J. Univ. Kuwait (Sci.) **19**, 1992

Indirect evidence of a diastem within the Eocene Dammam Formation in Kuwait

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ABSTRACT

The Middle Eocene Dammam Formation is underlain by evaporites of the Rus Formation and overlain uncomformably by sands of the Miocene Ghar Formation. The Formation is subdivided into three members. The lowest member is a nummulitic limestone with shale interlayers, whereas vuggy and cherty fossiliferous limestone and laminar, silty dolomite with lignitic interlayers constitute the partly silicified middle member. The uppermost member is a white, porous, granular or powdery dolomite containing chert interlayers and fossiliferous zones. It is capped by a silicified and karstified zone below the unconformity with the Ghar Formation. The Dammam is traditionally believed to form a continuous deposit of Middle Eocene age, bounded by an unconformity at the top. However, our study shows that another diastem exists within it because the boundary between the middle and upper members is karstified, silicified and was subjected to late-stage dolomitization. This indirect evidence suggests a brief period of non-deposition during Eocene time.

INTRODUCTION

The Dammam Formation is a 200–300 m thick dolomitized limestone of Middle Eocene age. It is underlain by Middle Eocene evaporites of the Rus Formation and overlain uncomformably by the Miocene-Pliocene clastic sediments of the Kuwait Group. The type locality of the Formation is the Dammam area in S. Arabia, where it displays an upward sequence of shales, fossiliferous limestones and dolomites. The stratigraphy of the Dammam Formation has been studied by various authors (O'Brien 1952; Owen & Nasr 1958; Steineke *et al.* 1958; Saker 1970; Al-Sayed *et al.* 1981; Lababidi & Hamdan 1985). Although the stratigraphic subdivisions of the Formation differ slightly between the different authors, there is general agreement that it is a continuous sequence bounded by an unconformity at the top. However, it is quite likely that there is at least one other diastem within the Dammam. Lack of obvious evidence may have caused most of the early authors to overlook this break, with the exception of Burdon & Al-Sharhan (1968). An unconformity within the Dammam Formation was proposed by these authors on the basis of an earlier unpublished report by the Parson Company, but they did not elaborate on this erosional surface. The objective of our study is to present some indirect evidence of

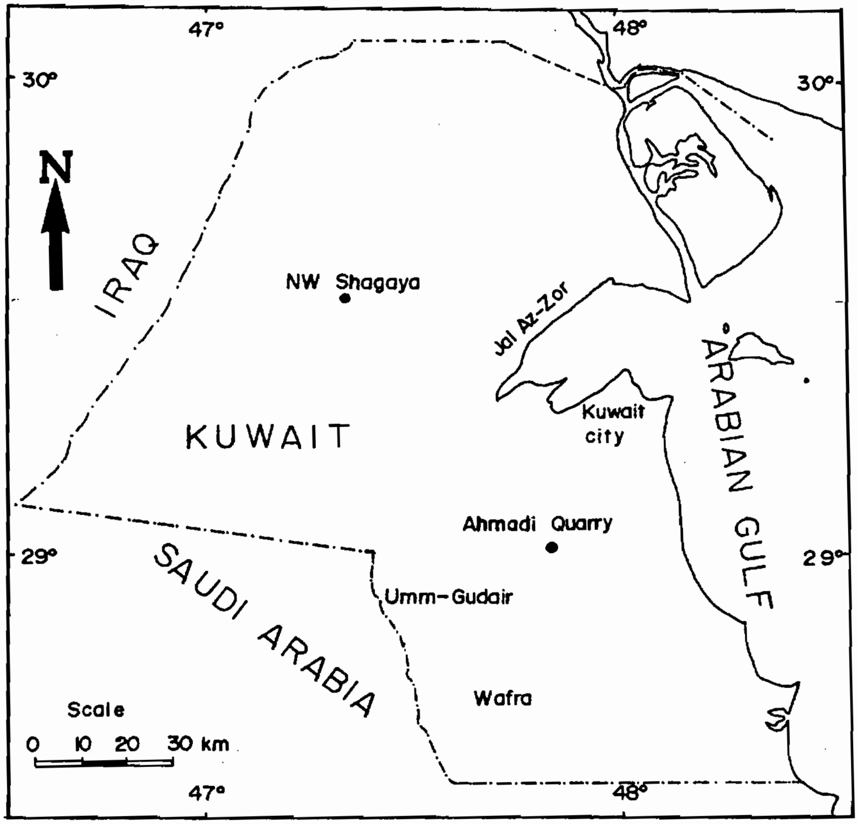

Fig. 1. Location of study areas in Kuwait.

the diastem. The work is based on cores and well-logs from recently drilled water wells from the Umm-Gudair and Wafra areas, southern Kuwait, and one water well from Shagaya area, northwestern Kuwait (Fig. 1).

Several water production wells and a few observation wells were drilled in the Umm-Gudair, Wafra and Shagaya areas by the Ministry of Electricity and Water for groundwater production. The wells were completed in January 1988. The observation wells and a few of the production wells were cored. Gamma ray, SP and resistivity logs were obtained from all wells.

The Dammam Formation does not outcrop in Kuwait, except in Ahmadi quarry, where the upper 15–20 m section is exposed. The unconformable upper boundary of the Dammam with the overlying Ghar Formation of Miocene age are well exposed in this quarry.

