Sci. J. Fac. Sci. Minufia Univ., 2009, Vol.XXIII(2).195 – 219

THE TURBIDITY SEQUENCE OF THE DUNGASH AREA SOUTH EASTERN DESERT OF EGYPT: CRITERIA FOR ITS ORIGIN

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ABSTRACT

Dungash is a part of the Arabian Nubian Shield; it consists mainly of thick clastic metasediments sequence consisting mainly of allochthonous and detrital constituents, over thrusted in some parts ophiolite oceanic crust (serpentinite nappes).

Field data revealed the presence of numerous serpentinite enclaves and clasts within the Dungash turbidity sequence, suggesting that they are affiliated to ophiolitic mélange.

X-ray diffraction (XRD) measurements and petrographical studies of the clastic metasedimentary rocks revealed that the recorded mineral assemblage support an ultramafic origin. The mineralogical studies and electron microprobe (EMP) analysis of the clastic metasediments indicate that these allochthonous turbidity materials at Dungash mostly affiliated to the ophiolitic mélange.

The Na_2O/K_2O, SiO_2/Al_2O_3 and Fe_2O_3/Al_2O_3 parameters applied to the metagreywackes, metasiltstone, and metamudstone, revealed that metamudstones are more mature than both metagreywackes and metasiltstones, but these rocks have the same range of mineral stability and were derived largely from the same source.

The high contents of the ferromagnesian elements (Fe, Mg, Mn, Cr, Ni and V) in sedimentary rocks are indicative an ultramafic source. The Cr/V ratio reflects the enrichment of chromium over other ferromagnesian components and points to the presence of chromite among the opaque minerals. The Y/Ni ratio of the analyzed clastic rocks is very low, indicating that mafic to ultramafic rocks are widespread in the source area. The high contents of ferromagnesian elements in the majority of the studied samples confirm this. The clastic metasediments follow the magmatic trend indicating that their source is igneous rocks.

Key words: Dungash turbidity sequence, ophiolitic mélange, and clastic metasediments.

INTRODUCTION

The Dungash turbidity sequence is a part of the Arabian Nubian Shield. The area locates about 18 km southeast of the Barramiya area at the intersection of 24° 57' 25" N and 33° 52' 30" E. The area lies along the tectonic boundary separating the southern and central Eastern Desert (Stern and Hedge 1985). The ophiolite mélange at Wadi Dungash occupies the western part of the Precambrian rocks of the Eastern Desert of Egypt. It forms the hanging wall of the major thrust, in Wadi Dungash which has lineation trends in a NEN-SWS and NE-SW direction (Abu El Ela 1985, Ashmawy 1987 and Abdel-Khalek et al. 1992).

Marten (1986) mentioned that the shear zones (up to about 10 m in width) are responsible for a pronounced E-W trend in the area. The clastic metasediments are made up of interbedded metamorphosed siliciclastic turbiditic sequence. This sequence comprises graphitic metamudstones, thin-bedded to laminated metasiltstones and fine-to medium-grained arenaceous and calcareous units. The sequence is folded, where clasts are moderately flattened. Marten (op. cit.) recorded anomalies in Ni (131, 201 ppm) and Cr (303, 333 ppm) in two chip samples of the weakly carbonate and altered clastic metasediments. He refers that these anomalies suggest that the flyschoid sediments were derived in part from obducted slabs of ophiolite.

Abdel-Khalek et al. (1992) noticed that the metavolcanics form elongated blocks and fragments inside the mélange matrix of Wadi Dungash. They are frequently fine to medium-grained, massive or sheared and displaying well developed lineation. Meta-andesites and metabasalts or their equivalent schists represent these rocks. The clastic metasedimentary rocks cover large parts in the study area, that mostly form the matrix enclosing the ophiolite fragments. The clastic metasediments are represented by metagreywackes, metasiltstones, phyllites and schists, all are within the zone of greenschist regional metamorphism. The different beds usually grade into each other without sharp boundaries. They are slightly and strongly sheared, folded and lineated. The metagreywackes include feldspathic and volcanic varieties. The latter contains andesitic rock fragments beside quartz and feldspar crystal fragments.

The Dungash metavolcanics and associated metapyroclastic rocks belong to the Shadli belt with an age of 711±10 Ma (Kroner et al. 1987). They were considered to be related to the younger metavolcanics (Stern 1981 and Abu El-Leil et al. 1988). The rocks pertain to greenschist metamorphic facies and were termed greenstone by El-Ramly and El-Far (1955).

Khalil et al. (2003) recorded the presence of dolomite, ankerite, calcite, rhodochrosite, siderite, magnesite, chromite and anatase in the clastic metasediments at Dungash area. Chromite and probably ilmenite are of magmatic origin and constituents of the country rocks. They add that under metamorphic conditions rutile and anatase were newly formed at the expense of the pre-existing ilmenite, whereas chromite remained stable.

Dourgham et al. (2008) analyzed the sulphide minerals hosted in the clastic metasediments at Dungash area and associating gold. The EMP electron microprobe analysis of pyrite indicates that cobalt amounts to 1.48 wt % and Nickel up to 0.75 wt %, where nickel content in pyrrhotite amounts to 0.64 wt % and cobalt content in arsenopyrite amounts to 0.42 wt %. These EMP analyses reflect that both Ni and Co were found in elevated concentrations in the clastic metasedimentary rocks.

Several geologists study the clastic metasedimentary rocks at Dungash area, which constitute flyschoid sediments of allochthonous and detrital constituents. These flyschoid sediments were derived in part from obducted slabs of ophiolite formed after serpentinite and its derivatives (Ashmawy 1987 and El-Gaby et al. 1990). The clastic metasediments mostly form the matrix enclosing the ophiolite fragments. The geology of the present ophiolite mélange distributed in the area was treated elsewhere (Abu El Ela 1985 and Abdel-Khalek et al. 1992).

The present study aims to reveal the origin of the Dungash turbidity sequence evidences that arrived at the geological, petrographical, mineralogical and geochemical studies whether, depending on the ophiolitic origin or not.

ANALYTICAL METHODS AND TECHNIQUES

Twenty-seven representative samples were collected from the different rock unites that constitute Dungash turbidity clastic metasedimentary sequence. These samples were subjected to petrographical (12 thin sections) and ore microscopy (7 polished surfaces).

XRD for bulk samples were performed using a Siemens 5000 diffractometer, with Cu-Ka radiation and a graphite monochromatic, operated at 40 mA and 40 KV, employing a 0.018 step size and 1 s counting time at the Department of Mineralogy, University of Wuerzburg Germany.. The X-ray patterns were obtained from powders, as well as oriented and ethylene-glycol treated samples.

Ten samples representing the metagreywackes, metamudstones and metasiltstones were selected for chemical analysis using Inductively Coupled Plasma spectrometer (ICP-ES) of Philips 50 MHz model Pv 8210 to determine quantitively the major oxides and trace elements. A series of volcanics and metasedimentary standard samples were used for the quantitative determinations (in the National Research Centre of Egypt, N.R.C.).

Electron microprobe studies were carried out using the SX-50 CAMECA microprobe at the Department of Mineralogy, University of Wuerzburg Germany. Operating conditions were 20 KV acceleration voltage, 15 nA beam current and 20-30s counting time. The beam diameter was set at 1 μm for all phases.

GEOLOGIC SETTING

The undertaken area occupied largely by early to late Precambrian (Pan-African) crystalline rocks comprising ophiolitic sequence, island arc assemblage and late to post magmatic assemblage cordilleran stage, in addition to basic and acidic dykes (Fig. 1). The ophiolitic rocks are represented mainly by serpentinites and related talc-carbonate rocks. These rocks are localized at the main entrance of Wadi Dungash in the western border of the mapped area.

