PRJ, Vol. 5 (January 1993); P. 56–61, 6 FIGS, 2 TABLES.

MICROPROBE ANALYSIS OF THE GLAUCONITE PELLETS OF THE LIDAM FORMATION NW SIRT BASIN, LIBYA

M. El-Bakai*

استخدام المسبار المجهري في دراسة حبيبات الجلوكونيت بتكوين الليدام بالمنطقة الشمالية الغربية لحوض سرت الترسيبي

محمود البكاي

تم تصنيف معدن الجلوكونيت في تكوين الليدام ، بالمنطقة الشمالية الغربية من حوض سرت الرسوبي ، إلى ثلاثة أنواع هي خضراء غامقة وخضراء فاتحة والصفراء البنية.

وقد بينت الفحوصات ، التي أجريت باستخدام المسبار المجهري ، للثلاثة أنواع بأن الحبيبات الصفراء البنية المصغرة كانت أصلاً حبيبات خضراء غامقة غير أن الألومينيوم السداسي الأوجه حل محل أيونات الحديديك والحديدوز وكذلك البوتاسيوم. وتعكس هذه الحبيبات ، الصفراء البنية ، التأثير الكبير لظروف الأكسدة ، إما من خلال التكثف أو أثناء تنقلها بواسطة تيارات المياه الضحلة العكرة في أوقات انخفاض مستوى مياه سطح البحر أثناء المرحلة السينومانية المتأخرة والمرحلة التورونية المبكرة. أما الحبيبات الداكنة اللون ربما تمثل المرحلة الإنتقالية ما بين النوعين الآخرين.

كما تبين الدراسة أن متوسط قيمة أكسيد البوتاسيوم بالحبيبات الخضراء الغامقة (معدن الجلوكونيت) يبلغ 8.7 الأمر الذي يعكس التركيز المحلي لأكسيد البوتاسيوم. وتشير استدارة حبيبات الجلوكونيت واحلال الدولوميت محلها بأنها ربما قد إنتقلت مبكراً على المنحدرات الخارجية. فحبيبات الجلوكونيت مؤشرات بحرية هامة ، عادة ما توجد بالبيئات الضحلة عند اعماق تتراوح بين 60 و500 م. فهي من خصائص الأجزاء الداخلية للأرفف القارية ، وتمثل هذه الطبقة الغنية بالجلوكونيت ، والتي ترجع إلى المرحلة السينومانية ، قاعدة تتابع يمثل تقدم مياه البحر.

ABSTRACT

The glauconite pellets of the Lidam Formation in north-west Sirt Basin, Libya, have been classified into three types. They are grass-green pellets, light-green pellets and brownish-yellow pellets.

The microprobe analysis of the three types shows that the brownish-yellow pellets are the same as grass-green pellets, but the Fe^{3+}, Fe^{2+} *and K were possibly replaced by* Al_{VI}. *These brownish-yellow grains reflect a history of more oxidizing conditions, either through subaerial exposure or transport in shallow turbulent waters during Upper Cenomanian-Lower Turonian low sea level stands. The light-green pellets represent the transition stage between the other two types. It also shows that the mean values of* K_2O *in the grass-green pellets (glauconite mineral) is 8.7 which reflect localized concentration of* K_2O. *The roundness of glauconite pellets and their replacement by dolomite suggest that they might have been transported early to the outer ramp. The glauconite pellets are a valuable marine indicator. They occur mainly in relatively shallow water, at depths between 60–500 m. They are particularly characteristic of the inner part of the continental shelf. This highly glauconitic bed of Cenomanian age mark the base of a transgressive sequence.*

*Petroeum Research Centre, P.O. Box 6431, Tripoli, G.S.P.L.A.J.

