J. Univ. Kuwait (Sci.) **16**, 1989

Microfacies analysis of Rumaila Formation and equivalents (Cenomanian) in Mesopotamian Basin, a statistical approach

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ABSTRACT

Detailed petrographic analysis has been carried out on samples of the Rumaila Formation and equivalents in sixteen selected boreholes in the Mesopotamian Basin. Four distinctive carbonate depositional microfacies are identified, namely: lime mudstone, fossiliferous lime mudstone, lime wackestone, and lime packstone.

The most common microfacies (i.e. fossiliferous lime mudstone and lime wackestone) are differentiated objectively by the application of the cluster analysis technique. Distance and product-moment similarity coefficients were used. A facies triangle and ratio map were constructed for each coefficient.

INTRODUCTION

The Rumaila Formation is widely distributed in south, southwestern, and central Iraq. It was described by Rabanit (1952) in an unpublished report as occurring in Well Zb-3 in southern Iraq and as being equivalent to the middle part of Khatiya Formation of the Wasia Group (Middle Cretaceous) of Kuwait. Smout (1956) was the first to use the term Rumaila Limestone. Owen & Nasr (1958) considered Well Zb-3 as a type section for the formation in Iraq, where it was encountered at depths between 7720 and 8072 ft (2353–2460 m).

Lithologically, it was described as consisting of two main members: (1) an upper fine-grained oligosteginal marly limestone and marl at the top and, (2) a fine-grained chalky limestone below (Owen & Nasr 1958; Dunnington 1959; Al-Naqib 1967; Al-Siddiki 1978; Buday 1980). The strata were assumed (by the same above mentioned authors) to be basinal deposits. Aqrawi (1983) and Aqrawi & Khaiwka (1986) concluded that the depositional environment of the Formation was the outer edge of an open shelf. This supposition is based on the carbonate composition and fossil content, as compared with the models of standard microfacies and depositional environment belts of carbonates proposed by Wilson (1975) and Flügel (1982).

The Formation is Cenomanian in age (Dunnington 1959; Chatton & Hart 1961; Al-Siddiki 1978; Ahmed 1979). It lies between the Mishrif Formation (Cenomanian-Early Turonian) above and the Ahmadi Formation (Cenomanian) below. The Rumaila Formation has conformable and gradational boundaries with both these Formations.

Owen & Nasr (1958) and Dunnington (1959) considered the Mahilban Formation in central Iraq to be an equivalent to both the Rumaila and Mishrif Formations. Chatton & Hart (1961) concluded that the Maotsi, Fahad, and Mahilban Formations (central Iraq) are equivalents of the Rumaila Formation only. This conclusion was supported by Al-Naqib (1967). Buday (1980) proposed a detailed study of the Rumaila Formation and its equivalents to settle its stratigraphic position. Aqrawi (1983) and Sherwani (1983) established that what were often termed equivalents were in fact tongues of the Rumaila and Mishrif Formations. If the Mahilban is an equivalent of the Rumaila in its lower part, the upper part of the Mahilban together with the Fahad and Maotsi Formations are dominantly Mishrif facies with several Rumaila tongues. These interdigitations result from tectonic instability within the basin.

MATERIALS AND METHODS

The Rumaila Formation and its equivalents were surveyed petrographically in 16 selected boreholes in central and southern Iraq (Fig. 1). Study of 177 core and cutting samples, using binocular, polarizing, and scanning electron microscopy, was used to describe the carbonate depositional microfacies.

Twelve constituents (variables) were counted from 101 selected thin sections of 13 wells, using line method point counting (Galehouse 1971). Three hundred grain counts with 4 μ grid spacing are considered adequate for this study. Point count data were compiled for each constituent in every well as number of counts and percentage (Table 1).

The data were treated statistically, using the cluster analysis technique (weighted-pairs group method) for both R and Q modes (Davis 1973) based on distance similarity coefficient (DSC) and product moment correlation coefficient (PMCC). The purpose was to determine the sedimentary microfacies and its areal distribution.

CARBONATE DEPOSITIONAL MICROFACIES

Detailed petrographic analysis of the thin sections revealed the existence of four major depositional microfacies. These were named using the carbonate classification of Dunham (1962).

