24	AVG
Quartz	38.19	33.46	35.60	35.73	40.22	36.73	37.14	40.19	35.56	38.65	34.41	38.56	39.95	37.26
Matrix	37.04	42.09	40.04	38.82	34.64	40.22	39.05	36.03	40.47	38.65	38.58	38.92	37.14	38.61
Plagioclase	09.14	08.09	06.67	07.41	06.50	07.58	07.62	07.20	06.08	06.84	08.24	06.85	08.44	07.44
Orthoclase	03.47	03.51	03.06	02.30	02.46	02.50	03.33	02.80	01.74	02.87	02.82	02.56	02.73	02.78
Rock. Fragments	03.47	02.16	03.34	04.39	03.68	03.19	02.86	04.02	03.58	04.66	04.48	02.71	02.31	03.45
Calcite	08.10	09.71	08.79	09.74	10.79	07.29	07.14	08.32	09.50	06.79	09.07	08.60	07.73	08.58
Others	00.58	00.97	02.50	01.62	01.72	02.50	02.86	01.18	03.07	01.54	02.40	01.80	01.70	01.88
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100

F. Associated Rocks of the Study area

Phyllites

Phyllite is a fine grained schistose metamorphic rock characterised by silky sheen on the cleavage surfaces due to abundant small crystals of mica and chlorite [10]. These rocks are frequently found intercalated with greywackes in the study area. Occasionally even found associated with metavolcanics and shales (Fig. 5a-d). The phyllites are fine grained, dark grey to grey in colour possess schistocity and are chloritic in nature (Fig. 5b). Sometimes tectonic disturbances in the form of minor faults, these faults are observed between phyllites and shales (Fig 5c). "Puckering" structure is commonly observed in phyllites (Fig. 5d). Folds and crumpled structures are also noticed in phyllites of the study area. The phyllites are composed mainly chlorite, biotite, sericite and quartz, less amount of feldspar, carbonate minerals. Quartz, biotite and carbonates are fine grained in nature, pyrite is the only opaque mineral which occurs parallel to and along the foliation.

Metavolcanics

Though metavolcanics occur in various greenstone belts, their field occurrence, association, petrochemical characters and their position in Lithostratigraphic succession in these greenstone belts differ considerably. In the investigated area, metavolcanics are found in Bailhongal and Chandanamatti in the Northern part of the Dharwad occur as the scanty out crops forming the smaller mounts, lower levels, along the road and nalla in Chandanamatti and Aminbhavi, and are associated with younger BIF's. Here in Chandanamatti, well-developed pillow structures with varying shapes and sizes are seen within metavolcanics exposed in the nalla cutting near village Chandanmatti. Here vesicles are noticed in the metavolcanics (Fig. 5e-f) near Chandanmatti NE of Dharwad. Volcanism is also noticed at Rampur in the vicinity of Dharwar (Fig. 5g).

Petrographically the Metavolcanics of the study area exhibit large variation in the grain size from being very fine to medium grained. It is usually noticed that the flaky minerals are linearly arranged. Some samples even show strong schistocity. The ground mass of the metavolcanics is mostly chloritic of green variety and is probably the result of recrystallization of the original minerals.

Banded iron formations (Fig. 5h) are fine grained, dark coloured and are strongly banded, the banding is due to the occurrence of silica and iron oxide minerals in alternate light and dark coloured layers. The silica bands are composed of finely crystalline mosaic of quartz dusted with opaque iron oxide whereas iron oxide bands usually consist of hematite, magnetite.

