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Petrography and Diagenesis of Jurassic Oncolitic Limestone in the Amran Group, Yemen Arab Republic

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ABSTRACT. The oncolitic and oolitic limestones within the Jurassic Amran Group of Yemen Arab Republic (Y.A.R.) display characteristic depositional and diagenetic structures. The oncoids have four types of laminations; (1) micritic, (2) grumose; (3) organodetrital-bearing and (4) clastic bearing laminations. Most of these laminae are concentric and continuous suggesting continued movements or agitated conditions during deposition. Some laminae are discontinuous and show local growth reflecting short periods of mild agitation or quiet conditions.

The porosity of the studied facies is the result of early and late diagenetic history. It includes primary pore spaces represented by fenestral vugs and secondary pore spaces resulting from the dissolution of carbonate grains as well as cement. Cementation and compaction are the main factors reducing the porosity of these sediments. Compaction due to burial is represented by concavo-convex and sutured contacts and microstyloites.

The present paper aims to throw some light on the petrographic and diagenetic features of oncoidal limestone associated with the Jurassic Amran Group in Yemen Arab Republic. The Amran Group has been an interesting research topic to many authors (*e.g.* Geukens 1966, Beydoun 1966, Abu Khadrah 1982, Abou Khadrah *et al.* 1984, El Anbaawy 1984, 1985; Shallan 1986 and others) for its economic importance, since it contains hydrocarbons' gypsum and lead-zinc ore deposits. This work is based on field and laboratory studies of material collected from four exposed stratigraphic sections; namely from west to east (1) Thula, (2) Thoma-Bayt Dahrah (3) Wadi Naham and (4) Wadi Al-Jawf (Fig. 1).

In the present study oncoids are considered to be of organic (algal) origin. The oncoids were previously named as lump by Wolf (1956b) whereas Dahanayake (1977) considered oncoids as simple bodies with central nuclei and an

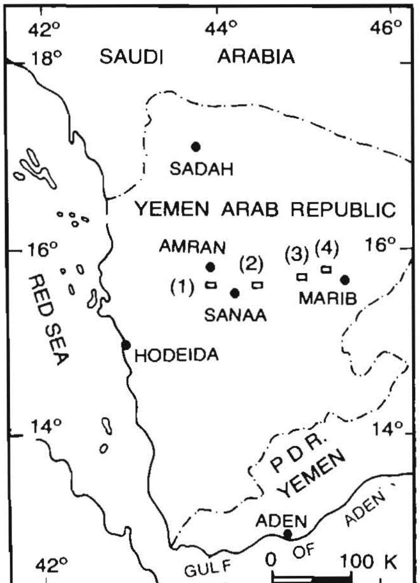
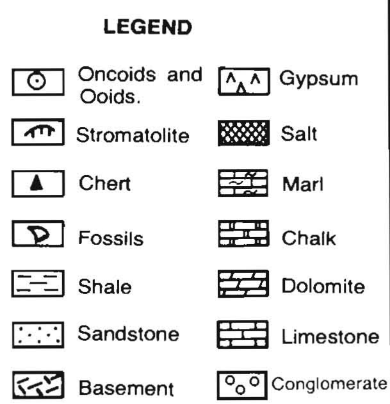


Fig. 1. Location map showing study sections: (1) Thula, (2) Thoma-Bayt Dahrah, (3) W. Naham and (4) W. Al-Jauf. ▭ Study sections.



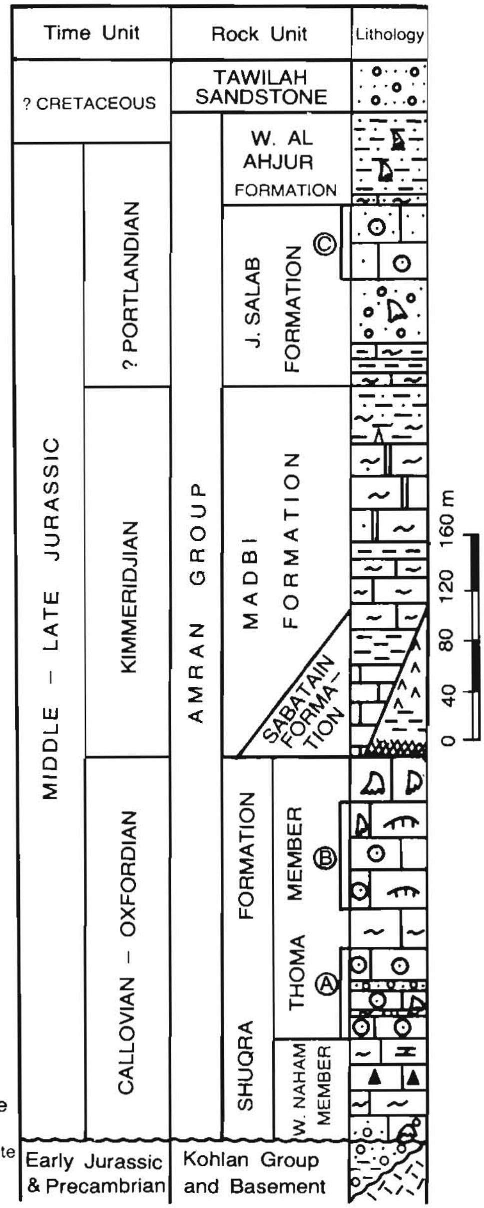


Fig. (2). Generalized composite stratigraphic section of the Amran Group, Yemen Arab Republic (Y.A.R.) – A, B and C are the study sequences.

