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CONTRIBUTIONS TO THE PETROGRAPHY AND GEOCHEMISTRY OF AKAREM COMPLEX ROCKS, SOUTH EASTERN DESERT, EGYPT

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ABSTRACT

Akarem mafic-ultramafic rocks are intruded successively following the increasing basicity; norite, unmineralized peridotites, mineralized peridotites, and pyroxenites. Hybrid rocks are the result of assimilation of norite by intrusive peridotite. These rocks are subjected to intense deuteric action, and may show low grade metamorphism.

Akarem rocks are of the alpine type, differentiated from komatiitic magma, under moderate to high pO_2. *This is in harmony with the early differentiation trend of the Skaergaard intrusion, showing enrichment of total iron, following the fractional crystallization of the system* MgO-FeO-Fe_2O_3-SiO_2 *under conditions of constant total composition.*

Akarem complex magma setting, may be in the volcanic arc environment, which took place along one of the series of ENE trending deep-seated tectonic structures, in the eastern Desert of Egypt.

INTRODUCTION

The Akarem mafic-ultramfic intrusion is located about 130 km east of Aswan at the intersection of latitude 24° 01´ N and Longitude 34° 08´E (Fig. 1). This area is shown as granodiorite and

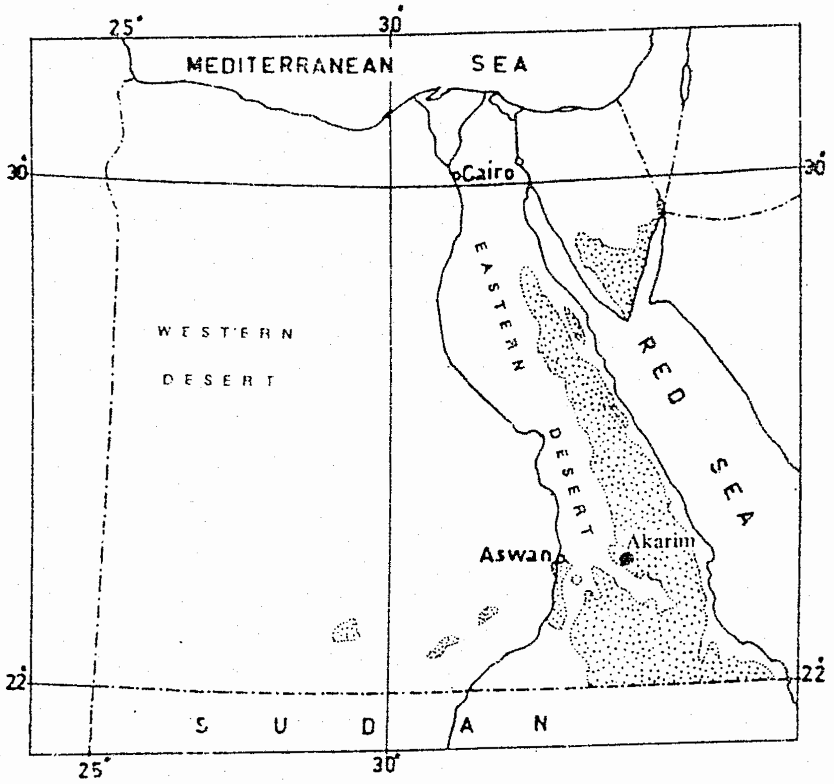

Fig. (1) : Location Map.

diorite on the 1 : 100,000 photogeological map (Hunting 1967). The presence of basic and ultrabasic rocks are confirmed by Bugrov and Shalaby (1973).

The Akarem complex consists of two seperate bodies, 1500 m. apart, which extends over a distance of 11.5 Km in ENE direction (Carter, 1975) (Fig. 2.). He (op. cit.) mentioned that five types predominate and in order of decreasing abundance these are norite, olivine melanorite, peridotite, pyroxenite and fine grained basic dyke rocks. Hybrid rocks resulting from the assimilation of norite by intrusive peridotite is an important feature.

From the field evidences, He (op. cit.) mentioned that the norites represent the primary intrusive phase, into which the olivine-rich rocks were later intruded. The peridotites can be grouped into early unmineralized peridotites and late mineralized peridotites. The pyroxenites represent a late phase of dyke intrusion which took place during and after the intrusion of the mineralized peridotites.

Carter (op.cit.) refered to that the age of the gabbro Akarem basic-ultrabasic intrusion is almost certainly later than the main episode of regional folding and the low grade metamorphism of the geosynclinal sediments, but predates the intrusion of the older granites.

Garson and krs (1976) believed that the intrusion of the mafic-ultramafic mass of Akarem took place along a fracture Zone, one of the series of ENE trending deep-seated tectonic structures in the Eastern Desert of Egypt.

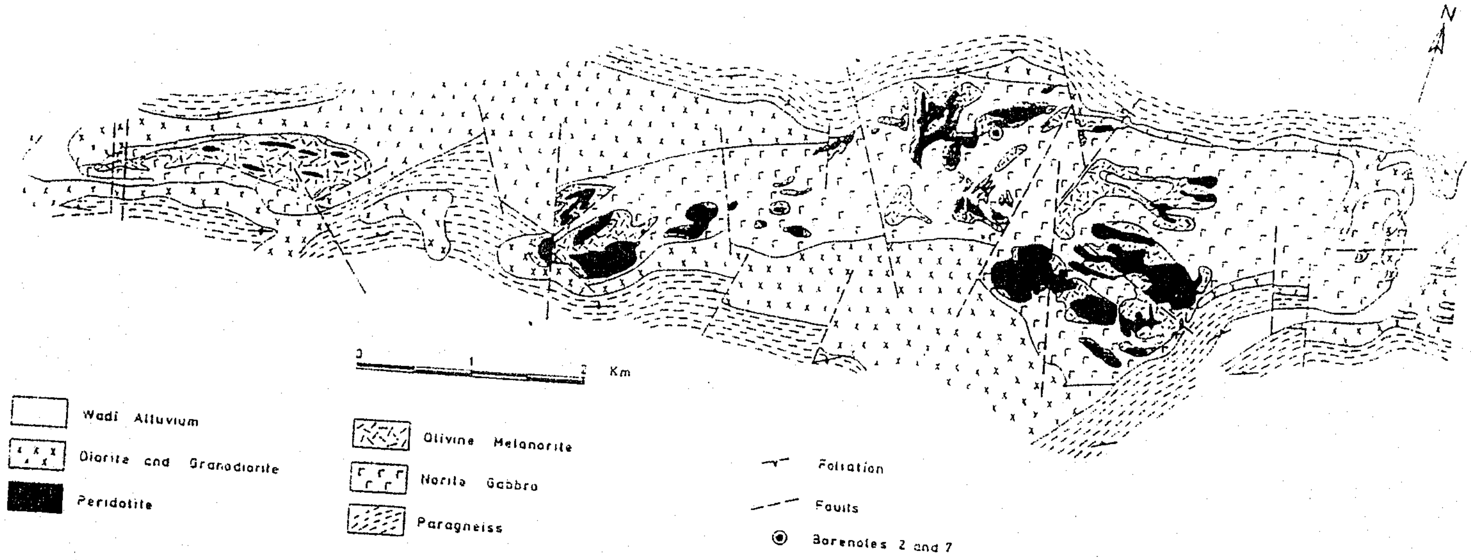

Fig. (2) : Geologic Map of Akarem Mafic-ultramafic complex.
(The map after carter, 1975)

The succesive intrusion of rocks of increasing basicity (Carter, 1975); norite, olivine melanorite, peridotite and finally mineralized peridotite and pyroxenites, is in accordance with the gradual deepening of a major fracture zone

The electron microprobe investigation of olivine in Akarem peridotites (Rasmy, 1982), declared that its average compostion is Fo_{76} ranging between Fo_{69}-Fo_{78}, showing a distinct deviation from the normal composition of dunite and peridotite olivine mentioned by Deer *et al.* (1966) which approximates Fo_{88}-Fo_{92}.