INTRODUCTION

The Lidam Formation in the study area (Fig. 1) is composed of very shallow marine carbonates with thin lenses of sandstones, particularly in the lower part. The lower part of the Lidam Formation shows a local mixing with the sandstone of the Bahi formaton. Very common greenish-grey dolomitic

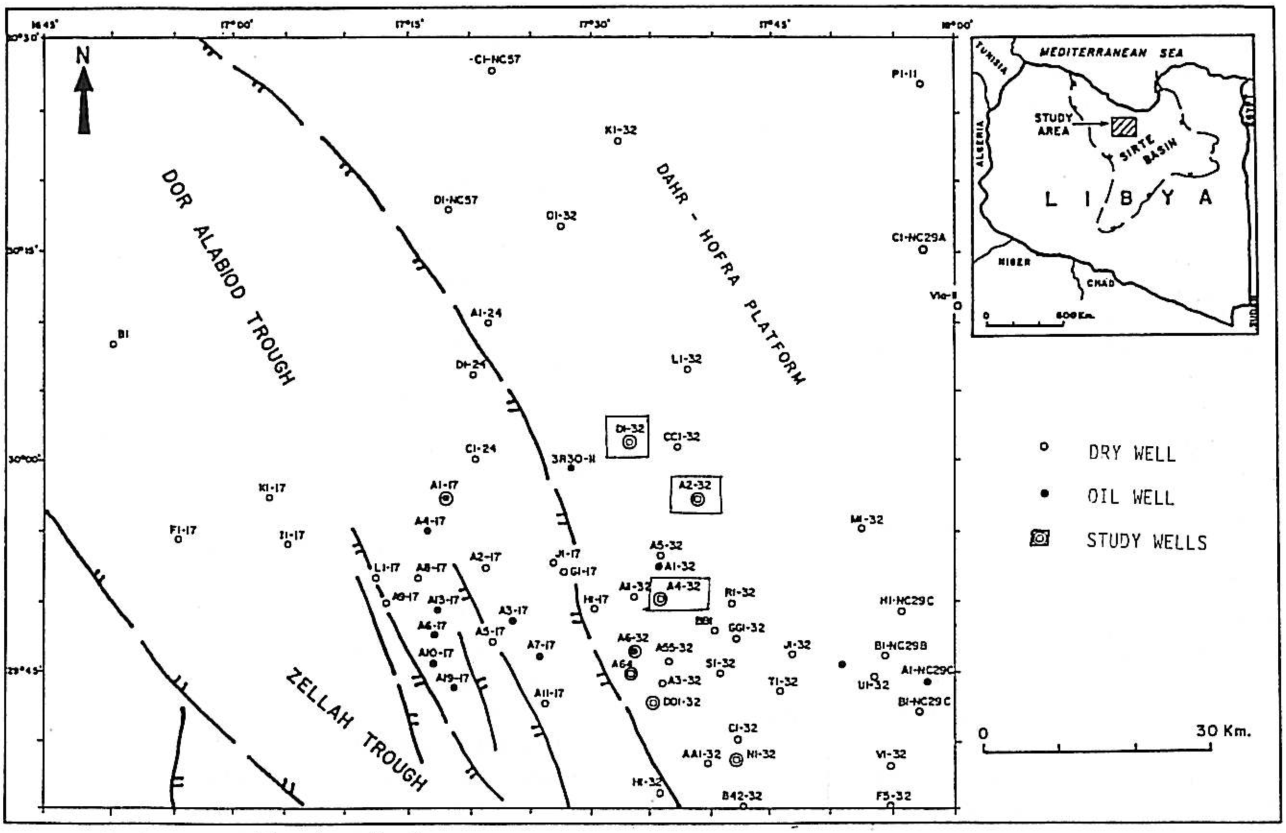

FIG. 1. Study area and location of wells.

glauconite beds were encountered in wells D1-32 and A2-32. Glauconite pellets were found throughout the Lidam sediments, but more commonly in the lower part (El-Bakai, 1989).

The Lidam Formation unconformably overlies various units including the Nubian Formation, the Bahi Formation and igneous-metamorphic basement. It is usually overlain by the Upper Cretaceous Etel Formation with apparent conformity (Barr and Weegar, 1972). The Lidam Formation is considered as Cenomanian in age by Barr and Weegar, (1972, p. 121–122). Hammuda *et al.* (1985), documented this formation as Cenomanian-Turonian in age.

STRATIGRAPHY

The Lidam formation in its type section (Fig. 2), consists mainly of well to moderately cemented calcarenite, calcilutite containing skeletal material and pellets at the upper part. The rock of the Lidam Formation in the lower part is dominante by dark greenish glauconitic dolomite. The thickness of this interval varies between 3 to 6 metres. The size of the glauconite pellets in the lower part of the formation ranges from 0.3 to 20 mm. This zone of glauconite probably represents the base of the Cenomanian transgression in the Sirt Basin.