The ophiolitic mélange constitutes the majority of the exposed rocks. It is represented by the clastic metasedimentary rocks that consist of metagreywackes, metasiltstones, metaconglomerates and subordinate metamudstones rocks (Fig. 2).

Metaconglomerates are completely confined within metagreywackes, extending more than 2 km. They have lens like shaped and extend in east-west trend (Fig. 1).

Metagreywackes show grey to greenish colouration and dominated by pale felsitic volcanic clasts, angular to subrounded and commonly amounts to 1.5 cm size, but locally much coarser (Fig. 3a). However, metagreywacke exposures show great variations in their textures, structures and mineral compositions, but exhibit uniformity in their foliation trend. Original banding, clastic nature are still preserved, and their direction of dip is also the same. These rocks cover about 60 % of the mapped area. Due to their wide distribution, they have gradational contact with the other rock types (Fig. 1).

Metasiltstones are moderately sorted, medium-grained, with common discrete detrital grains. Serpentinite enclaves are encountered within the metasiltstones (Fig. 3b). The field observation revealed that metasiltstones are largely intercalated with metagreywackes and metamudstones with graded contacts.

Metamudstones are tough dark green in colour with slight laminations. Mudstone's hand specimens occur as black, hard, non-foliated derived from very fine siliceous muddy sediments (Fig. 3c). They are fine grained, that commonly occur as matrix within other clastic metasedimentary assemblage. Metamudstones contain numerous enclaves and clasts of detrital grains of different sizes (i.e.

poorly sorted). The groundmass is of clay size, coarse quartz, plagioclase and orthoclase detrital grains, as well as allochthonous opaque minerals represent these enclaves. The original banding was traceable in the places examined far from the slate schist. Their grade of metamorphism decreases westwards the mapped area (Fig. 1). The rocks are jointed in various directions and have greenish-brown weathering colours. Original banding in these rocks is also observed in several tributaries of Wadi Dungash. Occasionally, these bands have a roughly east-west direction. They occasionally show well banded structure and include pebbly beds with pebbles of different sizes up to 1 cm. in diameter.

El Ramely and El Far (1955) mentioned that these metamudstones are definitely of sedimentary origin and that they pass gradually into the hornblende-schists, which is further evidence to the sedimentary origin of these schists also. The pebbly and slaty schists found to the northern part of Wadi Dungash are interbedded with thick beds of these mudstone rocks.

Slaty schists are represented mainly by siliceous and siliceous-argillaceous varieties. They occur as a lens like shaped and narrow stretches especially in the north eastern corner of the study area. This rock unit is controlled by east-west trend and entirely encountered within metagreywackes.

The island arc rocks are represented by metavolcanics that occupies the southern and south-eastern borders of the study area. They are of acidic to intermediate composition and consist mainly of metadacites and meta-andesites.

Lava breccia extruded in the contact between metavolcanic and metagreywackes rocks. It occurs also as sub circular shape completely surrounded by metagreywackes rocks (Fig. 3d).

Structurally: Dungash area lies along the tectonic boundary separating the Southern and Central Eastern Desert (Stern and Hedge 1985). Ophiolite mélange forms hanging wall of the major thrust. Meanwhile, the island arc rocks represent the footwall. The study area is affected by two main fault trends; NE-SW and E-W, the first faults trend is older than the second faults trend (Zalata et al., 1973).

. The sequence has been folded, where a weak to moderate cleavage is developed and the clasts are moderately flattened. The cleavage and related shear zones up to about 10 m in width are responsible for a pronounced E-W trend in the study area. The field observations pointed out that the E-W faults are largely controlled by major shear zone.

PETROGRAPHY

Metagreywacke consists of quartz and feldspar detrital grains and rock fragments set in a clayey matrix that affected later by low-grade metamorphism and altered to chlorite and sericite. The rocks are medium to coarse grained. Rock fragments, in some of these greywackes band may amounts to 0.5 cm. in diameter, whereas pebbles amount up to 1 cm. or more.

Microscopically, the mineral grains are angular or subangular quartz (up to 0.9 mm. in length) exhibiting undulose extinction, and feldspar essentially represented by plagioclase (up to 0.6 mm. in length) with little orthoclase (Fig. 4a). Rock fragments are varied in sizes and amount to 1 mm. in length. The proportion of mineral grains to rock fragments is about 2:1. The matrix constitutes small part of the rock relative to the mineral grains and fragments and is essentially of greenish chlorite with little biotite and sericite (Fig. 4a).

Metasiltstones is formed of clastic angular or subangular grains of quartz, feldspar, carbonate and biotite specks (up to 0.15 mm. in length) embedded in a very fine-grained matrix of quartzo-feldspathic granules, chlorite, graphitic material and sericite (Fig. 4b). Carbonate rich band is seen in the rock slice, carbonate forms also part of the matrix.

Metamudstones consist of deep brownish-green biotite small flakes and clots (up to 0.05 mm. in length) set in a finer matrix of quartz and little feldspar and contains fine aggregates of green chlorite flakes as well as larger grains of quartz and feldspar. Graphitic material is concentrated in lenticular patches elongated in oriented direction. These patches are devoid of biotite but contain chlorite. The rock is formed of biotite-bearing and chlorite-bearing bands in a sort of alternation. Chlorite is of a pale green variety. Biotite-bearing bands contain minute sericite specks (Fig. 4c). Quartz occurs as fine grains with subordinate feldspar. Clastic coarse quartz and feldspar grains are scattered in the rock slice (Fig. 4c).

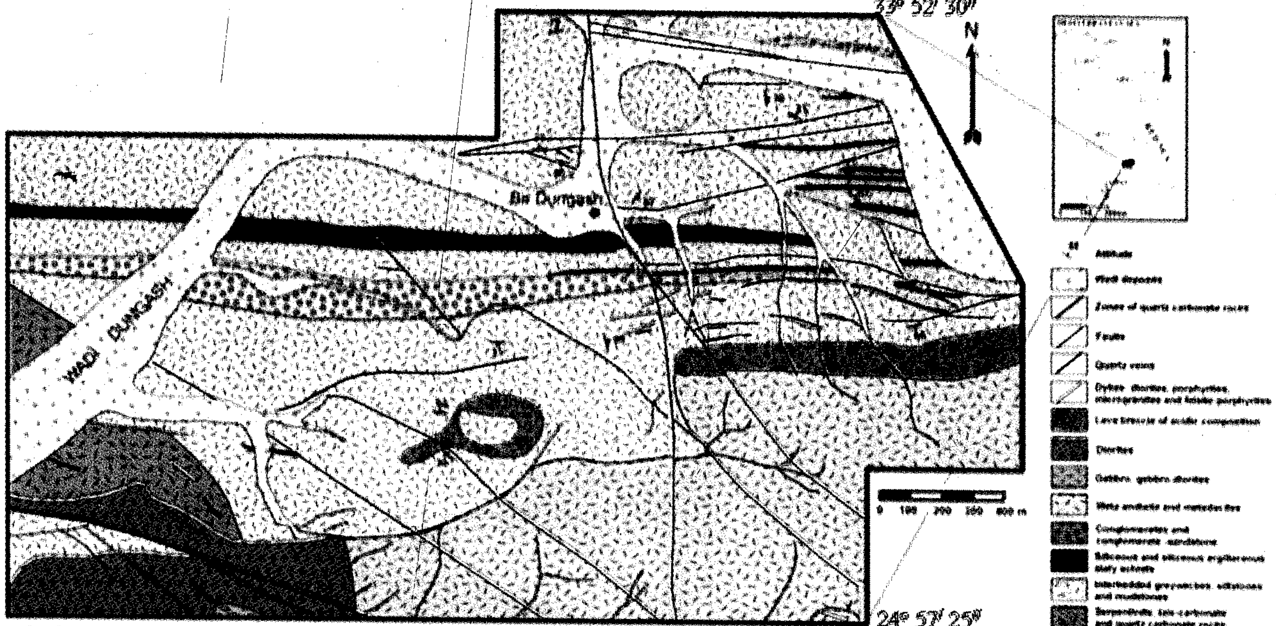


Fig. (2): Geologic map of Dungash modified after (Zalata et al., 1973)