STRATIGRAPHY OF THE DAMMAM FORMATION

Cores from wells in Umm-Gudair area are incomplete except for wells nos. 8 and 9. Coring is complete for the NW Shagaya well. The stratigraphic sequence of the Dammam Formation is established on the basis of Umm-Gudair wells nos. 8 and 9, Shagaya well and correlation with several other wells in Umm-Gudair area. Loca-

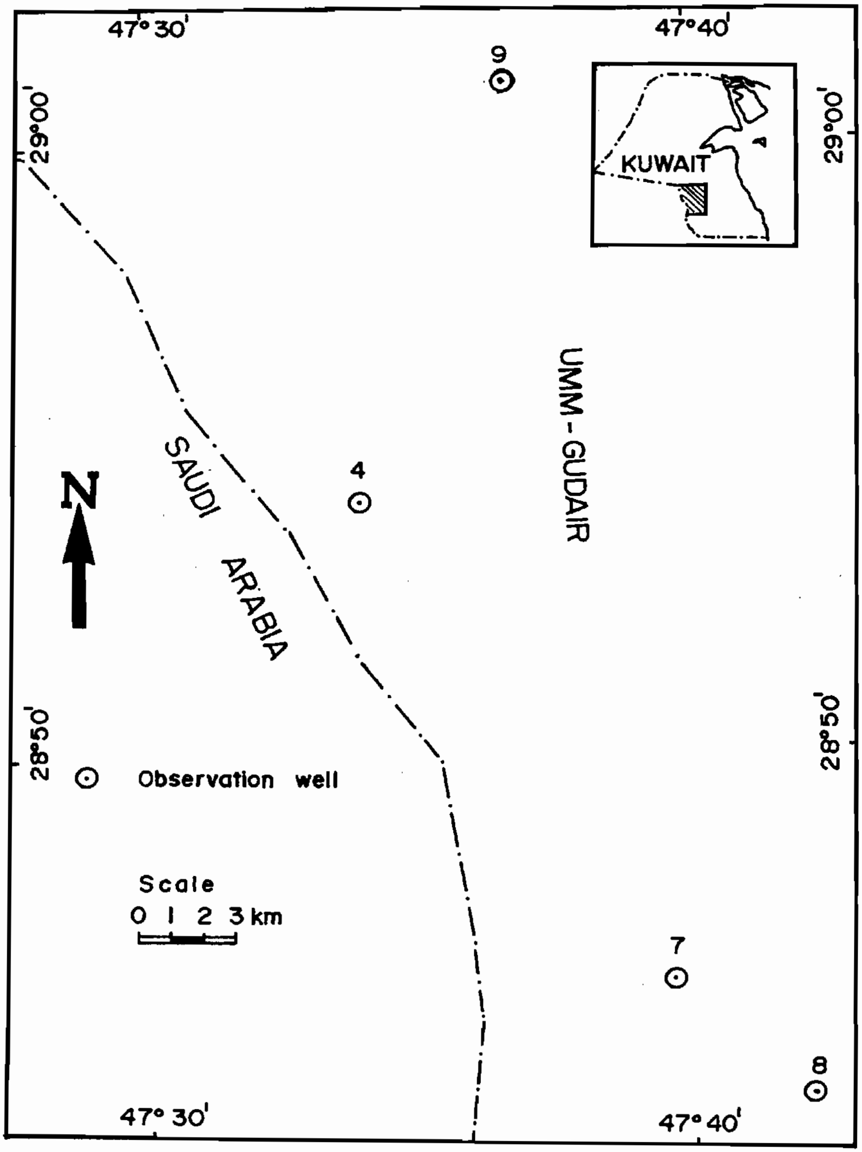

Fig. 2. Location of wells in Umm-Gudair area, Kuwait.

tion of Umm-Gudair wells nos. 4, 7, 8 and 9 is given in Fig. 2, and the detailed stratigraphic sequence of the Dammam Formation in Umm-Gudair and NW Shagaya wells is given in Figs 3–8. A brief description of the Formation is given below.

The Dammam Formation is subdivided into three members. The lowest member is a fossiliferous limestone with shale interlayers at the base and bituminous, banded, algal limestone interlayers towards the top. The middle member consists of dark brown laminar, cherty and dolomitic limestone with lignite interlayers and a vuggy, beige, fossiliferous and dolomitic limestone. The upper member is a friable,

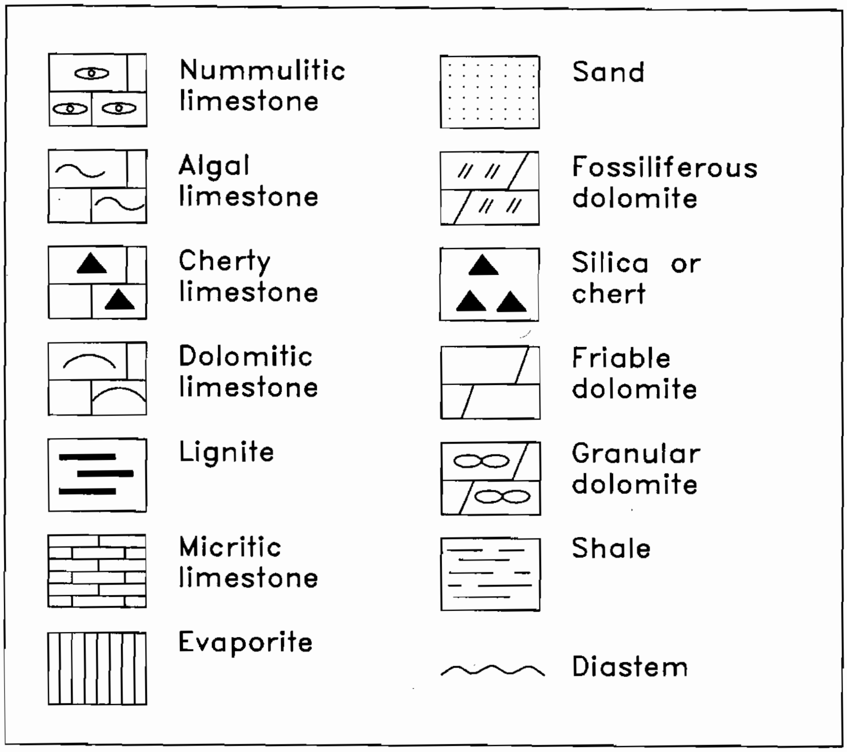

Fig. 3. Explanation of symbols that are used in Figs 4 to 8.

porous dolomite with occasional fossiliferous dolomite and chert intercalations. The diastem which is the subject of this study is between the middle and upper members of the Dammam Formation.