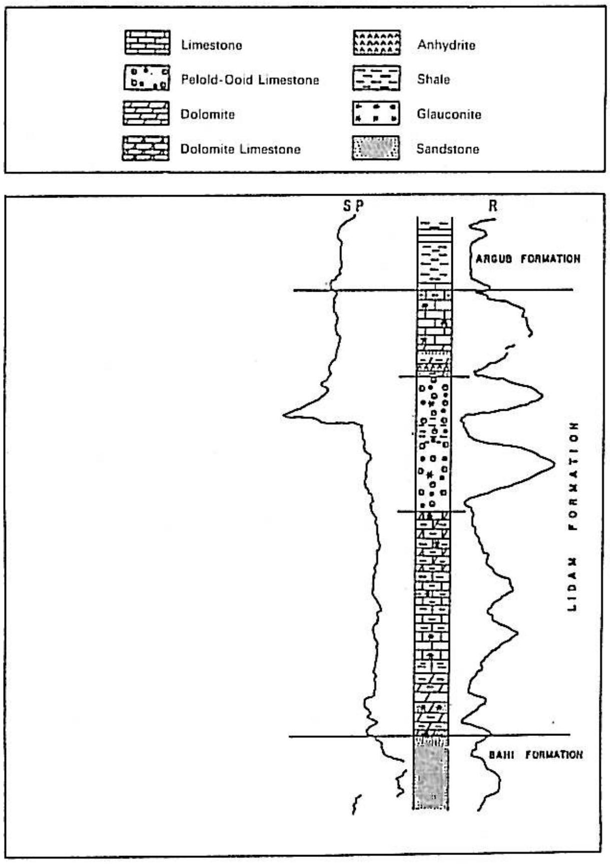

FIG. 2. Type well of the Lidam Formation in the study area (D1-32).

The Lidam Formation is considered Cenomanian in age. It is equivalent in age and, sometimes, in lithology to surface outcrops of the Yefren member and Nalut Formation in Jabal Nefusa North-Western Libya.

METHODS OF STUDY

Polished thin sections were prepared from selected core samples obtained from wells D1-32, A2-32 and A4-32.

The analysis of the glauconite pellets were made at the center and cortices of each pellet.

GENERAL STATEMENT

Glauconite is a mica mineral which occurs almost in marine sediments. It is generally accepted that glauconites are probably formed by marine diagenesis in shallow water during periods of slow or negative sedimentation. Its chemical formula is

$$(K, Na, Ca)_{1.2-2.0}(Fe^{+3}, Al, Fe^{+2}, Mg)_{4.0}$$
$$[Si_{7-7.6}Al_{1-0.4}O_{20}](OH)_4.n(H_2O)$$

The thickness of these intervals is 10 ft (3 m) in well A2-32 at depth 6215–6225 ft (1866–1869 m). It is 23 ft (7 m) thick in well D1-32 at depth 7190–7213 ft (2159–2166 m).

The polished slab cores are dark greenish-grey, highly bioturbated with pure dolomite concretions and assciated with pyrite nodules. No skeletal allochems can be observed in the thin-sections. Only interminate allochem ghosts occur, representing fossils completely replaced by either secondary anhydrite or dolomite crystals. Elsewhere in the Lidam Formaton e.g. the upper part of the formation, some glauconite had replaced shells or had filled micropores with echinoderms, bryozoans or foraminiferas.

The glauconite pellets are moderately well sorted and usually larger than the dolomite crystals and quartz grains. Their size range between 0.3 to 2 mm. The glauconite pellets are mainly well rounded to elliptical with rare irregular and narrow cracks. Their margins are limonite resulting from the oxidation of ferous iron (Adams *et al.*, 1984). They commonly occur in varying abundance throughout the entire sequence of the Lidam sediments in the study area (con. 32), and can be classified according to the colour into three types:

- Grass-green pellets
- Light-green pellets
- Brownish-yelow pellets

The three types are similar to those described by Baily and Atherton (1969).

Some glauconite pellets display brownish cores and pale green margins, while others show dark margins.