Fig. (2): The turbidite sequence of interbedded metaconglomerates, metasiltstones, metagreywackes, and metamudstones from E to W direction, the direction of topographic grain striking E-W fault looking south. *Abbreviations*: metaconglomerates (M. cong.), metasiltstone (M. Silt.), metagreywackes (M. Greyw), metamudstones (M. Mud.).

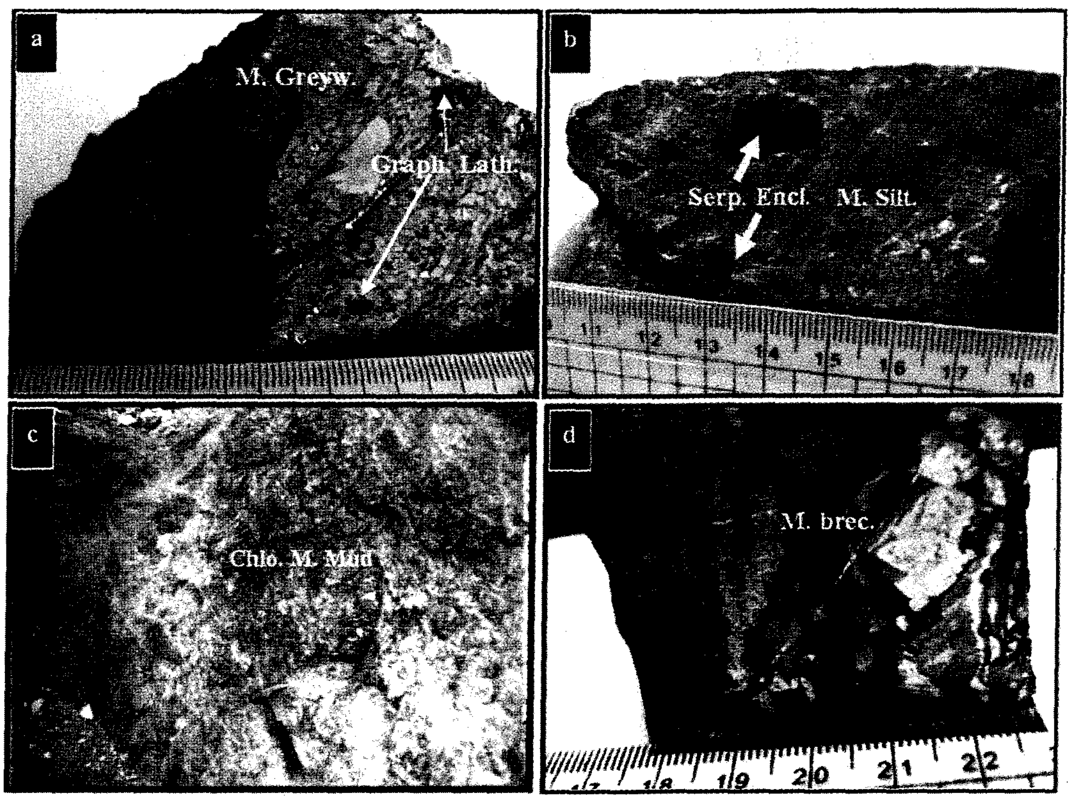
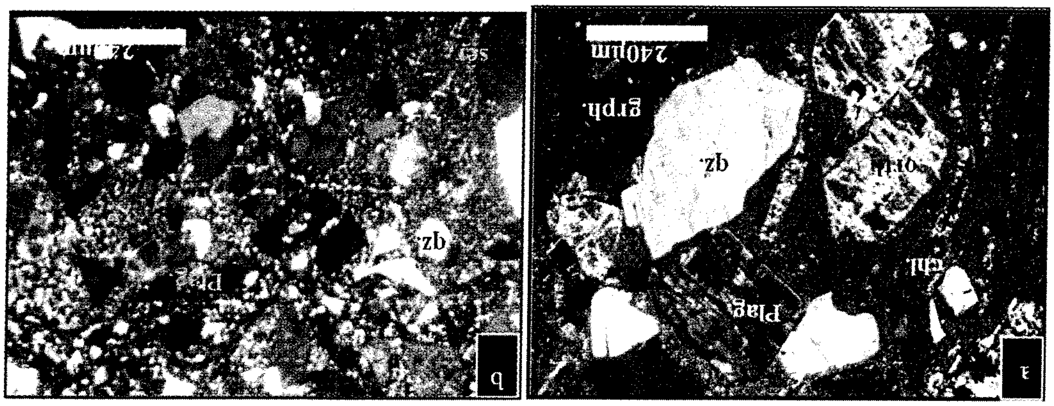


Fig. (3a): Metabreccia hand specimen consists of phenocrysts cemented by calcareous and siliceous materials. b) Detrital graphite lathes embedded within metagreywackes. c): Allochthonous serpentinite enclaves encountered within metasiltstones rock. d): Highly chloritized metamudstones bands enclosed in metagreywackes. Abbreviations: metabreccia (M. brec.), metasiltstone (M. Silt.), metagreywackes (M. Greyw), metamudstones (M. Mud.), chloritized metamudstones (Chlo. M. Mud.), serpentinites enclaves (Serp. Encl.) and graphite laths (Graph. Lath).



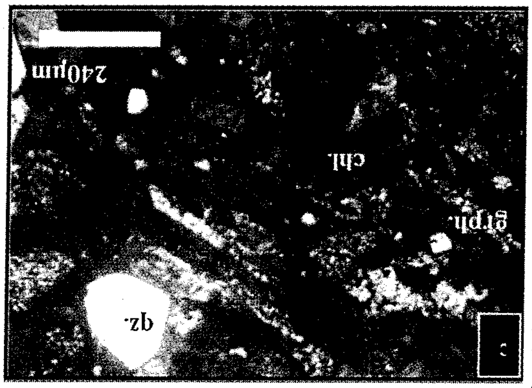


Fig. (4a): Metagreywackes: Coarse to medium quartz of undulose extinction, and large feldspar crystals, the matrix consists of chlorite with little biotite and sericite. b) Metasiltstones: Comprises quartz, feldspar, carbonate and biotite specks embedded in a very fine-grained matrix of quartzo-feldspathic granules, chlorite, graphitic material and sericite. c) Metamudstones: consists of biotite flakes set in a finer matrix of quartz and feldspar, chlorite. Graphitic material is concentrated in lenticular patches elongated in oriented direction. Abbreviations: Plagioclase (plag.), orthoclase (orth.), quartz (qz.), chlorite (chl.), biotite (bit.), sericite (ser.) and graphite (grph.).