LOWER MEMBER

The lower part of the Formation starts with nummulitic biomicrite (unit-a in Figs 4 to 8) with shale interlayers at the base (unit-b). The limestone is buff coloured, and hard, with little or no dolomitization, calcification or silicification. Fossils include *Nummulites* sp., *Alveolina* sp., *Discocyclina* sp., *Nummulites globulus*, and *Nummulites planulatus*. There are also ostracod, coral and mollusc fragments, and echinoid spines with rare bryozoa and sponge spicules. On the basis of fossils, a Middle Eocene age is assigned to the lower member of the Dammam Formation. The nummulitic limestone grades upward into a thin section of banded, algal limestone with bituminous impregnations (unit-c). The algal limestones are well layered and partially dolomitized. Rhomb-shaped dolomite crystals replace fossils and part of the micritic matrix, and the degree of dolomitization increases towards the top of the member. Cores in Shagaya area show that the lower member is dominantly a vuggy dolomitic limestone with abundant anhydrite interlayers (unit-m, in Fig. 7).

Benthonic foraminifera, algal and coral fragments and macro fossil shells, as well as the micritic matrix, suggest a shallow, low-energy lagoonal to shelf environment

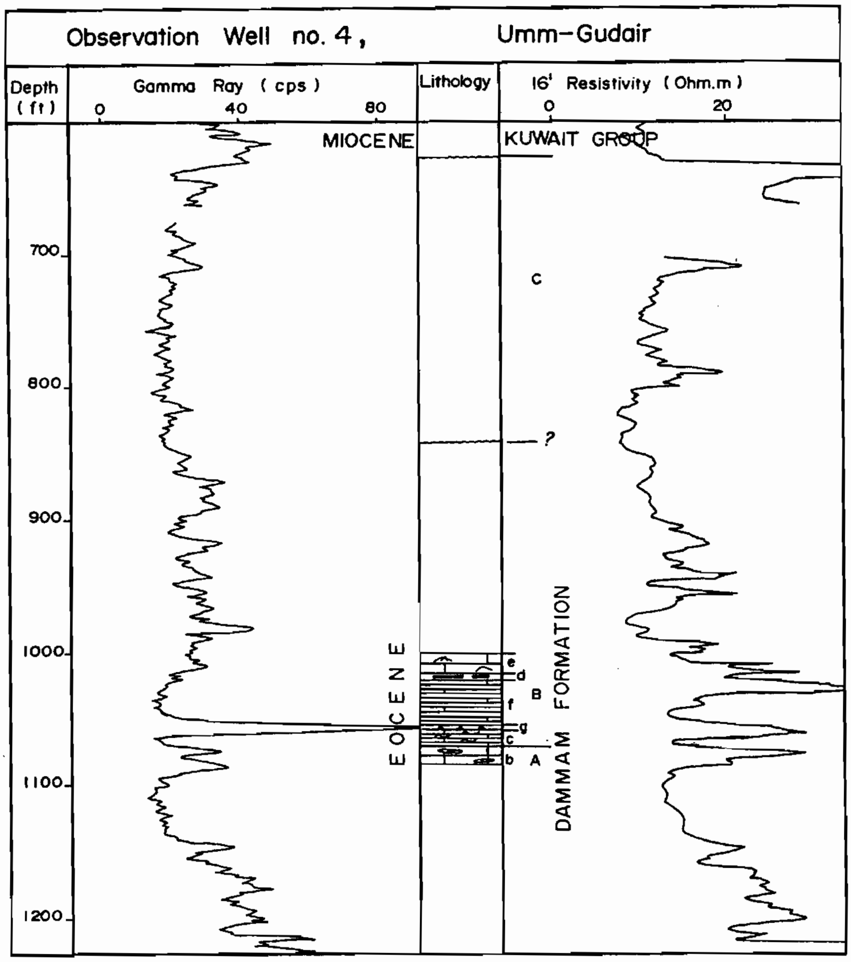

Fig. 4. Stratigraphic sequence of cored section of Umm-Gudair well no. 4, with gamma-ray and resistivity logs.

of deposition. The banded, algal limestones accumulated in a tidal flat environment. There is a gradual shallowing from the lower shales to the algal limestones.

MIDDLE MEMBER

The middle member is composed of intercalations of beige, compact, fossiliferous, dolomitic limestone (unit-e), and highly dolomitized and silicified fossiliferous, laminar-micrites (unit-f) with occasional silty and lignitic zones (unit-d) and dark chert nodules. Fossils include *Nummulites* sp., *Chapmainà* sp., *Orbitolites* sp., algae and corals. The thickness and frequency of lignitic layers increase towards the top of the member.

The middle member undergoes conspicuous lateral facies variation from south to north. Cores from water wells in Wafra area, south of Umm-Gudair, reveal that the topmost lignite layer is about 10–15 m thick. The middle member consists