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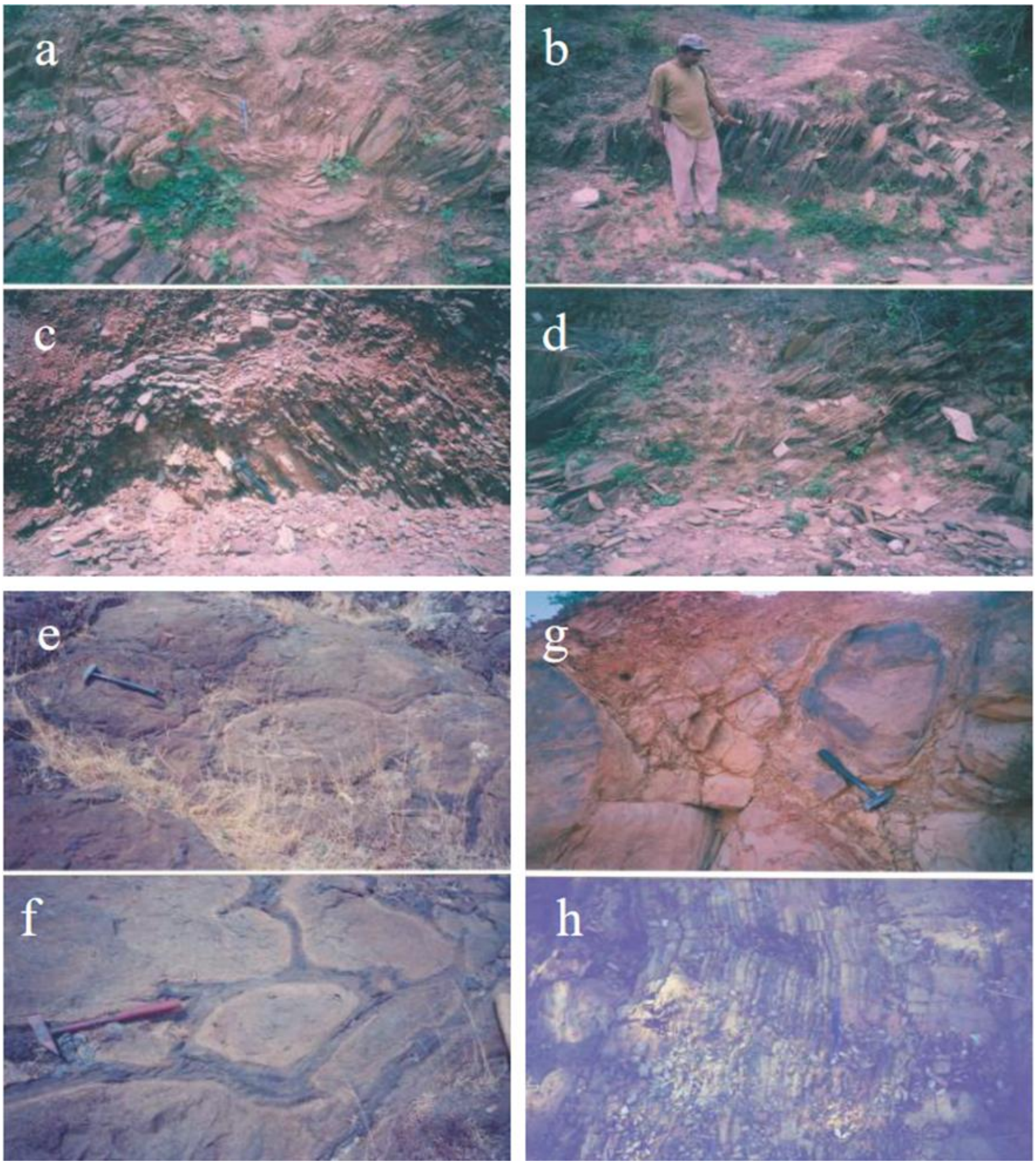

Fig. 5: (a-d) Field photographs shows occurrences of phyllites in the study area. **(e to f)** Metavolcanics and **(h)** Banded Iron Formation.

V. CONCLUSION

Field and petrographic evidences, such as the presence of fresh angular plagioclase and volcanic lithic fragments suggest that the Dharwar greywackes were deposited in turbidite regime very close to provenance in an unstable environment in which erosion, transportation and deposition were so rapid that there was very little scope for weathering and sorting of the clastic material. The detritus comprising felsic and mafic volcanics, feldspar and quartz suggest a mixed source in the provenance.

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