MINERALOGY

The mineralogical studies based on XRD measurements, opaque minerals studies and EMP analysis

X-Ray Diffraction

Figure (5) represents the compiled diffractograms for three samples. These samples were selected from the bulk samples of the metagreywackes, metasiltstones and metamudstones. The compiled mineral assemblage recorded by XRD comprises ankerite, clinochlore, muscovite, quartz, calcite, dolomite, kaolinite and pyrophyllite.

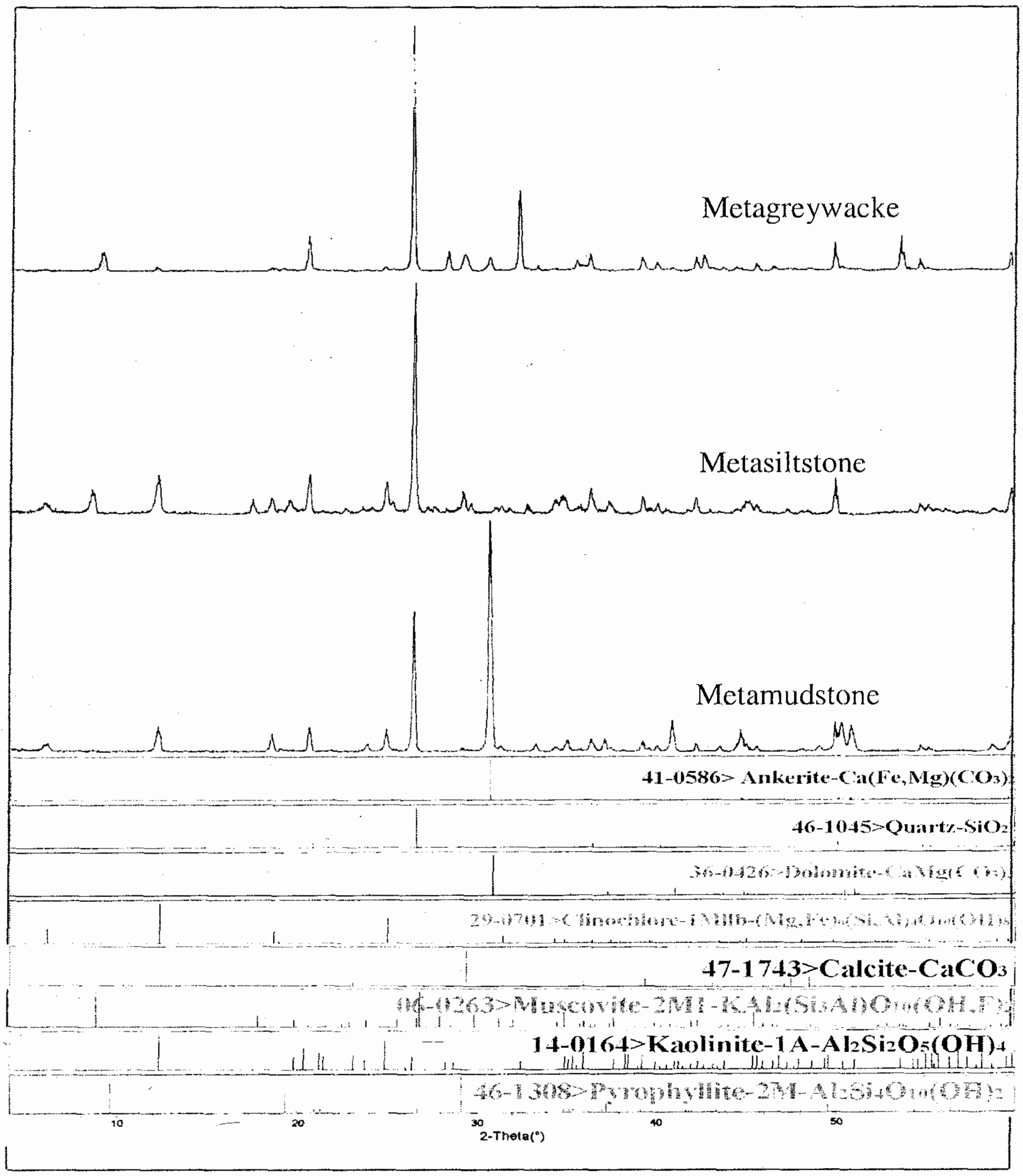


Fig. (5): Compiled diffractograms for the studied clastic metasediments rock varieties at Dungash.

Opaque Mineralogy

Four detrital opaque minerals were dispersed in the clastic metasedimentary rocks namely: pentlandite, millerite, chromite and hematite. The presence of these opaque minerals can be an evidence that the clastic metasediments are derived from ultramafic source.

Pentlandite [(Fe,Ni)9S8] occurs as fine to very fine grains disseminated in the clastic metasediments. The mineral grains outline show corroded outlines (Fig. 6a). Chromite (FeCr2O4) occurs as skeletal crystals or as fragmented portions, transported and accumulated as aggregates (Fig. 6b). Millerite (NiS) occurs as fine elongated grains with xenomorphic outlines (Fig. 6c). Occasionally, the mineral is recorded in close vicinity with pentlandite but less abundance. Hematite (Fe2O3) is found as coarse, well-developed crystals or highly fragmented clasts (Fig. 6d).

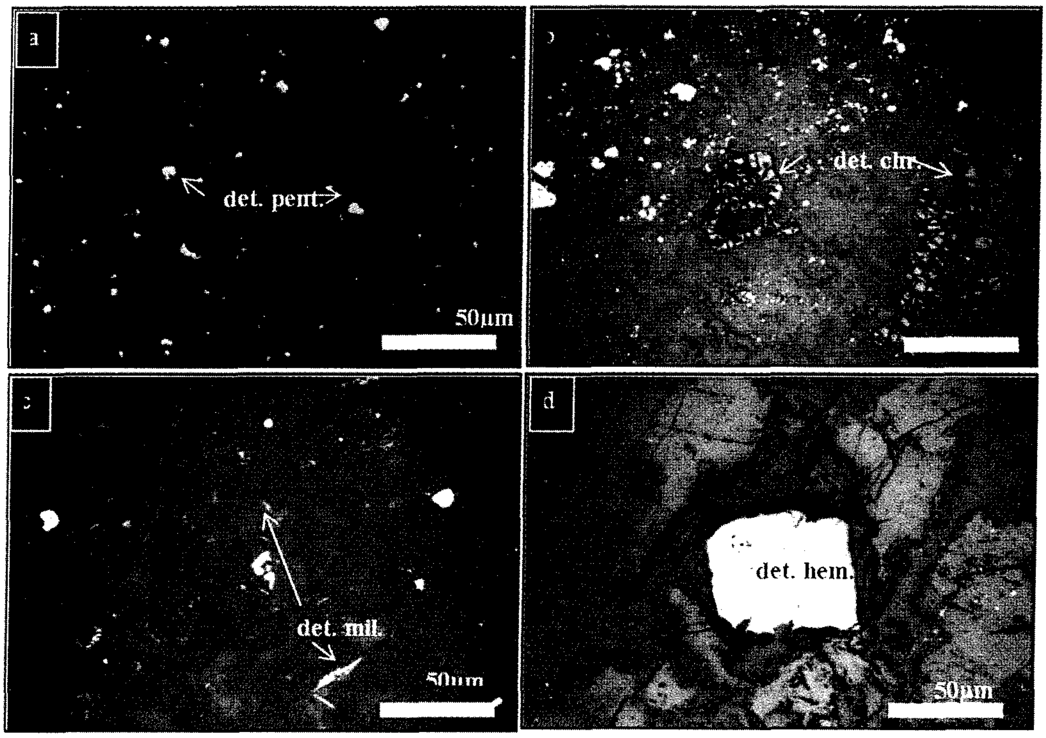


Fig. (6a) Fine to very fine pentlandite grains disseminated within the metasiltstones. b) Highly cracked and fragmented skeletal chromite crystals. c) Detrital elongated millerite with xenomorphic peripheries. d) Large detrital hematite crystal shows intensively corroded outlines. Abbreviations: Detrital pentlandite (det. pent.), detrital chromite (det. chr.), detrital millerite (det. mil.), and detrital hematite (det. hem.).