ELECTRON MICROPROBE ANALYSIS

Analysis of six polished thin-sections consisting of 30 to 75 glauconite grains using the Electron Microprobe shows significant differences between the three types of glauconite pellets. Microprobe analysis indicated higher content of FeO and K_2O for the grass-green and light grains, and lower content for the brownish grains. P_2O_5 and Al_2O_3 content are higher for the brownish pellets and much lower for the green pellets (Tables 1 and 2).

Iron and potassium: The analysis indicated that FeO content in the light-green pellets varies between 4.10% to 19.07% (mean 16.07%), FeO content in the grass-green pellets between 15.09% and 22.31% (mean 19%, Table 1), while in the brownish pellets FeO varies between 0.46% to 19.39% (mean 14.79%). Iron content was also found to vary significantly between the center and margin of the brownish grains. FeO content varied between 14.09% to 19.39% (mean 16.8%) in the margins of the brownish-yellow grains, whereas the variation is between 0.46% to 9.38% (mean 5.8%) in the core. Microprobe analysis of the grass-green glauconite pellets gave K_2O values from 7.97 to 9.36% (mean 8.7%) reflecting the highly localized concentration of K_2O.

The values of K_2O within the light-green glauconite grains range between 2.51% and 19.19% (mean 8.28%). The values within the brownish grains are from 0.2% to 9.1% (mean 8.15%). There are slight differences between the cores and margins of the light-green grains (mean value of cores is 7.68%, while it is slightly higher in the margins 8.98%). There are significant differences in K_2O values between the cortices and centers of the brownish grains; the mean value in cortices is 10.05% but in the center the mean value is much lower 6.15%.

Fig. 3 shows the relation between K_2O and FeO in the three glauconite pellets. The three glauconite grains show a direct correlation between FeO and K_2O. K_2O in light-green grains increases from about 7% at an FeO content of 12% to about 9.2% at an FeO content of 19%. It seems that potassium started to enter the glauconite during the second stage of formation after the grains have achieved and FeO content between 12–19% (Bornhold and Giresse, 1985). The same relationship was observed between K_2O and FeO in the grass-green and brownish-yellow glauconite grains (i.e. K_2O increases with increasing FeO content, see Fig. 3).