envelope of concentric laminations refered to by some as the cortex. During the field study, El Anbaawy (1984) used the term oolitic or pisolitic limestone for facies including both oncoids and ooids. The classification of stromatolites by Logan *et al.* (1964) refered to oncolites as spheroidal structures (SS), columnar stromatolites as vertically stacked hemispheroid (SH) and the domal stromatolites as laterally linked hemispheroid (LLH).

Geologic Setting

The oncoid bearing limestones studied belong to the Shuqra Formation (Thoma Member) and Jabal Salab Formation of the Amran Group. The Shuqra Formation represents the lower unit of the Amran Group in all the exposed sections at the study areas (Fig. 2). It rests unconformably either on basement rocks or the Kohlan Group (El Anbaawy 1984). The Thoma Member; the upper part of the Shuqra Formation, in its type locality consists of about 220 m thick of oncolitic, oolitic and stromatolitic limestones, biostromal limestone with marl and sandstone intercalations. It is conformable on the Wadi Naham Member and is unconformably overlain by the Sabatain and Madbi Formations (Fig. 2). The Jabal Salab Formation is encountered only at the top of Gebel Salab in Wadi Naham area (Fig. 1). It consists of 140 m thick of marl-argillite, bioclastic sandstones and oolitic, oncolitic limestones.

The studied oncoid bearing limestones are represented by three sequences; A, B and C. Two of these sequences (A and B) belong to the Thoma Member while the third (C) belongs to the Jabel Salab Formation (Fig. 2). The limestone sequence (A) is recorded in all the studied sections and is composed of sandy oolitic-oncolitic limestone interbedded with fossiliferous marly limestone and bioclastic sandstones with some conglomeratic horizons. The macrofossil assemblage recorded in this sequence is mainly echinoid spines, brachiopods, oysters and some corals. The limestone beds range in thickness from 70 cm to 2 m and are yellowish grey to pale brown in colour.

The sequence (B) is represented by narrow restricted bodies of stromatolitic limestone in which stromatolites occur as deeply burrowed subspherical and columnar bioherm deposits. The lower boundary is erosional while the upper one grades progressively upward and laterally into biostromal limestone of the top most part of Shukra Formation. It is composed of binding algae, stromatoporid and coral colonies (Fig. 3A) in addition to some clastic organic fragments and oncoid grains embedded in carbonate mud.

The limestone sequence (C) consists mainly of massive oncolitic limestone containing few shell fragments, ooid, quartz and feldspar grains. The algal origin of oncoids distinguishes them from morphologically similar bodies like ooids and pisoids of inorganic origin. The association of large oncoids with sand grains and their good sorting indicate their accumulation in a shallow high energy environment.

Two types of oncoids are recognized in the studied sequences. The first type is light brown in colour and ranges in size between 2 and 5 mm (Fig. 3B). The second type is darker brown in colour and is recorded in grains with a diameter less than 2 mm. The small size of the second type and their association with micritized bioclasts, ooid grains and algal nodules makes their identification difficult in the field. However, they could be distinguished easily by microscopic studies.

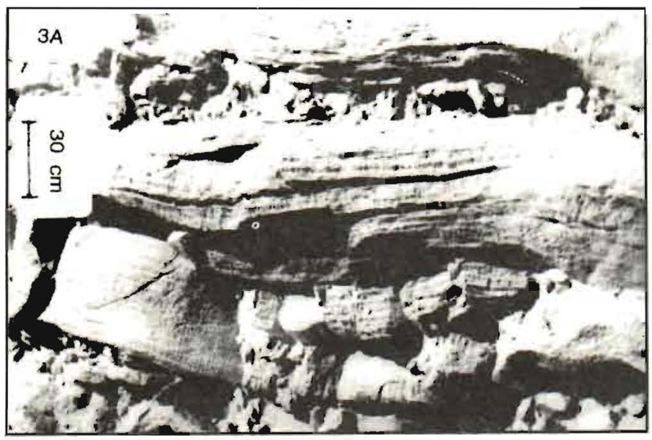


Fig. 3A. Stromatolitic carbonate bed at the top of Thoma Member.

Fig. 3B. Oncolitic carbonate with oncoid grains ranging in diameter between 2 to 5 mm.