Electron Microprobe (EMP)

The detrital opaque minerals were subjected to EMP analysis. It is carried out the presence of pentlandite, millerite, chromite and hematite. EMP analysis of chromite grains revealed that it contains high contents of aluminum and magnesium, with very limited variation, Chromite is of the aluminum rich type. The mineral has remarkable concentrations in titanium, vanadium and nickel (Table 1). Pentlandite shows elevated content of zinc (Table 2). Millerite shows remarkable quantities of iron and cobalt (Table 3). Hematite shows elevated contents of arsenic, nickel, lead and sulphur (Table 4).

Table (1): Microprobe analysis of detrital chromite at Dungash area.

S. No.	B_4	B_3	B_4	B_3	B_4	B_3	Average (n=6)
Chromite							
Ti	0.72	0.67	0.71	0.81	0.75	0.76	0.73
Al	8.94	7.92	8.77	8.56	8.45	8.8	8.57
Cr	25.2	25.79	25.28	25.49	26.14	25.9	25.63
V	0.13	0.13	0.13	0.12	0.14	0.13	0.13
Fe	29.06	29.3	29.13	29.32	28.41	28.57	28.96
Ni	0.047	0.03	0.047	0.04	0.04	0.047	0.04
Mg	3.44	4.12	3.65	3.48	3.58	3.6	3.64
O	32.05	31.86	31.91	31.79	32.02	31.83	31.91
Total	99.58	99.82	99.62	99.61	99.53	99.63	99.61

Table (2): Microprobe analysis of detrital pentlandite at Dungash area.

S. No.	B_4	B_3	B_4	B_3	B_4	B_3	Average (n=6)
				Pentlandite			
S	32.77	32.99	33.69	33.11	33.56	33.19	33.21
Fe	24.96	27.28	26.19	26.55	27.14	27.1	26.53
Zn	0.13	0.05	0.16	0.09	0.19	0.16	0.12
Ni	41.4	39.71	39.87	39.89	38.95	39.1	39.82
Total	99.26	99.98	99.91	99.64	99.84	99.55	99.68

Table (3): Microprobe analysis of detrital millerite at Dungash area.

S. No.	B_4	B_3	B_4	B_3	Average (n=4)
	Millerite				
S	36.01	36.66	35.78	36.16	36.15
Fe	0.74	0.74	0.81	0.89	0.79
Co	0.79	0.9	0.93	0.83	0.86
Ni	61.63	61.41	62.09	61.69	61.7
Total	99.17	99.71	99.61	99.57	99.5

Table (4): Microprobe analysis of detrital hematite at Dungash area.

S. No.	B_4	B_3	B_4	B_3	Average (n=4)
	Hematite				
As	1.34	0.61	0.19	0.26	0.6
S	0.39	0.48	0.51	0.62	0.5
Pb	0.11	0.1	0.05	0.09	0.07
Fe	44.13	50.97	49.83	47.75	48.17
Ni	1.45	0.38	0.17	0.83	0.7
O	52.02	47.13	48.62	50.09	49.46
Total	99.62	99.81	99.41	99.75	99.63

GEOCHEMISTRY

The chemical analysis of major and trace elements -after Dourgham et al (2008)- for 10 samples of fresh clastic metasedimentary rock samples are given in tables (5 & 6).

Classifications: (Fe_2O_3 $_{(total)}$ + MgO)-Na_2O-K_2O ternary diagram of Pettijohn et al. (1972) (Fig. 7) shows that metagreywacke and metasiltstone samples are plotted in the metagreywackes field. Mudstone samples are plotted in the lithic sandstones and arkose fields.

TiO_2 versus Ni binary diagram (Fig. 8) of Floyd et al. (1989) revealed that the majority of clastic metasediments samples follow the magmatic trend indicating that these clastic metasediments are derived from igneous rocks.

Table (5): Major oxides (Wt %) and chemical ratios of clastic metasediments at Dungash area.

Rock type	Metagreywacke					Metasiltstone					Metamudstone	
Sample	300	301	306	307	Ave.	308	309	310	311	Ave.	321	322
SiO_2	63.75	63.7	63.83	63.9	63.79	61	61.1	62.62	63.81	62.13	59.04	65.78
TiO_2	0.71	0.66	0.72	0.8	0.72	0.56	0.85	0.99	0.81	0.8	1.15	1.09
Al_2O_3	15.61	15.5	15.26	15.53	15.47	14.76	16.05	15.85	14.69	15.33	17.04	15.34
Fe_2O_3	3.05	3.14	3	3.02	3.05	2	2.56	3.08	3.01	2.66	3.9	3.02
FeO	0.37	0.29	0.39	0.25	0.32	5.27	5.71	5.57	5.14	5.42	2.54	2.56
MnO	0.15	0.14	0.15	0.15	0.14	0.17	0.19	0.22	0.2	0.19	0.18	0.08
MgO	1.63	1.8	1.72	1.64	1.69	4.7	4.61	4.44	4.92	4.66	5.43	1.93
CaO	4.62	4.65	4.51	4.65	4.6	2.59	2.13	2.18	1.66	2.14	2.29	0.74
Na_2O	2.63	2.77	2.63	2.61	2.66	3.6	3.72	1.55	2.74	2.9	1.67	0.85
K_2O	1.51	1.41	1.51	1.5	1.48	2.53	0.76	1.04	1.36	1.42	3.93	6.13
P_2O_5	0.22	0.25	0.26	0.26	0.24	0.19	0.23	0.2	0.11	0.18	0.22	0.17
LOI	5.61	5.32	5.83	5.62	5.5	2.43	2.03	2.16	1.46	2.02	2.6	2.08
Total	99.86	99.63	99.81	99.93	99.66	99.8	99.94	99.9	99.91	99.85	99.99	99.77
Na_2O/K_2O	1.74	1.96	1.74	1.73	1.79	1.42	4.89	1.49	2.01	2.04	0.42	0.14
SiO_2/Al_2O_3	4.08	4.10	4.18	4.12	4.12	4.13	3.8	3.95	4.34	4.05	3.46	4.29
Fe_2O_3/Al_2O_3	0.19	0.20	0.19	0.19	0.19	0.13	0.16	0.19	0.20	0.17	0.22	0.19

Table (6): Trace elements (ppm) for clastic metasediments and chemical ratios at Dungash area. (- Not detected --Under detection limit).

