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GEOCHEMICAL STUDIES USING TRACE ELEMENTS ANALYSIS OF SOURCE ROCKS AND RELATED CRUDE OIL IN THE GULF OF SUEZ, EGYPT

By

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دراسات جيوكيميائية بإستخدام العناصر الشحيحة للصخور المصدرية والزيت الخام في خليج السويس ـ مصر

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يساعد تواجد وتوزيع العناصر الشحيحة في كل من صخور المصدر والزيت الخام في عملية الإشعاعات الجيوكيميائية. وقد تم جمع عينات صخرية وزيت خام تمثل الحقول الأساسية في منطقة خليج السويس للحصول على نتائج خاصة بخمسة عشر عنصراً هي :
Al, Ba, Ca, Cr, Cu, Co, Fe, Mg, Mn, Ni, Sr, Ti, V, Zn, and Zr.
وقد عولجت المعلومات التي تم الحصول عليها إحصائياً وذلك لتحديد بعض العوامل والتجمعات التي تخص العلاقات بين صخور المصدر والزيت الخام. وقد اكتملت هذه الدراسة وحددت أربعة عوامل لكل من الصخور والزيت الخام. وهذه العوامل يمكن أن تقسم إلى ثلاث مجموعات هي عامل النشأه، وحددت امتصاص العناصر الشحيحة وعامل صخور المصدر. بالإضافة لذلك وبناءاً على تحليل المجموعات الإحصائي فقد تم تقسيم حقول البترول في خليج السويس إلى مجموعتين أساسيتين : الأولى تشتمل على حقول (رأس بحر وشعب علي) والتي تع في أقصى الجزء الجنوبي في حين تشتمل المجموعة الثانية على جقول (رأس مطارمه، عسل، أبو رديس، أكتوبر، رأس بدران، عامر، بكر، بلاعيم، رحمي ويوليو) والتي تقع في الجزء الشمالي والأوسط من خليج السويس، وترتبط هاتان المجموعتان إلى صخور مصدرية

Key Words : Geochemicel, Source Rocks, Crude Oil ,Gulf of Suez, Egypt.

ABSTRACT

The occurrence and distribution of trace elements in source rocks and crude oils is used to asses the process of geochemical exploration. Rock and crude oil samples representing the giant fields of the Gulf os Suez province were collected and analyzed for Al, Ba, Ca, Cr, Cu, Co, Fe, Mg, Mn, Ni, Sr, Ti, V, Zn, and Zr. The analyzed data were treated statistically to find some factors and clusters concerning the interrelation between the source rock and crude oils. The application of both factor and cluster analysis in this study revealed four factors for both rock and crude oil samples. These factors can be classified into three groups namely; the factor of diagenesis, trace elements adsorption factor and the factor of source rock. In addition to the cluster analysis separated the Gulf of Suez oilfields into two major groups; the first includes the oilfields (Ras Bahar and Shoab Ali) which located in the extreme southern part while the second group includes the oilfields (Ras Matarma-Asl-Abu Rudies-October-Ras Budran-Amer-Bakr-Belayim-Rahmi and July) these fields located in the northern and central parts of the Gulf of Suez. The two separated cluster groups may be related to multiple source rocks with different organic facies along the Gulf of Suez province.

INTRODUCTION

The presence of various trace elements in crude oils and its relation to the source rocks have been known for over 60 years. Recent advances in the analytical techniques, including inductively coupled plasma-emission spectrometry (ICE-ES) have led to a resurgence of interest in metal occurrence in petroleum and the application of these metallic trace elements for geochemical exploration purposes, recognizing oils from different basins or source rocks, correlating oils from different pools and establishing the environmental conditions of genesis and oil-source rock correlation.

Numerous geochemical studies have been done on the distribution of trace elements in crude oils and their relation with source rock, for example; {1, 2, 3, 4, 5, 6 and 7} The origin of these trace elements in crude oils are derived from different types of organic matter buried in sediments under reducing environments Yen, {8}. The oil producing zones in the Gulf of Suez are classified according to their ages into Miocene and Pre-Miocene reservoirs The Miocene reservoir includes the sandstones of Zeit, South Gharib, Belayim, Rudeis and Nukhul Formations while the Pre-Miocene reservoir includes the limestones of Middle Eocene and Upper Cretaceous and the Nubia sandstones of the Pre-Upper Cretaceous age.

The Egyptian General Petroleum Corporation (EGPC) {9} subdivided the Gulf of Suez into three structural provinces according to their structural setting (Fig. 1)
Northern province: this province include the Sudr, Al, Ras Matarma, Ras Budran and October oilfields.
Central province: it occupies the central uplifted part of the Gulf and characterized by shallow structure underlying the Miocene sediments in Ras Charib, Bakr, Amer, Balyim, July, Ramadan, Um el-Yusr and Morgan oilfields.
Southern province: it extends from the Morgan hinge zone in the north to the Esh el-Mallaha in the south including Ras Bahar and Shoab Ali oilfields.

Fifty crude oil samples were selected to represent the different pay zones (Miocene, Eocene, Upper Cretaceous and Pre-Upper cretaceous) of the Major fields of the Gulf of Suez and thirty eight core samples representing the source rocks within the sedimentary stratigraphic succession of the Gulf of Suez province (Fig.2).