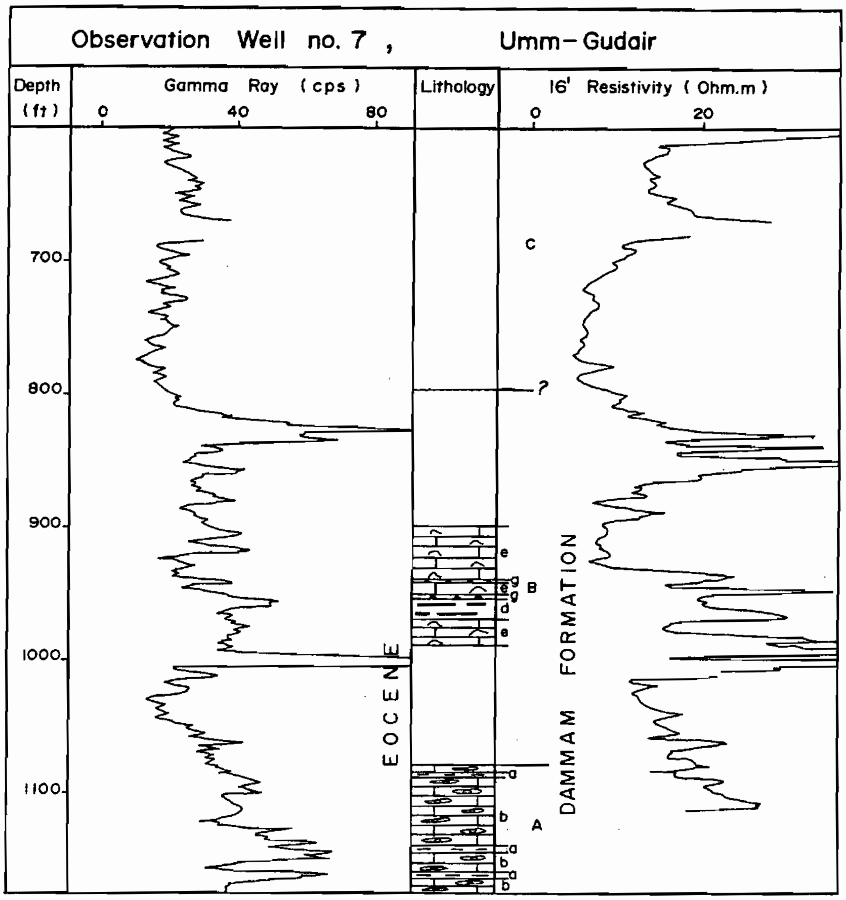

Fig. 5. Stratigraphic sequence of cored section of Umm-Gudair well no. 7, with gamma-ray and resistivity logs.

mainly of silty limestones with interlayers of lignitic siltstones and shales. The lignite layers are absent in the NW Shagaya well to the north. There are only thin organic-rich streaks within the uppermost part of the member. There is also an anhydrite interlayer (unit m). The middle member is essentially a regressive sequence from a tidal-flat/lagoon to swamp-salt marsh environment.

The middle member has undergone partial dolomitization. In some samples, the fossils are replaced but not the matrix. In some other samples, the micritic matrix is partially replaced by rhomb-shaped crystals of dolomite. Dolomitization seems to penetrate along zones of weakness and although it is not possible to ascertain definitely the nature of dolomitization, it is a secondary, late diagenetic feature. Dolomitization may be of mixed-water origin (Hanshaw *et al.* 1982). The dolomites of the lignitic zones are mostly calcitized.

Partially or totally silicified zones (unit-g) frequently underlie the lignitic layers directly, suggesting a close association. In most places, silica fills cracks and replaces walls of cracks. Gradual decrease in silification away from cracks suggests that silici-

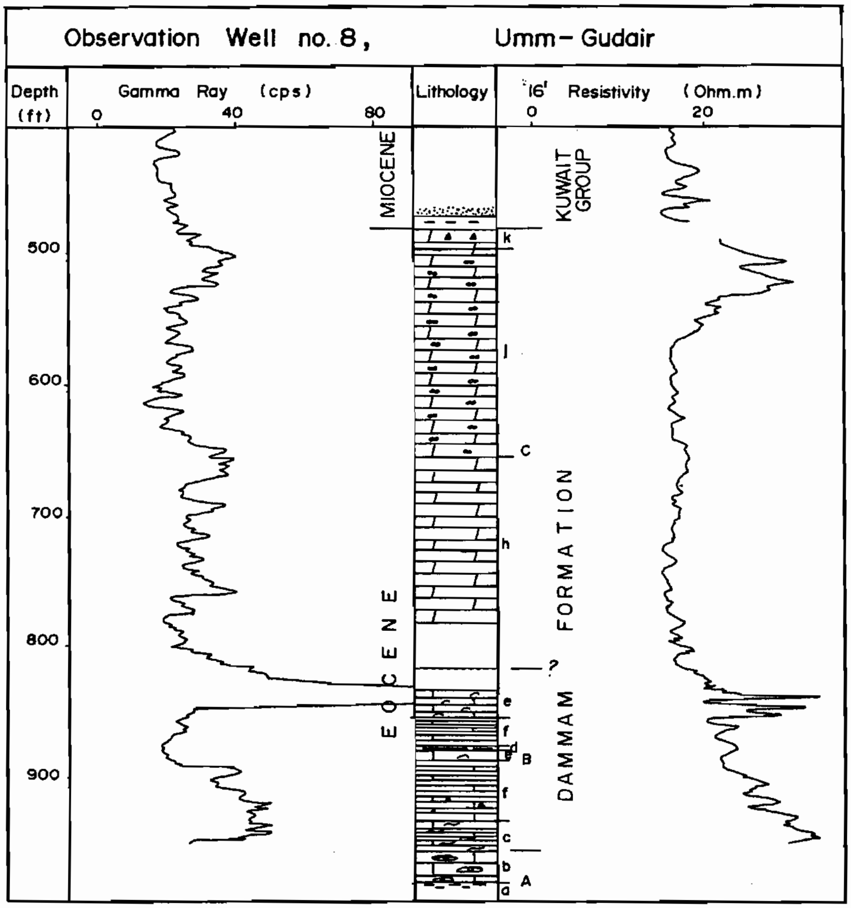

Fig. 6. Stratigraphic sequence of cored section of Umm-Gudair well no. 8, with gamma-ray and resistivity logs.

fication took place as a result of downward percolating acidic waters (Larsen & Chilingar 1979; Zenger & Dunham 1980; Dunham & Olson 1980). Thin section studies suggest that dolomitization preceeded silicification.

UPPER MEMBER

The middle member is overlain by friable, porous dolomites of the upper member. Litho- and biofacies of the upper member of the Formation are distinctly different from those of the lower part. Although it is hard to establish a definite stratigraphic sequence, the member starts with a cream buff-colored, porous, powdery, chalky-looking, fine-grained friable dolomite (unit-h). Further up, the member grades into a very porous, coarse granular dolomite (unit-j) with fossiliferous dolomitic limestone interlayers (unit-i). There is no silicification at the bottom of the unit, but towards the top, secondary chert nodules, lenses and layers begin to appear in the section.