Rock type	Metagreywacke					Metasiltstone					Metamudstone	
Sample	300	301	306	307	Ave.	308	309	310	311	Ave.	321	322
Ba	402	502	415	428	436	456	45	16	53	142	693	820
Rb	85	67	72	77	75	62	12	6	5	21	51	5
Sr	601	594	598	574	591	562	170	139	201	268	178	105
Y	13	14	15	19	15	15	7	6	-	7	22	12
Zr	139	170	153	151	153	161	55	41	75	83	356	80
Nb	9	13	12	8	10	10	-	2	-	3	7	-
Pb	16	14	10	12	13	15	47	40	48	37	17	20
Zn	68	76	69	66	69	73	57	33	30	48	179	20
Cu	30	25	20	24	24	18	95	95	85	73	16	30
Ni	25	32	36	42	33	17	63	50	42	43	82	91
V	48	65	62	52	56	51	63	28	53	48	108	33
Cr	60	68	73	66	66	76	42	41	50	52	148	107
Ta	1	1	-	1	0.75	-	-	1	-	0.25	-	-
Co	19	10	17	14	15	20	-	20	2	10	19	35
Li	1	-	2	1	1	-	-	9	-	2	-	-
Cr/V	1.25	1.04	1.17	1.27	1.18	1.49	0.66	1.46	0.94	1.08	1.37	3.24
Y/Ni	0.52	0.43	0.41	0.45	0.45	0.88	0.11	0.12	-	0.16	0.27	0.13

The data for Wadi Dungash rocks have been plotted on the silico-aluminate diagram (La Roche, 1965) (Fig. 9). The majority of metasiltstone samples are close to the basalt average within the Mg-clays domain. The metagreywackes samples plot in quartz-diorite. The diagram split the metamudstone samples into biotite and muscovite-orthoclase fields. All the clastic metasediments samples follow the igneous trend.

The Wadi Dungash rocks are enriched in both TiO_2 and FeO. Figure (10) shows that all of the metagreywackes and metamudstone samples are plotted in the anisotitaneous field, whereas the metasiltstone samples belong to the isotitaneous field of Bebien (1980).

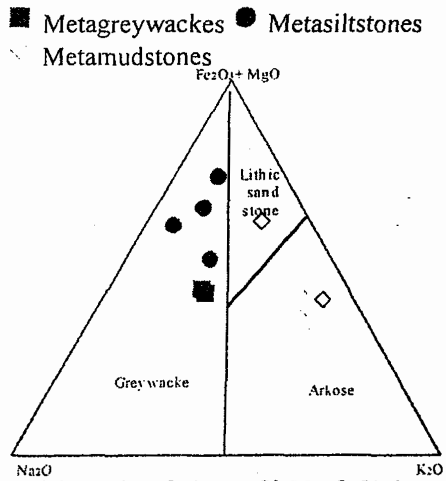


Fig. (7) : $(Fe_2O_3{}^*+MgO)$-Na_2O-K_2O ternary diagram of Pettijohn et al. (1972).

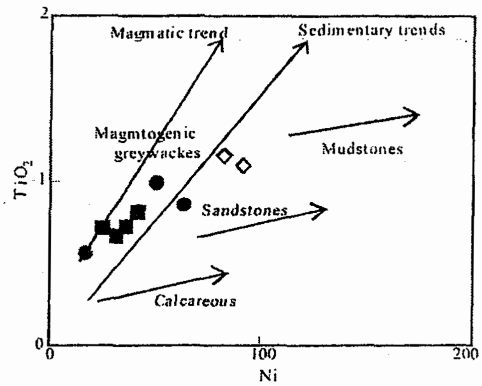


Fig. (8) : TiO_2 versus Ni binary diagram (Floyd et al. 1989).

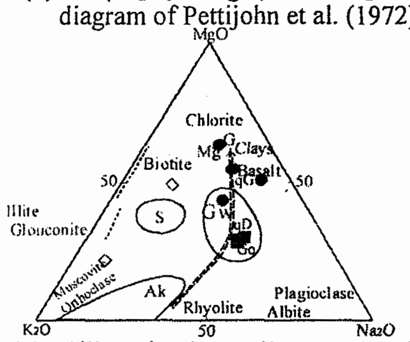


Fig. (9): Silico-aluminate diagram (La Roche, 1965), for Dungash rocks G- gabbro, qG-quartz-gabbro, qD-diorite, D-quartz-diorite, Go-Granodiorite, G-granites, S-Shale field, Gw-greywacke field, Ak-arkose field. The position of key minerals is also given. The dashed line shows the general trend of igneous rocks.

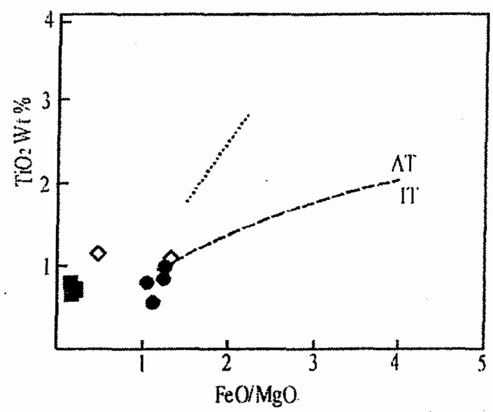


Fig. (10): Variation of TiO_2 vs. FeO/MgO for Wadi Dungash rocks-fields after Bebien (1980); IT: isotitaneous, AT: anisotitaneous.

Table (7): Niggli values for the mélange rocks of Wadi Dungash

R. type	Metagreywacke					Metasiltstone					Metamudstone	
S. No.	300	301	306	307	Ave.	308	309	310	311	Ave.	321	322
k	0.27	0.25	0.27	0.27	0.27	0.31	0.12	0.3	0.24	0.24	0.6	0.82
mg	0.85	0.88	0.85	0.88	0.86	0.6	0.58	0.57	0.62	0.59	0.7	0.56
fm	22.61	19.19	23.32	22.28	22.83	44.07	46.45	49.88	50.19	47.55	46.41	33.56
al	40.31	41.7	39.77	40.36	40.04	29.35	31.99	33.82	30.89	31.49	32.37	41.23
c	21.69	22.74	21.37	21.97	21.65	9.36	7.72	8.45	6.34	7.99	7.91	3.61
alk	15.39	16.36	15.53	15.37	15.47	17.22	13.83	7.84	12.57	12.95	13.3	21.59
si	279.35	290.78	282.23	281.72	280.3	213.21	206.76	226.82	227.79	216.71	190.43	300.16

Niggli values were used by Leake (1964) and Leake and Singh (1986) to differentiate between the ortho-and para-metamorphic rocks. The Niggli values for the Wadi Dungash rocks (Table 7) are plotted on the c-mg-(al-alk) ternary diagram (Fig. 11) from which all the clastic metasediments samples are close to mg corner and their distributions follow the igneous rocks trend. The plotting on (al-alk) vs. c binary diagram (Fig. 12) revealed that the metagreywackes samples plot in the normal clay field, meanwhile the both metasiltstone and metamudstone samples are plotted in sand field. The majority of the clastic metasediments samples (Fig. 12) follow the typical igneous differentiation trend proposed by Leake and Singh (1986).

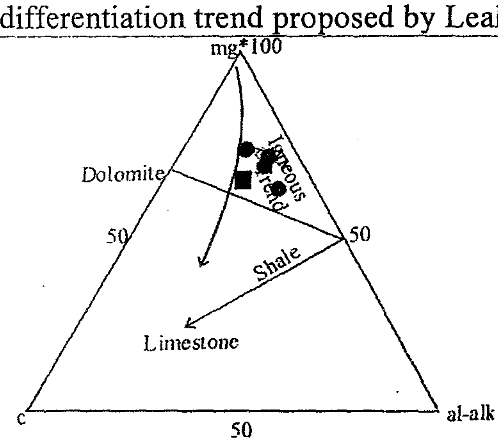


Fig. (11): c-mg-(al-alk) ternary diagram, for the Wadi Dungash rocks. Fields after Leake (1964).