Rasmy (op.cit) favoured the explanation of the genesis of copper-nickel sulphides related to mafic-ultramafic iutrusion of Akarem, to be magmatic seggregation from immiscible sulphide-silicate melt at depth.

The present work deals with detailed petrographic description, and geochemical investigations of some 17 representative core samples collected from the Akarem mafic-ultramatic intrusive rocks.

PETROGRAPHY

The petrographic varieties described in the present work forming Akarem mafic-ultramafic association are mainly norites, peridotites, pyroxenites and the hybrid rocks.

Norites : They are generally medium grained exhibiting hypediomorphic-granular texture. The main mineral constituent is the Opx represented by hypersthene, pleochroic with the formula X = purple, Y = pale greenish - brown and Z = pale green. It represents 20-50% of the rock constituents. Hypersthene alters mainly to tremolite exhibiting the pleochroic-formula X = pale yellowish green, Y = Z = pale green. It also alters to diopsidic-augite which has an extinction angle of 42°. This Cpx is colorless, but may show very faint pinkish to greenish coloration. The mineral alteration association of Opx-Cpx-Tr. is markedly noticed. Phlogopite mica occurs with very faint green coloration, as alteration product after Cpx, but in coherent association with tremolite. Schillerization and uralitization are common features of the hypersthene.

It is obvious that Opx protrudes plagioclases with a chemical alteration front as intergranular extension and following the inter-twin planes of the plagioclases. These plagioclases are mainly fresh laths and stumpy grains of labradorite (Ab_{45} An_{55}), commonly exhibiting simple twinning and undulose extinction. Lamellar twinning is clear but without very sharp lamellae due to strain effect, which is also portrayed through the deformation twin lamellae crossing other types of twinning. Fine carbonate patches occur mainly in association with labradorite. Iron oxides minerals mostly occuring in patchy form are scattered disposing other constituents but sometimes filling the fissures or cleavage planes.

Peridotites : They are of the lherzolite type, medium grained, exhibiting hypidiomorphic granular texture. Olivine representing the main constituent is generally rounded, exhibiting a cumulate texture.

The peridotites of Akarem mafic-ultramafic association are differentiated by Carter (1975) to early intruded unmineralized peridotites, and later mineralized peridotites. The main petrographic difference is the dense occurence of the opaques of the iron oxides minerals, and the Fe-Cu-Ni sulphides in the mineralized types.

Olivines representing 60 to 70% of the peridotites constituents are partially serpentinized with islands of skeletal olivines, to completely pseudomorphed by serpentine with few secondary tremolite. The alteration of olivines to talc can be noticed uncommonly. The fissures in the alterd olivines are filled with iddingisite. Green spinels are commonly noticed in association with serpentinized olivines.

Rounded and partially to completly serpentinized olivine grains-showing fine corona structure surrounding them-are enclosed ophitically in fractured Cpx. The fractures are filled with serpentinized material.

Clinopyroxenes representing nearly 15-20% of the rock constituents, are Augite. It is wcakly pleochroic with the formula X = Z = pale green, Y =pale yellowish green.

Augite with the extinction angle up to 42°, show simple and sometimes lamellar twinning. They are partially altered to colorless to greenish amphibole, tremolite, which semetimes substitute completly these pyroxenes, with few relics of the parent minerals. Augite is also altered to talc and carbonates. Uralitic amphiboles are not uncommonly observed after the clinopyroxene.

Hypersthene constitutes nearly 10-15 % of the rock. It is generally altered to tremolite, with some parts altered to talc, where fine anhedral grains of subangular green spinel are uncommonly associated with the alteration products (Fig 3).

Augite can be observed as lamellae crossing the hypersthene grains in the (100) plane. This Cpx are exsolved due to cooling (Deer *et al.*, 1966, p. 110).

Very few labradorite (0.5%) undulosed, fractured and showing broad lamellar twinning are protruded and surounded by secondary tremolite.

Lawsonite (Fig 4.) is noticed in some of the unmineralized peridotites, as fine laths in association with the secondary tremolite after pyroxenes. It is commonly disposed with opaque iron oxides minerals.

Phlogopite are also uncommonly observed in association with the alteration products after pyroxenes.

Pyroxenites (Websterite) : Hypersthene representing the main mineral constituent of the rock, occurs as cumulates of relatively large subhedral fractured plates. It is altered mainly to tremolite, but sometimes to carbonates, which also form interstetial patches. Secondary phlogopite is also commonly associate with other alteration productes. Hypersthene exhibits pronounced diopsidic clinopyroxene intergranular infelteration following the cleavage direction of the host.

Subrounded grains of augite, and small rounded grains of olivine, form intercumulates with the orthopyroxene.

Fig. (3) : Photomicrograph showing anhedral, subangular green spinel in association with tremolitic-hornblende after Hypersthene. P.P.L., X : 125.

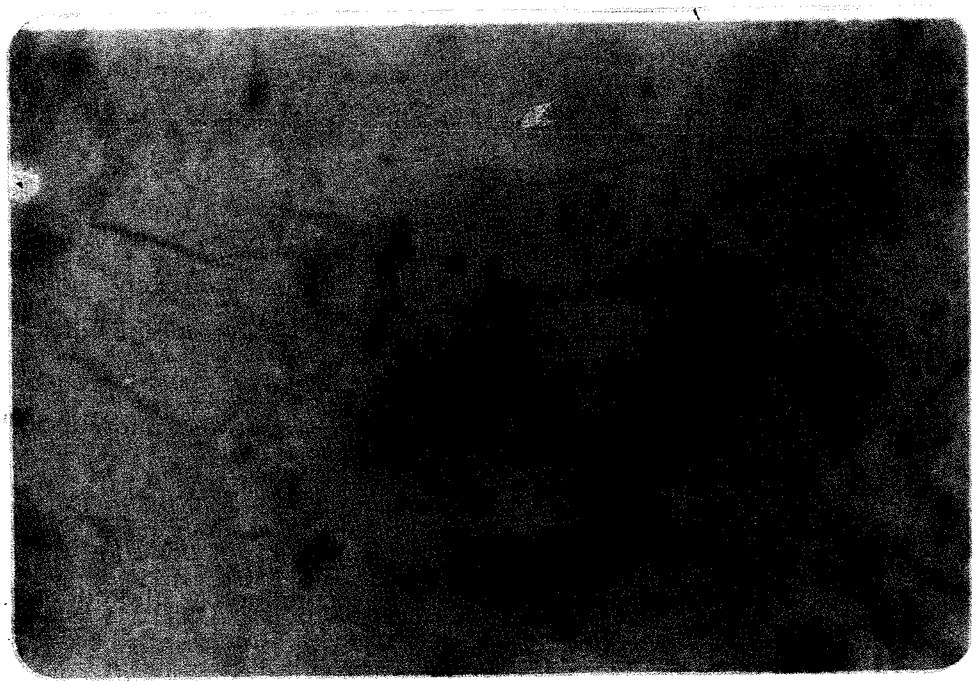

Fig. (4) : Photomicrograph of lawsonite disposed with opaques, and immersed in serpentine. P.P.L., X : 125.