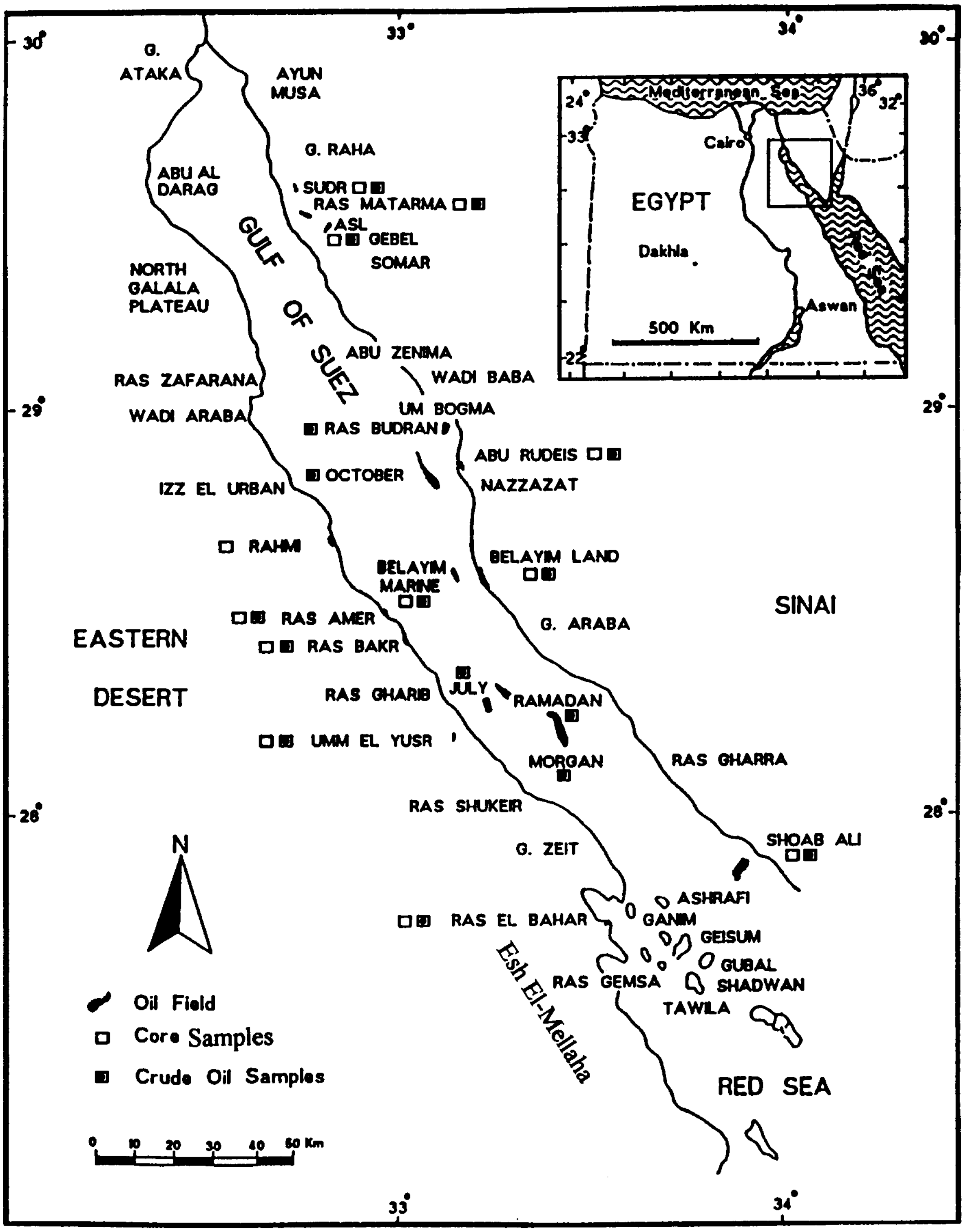

Fig. 1: Map of the Gulf of Suez showing the location of the studied samples.

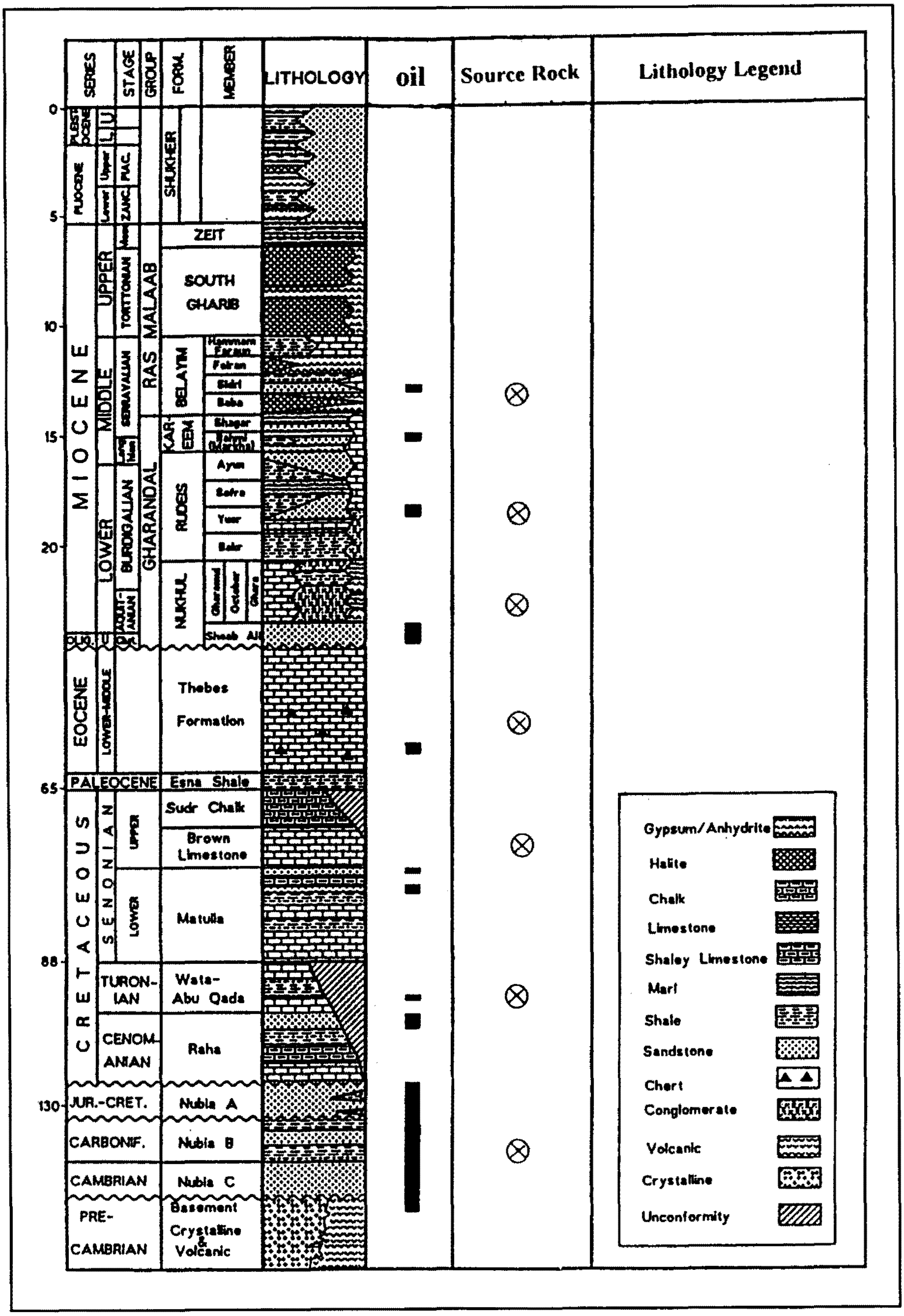

Fig. 2: Generalized stratigraphic sequence for the Gulf of Suez area including informations from the EGPC (9).

DATA PROCESSING AND COMPUTATION

The selected source rock and crude oil samples from the Gulf of Suez were analyzed for Al, Ba, Ca, Cr, Cu, Co, Fe, Mg, Mn, Ni, Sr, Ti, V, Zn, and Zr using the analytical technique of the Inductively Coupled Plasma (ICP) at the Geoscience Department of the Technical University of Berlin (Tables 1 & 2). The present work applies the interrelation between the trace elements and the concluded statistical parameters (factor and cluster analysis) to asses the genetic relation between source rocks and crude oil in the Gulf of Suez.

Analytical data are assigned to the SPSS/PC (Statistical Package for Social Sciences) program to carry out the factor analysis and the cluster analysis.

RESULTS AND DISCUSSIONS

The statistical results of crude oil and source rock data are discussed as follows:

A -Factor Analysis:

The R-mode factor analysis was carried out on the obtained data for crude oils and source rock sample revealed four factors (Table 3 & 4). The factors were classified into three groups as follows:

1. The first group which include Factor - 1 (Ca, Mg, Sr, Ba) in crude oil and Factor - 2 (Sr, Mg, Ca) in rock samples. These elements Ca, Mg, and SR, are combined together in this factor for both crude oils and source rocks especially the carbonate source rocks of the Middle Eocene and Upper Cretaceous. Ca, and Sr