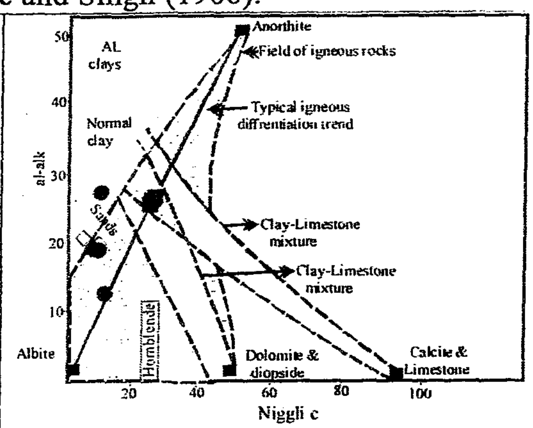


Fig. (12): (al-alk) vs. c plot for the wadi Dungash rocks. Fields after Leake and Singh (1986).

Identification of the mature and immature sediments can easily be done based on the chemical classification of sedimentary rocks (Pettijohn et al. 1972). Na_2O/K_2O

ratio represents an index of chemical maturity. The Na_2O/K_2O ratio of the metamudstones is < 0.5. Meanwhile the average of Na_2O/K_2O ratio for metagreywackes and metasiltstones are more than 1.5 (Table 5).

The SiO_2/Al_2O_3 ratio reflects the abundance of quartz and feldspar along with clay minerals (Potter 1978). The average of SiO_2/Al_2O_3 ratios of both siltstone and greywacke samples (Table 5) show the same values, and slightly less than the SiO_2/Al_2O_3 ratio of mudstone samples, indicating that these rocks have the same abundance of quartz and feldspar relative to clay minerals. The Fe_2O_3/Al_2O_3 ratio is successfully used as a measure of mineral stability (Herron 1988). The Fe_2O_3/Al_2O_3 ratio revealed that the Dungash metagreywacke, metasiltstone and metamudstone samples have the same range of mineral stability.

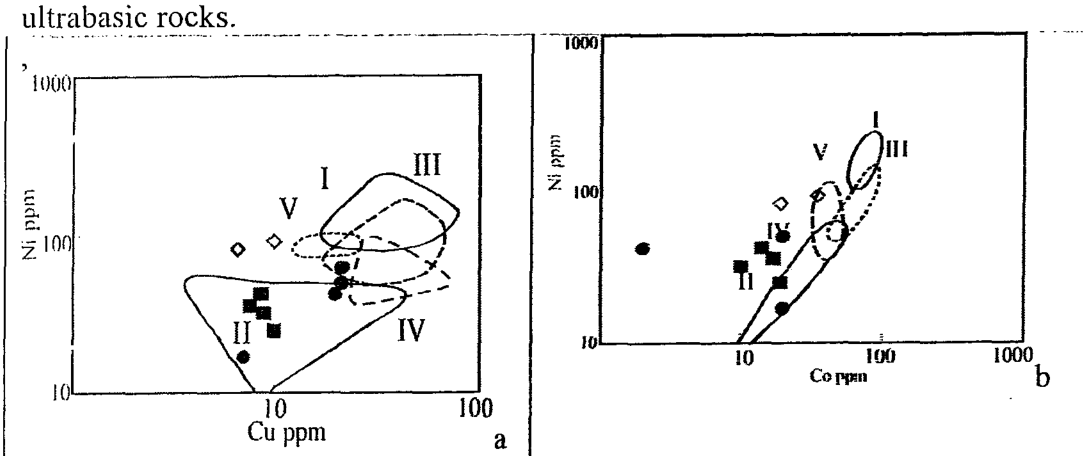
Trace elements were determined in 10 representative samples of different rocks from the ophiolitic mélange of Wadi Dungash (Table 6).

Nickel content in Wadi Dungash rocks ranges from 17 to 91 ppm, with an average of 48 ppm, which is remarkably lower than that for ultrabasic rocks. Nickel content is sharply depleted during metamorphic processes (serpentinization) this agree with (Loukola-Ruskeeniemi, 1999) results.

Chromium content ranges from 41 to 148 ppm. Cr average (73 ppm) is less than that of ultrabasic rocks (1600 ppm). However, Cr exhibits practically no mobility during metamorphism signifies its value (Frohlich, 1960) but Faust et al. (1956) and Wedepohl (1963) stated that serpentines derived from ultrabasic rocks are characterized by a Cr content higher than 100 ppm. The plotting of pairs of trace elements Ni, Co, Cr and Cu of Wadi Dungash rocks on Walker et al. (1960) diagrams (Fig. 13 A, B and C), show that the projection points of clastic metasediments samples are close to the fields of para-amphibolites of low to moderate alterations including metamorphism and ortho-amphibolites (intensely metamorphosed).

Vanadium content in the rocks from Wadi Dungash ranges from 28 to 108 ppm, with an average of 56 ppm. The average value is higher than that for ultrabasic rocks (40 ppm) that reported by Turekian and Wedepohl (1961) and lower than that of graphitic rocks given by Janda and Schroll (1960). This refers to the relatively high carbon content in these rocks whereas the ultrabasic rocks of Turekian and Wedepohl (1961) are poor in carbon. Vanadium as a typical biophile element is encountered in the graphite-bearing schists in amounts proportional to the carbon content (Peltola, 1968).

Cobalt content ranges from 2 to 35 ppm with an average 16 ppm. However, the average of cobalt in the clastic metasediments samples is less than that of the ultrabasic rocks (150 ppm) described by Turekian and Wedepohl (1961) but relatively higher than other averages in the different rock types. The higher Co content in the Wadi Dungash rocks may indicate their derivation from ultrabasic rocks.



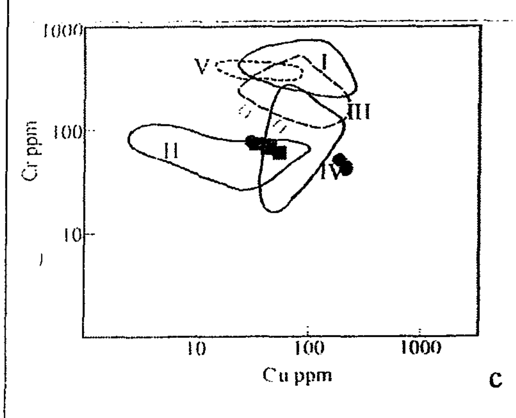


Fig. (13): Plots of the Wadi Dungash rocks on the discrimination diagrams for the trace elements
a-Ni vs. Cu, b- Ni vs. Co, c-Cr vs. Cu. The fields after Walker et al. (1960); I-unaltered and slightly altered basic magmatic rocks, II-para-amphibolites of low to moderate alterations including metamorphism, III-metamorphosed basic magmatic rocks, IV-ortho-amphibolites (intensely metamorphosed), V para-amphibolites (intensely metamorphosed),

Ferromagnesian elements (Fe, Mg, Mn, Cr, Ni, and V) are enriched in mafic and ultramafic rocks; their enrichment in sedimentary rocks may therefore be indicative of such source rocks. Cr/V ratio reflects the enrichment of chromium over other ferromagnesian components and points to presence of chromite among the opaque minerals (Table 5), which is comparable with Bock et al. (1998) results.
Y/Ni ratio in Dungash clastic metasedimentary rocks is relatively low (Table 6). This indicates that mafic or ultramafic rocks are widespread in source area (McLennan et al. 1983).