Augite showing lamellar and simple twinning protrudes plagioclases with a reaction front, through the inter-twin planes.

Labradorite of nearly An_{55} form 2-10% of the rock constituents. It exhibits relatively clear simple and lamellar twinning, nevertheless, strain effect are obvious in the undulose extinction, deformation twin lamellae and the reversed lamellar twinning. Some labradorite grains show normal zoning, where another type of reaction zoning is observed in the plagioclase grains protruded by pyroxenes.

Olivine forms 2 - 5 % of the rock constituents, occuring as fine to medium skeletal grains. It is relatively fresh, nevertheless serpentinization began from the fractures filled with iddingisite. Olivine occurs interstitially and also commonly engulfed in the orthopyroxene.

Opaques reaching up to 2% of the constituents are represented mainly by iron oxides minerals and Fe-Cu sulphides. They occur as scattered grains or filling the fissures.

Hybrid rocks : Those described by Carter (1975) in the core logs of Akarem complex as; plagioclase-peridotites, pyroxene rich peridotites and coarse grained olivine melanorite. Petrographically they are composed of the essential mineral association; orthopyroxene, olivine, plagioclase and their extensive alteration products.

Hypersthene occurs as subhedral to anhedral corroded grains, constituting nearly 30% of the rock. It is generally altered to greenish tremolite, and sometimes to carbonates, where the crystaloblastic amphibole laths are commonly immersed in the carbonates, with symplectic growth of opaque iron oxides minerals. These carbonate patches may form up to 10% of the rock constituents. The green spinel (Pleonaste), subhedral fine grains are not uncommonly associates these alteration products on the exepense of Opx. Schillerization and uralitization are common features of these Opx. It encloses poikilitic olivine, and invades plagiocalse.

Plagioclases as labradorite (An_{55}), represent about 15% of the rock constituents, exhibit undulose extinction, with the other stress effects, as fracturing, deformation twin lamellae and thinning and reversing of the twin lamellae. Plagioclases enclose pyroxenes, olivines and hornblende.

Rounded grains of olivines are commonly serpentinized with fractures filled with opaques.

Composite coronas :

Olivines on contact with plagioclases form composite coronas. The formation of this type of corona, has been studied in other localities. Sapountzis (1975) referd to the various hydrous as well as anhydrous corona assemblages produced by the reaction between olivine and plagioclases and discussed their deuteric origin. The hydrous olivine-plagiolase reaction can be formulated as;

Olivine+plagioclase+water⇒±magnetite+pyroxene±spinel+amphibole

Frodesen (1968) in describing coronas from the Hiasen gabbro intrusion, Bamble area, south Norway, claimes evidence for a two-stage formation involving a deuteric origin of the outer Opx-amphibole shell, and, a regional metamorphic origin for an inner bronzite-ore symplectite, and an outer amphibole-spinel symplectite relative to the first composite shell.

These findings are in harmony with the present study of coronas. Figures 5 and 6 illustrate the composite corona formation in these rocks. Olivine has peripherally been replaced by a composite shell. The inner one is orthopyroxene, sometimes with the development of magnetite-Opx symplectite. An optically distinct boundary between this composite inner shell and an outer amphibole shell. This outer shell generally portray a poorly defined zone of spinel-symplectite grading into pure amphibole towards plagioclase. The spinel is green (Pleonaste), and occurs as minute warm-shaped rods or vermicules. The outer amphibole shell can be noticed as a result of replacement of plagioclase, which integrates in some intergranular planes (Fig.5).

Esbensen (1978) regarded, as most of workers done, that the optical discontinuity between the inner and the outer shells representes the original olivine-plagioclase boundary.

This type of composite corona as mentioned by Esbensen (op. cit) represent a "Frozen" recored of the olivine-plagioclase interrelation, they represents a very early stage in the thermal cooling history of representing rocks. They are regarded as subsolidus re-equilibration of the olivine-plagioclase assemblage.

Fig. (5) : Photomicrograph showing the composite corona structure in olivine in contact with plagioclase. OL : Olivine. Opx : orthopyroxene. A : Amphibol. P : Plagioclase. Crossed Nicoles, X : 50.

Fig. (6) : Composite corona structure in olivine. The inner shell, showing the magnetite-Opx symplectite. The outer shell showing spinel (pleonast) symplectite with amphibole. P.P.L., X : 125.

He (op. cit.) mentioned also that the double coronas develop as a result of a two-way diffusion process across the original olivine-plagioclase interference. Magnesium and iron are partly diffusing out of the olivine to be incorporated in the growing amphibole combining with calcium, sodium, aluminum and silicon from plagioclase as well as the introduced H_2O.

GEOCHEMISTRY

Major elements determination of 17 representative samples of the mafic-ultramafic association of the Akarem complex are presented in table 1, where their averages and some other world averages are portrayed in table 2. These major elements were determined by the volumetric and gravimetric methodes of Bennet and Reed (1971). The normative minerals of these samples are listed in table 3. Some trace elements were determined with a Perkin-Elmer model 403 atomic absorption spectrophotometer following the technique of Medlin *et al.* (1969). The investigated trace elements are projected in table 4, with their averages and some world averages on table 5.

From tables 2 and 3, it is possible to follow the geochemical evolution of some of the major elements within each rock type. Generally norites and pyroxenites show more mafic affinities than the averages presented by Le Maitre (1976), where the formers contain more MgO and FeO^t and less calcium and total alkalies. The peridotites are generally comparable with the lherzolites and peridotites of Le Maitre (op. cit), nevertheless their content of MgO is slightly depleted. It is noteworthy, that the iron content is

Table (1) : Major element contents (wt%) of Akarem mafic-ultramfic rocks.

R. type	NORITES				PYROX.			U.M.PER.				M PER.				HYB.R.	
S. No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SiO_2	48.44	45.94	46.66	46.70	45.10	46.52	48.44	49.12	43.54	43.45	46.04	48.96	42.40	43.01	27.71	46.08	46.43
TiO_2	0.34	0.08	0.07	0.17	0.11	0.02	0.11	0.08	0.08	0.08	0.17	0.03	0.20	0.27	0.08	0.07	0.17
Al_2O_3	16.83	6.62	15.30	17.32	17.81	3.55	5.88	4.57	6.46	3.87	3.06	6.34	4.57	4.06	1.78	8.67	10.46
Fe_2O_3	3.20	5.70	1.86	2.64	9.02	6.51	3.29	3.13	5.88	2.56	5.20	3.67	8.14	3.22	28.66	5.73	4.16
FeO	7.86	9.96	8.00	6.97	3.69	16.97	9.35	7.65	8.86	18.72	9.36	7.52	12.38	16.22	18.23	9.60	11.97
MnO	0.02	0.07	0.01	0.02	0.01	0.02	0.02	0.10	0.04	0.01	0.01	0.02	0.16	0.24	0.01	0.02	0.30
MgO	11.10	23.55	16.81	13.69	12.63	18.37	25.17	27.25	23.86	20.07	30.17	22.16	23.61	19.17	14.42	18.81	18.19
CaO	11.60	6.26	8.52	8.98	9.47	4.27	5.08	5.44	8.50	7.43	2.63	7.70	6.93	5.39	6.16	8.16	5.78
Na_2O	1.06	0.54	0.91	1.36	0.83	1.48	0.59	0.40	0.77	1.06	0.96	0.76	0.41	0.57	0.24	0.66	0.31
K_2O	1.21	0.20	0.41	0.31	0.16	0.62	0.32	0.18	0.31	0.32	0.18	0.24	0.12	0.24	0.12	0.32	0.20
P_2O_5	0.02	0.01	0.03	0.03	0.02	0.02	0.03	0.02	0.02	0.07	0.03	0.03	0.08	0.07	0.14	0.02	0.09
H_2O^-	0.21	0.16	0.28	0.22	0.19	0.19	0.33	0.21	0.24	0.28	0.20	0.18	0.41	0.22	0.28	0.32	0.32
H_2O^+	0.66	0.35	0.92	0.84	0.69	0.74	0.82	0.93	0.84	1.21	1.44	1.86	0.55	1.24	1.89	0.99	0.94