Table 1. Microprobe Analysis for Glauconite

SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	SO_3	P_2O_5	Total	Spot	Notes
52.95	0.00	10.75	15.81	0.00	4.43	0.19	0.00	8.37	0.00	0.00	92.49	1	GGC
53.00	0.00	10.26	16.02	0.00	4.89	0.18	0.40	8.05	0.00	0.00	92.80	2	GGM
52.81	0.00	12.30	15.23	0.00	3.75	0.48	0.00	8.18	0.00	0.00	92.75	3	GBM
52.90	0.00	14.95	11.55	0.00	3.77	0.28	0.00	7.49	0.00	0.00	90.94	4	GBC
51.58	0.00	14.92	10.75	0.00	3.63	0.47	0.00	7.42	0.00	0.00	88.76	5	GMB
53.22	0.00	9.75	16.31	0.00	4.60	0.33	0.31	8.05	0.00	0.00	92.57	6	GLC
51.98	0.00	9.63	17.62	0.00	4.38	0.23	0.28	8.43	0.00	0.00	92.57	7	GLM
51.21	0.00	8.83	19.27	0.00	3.89	0.17	0.00	8.73	0.00	0.00	92.10	8	GGC
51.51	0.00	10.05	19.09	0.00	3.92	0.00	0.48	9.00	0.00	0.00	94.05	9	GGM
53.58	0.00	11.03	15.09	0.00	4.32	0.24	0.00	7.97	0.00	0.00	92.23	10	GGC
51.55	0.00	9.80	16.55	0.00	4.18	0.24	0.00	8.02	0.00	0.26	90.60	11	GGM
52.34	0.00	11.37	15.48	0.00	3.75	0.32	0.00	8.25	0.00	0.22	91.73	12	GBC
52.43	0.00	11.99	15.16	0.00	3.73	0.37	0.00	8.25	0.20	0.35	92.48	13	GBM
51.92	0.00	11.39	15.97	0.00	3.92	0.28	0.00	4.46	0.22	0.26	92.42	14	GLC
52.75	0.00	9.97	17.03	0.00	4.20	0.28	0.00	8.88	0.00	0.22	93.33	15	GLM
49.22	0.00	11.96	14.09	0.00	4.20	2.32	0.00	7.62	0.22	1.83	91.46	16	GBM
49.39	0.00	11.49	14.54	0.00	3.85	0.20	0.00	7.74	0.00	0.36	87.57	17	GLM
52.26	0.00	11.80	16.16	0.00	3.63	0.48	0.00	8.43	0.23	0.29	93.28	18	GLM
49.70	0.00	8.16	20.42	0.00	3.46	0.17	0.39	9.26	0.00	0.00	91.56	19	GBC
52.31	0.00	12.53	12.38	0.00	4.25	0.29	0.00	6.933	0.27	0.34	89.30	20	GLC
52.25	0.00	12.52	12.94	0.00	4.45	0.53	0.00	7.36	0.26	0.24	90.55	21	GLM
51.40	0.00	8.70	17.19	0.00	4.31	0.00	0.00	8.21	0.00	0.33	90.14	22	GGC
51.96	0.00	8.67	17.49	0.00	4.17	0.26	0.00	8.33	0.22	0.22	91.32	23	GGM
51.94	0.00	8.75	19.07	0.00	3.58	0.52	0.26	9.19	0.00	0.35	93.66	24	GLC
51.31	0.00	9.97	18.74	0.00	3.29	0.64	0.00	9.05	0.00	0.56	93.56	25	GLM
51.34	0.00	7.96	21.14	0.00	3.24	0.19	0.00	8.98	0.00	0.00	92.85	26	GGC
50.01	0.00	8.07	20.99	0.00	3.09	0.37	0.00	8.89	0.00	0.36	91.78	27	GGM
51.26	0.00	8.50	20.62	0.00	3.38	0.52	0.00	9.30	0.00	0.31	93.89	28	GGM
51.10	0.00	9.94	19.39	0.00	3.24	0.49	0.00	9.10	0.00	0.38	93.64	29	GBM
51.29	0.00	8.85	19.76	0.00	3.41	0.00	0.00	9.21	0.00	0.26	92.78	30	GBC
51.19	0.00	9.33	19.84	0.00	3.46	0.20	0.29	9.36	0.00	0.31	93.98	31	GGM
50.27	0.00	10.57	17.81	0.00	2.95	2.08	0.00	8.21	0.26	1.40	93.55	32	GLC
52.67	0.00	12.89	16.02	0.00	3.11	0.63	0.36	8.53	0.00	0.34	94.55	33	GLM
51.79	0.00	11.40	16.69	0.00	3.41	0.71	0.34	8.89	0.00	0.61	93.84	34	GBM
51.64	0.00	7.89	20.78	0.00	3.39	0.19	0.00	9.01	0.00	0.36	93.26	35	GGC
48.70	0.00	10.63	17.76	0.00	3.64	1.71	0.00	8.56	0.00	0.38	91.38	36	GGM
50.18	0.00	7.85	21.19	0.00	3.16	0.44	0.00	8.80	0.00	0.62	92.24	37	GGM
50.11	0.00	9.80	19.14	0.00	3.00	0.99	0.00	8.61	0.00	0.80	92.45	38	GGM
49.00	0.00	9.84	18.64	0.00	2.88	2.44	0.00	8.72	0.21	1.96	93.69	39	GBM
48.91	0.00	10.69	19.47	0.00	2.24	0.19	0.34	8.59	0.00	0.33	90.76	40	GGC
49.72	0.00	8.40	22.31	0.00	2.79	0.50	0.34	8.82	0.22	0.37	93.47	41	GGM

Aluminum: Microprobe analysis of the glauconite grains yielded a mean value of 8.9% Al_2O_3 in grass-green pellets, with about 1% increase in the margins. The light-green pellets gave a mean value of 9.73% Al_2O_3 at the margins and 2.03% in the core. The mean value of Al_2O_3 content in the brownish grains is 12.35%, with about 3.1% differences between the inner core (mean 9.25%) and the exterior cortex (mean 13.91%).

The inverse relationship between FeO and Al_2O_3 (Fig. 4) is apparent for both light and grass-green pellets, but unclear for the brownish-yellow grains.