Well Name	Age	Fe	Al	Ca	Mg	Mn	Zn	Cr	Cu	Ti	Ba	Sr	Co	Ni	V	Zr
BL	Miocene	500.00	30000.00	516.00	110.00	5.00	18.50	15.00	6.50	.50	1.00	50.00	5.00	52.00	85.00	2.50
EB112-37	Miocene	500.00	36500.00	580.00	43.00	6.00	17.50	18.00	8.00	4.00	3.00	50.00	1.50	58.00	98.00	2.00
EB112-1	Miocene	78000.00	100500.00	992.00	73.00	13.00	46.50	11.00	12.50	1.50	5.00	53.00	5.00	165.00	96.00	3.00
BM	Miocene	24500.00	94500.00	2985.00	602.00	6.50	22.50	46.00	11.50	3.50	5.00	79.00	6.00	59.00	63.00	2.50
BL	Miocene	35500.00	97500.00	2646.00	443.00	7.50	35.50	56.00	19.50	7.50	7.00	53.00	5.00	119.00	84.00	2.00
EB112-32	Miocene	6000.00	24500.00	930.00	82.00	3.00	25.50	12.00	3.50	1.00	5.00	51.00	.50	88.50	89.00	.50
BM	Miocene	8500.00	9500.00	378.00	16.00	1.50	35.00	14.00	13.00	5.50	5.00	52.00	1.50	92.50	96.00	3.00
113-A-8	Miocene	14500.00	9000.00	668.00	107.00	7.50	31.00	34.00	13.00	6.50	4.00	22.00	1.00	125.00	99.00	1.00
EB112-2	Miocene	39000.00	93500.00	682.00	57.00	7.50	85.00	45.50	4.50	4.00	3.00	8.00	4.00	121.00	88.00	2.00
EB112-3	Miocene	45000.00	104500.00	1145.00	60.00	5.00	24.00	16.00	54.00	.50	1.50	9.00	5.00	132.00	86.00	2.00
BL-1	Miocene	1500.00	74500.00	1491.00	135.00	5.50	32.00	18.00	7.00	4.00	1.50	1.00	6.00	87.00	82.00	3.50
BL-2	Miocene	16500.00	85500.00	2583.00	408.00	7.50	24.00	53.00	8.00	8.00	2.50	73.50	2.50	114.00	92.00	2.00
BM	Miocene	19000.00	82500.00	443.00	50.00	5.00	10.00	15.50	8.50	4.00	6.00	10.50	3.00	58.00	85.00	2.00
EB112-42	Miocene	21500.00	100000.00	1316.00	42.00	4.00	25.00	23.50	13.50	7.00	.50	11.00	4.00	132.00	86.00	.50
ARS-3	Miocene	41500.00	86500.00	967.00	52.00	6.50	37.00	41.00	6.50	3.00	2.00	9.00	5.00	146.00	22.00	3.00
BL	Miocene	12500.00	96000.00	1972.00	282.00	5.00	10.00	120.00	27.50	4.00	3.50	38.50	6.00	178.00	96.00	4.00
EB112-55	Miocene	16000.00	5500.00	734.00	67.00	3.00	24.00	37.50	14.00	5.00	4.00	27.00	4.00	163.00	95.00	2.00
BM-2	Miocene	13000.00	95000.00	1740.00	60.00	3.00	20.00	37.00	9.00	3.50	5.00	30.00	5.00	66.00	73.00	.50
SA-D5	Miocene	12500.00	98500.00	4500.00	205.00	4.00	36.00	13.00	54.00	2.50	5.50	231.00	.50	31.00	217.00	2.00
SA-D15	Miocene	12500.00	90000.00	673.00	75.00	2.50	13.00	28.00	7.00	3.50	3.00	7.50	8.50	67.00	272.00	.50
WBM-1	Miocene	5500.00	92000.00	599.00	24.00	1.00	28.00	22.00	3.00	1.00	4.50	50.00	1.00	33.00	83.00	4.00
113-M-39	Miocene	33500.00	11000.00	716.00	16.00	5.00	27.00	9.00	10.00	2.00	1.00	50.00	6.00	27.00	84.00	1.00
ARS	Miocene	21500.00	97000.00	1125.00	25.00	5.00	21.00	74.00	68.00	3.50	2.00	52.50	6.00	113.00	28.00	2.50
MAT-3	Miocene	16500.00	88000.00	717.00	42.00	9.00	38.50	26.50	3.00	4.00	4.00	17.00	2.50	65.00	32.00	2.00
Bahar-2	Miocene	35500.00	90500.00	1194.00	35.00	6.50	48.50	16.50	11.00	1.50	4.50	8.50	3.50	39.50	238.00	4.00
Bahar-3	Miocene	17000.00	98000.00	1170.00	75.00	7.00	30.50	41.50	10.00	2.50	5.00	37.00	4.00	40.50	234.00	1.00
Bakr-4	Miocene	17500.00	97000.00	1756.00	246.00	8.00	41.50	26.00	18.50	2.00	8.00	32.00	6.00	83.50	181.00	5.00
EE-85-1	Miocene	122000.00	88000.00	4530.00	60.00	3.00	29.50	25.50	10.00	4.00	4.00	36.00	5.00	59.50	35.00	3.00
Yusr-35	Miocene	22000.00	81000.00	1152.00	34.00	5.50	18.50	31.00	8.00	2.50	1.50	41.00	5.50	104.50	60.00	2.50
Sudr	Miocene	125000.00	88500.00	580.00	24.00	3.50	15.50	20.50	12.50	3.00	3.00	40.50	5.00	56.50	50.00	6.00
Asl	Miocene	26500.00	96500.00	750.00	34.00	5.50	41.00	24.50	11.50	2.00	6.50	37.50	5.00	38.50	38.00	3.50
113-A-1	Miocene	17500.00	85000.00	868.00	262.00	3.00	37.00	37.50	10.50	5.50	4.50	36.00	6.00	97.50	100.00	3.00
MAT-6	Eocene	14500.00	10500.00	1781.00	73.00	1.50	32.50	13.00	7.00	2.00	4.00	37.00	5.00	73.00	35.00	.50
Bakr-35	Eocene	10500.00	10000.00	408.00	182.00	4.50	8.50	20.00	9.50	2.50	6.00	38.00	5.50	76.50	96.00	2.00
EB BM-19	U.Cret.	19500.00	90500.00	908.00	60.00	4.00	71.00	33.50	23.50	.50	4.00	27.00	1.00	73.50	95.00	.50
ARS-23	U.Cret.	2500.00	29000.00	640.00	29.00	6.00	28.50	26.00	10.50	1.00	8.00	37.00	3.00	64.00	95.50	3.00
Amer	U.Cret	25500.00	94500.00	530.00	28.00	11.00	175.50	25.00	22.50	1.50	4.50	11.00	4.00	34.00	95.00	1.50
Bakr-31	U.Cret	11000.00	40000.00	731.00	108.50	4.50	9.50	20.50	11.00	3.50	26.50	19.00	2.50	97.00	94.00	4.50
Bakr-27	U.Cret	17000.00	80000.00	918.00	59.50	3.50	24.50	23.00	10.50	2.50	7.50	9.50	3.50	39.50	228.00	2.00
BM-39	U.Cret	17000.00	94000.00	845.00	30.50	3.00	36.00	24.00	9.50	2.50	5.00	18.00	4.00	43.50	135.00	2.50
ARS-3	Paleoz.	21500.00	95000.00	630.00	46.50	13.00	39.00	45.00	7.50	7.50	7.00	97.00	3.00	106.00	89.00	.50
SA-15	Paleoz.	65500.00	16500.00	2235.00	211.50	16.00	46.00	125.00	44.00	5.50	26.50	88.00	4.50	94.00	262.00	2.00
WBM-24	Paleoz.	30500.00	88000.00	1000.00	30.50	9.00	76.00	50.00	23.00	3.00	5.00	78.00	5.00	119.00	149.00	2.00
EE 85-11	Paleoz.	18000.00	84000.00	711.00	50.50	8.00	44.00	62.00	11.50	4.00	3.50	130.00	6.50	98.00	48.00	1.00
Bakr-26	Paleoz.	18000.00	85000.00	3610.00	590.00	7.00	19.00	60.00	10.00	5.00	4.00	112.00	7.00	117.00	69.00	4.00
Bahar-24	Paleoz.	36000.00	45000.00	798.00	140.00	6.50	38.00	59.00	10.00	5.50	4.50	136.00	6.00	108.00	63.00	4.50
J-12	Paleoz.	19000.00	50000.00	956.00	73.00	8.00	38.50	66.00	18.50	2.50	8.50	38.00	5.00	104.00	134.00	1.00
October	Paleoz.	18000.00	12000.00	595.00	120.50	11.00	41.00	56.00	17.00	3.50	18.50	108.00	3.50	56.00	59.00	5.00
Ramadan	Paleoz.	12000.00	56000.00	1674.00	353.50	7.00	32.00	60.00	11.00	2.50	136.00	80.00	2.50	38.00	150.00	1.00
Bakr-69	Paleoz.	63000.00	63000.00	932.50	54.50	44.00	28.00	48.00	18.50	3.00	38.50	94.00	3.00	97.00	62.00	2.50

Table- 1: The well name, ages and results of elemental analysis of crude oil sample in the Gulf of Suez.