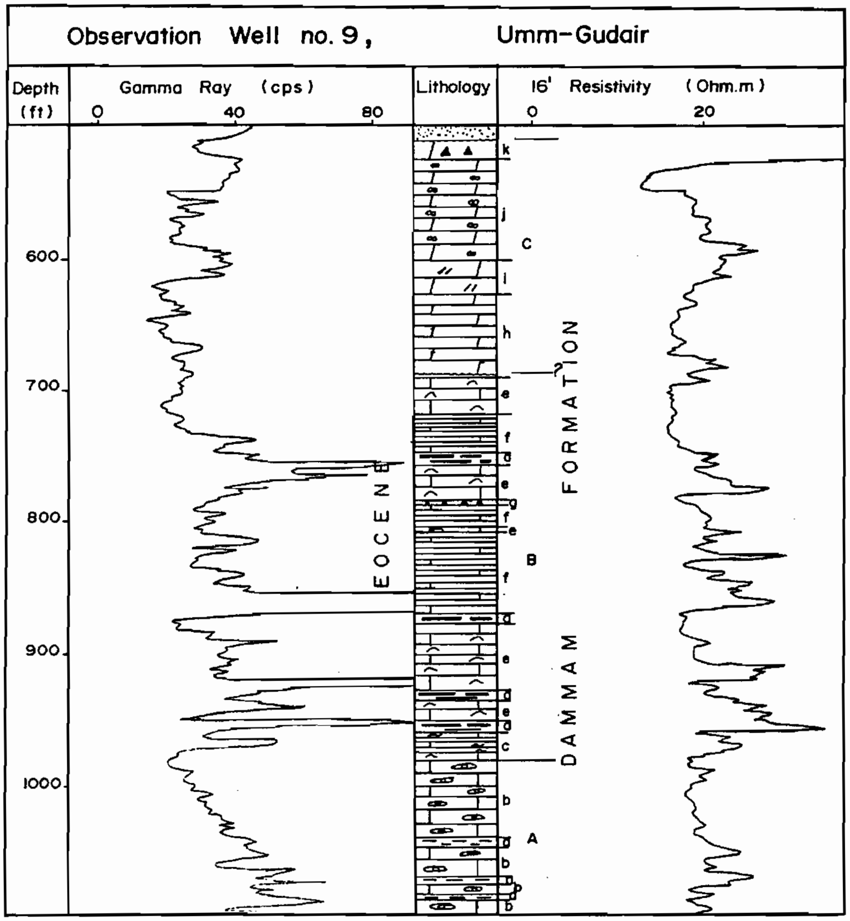

Fig. 7. Stratigraphic sequence of cored section of Umm-Gudair well no. 9, with gamma-ray and resistivity logs.

Chert layers are confined to thinly bedded, dense dolomitic biomicrite zones within the massive, porous-granular dolomites. There is also a porcellaneous, dense dolomite which seems to replace earlier dolomites. The dense dolomite occurs as nodules near the top of the formation and increases in abundance towards the unconformity.

In the uppermost part, just below the unconformity, the member is characterized by a chaotic and fragmented zone (unit-k). Collapse chert breccia was formed as a result of karstification, and by dissolution of dolomites below the unconformity, and the dolomites are partially calcitized. Loose sands of the overlying Ghar Formation (unit l), which filled solution fractures and cavities in the underlying dolomite during deposition, were mixed with chert breccia during collapse of cavities and sinkholes.

Foraminifera which occur within the fossiliferous horizons of the dolomite include the following: *Praerhapydionina huberi* Henson, *Dendritina* cf. *dusenburgi* Henson, *Praerhapydionina* cf. *delicata* Henson, *Dendritina* cf. *glynnjonesi*, *Cyclogyra* sp., *Spirolina* cf. *cylindracea* Lamarck, *Spirolina* sp., *Coskinolina?* sp., *Discorinopsis?*

sp. and miliolidae. There are also various macrofossils including gastropods, echinoids, and brachipods. On the basis of the fossils a possible Middle-Upper Eocene age is assigned to the member.

The dolomites of the upper member of the Dammam Formation probably accumulated in a very shallow lagoonal to tidal-flat environment of deposition. The member accumulated as biomicrite or pelmicrite in a lagoon and was dolomitized immediately after deposition, probably by seepage reflux dolomitization or evaporative pumping during the final regressive stages (Adams & Rhodes 1982; Hsu & Siegenthaler 1982). Some vugs may have been originally filled with evaporitic minerals which were dissolved away subsequently. Presence of gypsum within the dolomites of Ahmadi quarry confirms the point that evaporites may have accumulated along with dolomites. Complete dolomitization, volume by volume replacement, euhedral dolomite crystals, and solution vugs support such a model. The fine-grained, dense dolomites devoid of fossils may have accumulated as primary dolomites in tidal-flat environments. There are also some spheroidal dolomites that fill the cavities in the host dolomite. These spheroidal dolomites belong to a second generation of dolomitization, and are probably post-karstic (Gunatilaka *et al.* 1987).

Silicification of the top of the upper member is probably related to percolation of acidic groundwater during the nondepositional stage in Oligocene time (Larsen & Chilingar 1979). The increasing degree of silicification and chert towards the unconformable upper boundary, abundance of chert lenses along well-bedded zones, penetration of silica from fractures into the host rock, all support the idea that silicification was caused by acidic waters percolating down through fractures.

Silicification of the upper member is not regional. Extensive silicification and karstification can be observed below the unconformity at the Ahmadi rock quarry. Chert, and chert breccia are confined to only a narrow uppermost strip of the member below the unconformity in Umm-Gudair area. There is no silicification in cores of the member from Shagaya area, only a thin strip with chert fragments along the upper boundary. The dolomites gradually become argillaceous and sandy towards the top and are overlain by the argillaceous sands of the Ghar Formation.