(1) Lime mudstone: Consisting of lime mud only which had been extensively affected by dolomitization and neomorphism. The whole facies is sometimes altered (locally completely) to dolomite (dolostone).
(2) Fossiliferous lime mudstone: This differs from the previous facies in its content of allochems, including some planktonic fossils, molluscs bioclasts, sponge spicules, and echinoderm fragments. The allochems do not exceed ten percent of the whole facies (i.e. it is a highly mud-supported facies). Compaction, dolomi-

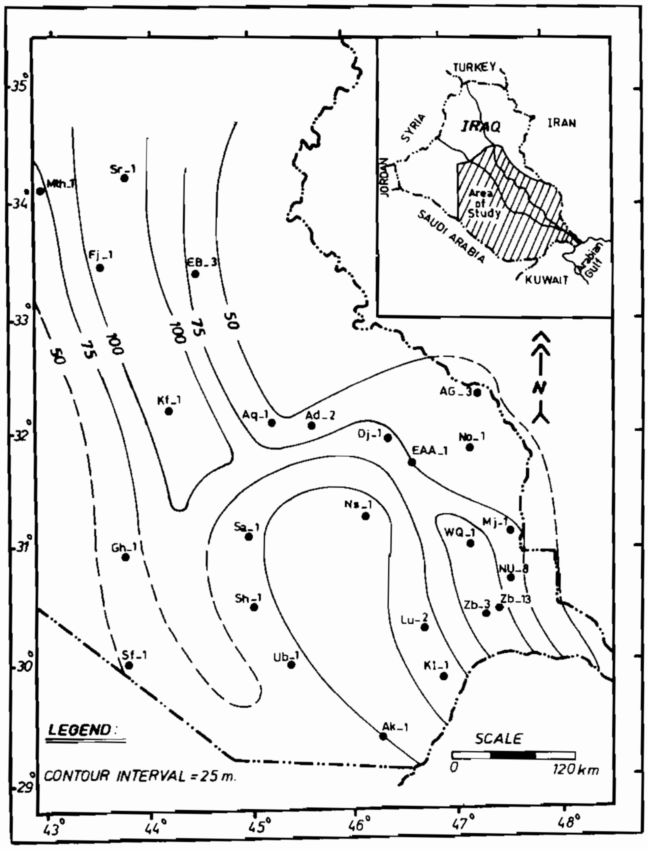

Fig. 1. Map of Iraq showing the area of study (inset) and the location of boreholes and isopachytes of the Rumaila Formation in the Mesopotamian Basin, central and southern Iraq.

tization, neomorphism, and pyritization were the main diagenetic processes. It is one of the two most common and distinctive microfacies of the formation.

(3) Lime wackestone: In this facies the allochems range from 10 to 50%. It is still mud-supported. The facies may be divided into three submicrofacies on the basis of common allochems types.

(*a*) Fossiliferous lime wackestone: The main allochems are planktonic foraminifera, *Globigerina*, and *Oligostegina*. This is the other most common and distinct microfacies in addition to the fossiliferous lime mudstone.

(*b*) Bioclastic lime wackestone: Distinguished by a large percentage of mollusc bioclasts (mainly in central Iraq boreholes).

(*c*) Intraclastic lime wackestone: Intraclasts are the main type of allochems in this microfacies.

The lime wackestone microfacies was generally affected by dolomitization, pressure solution, neomorphism, pyritization, and cementation. It is the second most common microfacies in general after fossiliferous lime mudstone.

Table 1. Data matrix of twelve petrographic constituents (variables) in thirteen studied boreholes (samples). (Note: upper diagonal is the number of counts and lower diagonal is the percentage)