Well Name	Age	Fe	Al	Ca	Mg	Mn	Zn	Cr	Cu	Ti	Ba	Sr	Co	Ni	V	Zr
Ras Mat-7	Eocene	800	930	64200	180	5	37	14	7	30	40	160	12	11	11	12
113-M-6	Eocene	2900	3650	41600	280	5	30	65	8	164	32	135	14	19	9	16
Rahmi-1	Eocene	300	120	79000	90	5	29	21	5	5	26	154	16	5	15	12
ARS-6	Eocene	1500	270	7810	50	5	60	132	5	5	13	13	13	12	12	12
Ras Mat-6	Eocene	9700	14700	12690	1580	101	26	21	14	723	974	41	15	6	63	24
Rud-Sid	Eocene	3600	3910	34200	1370	19	48	27	5	206	1012	120	12	5	5	8
113-A-14	Eocene	900	550	56600	780	5	27	31	9	5	339	142	10	7	16	12
Rud-Sid	Eocene	1100	670	52000	2370	5	26	27	10	16	333	90	8	6	14	12
113-3	Eocene	3400	2470	55200	1510	94	28	26	7	138	355	97	9	18	12	14
WB	Eocene	900	1020	76200	110	6	3	18	5	81	13	132	13	5	23	13
BM-30	Eocene	700	590	81000	90	7	8	10	5	14	12	100	15	5	14	12
113-M-6	Eocene	500	650	79000	160	108	100	13	5	59	73	80	14	5	72	12
Bakr-7	Eocene	700	500	80600	90	8	20	14	5	9	29	151	13	5	13	14
B-113-A25	Eocene	5400	1780	39800	410	77	42	39	11	106	1071	117	12	8	12	13
Bm-1	Eocene	1700	1230	73200	480	16	52	11	7	34	139	165	16	11	11	16
Bm-6	Eocene	900	1210	44000	220	5	23	21	6	41	189	84	14	5	9	14
BM-3	Eocene	1000	900	71900	230	23	19	10	6	32	340	144	12	5	5	12
113-3	Eocene	8700	7560	6270	670	5	32	58	9	652	48	71	15	9	13	12
Rahmi-2	Miocene	6900	6690	180	550	5	11	124	7	1090	43	50	12	6	5	13
B-113 A5	Miocene	8100	18800	1240	1510	5	24	17	24	946	49	30	14	8	12	12
B 113 A15	Miocene	800	220	80000	930	11	50	6	5	5	14	30	13	5	10	9
Bakr-17	Miocene	9000	7840	22590	3680	100	13	13	5	478	16	18	16	5	9	20
ARS-5	Miocene	4000	8960	8830	2220	47	26	19	7	572	61	11	13	5	8	13
ARS_3	Miocene	4000	5410	24900	1030	6	32	18	10	328	20	92	12	7	8	12
WB	Miocene	7300	16400	11950	4110	83	10	16	14	756	24	36	12	5	22	33
BM-11	Miocene	3700	6130	27310	4240	164	7	53	5	488	42	54	15	14	9	16
113-A14	Miocene	6500	9200	17930	2000	143	10	22	13	588	52	55	14	8	6	21
Bl 113 A6	Miocene	7200	9620	14020	1780	183	9	143	16	552	48	46	13	75	13	22
BM	Miocene	3320	4580	19840	1440	38	30	39	5	547	26	45	11	15	5	34
Bl 113 A6	Miocene	5800	7250	25090	2460	165	11	23	17	403	49	54	12	6	18	13
Amer-2	Miocene	15000	19700	6360	1880	5	32	20	16	1061	55	46	15	20	24	35
Rahmi-3	Miocene	49000	3790	14990	3020	406	9	8	5	358	22	81	13	20	11	19
W-BL	Paleoz.	5500	3250	47200	1280	47	9	23	5	314	37	94	11	5	11	10
Ras Bah-2	Paleoz.	4100	4610	32200	980	7	54	14	5	340	21	81	10	6	65	8
SA-D4	U.Cret.	3200	2950	36400	1310	11	42	93	5	212	18	74	13	5	85	9
Ras Bah-4	U.Cret.	5500	7120	25010	1250	47	14	30	5	446	32	60	16	47	5	23
SA-D5	U.Cret.	5800	4840	24030	1440	32	36	23	5	320	15	98	18	5	10	12
Bl	U.Cret.	7900	192000	7100	1540	5	23	23	12	971	47	23	12	5	11	14

Table- 2: The well names, ages and results of elemental analysis of source rock samples in the Gulf of Suez.

are considered the main elements forming the carbonate rock of marine origin and the presence of Mg reflecting the dolomitic nature due to the effect of the diagenetic processes, this processes is accompanied by decreasing of Ca and Sr but the Mg is increased so we considered these factors as the factors of diagenesis.

2. The second group include Factor - 2 (Ni, Ti, Cr, V) and Factor - 4 (Mn, Zn, Cu, Co) in crude oils and Factor -1 (Ni, Cr, Ti, V, Cu) and Factor - 4 (Co, Zn, Mn, Ba) in rock samples. The elements of these factors reflect the adsorption processes of these elements on the outer surfaces of the minerals constituting the source rocks. Some of the elements such as Ni, Cr, and Ti have the affinity to be adsorbed on the surface of clay minerals constituting the source rock of Miocene shale and the Black shale of the PreUpper Cretaceous and the other elements such as Mn, Zn, Co, and Ba have the affinity to be adsorbed on the surface of dark limestone source rocks of Middle Eocene and Upper Cretaceous. These elements are highly adsorbed on the surface of source rocks after the migration of crude oil to reservoir rocks, so the group of these factors can be termed the trace elements adsorption factors.
3. The third group include Factor - 3 (Al, Fe, Zr) for crude oil and Factor - 3 (Al, Fe, Zr) for the rock samples. The presence of Al reflect the presence of clay content in the source rock and the Fe content suggest a penecontemporaneous precipitation of the essential and ferromagnesian minerals under marine conditions, these minerals constituting the multiple source rocks for oil generation in the Gulf of Suez, so we considered this factor as the factor of source rock.

From this work it has been shown that there is a variation in the adsorbed elements contents which can be related to the different source rock types. Some of these elements associations (V, Ni, Ti, Cr) are strongly adsorbed in shale source rock with low maturity crude oils as evidenced by Barwise {10}. The other trace elements association such as (Mn, Zn, Co, Cu) are concentrated in carbonate source rocks. Figures (3 &4) explain the positive factor scores for some wells of the Gulf of Suez indicating that the source rock is the shale type, while the negative factor scores for the other wells indicate that the source rock is limestone type.