Ahmadi rock quarry is located along the Burgan structural high, which has existed as an uplift since Middle Mesozoic and was rejuvenated several times. The Burgan uplift also forms an inconspicuous physiographic high, whereas the Umm-Gudair area lies on the western flanks of this regional uplift. Shagaya is situated close to the northwestern trough. Anticlinal areas must have remained above water and subject to erosion for a longer time than the synclinal trough, and the close relationship between structural features and degree of karstification and silicification suggests that silicification must be related to the unconformity.

WELL-LOG PATTERNS OF THE DAMMAM FORMATION

Gamma-ray and resistivity patterns of the Dammam Formation and overlying Kuwait group are explained below. GR and resistivity logs of Umm-Gudair wells nos 4, 7, 8 and 9 (Fig. 2), and the NW Shagaya well are presented in Figs 4–8, and log correlation diagram is given in Fig. 9. Boreholes are left hanging within the Dammam Formation. The boundary between the Dammam Formation and underlying Rus evaporites could not be shown on the correlation diagram. The logs are

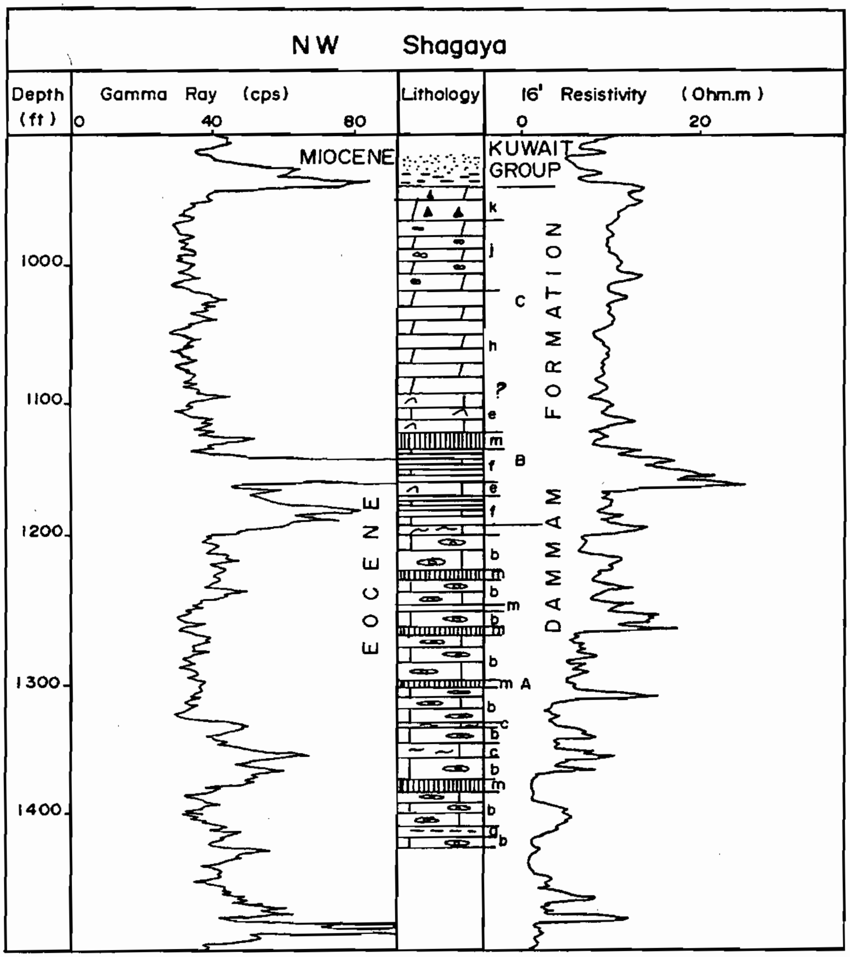

Fig. 8. Stratigraphic sequence of cored section of NW Shagaya wells, with gamma-ray and resistivity logs.

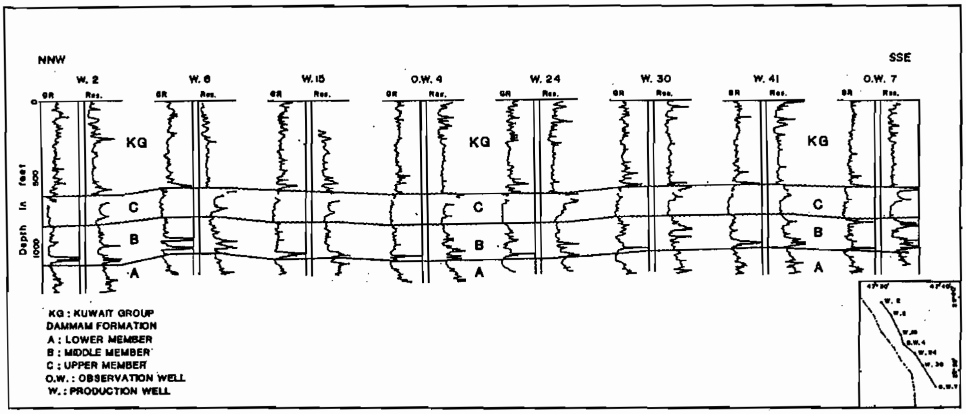

Fig. 9. Log-correlation diagram of Umm-Gudair water wells.

included because coring is discontinuous in the wells. Besides, logs reveal characteristic sequences of the Dammam Formation and additional clues as to the diastem. Gamma-ray logs indicate shales and shaly zones, as well as limestones and dolomites that are rich in uranium associated with organic matter. Resistivity logs may distinguish porous and non-porous zones. The Formation water is brackish. High resistivity indicates tight, non-porous zones. Variation of porosity in turn is related to variation in the degree of silicification. The log characteristics of the Dammam Formation are summarized as follows.