Silicon: There are little differences in SiO_2 content in the three types of glauconite grains. The mean value is 51.06% SiO_2 in the grass-green pellets. It is 52% and 51.77% in the light-green and brownish-yellow glauconite pellets respectively.

Magnesium: The miroprobe analysis showed slight difference of MgO content in the three types of glauconite pellets. The mean values in the grass-green, the brownish-yellow grains and the light-green pellets are 3.62%, 3.68% and 3.93% respectively.

DISCUSSION AND CONCLUSION

From the microprobe analysis (Tables 1 and 2), the following observations are made;

- The Al content is higher in the brownish-yellow grains than in the grass-green and is intermediate in the light-green pellets.
- The K content is slightly higher in the grass-green pellets than in the brownish-yellow pellets.

Table 2. Formula on Basis of Si + Al + Ti + Fe + Mn + Ca = 12, O = 22

Si	Al_{IV}	Al_{VI}	Fe_3	Fe_2	Mn	Mg	Ca	Na	K	S	P	Spot	Notes
7.44	0.56	1.22	1.79	0.07	0.00	0.93	0.03	0.00	1.50	0.00	0.00	1	GGC
7.41	0.59	1.11	1.87	0.00	0.00	1.02	0.03	0.11	1.44	0.00	0.00	2	GGM
7.40	0.60	1.43	1.56	0.22	0.00	0.78	0.07	0.00	1.46	0.00	0.00	3	GBM
7.40	0.60	1.86	1.32	0.03	0.00	0.79	0.04	0.00	1.36	0.00	0.00	4	GBC
7.41	0.59	1.93	1.16	0.13	0.00	0.78	0.07	0.00	1.36	0.00	0.00	5	GBM
7.50	0.51	1.11	1.76	0.16	0.00	0.97	0.05	0.09	1.45	0.00	0.00	6	GLC
7.37	0.63	0.98	1.97	0.12	0.00	0.93	0.04	0.08	1.53	0.00	0.00	7	GLM
7.36	0.64	0.85	2.14	0.18	0.00	0.83	0.03	0.00	1.6	0.00	0.00	8	GGC
7.26	0.74	0.93	2.07	0.18	0.00	0.82	0.00	0.13	1.62	0.00	0.00	9	GGC
7.51	0.50	1.33	1.67	0.10	0.00	0.90	0.04	0.00	1.43	0.00	0.00	10	GGC
7.44	0.56	1.10	1.75	0.25	0.00	0.90	0.04	0.00	1.48	0.00	0.03	11	GGM
7.45	0.55	1.36	1.46	0.39	0.00	0.80	0.05	0.00	1.50	0.00	0.03	12	GBC
7.42	0.59	1.42	1.22	0.57	0.00	0.79	0.06	0.00	1.49	0.02	0.04	13	GBM
7.37	0.63	1.28	1.44	0.45	0.00	0.83	0.04	0.00	1.53	0.02	0.03	14	GLC
7.45	0.55	1.11	1.63	0.38	0.00	0.88	0.04	0.00	1.60	0.00	0.03	15	GLM
7.26	0.74	1.34	0.00	1.74	0.00	0.92	0.37	0.00	1.43	0.02	0.23	16	GBM
7.33	0.67	1.34	1.57	0.24	0.00	0.85	0.03	0.00	1.47	0.00	0.05	17	GLM
7.37	0.63	1.33	1.32	0.59	0.00	0.76	0.07	0.00	1.52	0.02	0.04	18	GLM
7.31	0.69	0.73	2.06	0.46	0.00	0.76	0.03	0.11	1.74	0.00	0.00	19	GGC
7.50	0.51	1.61	1.16	0.32	0.00	0.91	0.05	0.00	1.27	0.03	0.04	20	GLC
7.42	0.58	1.52	1.25	0.29	0.00	0.94	0.08	0.00	1.33	0.03	0.03	21	GLM
7.48	0.52	0.97	1.82	0.27	0.00	0.94	0.00	0.00	1.52	0.00	0.04	22	GGC
7.51	0.49	0.99	1.61	0.51	0.00	0.90	0.04	0.00	1.54	0.02	0.03	23	GGM
7.46	0.54	0.94	1.47	0.82	0.00	0.77	0.08	0.07	1.68	0.00	0.04	24	GLC
7.36	0.64	1.05	1.40	0.85	0.00	0.70	0.10	0.00	1.66	0.00	0.07	25	GLM
7.40	0.60	0.76	2.13	0.42	0.00	0.70	0.03	0.00	1.65	0.00	0.00	26	GGC
7.35	0.65	0.74	1.90	0.68	0.00	0.68	0.06	0.00	1.67	0.00	0.05	27	GGM
7.36	0.64	0.80	1.79	0.69	0.00	0.72	0.08	0.00	1.70	0.00	0.04	28	GGM
7.31	0.69	0.99	1.66	0.66	0.00	0.69	0.08	0.00	1.66	0.00	0.05	29	GBM
7.39	0.61	0.89	1.88	0.51	0.00	0.73	0.00	0.00	1.69	0.00	0.03	30	GGC
7.32	0.68	0.89	1.76	0.62	0.00	0.74	0.03	0.08	1.71	0.00	0.04	31	GGM
7.36	0.65	1.18	0.25	1.93	0.00	0.64	0.33	0.00	1.53	0.03	0.17	32	GLC
7.36	0.64	1.48	1.15	0.72	0.00	0.65	0.09	0.09	1.52	0.00	0.04	33	GLM
7.38	0.63	1.29	1.04	0.95	0.00	0.72	0.11	0.09	1.62	0.00	0.07	34	GBM
7.43	0.57	0.77	1.86	0.64	0.00	0.73	0.03	0.00	1.65	0.00	0.04	35	GGC
7.17	0.83	1.02	1.43	0.76	0.00	0.80	0.27	0.00	1.61	0.00	0.05	36	GGM
7.36	0.64	0.71	1.76	0.83	0.00	0.69	0.07	0.00	1.65	0.00	0.08	37	GGM
7.32	0.68	1.01	1.26	1.08	0.00	0.65	0.16	0.00	1.61	0.00	0.10	38	GGM
7.31	0.69	1.04	0.00	2.32	0.00	0.64	0.39	0.00	1.66	0.02	0.25	39	GBM
7.23	0.77	1.10	1.68	0.73	0.00	0.49	0.03	0.10	1.62	0.00	0.04	40	GGC
7.24	0.76	0.68	1.82	0.89	0.00	0.61	0.08	0.10	1.64	0.02	0.05	41	GGM