Variable	Factor-1	Factor-2	Factor-3	Factor-4	Communality
Ca	0.78151	-0.03872	0.35959	-0.10288	0.39219
Mg	0.75657	0.26986	0.10189	-0.28093	0.65474
Sr	0.67412	0.03978	-0.13735	0.18453	0.75215
Ba	0.38811	-0.06644	-0.48939	0.25051	0.75216
Ni	-0.06717	0.80541	0.17819	0.09733	0.45728
Ti	0.25909	0.69732	-0.05846	-0.14614	0.49991
Cr	0.48877	0.55544	0.00491	0.32756	0.51544
V	0.34713	0.41577	-0.17212	0.07586	0.73452
Al	0.14665	-0.18915	0.64739	0.15331	0.63784
Zr	0.04001	0.27241	0.58897	-0.09587	0.69443
Fe	-0.01507	0.07121	0.55125	0.45417	0.50894
Mn	0.09786	0.26308	-0.17078	0.72793	0.57815
Zn	-0.15411	-0.24686	0.03822	0.57082	0.32875
Cu	0.38655	-0.04432	0.19443	0.45055	0.41199
Co	-0.01948	0.02983	0.06293	0.44604	0.20418
Eigenvalue	2.76454	2.41175	2.04176	1.16149	
Pct of Var.	19.9	18.7	16.6	14.8	
Cum. Pct.	19.9	38.6	55.2	70	

Table- 3: R-mode factor analysis of crude oil data, Gulf Suez.

Variable	Factor-1	Factor-2	Factor-3	Factor-4	Communality
Ni	0.83686	-0.16731	0.07545	0.07901	0.57798
Cr	0.71303	0.27061	0.22265	-0.07907	0.74026
Ti	0.64811	0.16411	-0.33768	0.16232	0.76951
V	0.64231	-0.12637	-0.15814	-0.21664	0.58734
Cu	0.63287	0.08145	-0.00128	-0.05314	0.43692
Sr	-0.24065	0.80868	-0.20376	-0.12694	0.47534
Mg	0.42353	0.66558	0.00848	0.22199	0.44531
Ca	0.13537	0.46526	0.24777	-0.42328	0.67173
Al	0.06515	0.34082	0.68987	0.15181	0.61937
Fe	0.30965	-0.16389	0.66863	-0.19288	0.49998
Zr	-0.12297	-0.03328	0.64811	0.09505	0.73738
Co	-0.00826	0.08402	0.19056	0.78801	0.49748
Zn	-0.06676	-0.07191	0.08724	0.74156	0.50047
Mn	0.19334	0.00641	0.22702	0.69931	0.56715
Ba	-0.20081	0.43901	-0.04886	0.51463	0.39672
Eigenvalue	4.56987	2.52765	2.01041	1.44311	
Pct of Var.	30.5	16.9	13.4	9.6	
Cum. Pct.	30.5	47.3	60.7	70.3	

Table- 4: R-mode factor analysis of source rock data, Gulf of Suez.

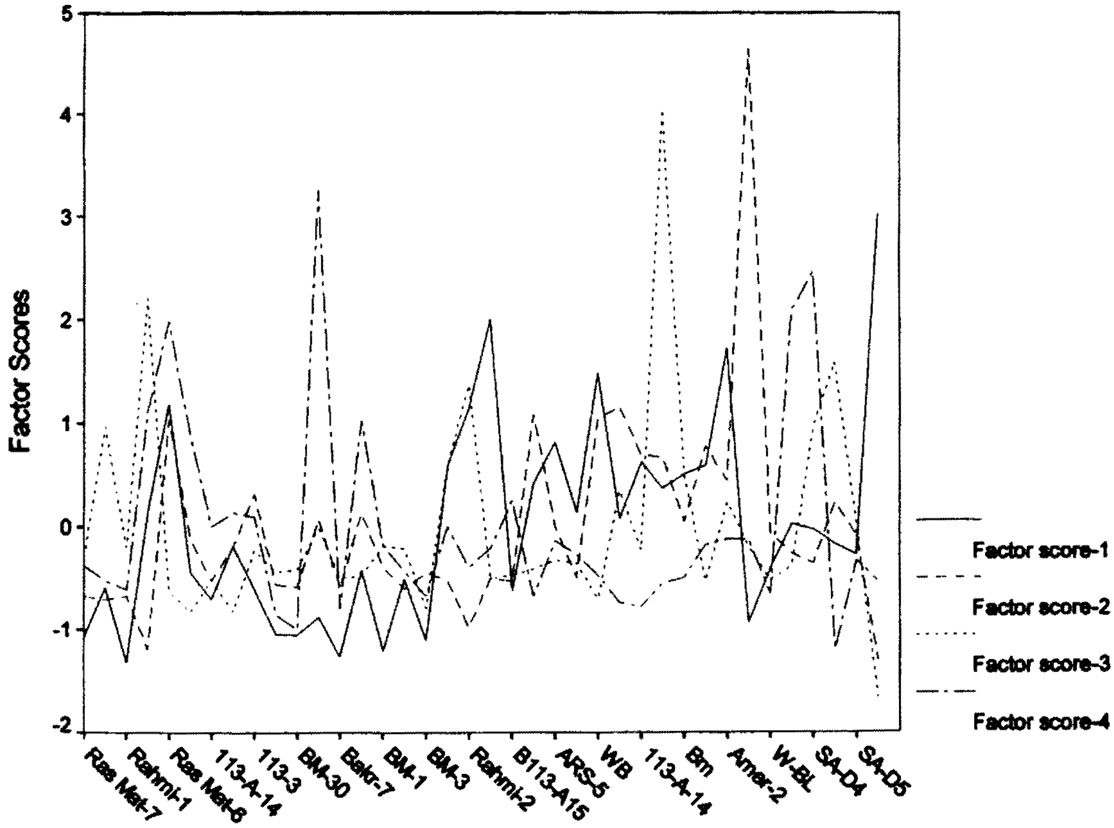

Fig. 3: Factor scores 1.2.3. & 4 to the studied rock samples in the Gulf of Suez.