Table (2) : Averages of Akarem rocks and some other world averages.

	NORITES	PYROX.	U.M.PER.	M.PER.	HYB.R.	I	II	III	IV	V	VI
SiO_2	46.25	48.03	45.49	37.71	46.26	50.44	46.27	42.52	42.26	40.26	40.89
TiO_2	0.15	0.07	0.09	0.18	0.12	1.00	1.47	0.42	0.63	0.16	0.20
Al_2O_3	14.78	4.67	4.93	5.14	9.57	16.28	7.16	4.11	4.23	1.78	2.69
Fe_2O_3	4.48	4.31	4.33	13.34	4.95	2.21	4.27	4.82	3.61	9.60	10.66
FeO	6.50	11.32	8.89	15.61	10.79	7.19	7.18	6.96	6.58		
MnO	0.03	0.05	0.02	0.14	0.17	0.14	0.16	0.17	0.41	0.15	0.15
MgO	15.56	23.60	24.07	19.07	18.50	8.73	16.04	28.37	31.24	33.30	31.56
CaO	8.97	4.93	6.57	6.16	6.97	9.41	14.08	5.32	5.05	3.57	3.59
Na_2O	0.94	0.94	0.89	0.14	0.49	2.26	0.92	0.55	0.49	0.00	0.03
K_2O	0.46	0.37	0.26	0.16	0.26	0.70	0.64	0.25	0.34	0.02	0.02
P_2O_5	0.02	0.02	0.24	0.10	0.06	0.15	0.38	0.11	0.10	-	-
H_2O^-	0.21	0.24	0.22	0.30	0.32	0.13	0.14	0.03	0.31	0.98	0.97
H_2O^+	0.69	0.83	1.34	1.23	0.97	0.84	0.13	1.07	3.91	8.85	8.66

I- Norites, II- Pyroxinites, III- Lherzolites, and IV- peridotites. (Le Maitre, 1976).

V- Serpentinized Peridotites and

VI- Peridotites (Komatitic Lava, South Africa, Villaume and Rose, (1977).

Table (3) : Niggli Norm values of Akarem rocks.

R. Type	S.No.	Ap	Il	Or	Ab	An	Mt	He	Di	Ol	Hy	Q
	1	0.05	0.48	7.20	9.55	37.83	3.36	-	15.94	20.45	5.15	-
	2	0.02	0.11	1.15	4.80	14.93	5.90	-	12.57	26.23	43.31	-
NORITES	3	0.06	0.10	2.39	8.08	36.07	1.92	-	4.45	22.98	23.95	-
	4	0.06	0.24	1.83	12.19	40.17	2.76	-	3.29	16.08	23.39	-
	5	0.04	0.15	0.96	7.53	44.87	8.46	0.71	1.98	-	34.24	1.06
	6	0.04	0.04	3.75	13.60	1.25	6.96	-	16.25	23.87	34.23	-
PYROX.	7	0.05	0.16	1.85	5.20	12.18	3.36	-	9.86	22.70	44.65	-
	8	0.04	0.11	1.04	3.50	9.88	3.19	-	13.02	20.96	48.28	-
	9	0.05	0.10	1.80	6.80	13.08	6.06	-	22.62	40.49	9.01	-
	10	0.15	0.11	1.90	9.70	4.95	2.73	-	25.70	49.20	5.56	-
U.M.PER	11	0.05	0.22	1.05	8.35	3.40	5.27	-	7.27	39.07	35.33	-
	12	0.05	0.04	1.40	6.80	13.10	3.81	-	19.80	14.88	40.12	-
	13	0.17	0.28	0.71	3.68	10.76	8.49	-	18.83	34.49	23.10	-
M.PER	14	0.15	0.38	1.45	5.22	21.88	3.43	-	3.93	35.28	28.28	-
	15	0.32	0.12	0.80	2.45	3.88	33.87	-	23.74	22.64	12.19	-
HYB. R.	16	0.05	0.10	1.90	5.95	19.73	6.03	-	16.72	16.20	33.32	-
	17	0.19	0.24	1.20	2.82	26.92	4.41	-	1.24	10.19	52.79	-

Table (4) : Distribution of Trace Elements (ppm) in Akarem rocks.

R. Type	S. No	Ni	Co	V	Cr	Sr	Ba
	1	50	39	52	270	40	22
	2	30	40	223	320	200	45
NORITES	3	15	36	180	240	12	40
	4	200	50	111	280	200	22
	5	20	42	66	240	66	22
	6	200	100	212	890	10	30
PYROX	7	200	80	436	1350	20	28
	8	350	133	163	550	68	48
	9	150	81	188	640	50	34
U.M.PER.	10	985	100	56	310	10	38
	11	20	20	40	300	10	25
	12	50	15	22	1520	10	25
	13	4150	95	50	235	12	30
M.PER	14	3250	113	173	413	10	52
	15	4050	184	32	312	12	30
HYB. R.	16	200	80	241	610	100	26
	17	1380	192	193	488	20	48

Table (5) : Trace elements averages (ppm) of Akarem Rocks and some other world averages.

	NOR	PYRX	U.M. PER	M.PER	HYB.R.	I	II	III	IV
Ni	63	250	301	3816	790	-	-	123	200
Co	41	104	54	130	136	237	176	-	-
V	126	270	77	85	217	37	99	289	110
Cr	270	930	692	320	549	-	-	296	900
Sr	104	33	20	11	60	12	12	123	110
Ba	30	35	31	37	37	5	18	12	10

I- South Africa peridotites in komatitic lava (villaume and Rose, 1972)

II- Candaian peridotites in komatitie lava (Villanme and Rose, 1977).

III- Mid Altantic Ridge Basalts and IV. Layered gabbro from 00°N, 17°N, Romocke Trench (MAR) (Thompson, 1973).

obviously high in the mineralized peridotites.

Refering to the peridotites from the komatitic lava of South Africa (Villaume and Rose, 1977), it is evident that the present peridotites are less in mafic character, but not so far from these komatitic varieties.

TiO_2 content of the rocks of Akarem complex is obviously lower than that of the world averages, but is in harmony with that of S. Africa komatites. That confirms the high mafic character of the rocks of the present complex.