Variables / Samples	(1) Oligosteginid	(2) Heterohelix sp.	(3) Hedbergella ssp.	(4) Discorbis sp.	(5) Algae	(6) Textulariid	(7) Others	(8) Molluscs bioclasts	(9) Micrite	(10) Sparite	(11) Dolomite	(12) Detrital quartz and intracl-asts	Total no. of counts	No. of slides
1. Sf_1	43 / 3.49	84 / 6.81	110 / 8.92	35 / 2.84	10 / 0.81	10 / 0.81	36 / 2.92	67 / 5.43	690 / 56.00	62 / 5.03	85 / 6.89	— / —	1232 / 99.95	6
2. Sh_1	120 / 7.98	75 / 4.99	49 / 3.26	15 / 0.99	8 / 0.53	5 / 0.33	35 / 2.32	98 / 6.52	909 / 60.47	45 / 2.99	144 / 9.58	— / —	1503 / 99.96	7
3. Lu_2	189 / 18.60	60 / 5.90	38 / 3.74	12 / 1.18	— / —	2 / 0.19	7 / 0.68	53 / 5.21	626 / 61.61	29 / 2.85	— / —	— / —	1016 / 99.96	8
4. Zb_3	384 / 8.26	309 / 6.64	268 / 5.76	120 / 2.58	20 / 0.43	13 / 0.27	172 / 3.70	260 / 5.59	2795 / 60.13	134 / 2.88	156 / 3.35	17 / 0.36	4648 / 99.95	18
5. Zb_13	97 / 7.42	31 / 2.37	14 / 1.07	14 / 1.07	3 / 0.22	4 / 0.30	30 / 2.29	131 / 10.02	885 / 67.7	46 / 3.51	52 / 3.97	— / —	1307 / 99.94	6
6. WQ_1	140 / 4.69	131 / 4.39	198 / 6.63	26 / 0.87	16 / 0.53	3 / 0.10	125 / 4.18	137 / 4.59	1618 / 54.22	66 / 2.21	524 / 17.56	— / —	2984 / 99.97	10
7. Kf_1	67 / 4.20	134 / 8.41	158 / 9.91	21 / 1.31	14 / 0.87	3 / 0.18	41 / 2.57	90 / 5.64	888 / 55.74	22 / 1.38	144 / 9.03	11 / 0.69	1593 / 99.93	6
8. Aq_1	71 / 5.01	29 / 2.04	68 / 4.80	33 / 2.33	28 / 1.97	4 / 0.28	6 / 0.42	173 / 12.22	944 / 66.71	49 / 3.46	— / —	10 / 0.70	1415 / 99.94	8
9. Sa_1	89 / 3.35	142 / 5.35	101 / 3.81	98 / 3.69	22 / 0.82	6 / 0.22	129 / 4.86	178	1367 / 51.56	48 / 1.81	471 / 17.76	— / —	2651 / 99.94	10
10. EB_3	80 / 6.17	32 / 2.47	35 / 2.70	2 / 0.15	25 / 1.93	8 / 0.61	41 / 3.16	72 / 5.55	720 / 55.59	97 / 7.49	166 / 12.81	17 / 1.31	1295 / 99.94	6
11. Fj_1	95 / 8.75	47 / 4.33	40 / 3.68	13 / 1.19	3 / 0.27	— / —	30 / 2.76	49 / 4.51	714 / 65.80	14 / 1.29	78 / 7.18	2 / 0.18	1085 / 99.94	6
12. Nf_1	43 / 3.35	48 / 3.75	56 / 4.37	66 / 5.15	6 / 0.46	10 / 0.78	41 / 3.20	94 / 7.34	783 / 61.17	43 / 3.35	88 / 6.87	2 / 0.15	1280 / 99.94	6
13. Sr_1	84 / 7.82	5 / 0.46	— / —	6 / 0.55	16 / 1.48	9 / 0.83	10 / 0.93	168 / 15.64	575 / 53.53	39 / 3.63	162 / 15.08	— / —	1074 / 99.95	5