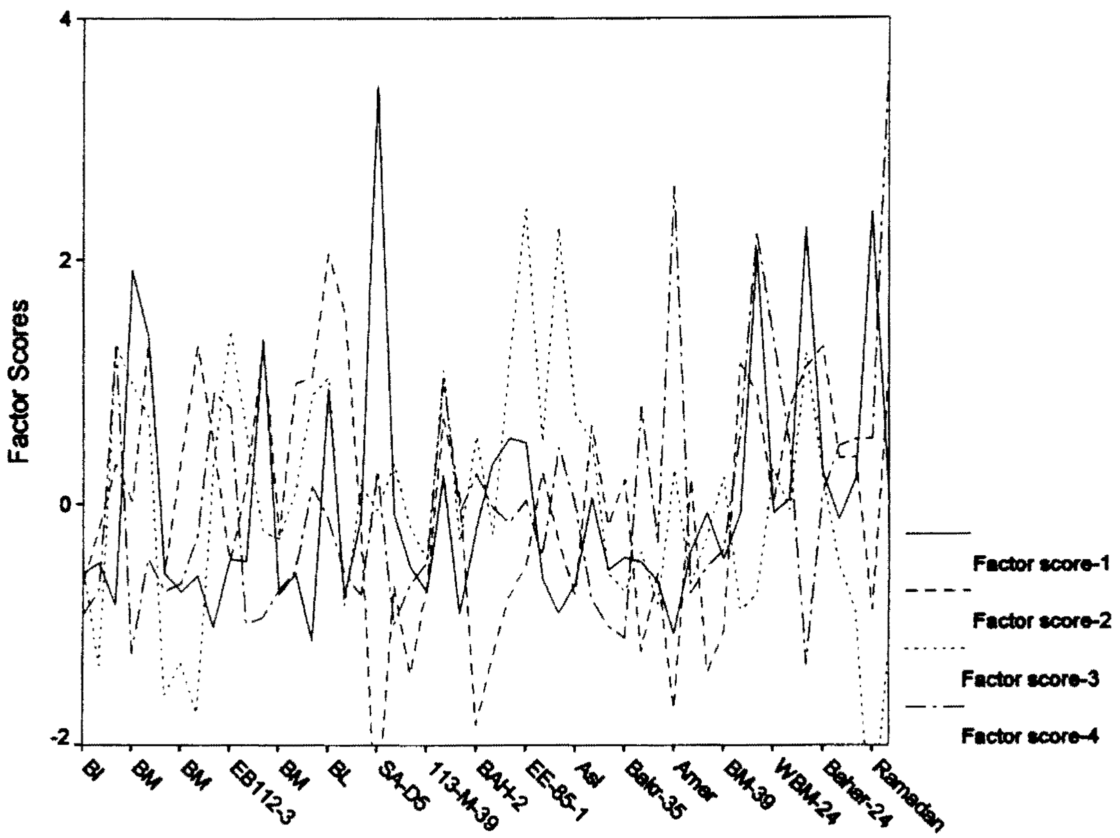

Fig. 4: Factor scores 1.2.3. & 4 to the studied crude oil samples in the Gulf of Suez.

Based on this study and many others such as Rohrback {11}, Barkat {12} and Mostafa {13} the source rocks exist within the Miocene age (shale rocks of Belayim, Kareem and Rudies Formations) and within the Pre-Miocene; the Eocene limestone rock (Thebes Formation), Brown Limestone of Upper Senonian and the Black Shale of Pre-Upper Cretaceous age.

B - Cluster Analysis

The dendrogram cluster analysis of the crude oils and the source rocks (Figs 5 & 6) showed two different groups. The first one includes the wells from the oilfields located in the southern part of the Gulf of Suez (Ras Bahar and Shoab Ali) fields.

The second group includes the wells of the northern and central oilfields of the Gulf of Suez (Ras Matarma, Asl, Abu Rudies, October, Ras Budran, Amer, Bakr, Belayim, Rahmi and July) fields.

The two separated cluster groups reflect the presence of two different types of source rocks within the stratigraphic column of the Gulf of Suez the shale sequence of the Miocene and Pre-Upper Cretaceous and the carbonate rocks of the Middle Eocene and Upper Cretaceous ages in addition to the presence of three oil groups throughout the Gulf of Suez Provinces northern, central and southern parts as evidenced by {13} which are related to the presence of a multiple source rocks and the difference in organic facies, where the source rocks containing different types of kerogen I, I-II and II which are capable for generation of oil and gas .

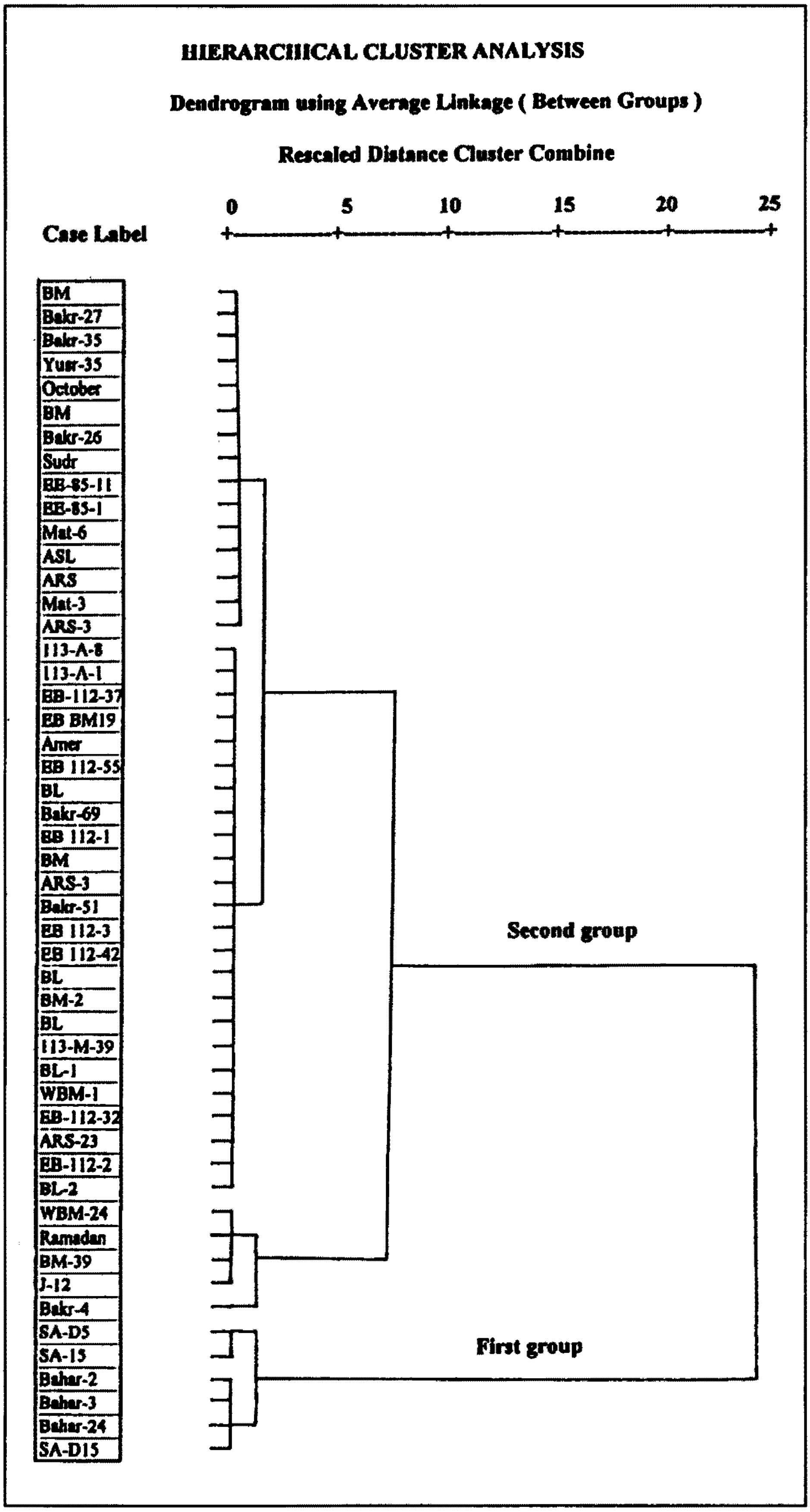

Fig. 5: Dendrogram Cluster Analysis of crude oil samples from the Gulf of Suez.