LOWER MEMBER

The GR log starts within the lower member with a high, and irregularly fluctuating pattern in the lowermost part of the member, where shales and nummulitic limestones are interlayered. The GR readings decrease upward with decreasing shale content and then start to rise and fluctuate upward across bituminous algal limestone interlayers at the top of the member. Resistivity values are low at the top, indicating high porosity. Irregular fluctuations reflect the shale-carbonate interlayering towards the bottom.

MIDDLE MEMBER

This member is characterised by irregular fluctuations of the gamma ray, with some anomalous kicks which correspond to interlayers of organic-rich zones within the carbonates. The lowermost bitumen-impregnated layer, as well as the middle and uppermost silty layers, register high anomalous gamma-ray values. Resistivity values gradually increase towards the uppermost lignitic layer. Resistivity fluctuations are probably due to fracturing and solution cavities within tight zones. The increasing resistivity values are probably due to gradual increase in silicification towards the top of the Middle member.

UPPER MEMBER

GR and resistivity patterns also show two distinct zones with gradational boundary within the Upper member of the Dammam Formation. The lower part of the member is characterized by uniform low gamma-ray and resistivity readings at the bottom, which correspond to a clean, porous carbonate facies. There are occasional discontinuous resistivity kicks within this zone which probably correspond to chert interlayers within the porous dolomites.

The fragmented cherty zone of the Dammam Formation right below the unconformity is revealed by erratically high and fluctuating resistivity values. The resistivity values gradually increase and start to fluctuate upward towards the unconformity. The increasing resistivity is due to decreasing porosity caused by silicification. Resistivity fluctuations are due to fracture widening and karstic features. The resistivity readings show a sharp decline above the unconformity, reflecting the porous loose sands of the Ghar Formation.

INDIRECT EVIDENCE OF A DIASTEM BETWEEN LOWER AND UPPER MEMBERS OF THE DAMMAM FORMATION

Our brief explanation of the stratigraphic sequence and corresponding GR-resistivity pattern of the Dammam and overlying Kuwait Group reveal a few significant clues as to the presence of a diastem between the lower and upper members of the Dammam Formation, directly above the lignitic shale layer. These clues are summarized collectively below.

A. *Evidence related to depositional history of the Dammam Formation*

The lignitic layers within the upper part of the middle member indicate a swamp or salt-marsh environment. The lower member of the Dammam Formation is a carbonate deposit of shallow marine environment. Gradual passage from nummulitic limestones to lignitic layers suggests a regression towards the end of Middle Eocene. The regression was followed by another transgression, possibly in Middle-Upper Eocene which resulted in deposition of biomicrites and pelmicrites of the third member in lagoonal to tidal-flat environments.

The lithofacies of the lower members bears no similarity to the upper member. The lower member is a dense, hard, bedded or laminar biomicrite which is only partially dolomitized. The upper member is a friable, very porous dolomite with secondary chert interlayers. Biofacies of the two members are also distinct. The lower member is characterized by benthonic foraminifera, whereas the upper member has abundant macro fossils.

B. *Evidence related to diagenetic history of the Dammam Formation*

SILICIFICATION

The unconformity between Dammam and Ghar Formations is characterized by a silicified and karstic zone at the uppermost part of the Dammam Formation. Degree of silicification decreases downward, and is probably related to percolation of acidic groundwater during periods of exposures.

Similarly, there is silicification towards the top of the middle member, below the lignitic layers. Silicification is confined to upper parts of the member. The nummulitic limestones below the bituminous algal limestone are not silicified at all. The presence of lignitic layers and gradual increase of silicification towards such layers and towards the top of the middle member reveal that silicification may have been due to percolating acidic waters.

There is a distinct gap between the silicified zone of the middle member and the silicified topmost zone of the upper member, and the sediments immediately above the middle member are not at all silicified. Silicification of the middle member must have taken place at an earlier time, probably prior to deposition of the upper member.

DOLOMITIZATION

A similar argument can be put forward in regard to dolomitization. The lower part of the Dammam Formation has undergone partial dolomitization. The upper member has at least two stages of dolomitization, an early stage of complete dolomitization followed by a second stage of partial dolomitization. The second stage produced porcellaneous dolomites and was followed by calcitization. There is at least one more stage of post-karstic dolomitization when the spheroidal primary dolomites formed in cavities of the host dolomite (Gunatilaka *et al.* 1987).

The second stage dolomitization and silicification of the third member are confined to the upper zones and bear no connection to the silicification and dolomitization of the middle member. The dolomitization of the middle and upper members must have taken place at different times. The lower and middle members were probably dolomitized prior to deposition of the upper member.

KARSTIFICATION

Karstic features on top of the Dammam Formation can be well observed at Ahmadi quarry. The unconformity above the lignitic middle member is not exposed. However, drill hole logs provide indirect evidence of karstic features towards the top of the middle member, and the unconformity at the top of the Dammam Formation is revealed by a gradual increase in resistivity with increasing fluctuations, followed by a sharp decline in resistivity values. There is a similar increase in resistivity values accompanied by an increasing degree of fluctuation towards the top of the middle member. There is no connection between the lower karstic zone below the lignite and the upper karstic zone below the unconformity at the top. Both resistivity and gamma-ray logs measure uniform low values directly above the lignitic shales, indicating a clean, porous carbonate facies with no karstic features and silicification.

CONCLUSION

Although lack of fossil evidence precludes a definite conclusion, indirect evidence suggests a minor break within the Dammam Formation. A study of the upper boundary of this formation reveals that there is karstification, silicification and at a late stage, mixed-water type dolomitization below the unconformity. Similar features are observed below the top of the middle member. This analogy suggests the presence of another minor break in sedimentation after the deposition of the middle member. The depositional sequence gives additional clues. Upward gradation from a nummulitic limestone into lignitic silty shales signals a regression, and this was followed by a second stage of transgression and regression when the upper member accumulated. The second regression is marked by the unconformity at the top of the Dammam Formation.