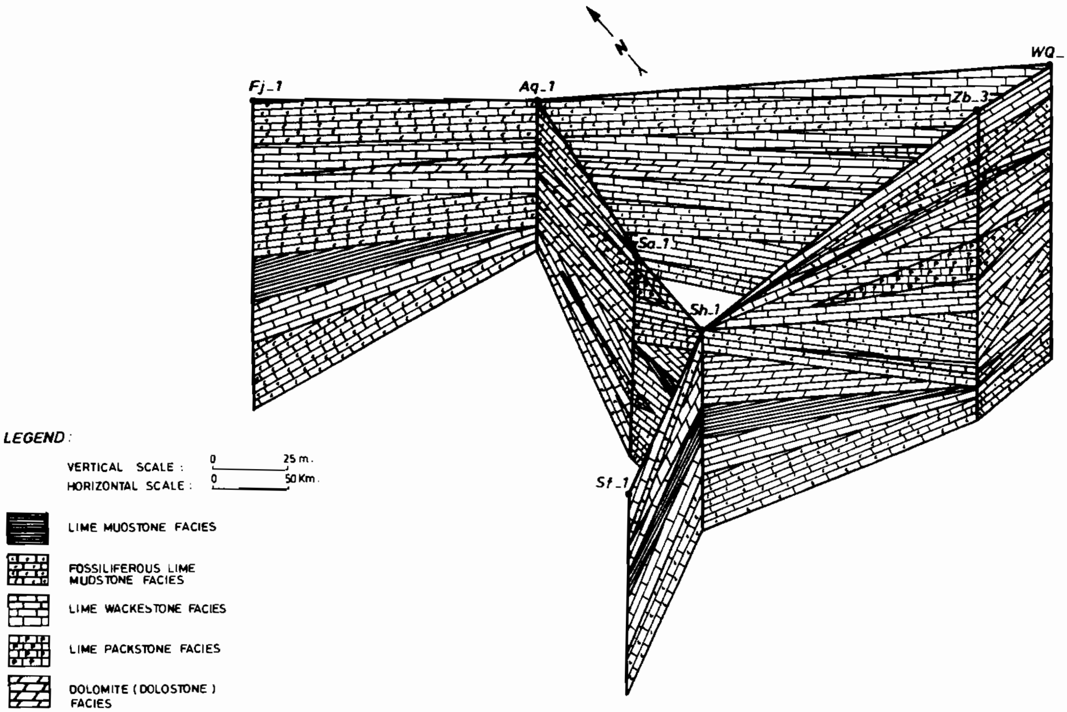

Fig. 2. Fence diagram of seven selected boreholes showing the major depositional microfacies of the Rumaila Formation and their vertical variations and lateral extensions. (Note: Well WQ-1 is extended toward the west to show its facies change vertically).

(4) Fossiliferous lime packstone: This consists mainly of planktonic allochems exceeding 50% grain-support, but still the matrix is lime mud. It is a less common microfacies, with slightly variable diagenesis.

A fence diagram of the major depositional microfacies and dolomites in several selected boreholes from central and southern Iraq is given in Fig. 2.

STATISTICAL ANALYSIS, FACIES TRIANGLE AND RATIO MAPS

The weighted-pairs group method of cluster analysis was applied to the data (Table 1) for comparison. Two R-mode (comparing pairs of variables for all samples) and two Q-mode (comparing pairs of samples for all variables) dendrograms were obtained, one for each of the two similarity coefficients, DSC and PMCC, respectively (Figs 3 & 4). Three end groups from every R and Q-mode dendrogram were chosen for the purpose of multicomponent (facies triangle) single-contour system facies analysis.

The percentages of constituents within a single end group (I, II and III) of each R-mode dendrogram were combined for each coefficient at each well (Table 2). Every well was projected as a three dimensional point (i.e. point of three R-mode chosen end groups of combined percentages) on the facies triangle. The facies triangles were divided according to conventionally established ratio limits (Krumbein

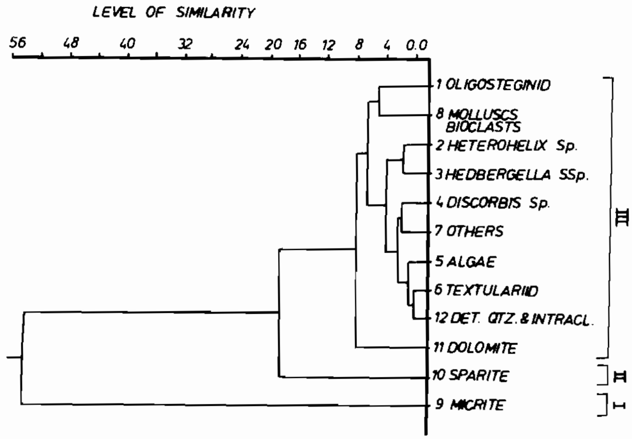

Fig. 3a. R-mode cluster analysis distance similarity coefficient (DSC) showing three end groups of the variables.