Fe_3 value is much higher in the grass-green than in both light-green and brownish-yellow pellets.

The Electron Microprobe analysis leads to the conclusion that the brownish-yellow pellets were grass-green pellets (glauconite mineral), but the $Fe3^{+}$ were possibly replaced by Al_{VI} (aluminum octahedral). The Fe^{2+} and K were also replaced by Al_{VI}. As a result the grass-green pellets were changed to brownish-yellow pellets. These commonly brownish glauctonite grains, reflect a history of more oxidizing conditions, either through subaerial exposure or transport in shallow turbulent waters during Upper Cenomanian-Lower Turonian low sea-level stands (Giresse and Odi, 1973). The light-green grains were the transition stage between the grass-green and brownish yellow pellets (i.e. brownish yellow and light-green glauconite pellets were formerly all grass-green pellets). The roundness and size of the glauconite pellets found in the outer ramp are incompatible with their setting and strongly suggest that they were transported, and their replacement by late dolomitization (Fig. 5 and 6) suggest that they were transported early.

The glauconite is a valuable marine indicator and it occurs most commonly in relatively shallow water between 60 and 500 m, forming up to 90% of the sediment of the formation. The abundance of glauconite pellets in the base of the Lidam Formation and in the top of the Bahi Formation (both shallow marine deposits), is probably related to the availability of iron from the alteration of the abundant micaceous minerals. These glauconite grains are likely true faecal pellets produced in a large quantity by filter-feeding organisms, and are,

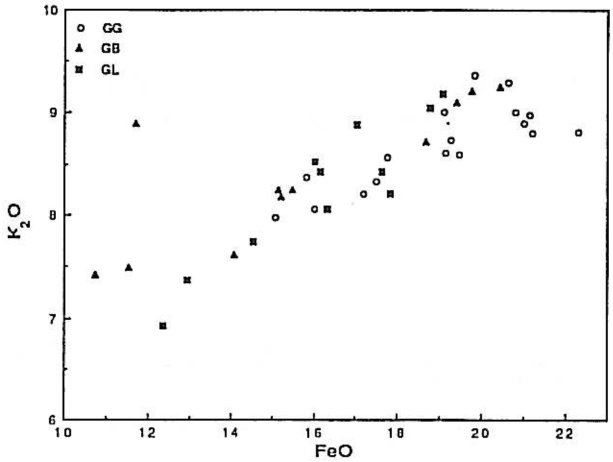

FIG. 3. Relationship between K_2O and FeO for grass-green grains (GG), brownish yellow grains (GB) and light-green grains (GL).