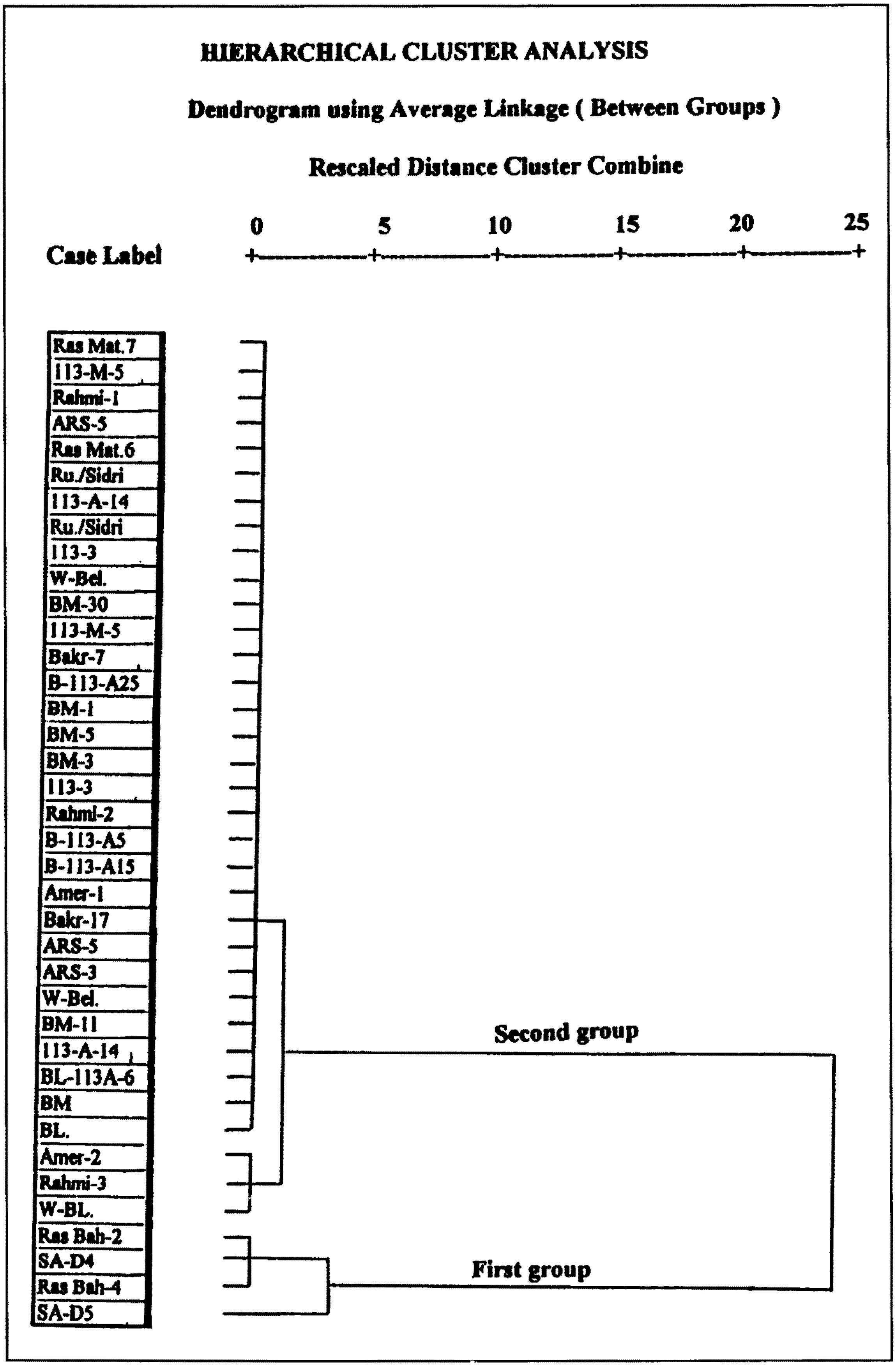

Fig. 6: Dendrogramk cluster analysis of source rock samples from the Gulf of Suez.

Trace Elements distribution In crude oils and Source Rocks

The distribution of trace elements in the studied crude oil samples and the related source rocks in the Gulf of Suez are illustrated in figures (7 & 8).

1 - Iron and Aluminum

Concentration of Fe and Al is very high, where Fe is reaches to 120000 ppm in crude oils and 35000 ppm in source rocks, while Al reaches to 100000 ppm in crude oils and 30000 ppm in source rocks. The very high concentration of these two elements is due to the dominance of these two elements in the essential and ferromagnesian minerals constituting the source rocks for the generated crude oils. This is explained before in the discussion of the factor analysis.

2 - Calcium and Magnesium

Calcium and Mg show an inverse relation in crude oils and source rocks where the increasing of Ca is accompanied by the decreasing of Mg. The Maximum concentration of Ca in crude oils reaches to 4500 ppm and in source rocks 80000 ppm while the concentration of Mg in crude oils is 500 ppm and in source rock is 300 ppm. The inverse relation between the two elements may be related to the presence of dolomitisation in carbonate source rock due to the development of diagenesis where the source rocks have been subjected to the high pressure lead to the migration of crude oils to the reservoir rocks. This is evidenced from the factor of diagenesis.

3 - The adsorbed elements

Vanadium, Nickel, Chromium and Copper.

The higher concentration of the adsorbed elements is V and Ni. These two elements are considered the greatest abundance almost in all crude oils, {14}. They present as metalloporphyrine (Vanadyle and Nickelous porphyrins). The maximum concentration of V and Ni in crude oils are 280 ppm and 170 ppm while in source rocks reached to 90 ppm and 110 ppm, respectively.