The plotting of Akarem mafic-ultramafic rocks on the ternary diagram of the normative Ol-Cpx-Opx (Streckeisen, 1976) (FIg 7.) reveals that the unmineralized peridotites are mostly lherzolites, whereas the other types are in the olivine-websterite, with one norite sample barren of normative olivine is located in the orthopyroxenite field.

According to De La Roche *et al.* (1980), the present work rocks are plotted (Fig 8.) mainly in fields of peridotites (lherzolite-harzbergite) and norite-gabbro. That is in harmony with the petrography of the rocks.

Variation of the ratio FeO^t/MgO vs FeO^t (Fig. 9), indicates that the plotted Akarem rocks fall within the Skaergaard field (Miyashiro, 1975).

The relation between the ratio $FeO^t/(FeO^t + MgO)$ and Al_2O_3 (Fig. 10), shows that the Akarem mafic-ultramafic rocks are mostly plotted in the field of cumulate-komatites, whereas the norites are

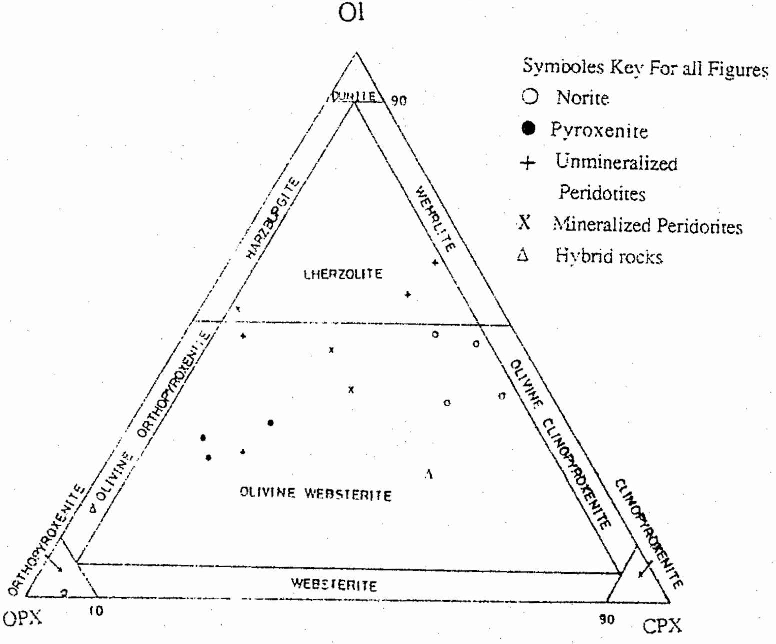

Fig. (7) : Normative Ol-Opx-Cpx ternary diagram for Akarem mafic-ultramatic rocks, (Streckeisen, 1976).

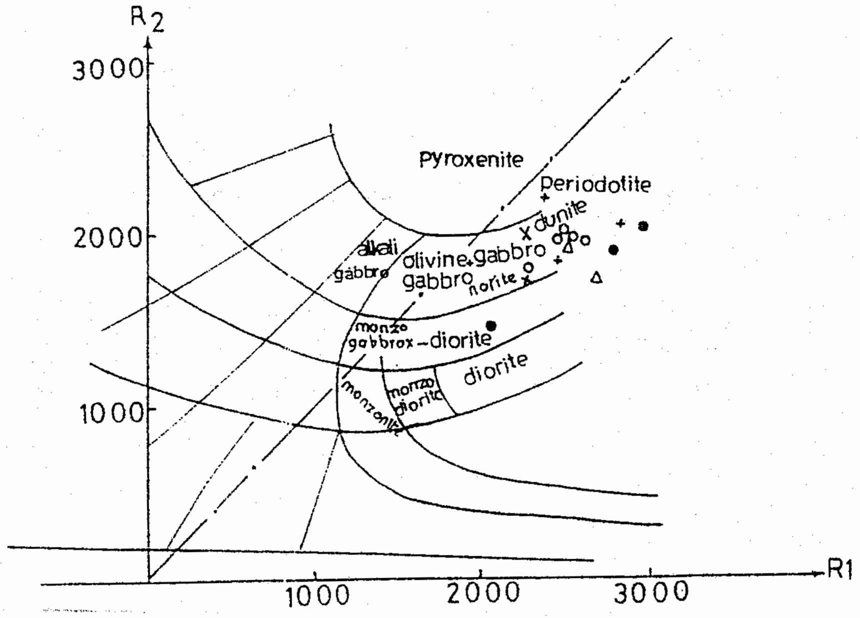

Fig. (8) : Classification of the Akarem mafic-ultramafic rocks using R_1-R_2 diagram (De La Roche *et al* 1980).

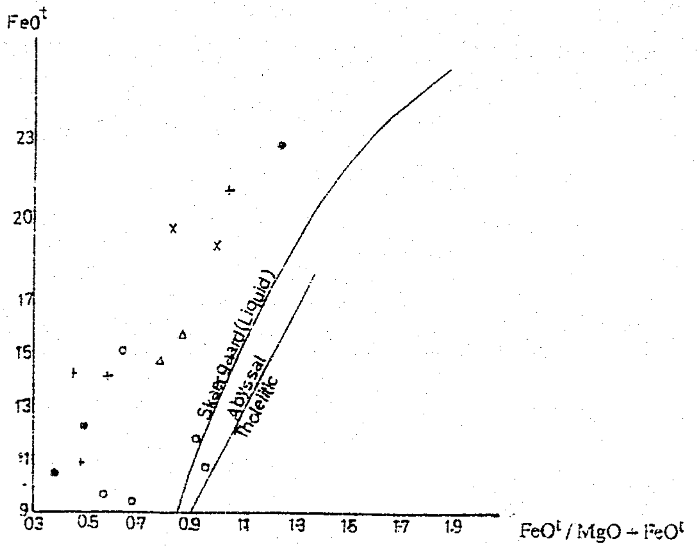

Fig. (9) : FeO^t vs FeO^t / MgO + FeO^t relation of Akarem rocks. Trends after Miyashiro (1975).

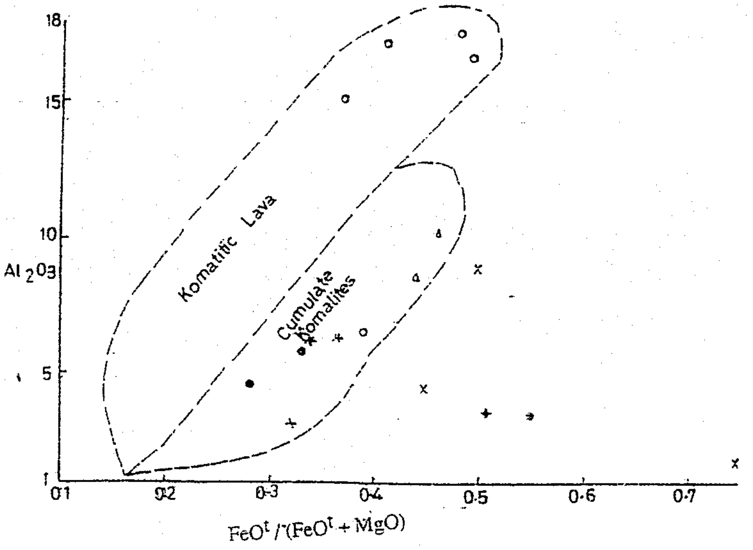

Fig. (10) : Plot of Akarem rocks FeO^t/(FeO^t + MgO) vs Al_2O_3. The fields after Arndt *et al.* (1977).

located in the field of komatitic lava of Arndt et al. (1977). It is noteworthy, that the komatitic magma is characterized by a low $FeO^t/(FeO^t + MgO)$ ratio for a given Al_2O_3 content as compared with the tholeiitic magma. This indicates that the high mafic affinities of the present rocks could also be attributed to olivine and Opx cumulates, refered to in the petrography.