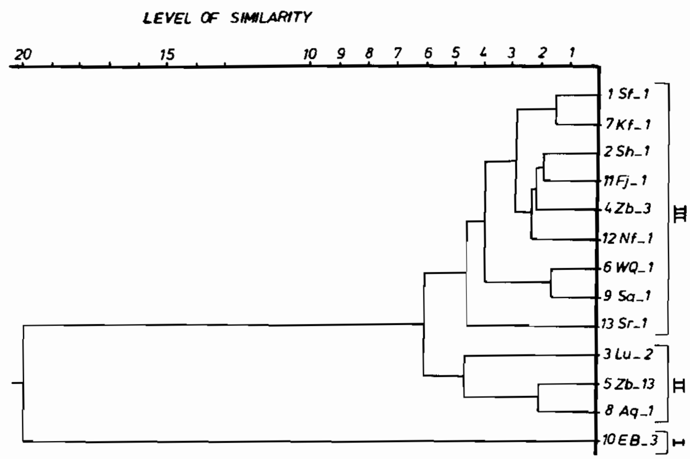

Fig. 3b. Q-mode cluster analysis using distance similarity coefficient (DSC) showing three end groups of the samples.

& Sloss 1963). The ratio contours were plotted between the projected points (wells) on the location map with the aim of constructing ratio maps of microfacies from the facies triangle (Table 2 and Figs 5 & 6). Both ratio maps revealed the two most common and distinct microfacies of the formation: fossiliferous lime mudstone and lime wackestone.

The Q-mode results based on two coefficients were identical, except for the grouping of Well Zb-13 and Well Aq-1 with Well Lu-2 when using DSC. These three wells show the same dominant microfacies (fossiliferous lime mudstone).

DISCUSSION AND CONCLUSIONS

The clustering of the two coefficients in both R and Q-mode analysis showed no great variation, but the distance similarity coefficient (DSC) is still preferred to the

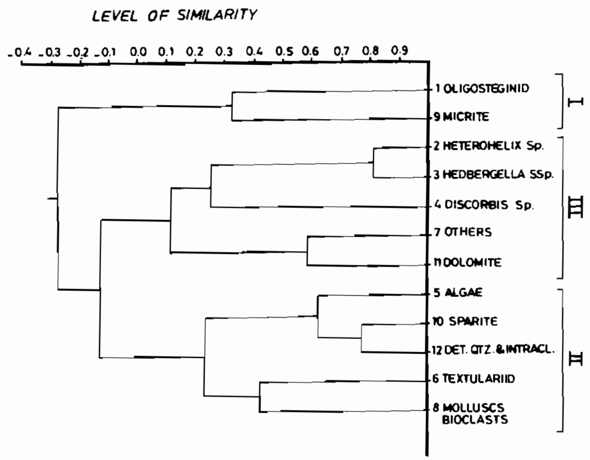

Fig. 4a. R-mode cluster analysis using product moment correlation coefficient (PMCC) showing three end groups of the variables.

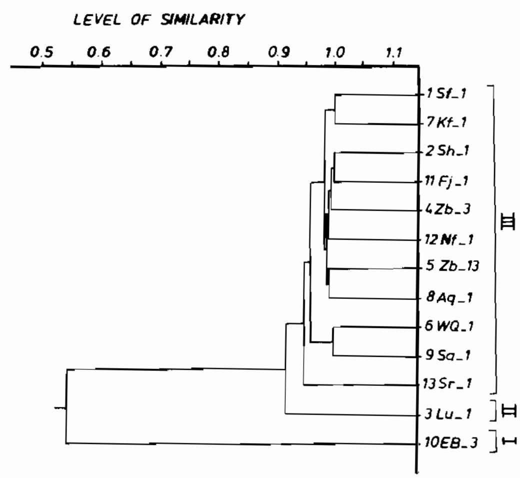

Fig. 4b. Q-mode cluster analysis using product moment correlation coefficient (PMCC) showing three end groups of the samples.

product moment correlation coefficient (PMCC) in R-mode cluster analysis because of its more meaningful categorizing of environmentally related variables. The efficiency of this coefficient (DSC) in classification of sedimentary facies has been mentioned by Harbough & Merriam (1968), Khaiwka *et al.* (1981) and Aqrawi & Darmoian (1988).

The R-mode facies triangle of each coefficient revealed only the most common and distinct microfacies. The ratio maps of these microfacies have clarified their regional distribution in the area of study.