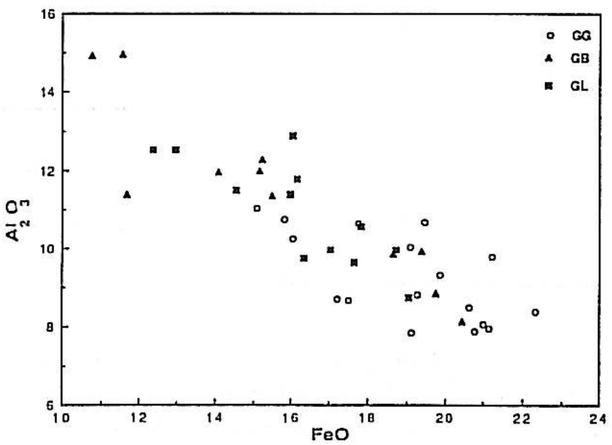

FIG. 4. Relationship between Al_2O_3 and FeO for the same grains in (Fig. 3).

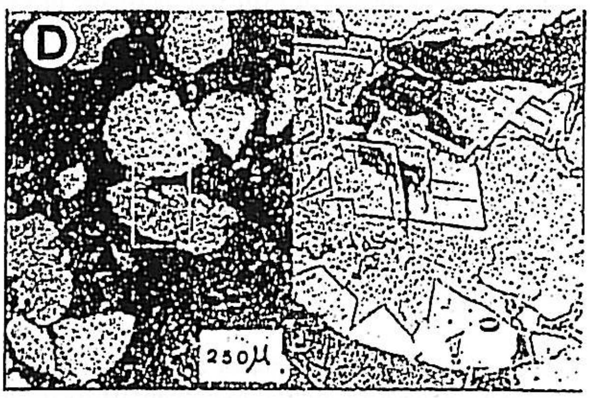

FIG. 5. Microphotograph (SEM) showing the replacement of glauconite pellets by late dolomite.

therefore, essential characteristic of the inner part of the continental shelf (Pryor, 1975). The glauconite within fossils suggests that it developed early and may have been associated with the dissolution of aragonite (Pedley and Bennet, 1985).

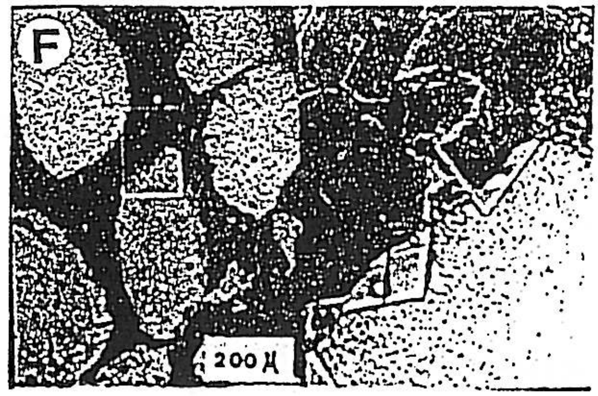

FIG. 6. Microphotograph (SEM) showing the beginning of replacement of glauconite pellets by dolomite.

ACKNOWLEDGEMENT

I would like to express my thanks to the management of the Petroleum Reseach Centre. Special thanks to Mr. M. Idris, the Secretary of People's Committee of the PRC for permission to publish this work. I am grateful to Mr. F. Wilkinson from the Geology Department, Hull University, for his help with microprobe uses. I would like to extend my thanks to my friends and collegues in the PRC. My thanks are also due to Waha Oil Company of Libya, in particular Mr. R. Abu Rawi, the Exploration Manager and the technical staff for providing the core samples used in this study.

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