The Akarem mafic-ultramafic rocks are comparable with other komatites characterized by low TiO_2 content (Arndt *et al.*, 1977), where on the variation diagram SiO_2 vs TiO_2 (Fig 11.), their plotting are scattered in the area of komatites defined by Arndt *et al.* (op. cit.). Again this confirms the komatitic magma type of the present work rocks. Kennedy (1955), noted that under modest oxygen pressure iron is removed earlier as magnetite, but when the pO_2 is low no Fe_2O_3 and thus no spinel is formed. The appearance of spinel in the present rocks, and the decrease of Osborn's Iron Index with the increase of SiO_2 (Fig. 12) indicates the moderate to high pO_2 prevailing through the course of mineral seperation of these rocks.

Plotting of the mafic-ultramafic rocks under investigation are compared with the n-24 curve (Fig. 12), representing the fractional crystallization of the system $MgO\text{-}FeO\text{-}Fe_2O_3\text{-}SiO_2$ melt of composition n under conditions of constant total composition (Osborn, 1959). Although those rocks show obvious contradiction with the trend of the Japanese tholeiites (Nockolds, 1954), yet they are in harmony with the trend of the Skaergaard intrusion (Wager, 1960).

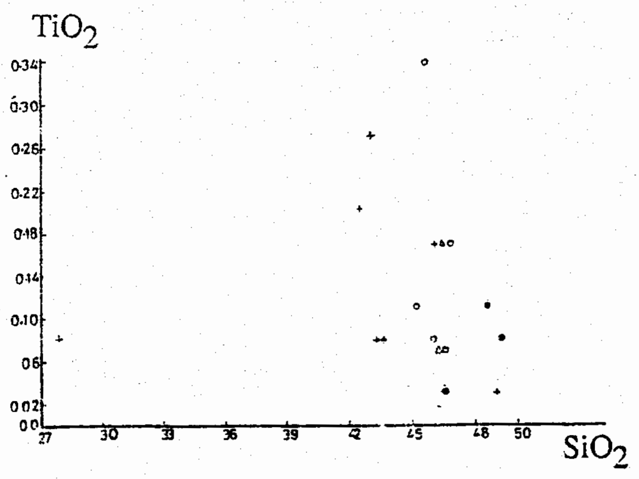

Fig. (11) : SiO_2 vs TiO_2 variation diagram of Akarem mafic-ultramafic rocks.

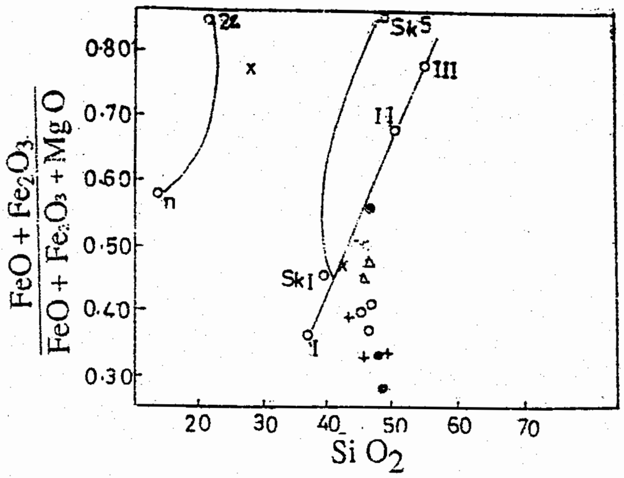

Fig. (12) : Comparison of the Akarem rocks fractionation trend with the experimental system MgO-FeO-Fe_2O_3-SiO_2 and natural magma series.

-n-24 represents the fractional cystallizataion of an artificial melt under conditions of constant total composition (Osborne, 1959)

-Sk_1-Ak_5 represent successive liquids of the Skaergaard intrusion (Wager, 1960)

-I-III reprisent tholeiitic olivine basalt to thoieiitic andesite.

Figure (13) shows that the course of differentiation of Akarem magma in the system FeO^t-(Na_2O + K_2O) - MgO is absolutly parallel to the trend of the early differentiates of Skaergaard intrusion showing the enrichment of total iron (Srivastava, 1975), but with more mafic affinities than the Skaergaard.

The strong mafic affinities of Akarem rocks are also asserted by location around the field of komatites of Coleman (1977) on the FAM diagram (Fig. 14).

It is noteworthy, that the plotting of Akarem rocks on the FAM ternary diagram (Fig. 15) after Thorpe (1974) indicat that they locate mainly in the field of Alpine-type ultramafic and gabbroic rocks (Thayer, 1967).

The komatitic magma type of the present work rocks is well projected by their plotting on the (Fe_2O_3 + FeO + TiO_2) - Al_2O_3-MgO diagram (Fig. 16) of Jensen (1976).

The average content of MgO in the peridotites, pyroxenites and hybrid rocks of Akarem are relatively more than the limit of 18% MgO of the komatitic ultramafic lava of Arndt & Nisbet (1982) where the norites are within the range of komatitic basalt of the same authors (op. cit.).

On the TiO_2-MnO.10-P_2O_5.10 ternary diagram with the fields representing the tectonic environment modified by Hall (1987) after Mullen (1983), the Akarem mafic-ultramafic rocks are scattered (Fig. 17) around the field of volcanic arc basalts, and oceanic island basalts, but mostly related to the volcanic arc basalts This

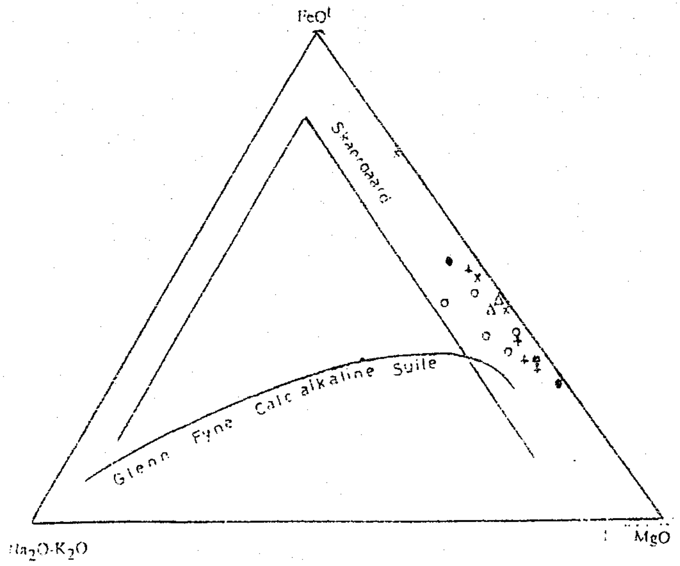

Fig. (13) : Differentiation of Akarem mafic-ultramafic rocks, compared with the Skaergaard intrusion, and the Glenn Fyne calc alkaline suite.