The utility of this method and technique in determining sedimentary facies in poorly known areas was mentioned by Khaiwka *et al.* (1981), especially when data are limited. It is important to mention that the statistically determined microfacies

Table 2. Three end group percentages for every borehole as revealed by R-mode cluster analysis for every coefficient used.

Wells	Groups I	II	III	Total
1	56·00	5·03	33·92	99·95
2	60·47	2·99	36·50	99·96
3	61·61	2·85	35·50	99·96
4	60·13	2·88	36·94	99·95
5	67·70	3·51	28·73	99·94
6	54·22	2·21	43·54	99·97
7	55·74	1·38	42·81	99·93
8	66·71	3·46	29·77	99·94
9	51·56	1·31	46·57	99·94
10	55·59	7·49	36·86	99·94
11	65·80	1·29	32·85	99·94
12	61·17	3·35	35·42	99·94
13	53·53	3·53	42·89	99·95
Using distance similarity correlation coefficient				
1	59·49	12·08	28·38	99·95
2	68·45	10·37	21·14	99·96
3	30·21	8·25	11·50	99·96
4	68·39	9·53	22·04	99·95
5	75·12	14·05	10·77	99·94
6	58·91	7·43	33·60	99·97
7	59·94	3·76	31·23	99·93
8	71·72	18·63	9·59	99·94
9	54·91	8·93	36·10	99·94
10	61·76	16·89	21·29	99·94
11	74·55	6·25	19·14	99·94
12	64·52	12·08	23·34	99·94
13	61·35	21·38	17·02	99·95
Using product-moment correlation coefficient				

were only the most common and distinctive, but they are reliable enough in reconstructing the depositional environments of the formation.

The grouping of Well Zb-3 and Well Aq-1 with Well Lu-2 when using DSC in Q-mode analysis was referred to the location of these three wells along the depositional axis of the formation and Cenomanian equivalents (Ibrahim 1979). Moreover, they are nearly of the same depositional microfacies. It is worth mentioning that the separation of Well EB-3 by Q-mode results of both coefficients is due to extensive diagenesis effects.

ACKNOWLEDGEMENT

Thanks are due to the Oil Exploration Company of Iraq for providing samples and for permission to publish this work. Thanks are extended to Dr Fadhil Sadooni for a first reading of the draft manuscript and to the Computer Centre of the Ministry of Agriculture and Irrigation, Iraq for managing the computer work.