ACKNOWLEDGEMENT

We would like to express our sincere thanks to the Groundwater Department of the Ministry of Electricity and Water for kindly providing us with data.

REFERENCES

Adams, J.E. & Rhodes, M.L. 1982. Dolomitization by seepage refluxion. In: **Zenger, D.H. & Mazzullo, S.J. (Eds).** Dolomitization. Benchmark Papers in Geology **65**: 157–66. Hutchinson Ross Publishing Co., New York.

Al-Sayed, S.O., Al-Yaqubi, A. & Senay, Y. 1981. Geology and groundwater hydrology of the State of Kuwait. In: **Abulezz, M.S. (Ed.).** First Symposium on the Future Development of Water Resources in the Gulf and Arabian Peninsula. Journal of the Gulf and Arabian Peninsula Studies, Kuwait University **1**: 5–67.

Burdon, D.J. & Al-Sharhan, A. 1968. The problem of the paleokarstic Dammam limestone aquifer in Kuwait. Journal of Hydrology **6**: 385–404.

Dunham, J.B. & Olson, E. 1980. Shallow subsurface dolomitization of subtidally deposited carbonate sediments in the Hanson Creek Formation (Ordovician-Silurian) of Central Nevada. In: **Zenger, D.H., Dunham, J.B. & Ethington, R.L. (Eds).** Concepts and models of dolomitization. Society for Economic Palaeontologists and Mineralogists Special Publication **28**: 139–61.

Gunatilaka, A., Al-Zamel, A., Shearman, D.J. & Reda, A. 1987. A spherulitic fabric in selectively dolomitized crustacean burrows, Northern Kuwait. Journal of Sedimentary Petrology **57**: 922–27.

Hanshaw, B.B., Back, W. & Deike, R.G. 1982. A geochemical hypothesis for dolomitization by groundwater. In: **Zenger, D.H. & Mazzullo, S.J. (Eds).** Dolomitization. Benchmark papers in Geology **65**: 211–27. Hutchinson Ross Publishing Co., New York.

Hsu, K.J. & Siegenthaler, C. 1982. Preliminary experiments on hydrodynamic movement induced by evaporation and their bearing in the dolomite problem. In: **Zenger, D.H. & Mazzullo, S.J. (Eds).** Dolomitization. Benchmark papers in Geology. **65**: 166–81. Hutchinson Ross Publishing Co., New York.

Lababidi, M.M. & Hamdan, A.N. 1985. Preliminary lithostratigraphic correlation study in OAPEC member countries. OAPEC Energy Resources Department, Kuwait, pp. 171.

Larsen, G. & Chilingar, G.V. 1979. Diagenesis in sediments and sedimentary rocks. Developments in Sedimentology **25** A. Elsevier, Amsterdam.

O'Brien, C.A.E. 1952. Stratigraphical study of the Eocene upper limestone in southern Kuwait. Kuwait Oil Co. (unpublished report).

Owen, R.M. & Nasr, S.W. 1958. Stratigraphy of Kuwait-Basra Area. Habitat of Oil. American Association of Petroleum Geologists Symposium, pp. 1252–78.

Saker, I.M. 1970. Geological and hydrological studies of Shagaya area, Kuwait. M.Sc. thesis, University of Kuwait (unpublished).

Steineke, M., Bramkamp, R.A. & Sander, N.J. 1958. Stratigraphy of Eastern Saudi Arabia. In: **Weeks, L.G. (Ed.).** Habitat of Oil. American Association of Petroleum Geologists Symposium, pp. 1294–1329.

Zenger, D.H. & Dunham, J.B. 1980. Concepts and models of dolomitization—An introduction. In: **Zenger, D.H., Dunham, J.B. & Ethington, R.L. (Eds).** Concepts and models of dolomitization. Society for Economic Palaeontologists and Mineralogists Special Publication **28**: 1–9.

(Received 30 May 1989, revised 10 December 1989)

شواهد غير مباشرة لتواجد ثغرة ترسيبية في تكوين الدمام الايوسيني في الكويت

اسماعيل أوزكايا و ايمان العوضي
قسم الجيولوجيا بجامعة الكويت ،
ص . ب . ٥٩٦٩ ، الصفاة ١٣٠٦٠ ،
الكويت

خلاصة

إن تكوين الدمام الميوسيني الأوسط يقع بين متبخرات تكوين الرص التي تحده من أسفل ، وبين تكوين الغار الميوسيني الذي يحده بدون تطابق من أعلى . وينقسم تكوين الدمام إلى ثلاثة آفاق ، يتكون الأفق الأسفل منها من حجر جيري نميوليتي حاوٍ لطبقات طفل ، في حين يتكون الأفق الأوسط منها من ترصص متداخل بين حجر جيرى أحفوري متنخر ومتصون ، ودولومايت غريني إنسيابي متداخل مع طبقات فحم اللجنايت ، كما ان هذا الأفق الأوسط متسلك في بعض أجزائه . أما الأفق الأعلى فيتكون من دولومايت أبيض هش مسامي إلى حبيبي ، أو دولومايت دقيقي شامل لطبقات متداخلة من الصوان والنطق الأحفورية . ويحبس تكوين الدمام من أعلى نطاق متسلك ومنخور تحت سطح اللاتوافق مع تكوين الغار .

وخلافا للاعتقاد الشائع بأن تكوين الدمام قد نتج عن تـرسيب مطرد في عصر الأيـوسين الأوسط محدد بسطح لاتوافقي من أعلى ، فأن دراستنا تشير إلى وجود ثغرة ترسيب زمنية أخرى داخل تكوين الدمام نفســه ، حيث ان الحد بين الأفقين الأوسط والأعلى قد نخر وتسلك وتعرض إلى دلمته متأخرة ، ويشير ذلك بدلائل غير مباشرة إلى إنقضاء فترة وجيزة انعدم فيها الترسيب خلال عصر الأيوسين .