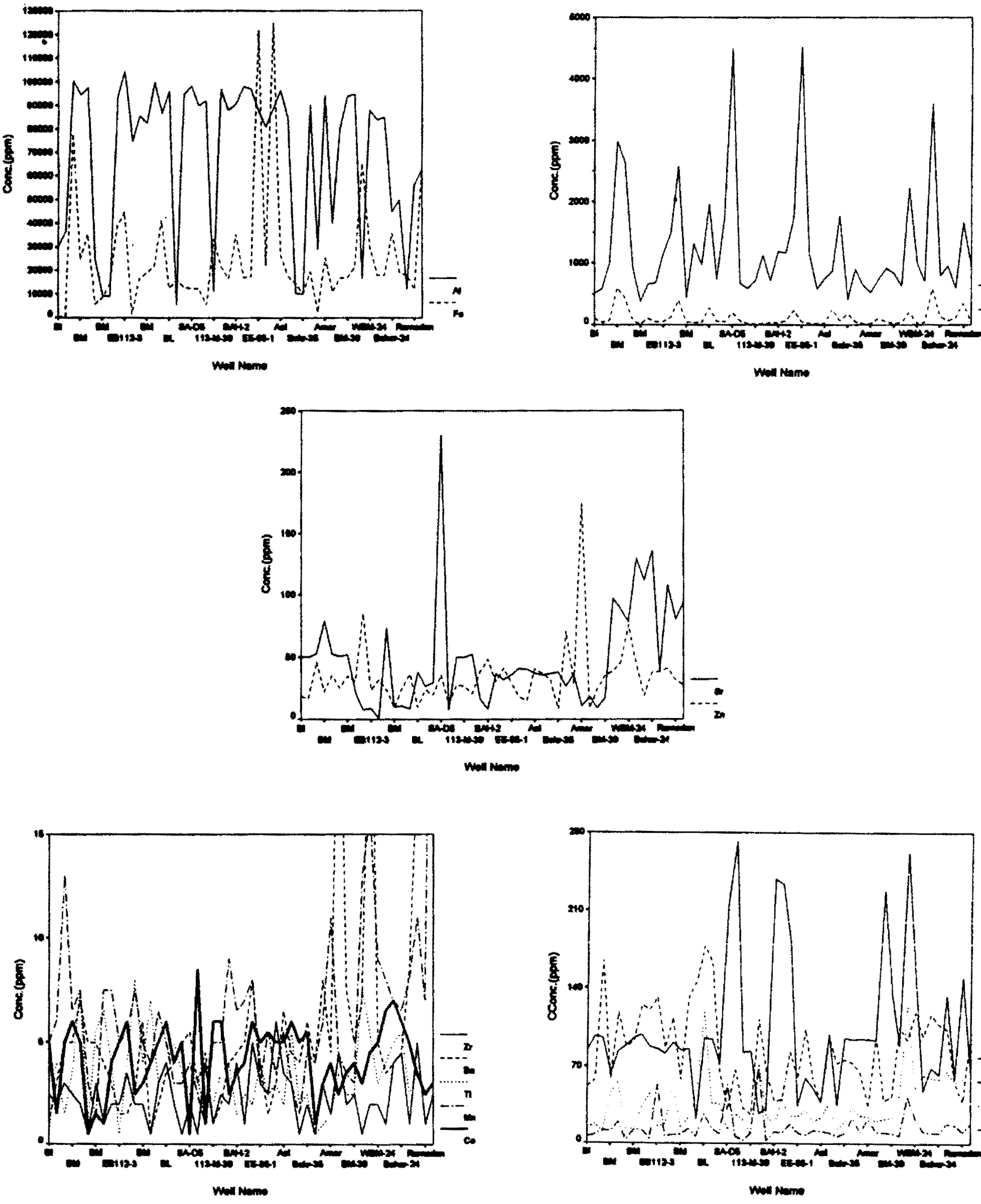

Fig. 7: Concentration of trace elements in the studied crude oil samples in the Gulf of Suez.

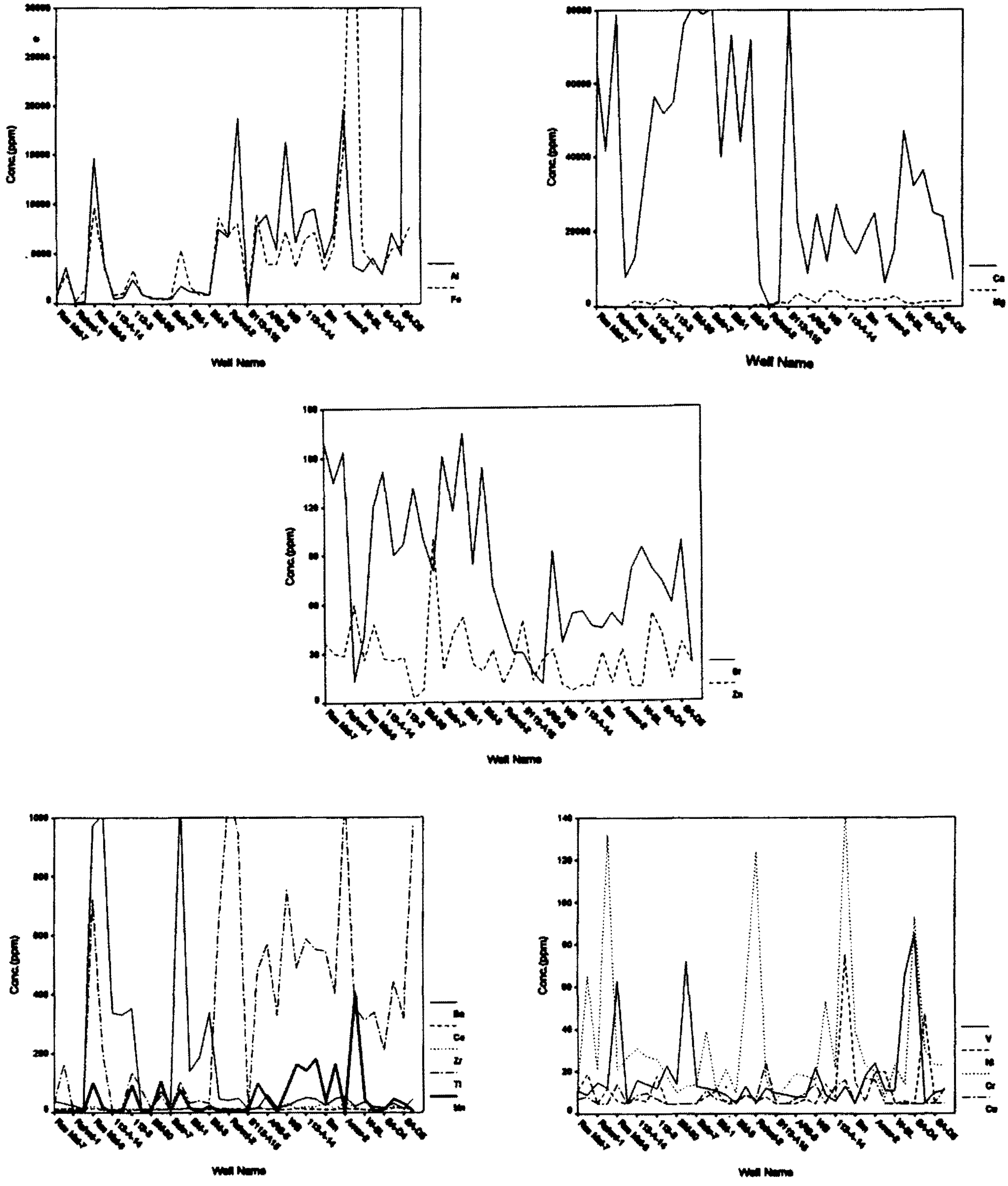

Fig. 8: Concentrations of trace elements in the studied rock samples in the Gulf of Suez.

The Cr and Cu are of very low concentrations in crude oils range up to 100 ppm and 35 ppm while in source rock range up to 105 ppm and 20 ppm respectively. The variation of the concentration of these elements in crude oil and source rocks are related to the migration processes where it causes the retention of high molecular weight material of asphaltene which incorporated to the trace elements in crude oils leaving the source rocks with low concentrations.

Strontium and Zinc

Strontion and Zn show a parallel relation with each other in the studied crude oil sample and source rocks. In crude oils they range between 220 and 200 ppm while in source rock they varies between 170 and 100 ppm.

Cobalt, Barium, Titanium, Manganese and Zirconium

These elements are the less abundant elements in crude oil samples where their concentrations range between 0.5 to 12 ppm and the low concentrations of these elements in the studied crude oil samples may be related to the low concentration of these elements in the organic matter during the oil generation.

The concentration of Ba and Ti are very high in source rock samples relative to their concentrations in crude oils where they reached to 1000 ppm and the other elements Co, Zr, and Mn are very low concentrations ranging between 0.5 ppm to 150ppm.

The varied concentration of these elements in source rock are related to that these rocks are present at different depths and subjected to different stages of thermal maturation.

CONCLUSIONS

The statistical treatment of the determined trace elements Al, Ba, Ca, Cr, Cu, Co, Fe, Mn, Mg, Ni, Sr, Ti, V, Zn and Zr in the studied crude oil samples and the related source rocks in the Gulf of Suez province revealed three factor groups namely; the factor of diagenesis, the factor of source rock and the trace elements adsorption factor. The concluded factor scores are used to asses the type of source rocks, where the positive factor scores indicate that the source rock is shale due to the high affinity of clay minerals to adsorb the trace elements on its surface such as V, Ni, Ti, Cr while the negative factor scores indicates that the source rock is carbonate rocks and characterized by adsorption of Mn, Zn, Co, Cu. The cluster analysis differentiate the Gulf of Suez into two major provinces based on the trace elements contents, the northern and central province which includes (Ras Matarma- Asl- Abu Rudies- October- Ras Budran- Amer-Bakr-Belayim- Rahmi and July) oilfields while the southern region includes (Ras Bahar and Shoab Ali) oilfields.

The higher concentration of trace elements in source rocks relative to the crude oils are related to the retention of these elements on the surface of minerals constituting the source rocks after the migration process and presence of these elements in crude oils are due to the leaching of the elements during the migration.

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