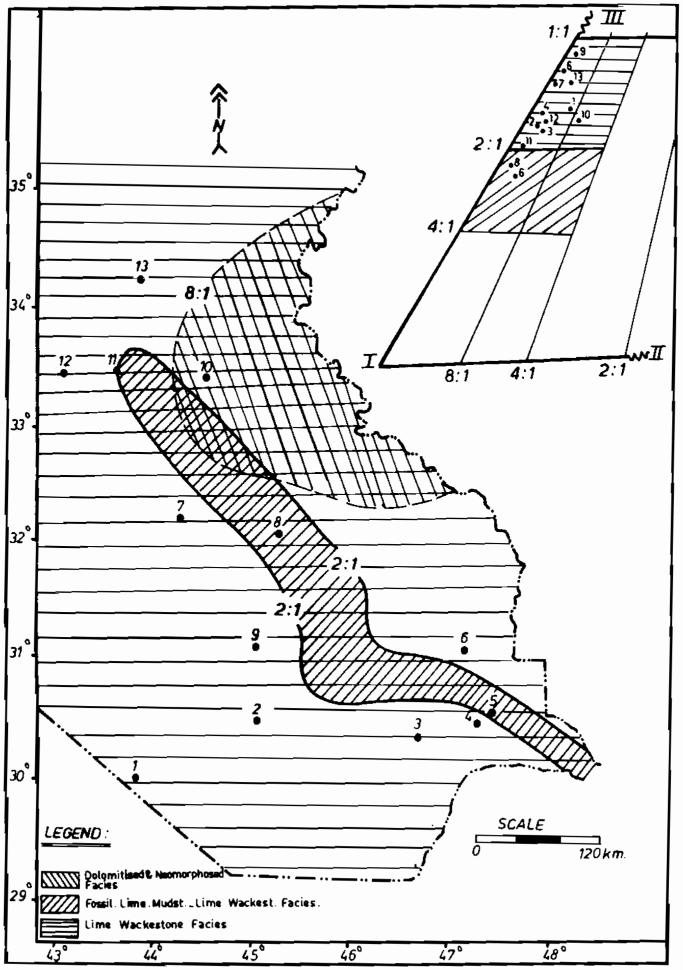

Fig. 5

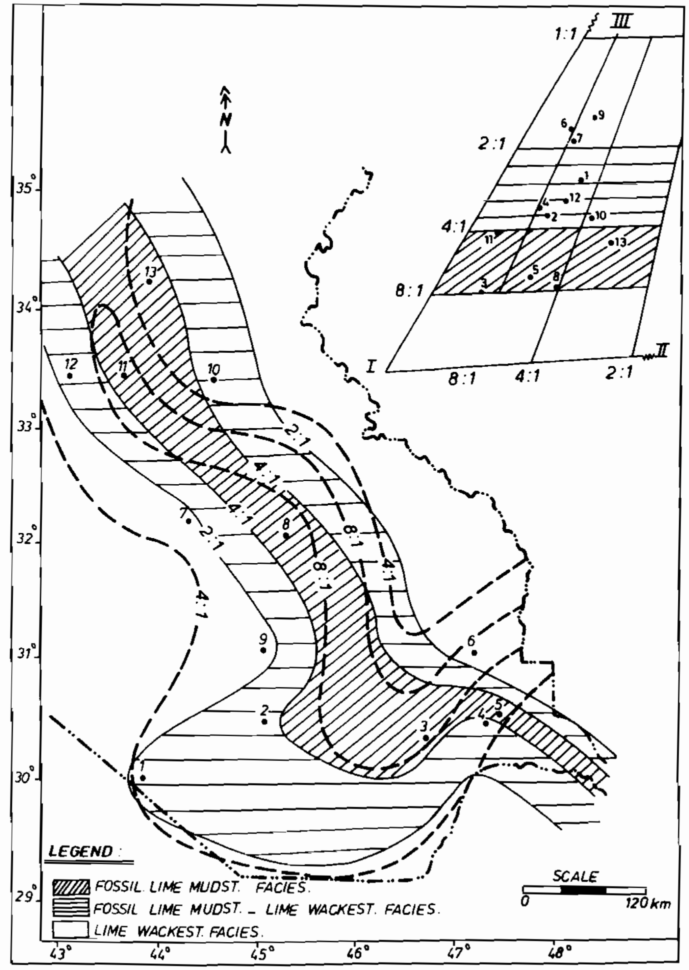

Fig. 6

Fig. 5. R and Q-mode cluster analysis facies triangle and ratio map, using distance similarity coefficient (DSC).
Fig. 6. R and Q-mode cluster analysis facies triangle and ratio map, using product moment correlation coefficient (PMCC).

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(Received 30 September 1986, revised 15 May 1988)

تحليل إحصائي للسحنات المجهرية لتكوين الرميلة ومكافئاته (سينوماني) في حوض ما بين النهرين

عدنان عبدالرزاق عقراوي
مركز علوم البحار ، بجامعة البصرة ،
البصرة ، العراق

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جامعة بغداد ، العراق

خلاصة

من خلال الدراسة المجهرية المستفيضة لشرائح صخرية من اللباب والفتات لتكوين الرميلة ومكافئاته مأخوذة من آبار مختارة في وسط وجنوب العراق ، أمكن تمييز أربع سحنات كاربوناتية رسوبية مجهرية هي : الحجر الجيري الطيني ، والحجر الجيري الطيني الأحفوري ، والحجر الجيري الفتاتي ، والحجر الجيري المرصوص .

وباستخدام طرق التحليل الإحصائي العنقودي ، تم تمييز النوعين الأكثر شيوعا من السحنات المجهرية ، وهما الحجر الجيري الطيني الأحفوري والحجر الجيري الفتاتي . ويعتمد هذا التحليل على استخدام معاملات إحصائية مختلفة لتحديد مقدار التشابه بين العينات . وفي النهاية أعدت مثلثات سحنية وخرائط كنتورية للنسب السحنية لكل معامل من معاملات التشابه المستخدمة في التحليل العنقودي .