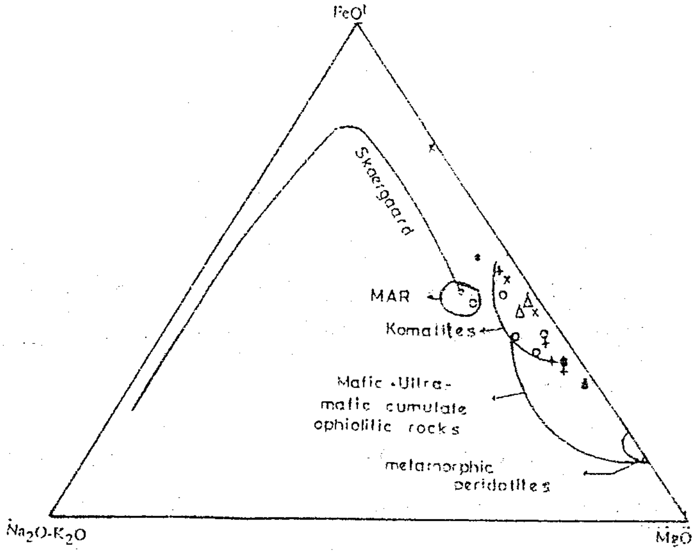

Fig. (14) : FAM Diagram, Showing the compositional trend of Akarem rocks, relative to some other rock trends, after Coleman (1977).

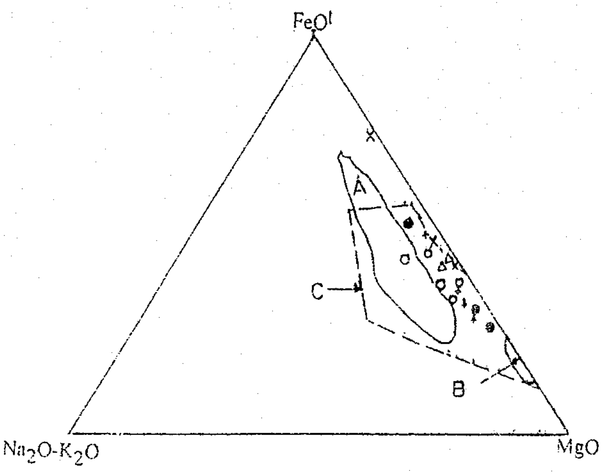

Fig. (15) : Plot of Akarem mafic-ultramafic rocks on FAM diagram.
A : field of MAR gabbros (Miyashiro et al. 1970).
B : Field of MAR serpentinites (Miyashiro et al. 1969).

C : Alpine type ultramafic and gabbroic rocks from Thayer (1967).

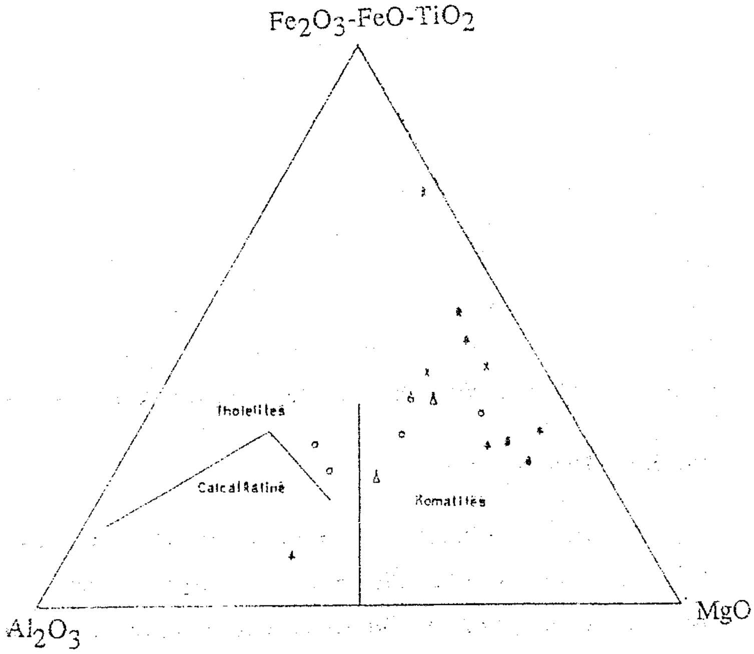

Fig. (16) : Range of the composition of Akarem mafic-ultramafic varieties. The ternary diagram Fe_2O_3 + FeO + TiO_2 - Al_2O_3 - MgO Fields after Jensen (1976).

scattering may be due to the intense alterations and the low grade metamorphism to which the rocks are subjected.

The trace elements content of Akarem mafic-ultramafic rocks (Table 4.), and their averages with some other world averages (Table 5) show that the Akarem rocks are generally comparable with MARB, layerd gabbros of MAR, and the komatites of South Africa and Canada.

Barium and Strontium

The Ba and Sr contents of Akarem rocks are similar to those of most other types of the ultramafic rocks (Fig 18.), especially those of the Archean ultramafic lavas of the komatitic affinities.

The slightly higher content of these elements can be correlated with the increase of Ca content through the course of mineral fractionation. In addition to that, the obvious lower content of Ba in the Archean ultramafic rocks of South Africa and Canada might be expected from the relative mobilities of these elements during serpentinization (the degree of serpentinization is based on their correlation according to the H_2O^+ content, mentioned by Thayer (1966)), where Ba and Ca were depleted by serpentinization.

Nickel and Cobalt :

Cobalt are expected to behave simillar to Nickel during most magmatic processes (Burns and Fyfe, 1964).The previous suggestion is clear in Akarem rocks (Fig 19.), and is also in accordance with the findings of Rasmy (1982) about the co-existance of Ni & Co in olivines and the seggregated sulphides such as; pentaldite, variolite, machinawite, pyrrhotite and

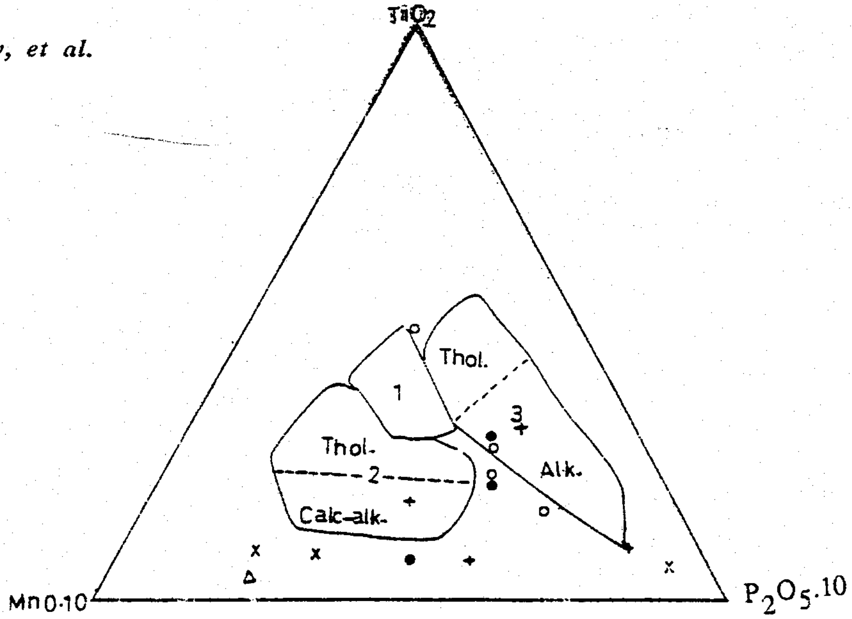

Fig. (17) : TiO_2-MnO x 10-P_2O_5 X 10 plot of Akarem mafic-ultramafic rocks. The fields are after Hall (1987) modified from Mullen.