DISCUSSION

The Dungash turbidity sequence lies along the tectonic boundary separating the southern and central Eastern Desert that carried out by Stern and Hedge (1985). It consists mainly of thick clastic metasedimentary rocks. In the field, serpentinite enclaves and clasts are encountered within the clastic metasediments. This is concordant with Ashmawy (1987) statement that serpentinite bodies at Wadi Dungash and its derivatives have no sign of thermal contact on the enveloping rocks, emphasizing that these rock bodies are allochthonous. Ashmawy (op. cit.) and El-Gaby et al. (1990) interpreted the whole pile of rocks as a remnant of obducted oceanic crust and emphasized the origin of this turbidity sequence as made up of allochthonous and detrital constituents formed after serpentinite and its derivatives. The clastic metasediments rocks in the studied area mostly form the matrix enclosing the ophiolite fragments, indicating that these clastic metasediments were derived from ultramafic rocks.

The petrographical studies and XRD measurements of the metagreywackes, metasiltstones and metamudstones revealed that these clastic metasedimentary rocks consist of detrital quartz, feldspars, biotite, chlorite, sericite, quartzo-feldspathic granulates, graphitic materials, calcite, dolomite and ankerite, in addition to rock fragments. *Dolomite* is typically associated with the altered ultrabasic igneous rocks where it may occur with magnesite in serpentinites and talc-bearing rocks (Yigit, 2006 and Muir, 2002). *Ankarite* [$Ca(Fe,Mg,Mn)(CO_3)_2$] is one of the most characteristic alteration minerals of the ultrabasic rocks. It is formed by the chemical breakdown of amphiboles, pyroxenes and feldspar (Boyle 1979 and Hunt et al. 2005). *Graphite* is an altered product of peridotites (Pearson et al. 1994 and Hollister 1980). There is close vicinity between graphitic materials and carbonate minerals and the basic-ultrabasic ophiolitic rocks as obtained by Hunt et al. (2005) and Bierlein et al. (2004).

Rutile (ά-TiO_2), *anatase* (β-TiO_2), *rhodochrosite* ($MnCO_3$) *and siderite* ($FeCO_3$) were recorded in the clastic metasedimentary rocks at Dungash (Khalil et al., 2003). Abu El Ela (1985) recorded also *magnesite* ($MgCO_3$), *asbestos* [$(Mg_6(OH)_6Si_4O_{11}.(H_2O)$] and *talc* [$Mg_3Si_4O_{10}(OH)_2$] in Wadi Dungash rocks. The origin of *siderite* ($FeCO_3$) is not entirely certain as a result of weathering of ultramafic rocks (Deer et al, 1982). *Rhodochrosite* is usually enriched in ultramafic carbonates (Mark et al. 2005, and Solomona et al. 2004). *Magnesite* is formed by alteration of ultramafic rocks (peridotites and serpentinites) through the action of waters containing carbonic acid (Ashley and Craw, 2004 and Christie and Brathwaite, 2003). *Asbestos* is usually an alteration product of serpentine asbestos (Kraus et al. 1951). *Talc* [$Mg_3Si_4O_{10}(OH)_2$] is usually formed by the chemical breakdown of ultrabasic body Deer et al. (1982).

The mineral assemblages recorded in the present study or by Abu El Ela (1985) and Khalil et al. (2003) and are good criteria supporting affiliation the Dungash turbidity sequence to ultrabasic rocks and represent ophiolitic mélange.

The mineralogical studies and EMP analysis revealed that pentlandite, millerite, chromite and hematite detrital grains are scattered within the Dungash clastic metasediments. *Pentlandite* is usually formed in the early stage of magmatic crystallization and closely connected with ultramafic rocks (Stone et al., 2004 and Seat et al., 2004). *Millerite* (NiS) is an oxidation product formed in the first stage of Ni-rich ores weathering. It occurs mostly in many types of serpentinites (Garutil et al., 2007, and Uysal et al. 2005). *Chromite* is limited to mafic magmatic rocks such as peridotites and pyroxenites (Richards et al., 2006 and Milesi et al., 2002). The presence of these opaque detrital minerals supports the ultramafic origin of these minerals.

The chemical study of the analyzed metagreywackes, metasiltstones and metamudstones samples have revealed that they follow the magmatic trend, suggesting that their source is of an igneous origin. All the clastic metasedimentary rocks are enriched in TiO_2. The Na_2O/K_2O (Pettijohn et al. 1972), SiO_2/Al_2O_3 (Potter 1978) and Fe_2O_3/Al_2O_3 (Herron 1988) parameters were applied to the metagreywackes, metasiltstone, and metamudstone forming Dungash turbidity sequence. These parameters have revealed that although metamudstones are more mature than metagreywackes and metasiltstones, but these rock varieties have the same abundance of quartz and feldspar along with clay minerals and have the same range of mineral stability. These results indicate that these clastic rocks were derived largely from the same source.

The Co, V, Cr and Ni contents in the clastic metasediments indicate that they have an average V content more than the average of V in the ultrabasic rocks (40 ppm) given by Turekian and Wedepohl (1961) and lower than that of graphitic rocks. This refers to the relatively high carbon content in these rocks; whereas the ultrabasic are poor in carbon. However, the average of cobalt in the clastic metasediments is less than that of ultrabasic rocks (150 ppm) described by Turekian and Wedepohl (1961) but relatively higher than other averages in the different rock types. The high Co content in the Wadi Dungash rocks indicates their derivation from ultrabasic rocks as confirmed by Faust et al. (1956). The nickel average is remarkably lower than that for ultrabasic rocks (2000 ppm). Nickel content is sharply depleted during metamorphic processes (serpentinization). Cr exhibits practically no mobility during metamorphism (Frohlich, 1960), but Faust et al. (1956) and Wedepohl (1963) stated that serpentines derived from ultrabasic rocks are characterized by a Cr content higher than 100 ppm.

The ferromagnesian elements are enriched in the clastic metasediments. The low value of Y/Ni ratio in the analyzed clastic metasedimentary rocks indicates that the mafic or ultramafic rocks are widespread in source area (McLennan et al., 1983). The Cr/V ratio reflects the enrichment of chromium over other ferromagnesian components and points to the presence of chromite among the opaque minerals, may therefore be indicative of such source rocks as derived from ultramafic rocks; this is in concord with the work of Bock et al. (1998) in their study area. High detrital chromite in metagreywackes, metasiltstones and mudstone polished sections suggests mafic or ultramafic sources for these clastic metasediments. The interpretations of the geochemical data are additional criteria for the ophiolitic mélange origin of the Dungash turbidity sequence.

CONCLUSION

Several criteria are recorded in the present study to reveal the origin of Dungash turbidity sequence: The field data revealed the presence of serpentinite enclaves and clasts within the clastic metasediments, emphasizing that these rock bodies are allochthonous.

The petrographical, XRD, mineralogical and EMP studies of the clastic metasediments have revealed the presence of dispersed detrital pentlandite, millerite, chromite and hematite. The record of these minerals in the clastic metasedimentary rocks indicates formation in an early stage of magmatic crystallization, or as alteration products convenient ultramafic crystallization.

Interpretations of the geochemical data of the clastic metasediments show that they follow igneous rocks trend. Metamudstones are more mature than both metagreywackes and metasiltstones, but all of these rocks have the same range of mineral stability and they were derived largely from the same source. The high values of the ferromagnesian elements in sedimentary rocks are indicative of a source area. The high Cr/V ratio reflects the enrichment of chromium over other ferromagnesian components. Meanwhile, the Y/Ni ratio should be low if mafic or ultramafic rocks are widespread in source area. The data arrived by the geological, petrographical, mineralogical and geochemical studies suggest an ophiolite origin of the Dungash turbidity sequence.

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