1- Ocean ridge basalts
2- Volcanic arc basalts
3- Oceanic island basalts

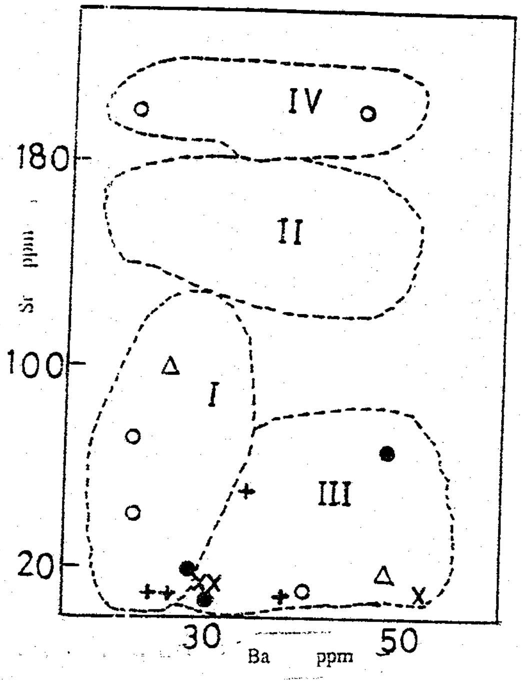

Fig. (18) : Ba vs Sr plot of Akarem rocks. Fields after Villaume and Rose (1977). I. Archean greenstone basalts. II. Alpine ultramafic rocks. III. Archean ultramafic lavas (south Africa). IV. MOR ultramafic rocks.

chalcopyrite.

The average Ni content of Akarem rocks as a whole is about 1044 ppm, and that is relatively in harmony with the 1500 ppm average Ni content of most other types of peridotitic ultramafic rocks (Fisher *et al.* 1969). Nevertheless the average of each rock type of Akarem (Table 5) exhibits the high concenteration of Ni mainly in the mineralized peridotites, with strong depletion in the other rock types through fractionation. that decrease in Ni content of the magma as fractionation progressed was due to its entry into early crystals in excess of the amount present in the magma (Wager & Mitchell, 1951).

In Akarem rocks Ni enters the early formed olivines and Opx as well as iron and nickel sulphides (Rasmy, 1982, Niazy *et al.* 1985).

The average content of Co in Akarem rocks as a whole (93 ppm) is also close to the average of all the ultramafic rocks (110 ppm) (Steuber and Gales, 1967).

Vanadium and Chromium

Vanadium generally increases with the increase of FeO^t and TiO_2 (Fig. 20), and its average in Akarem rocks is compared with those of the world komatites and other ultramafic rocks (Table 5).

Chromium behaves the same as vanadium, although its close association with Fe^{3+} indicates its increase where magnetite and chromite are extensively formed as in pyroxenite and peridotites (Niazy et al. 1985). Generally the chromium contents of Akarem

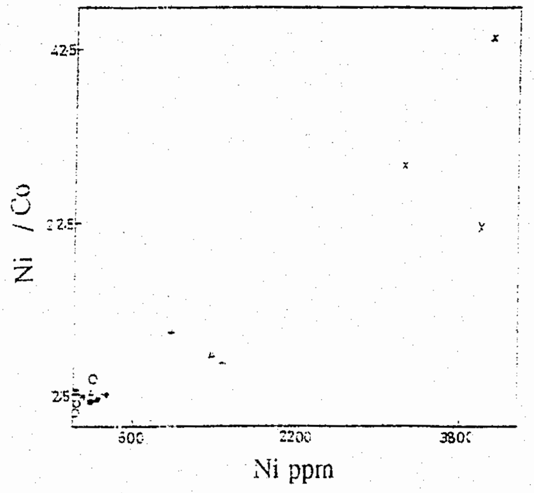

Fig. (19) : Plot of Akarem mafic-ultramafic rocks on the variation diagram Ni vs the ratio Ni / Co.

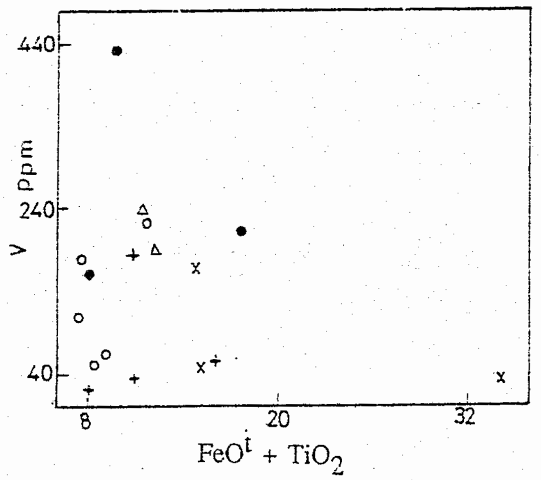

Fig. (20) : Plot of the Akarem rocks on the variation diagram. V ppm vs (FeO^t + TiO$_2$)%.

rocks are within the range of the other averages of ultramafic rocks (Table 5).

CONCLUSION

The Akarem mafic-ultramafic rocks are intruded successively following the increasing basicity; norite, unmineralized peridotites, mineralized peridotites and pyroxenites. Hybrid rocks are the result of assimilation of norite by intrusive peridotite.

Iutrusion of rocks have taken place along one of the series of ENE trending deep-seated tectonic structures in the Eastern Desert of Egypt.

The rocks portray composite corona structure, which reveals that Akarem mafic-ultramafic complex are affected by intense deuteric action and low grade regional metamorphism.

Geochemically the Akarem complex rocks are of the alpine type, showing strong mafic affinities. They are comparable with the cumulate-komatites and komatitic lava from other locations. The differentiation of the komatitic magma forming the Akarem rocks most probably occured under moderate to high pO_2, following the fractional crystallization of the system MgO-FeO-Fe_2O_3-SiO_2 under conditions of constant total composition. This is in harmony with the early differentiation of the Skaergaard intrusion, showing enrichment of total iron.

The Akarem complex magma setting, may be in the volcanic arc environment.

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اضافات إلى بتروجرافية وجيوكيميائية صخور متراكب عكارم ، الصحراء الشرقية الجنوبية مصر

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انبثق متراكب الصخور القاعدية وفوق القاعدية فى عكارم متتابعا مع زيادة القاعدية ، نوريت ، بيريدوتيت غير ممعدن ، بيريدوتيت ممّعدن وبيروكسينيت . ونتجت الصخور المهجنة من هضم النوريت بالبريدوتيت المتداخل . وهذه الصخور قد تعرضت لتحلل مائى شديد ، وقد تظهر مرتبة تحول منخفضة .

وصخور عكارم من النوع الألبى ، خلصت من مجماكوماتيتية تحت ضغط أكسجين عالى. وهذا متوافق مع اتجاه الاستخلاص لتداخل اسكرجارد . مظهرا الغنى فى الحديد، متتبعا خطى التبلور التجزئى للنظام $MgO-FeO-Fe_2O_3-SiO_2$ تحت ظروف ثبات التركيب .

وقد تكون المجما المكونة لمتراكب عكارم قد استقرت فى بيئة القوس البركانى . وهذا كان على واحد من خطوط التراكيب التكتونية العميقة مع اتجاه شمال شرق فى الصحراء الشرقية المصرية .