Petrographic Study

Microscopic studies showed that the oncoids are represented by simple and compound grains. The simple oncoids are composed of a nucleus surrounded by an envelope consisting of one or more cycles of laminae resulting in superficial and normal oncoids (Figs. 4A and 4B) respectively. The term compound oncoid is used to describe the grains composed of more than one oncoid grain surrounded by a common concentric lamina (Fig. 4C). The nuclei are composed of quartz grains, gastropod shells, echinoid spines, shell fragments and rare intraclasts. In some cases it is difficult to distinguish the nucleus from the envelope due to grain

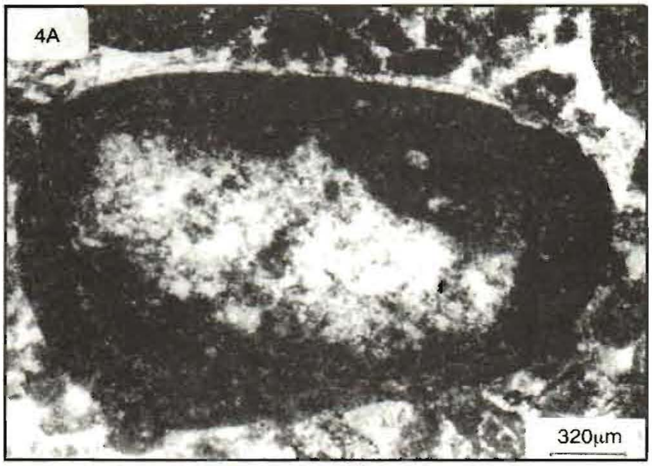


Fig. 4A. Elliptical superficial oncoid grain in which the diameter of nucleus is greater than the thickness of envelope. Crossed Nicols (C.N.)

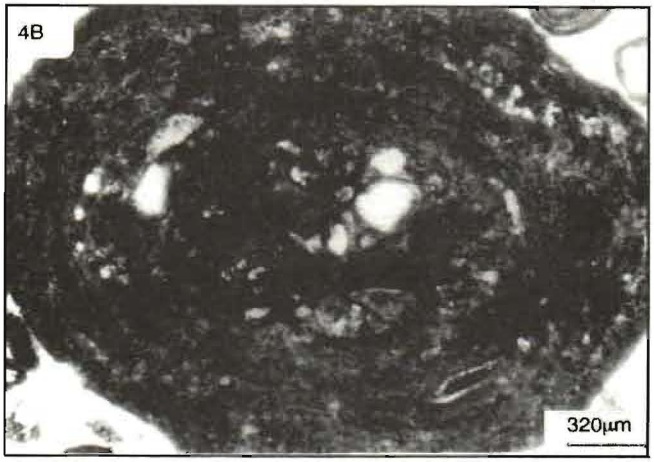


Fig. 4B. Spherical normal oncoid grain in which the diameter of nucleus is less than the thickness of envelope. C.N.

dimunition (Fig. 4D). The oncoid grains are associated with structureless globular bodies (algal nodules) and pellets which lack lamination or nuclei (Fig. 4E). These bodies were named algal pellets and grains by Wolf (1965a) and pseudo-oncoids by Dahanayake (1977).

On the basis of textural and compositional variations, the authors recognized four types of laminations in the studied oncoid grains. These are: micritic,

Fig. 4C. Compound oncoid grain composed of concentric algal laminae encrusting more than one oncoid grain. C.N.

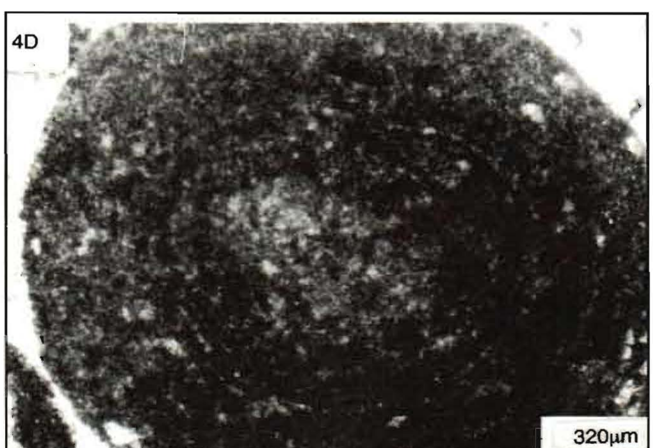


Fig. 4D. Normal oncoid in which grain dimunition affected both nucleus and envelope. It is difficult to distinguish between them. C.N.

grumose, organodetrital bearing and clastic-bearing laminations. The first three types were previously described by Dahanayake (1977) in the oncoids from the Upper Jurassic carbonates of the French Jura whereas the fourth is clearly observed in the oncoids in the present work. The micritic laminations are composed of compact dense microcrystalline calcite crystals (micrite) with remnant sparry calcite crystals (Fig. 5A). The grumose laminations are also composed of compact, dense microcrystalline calcite but with patches of sparite

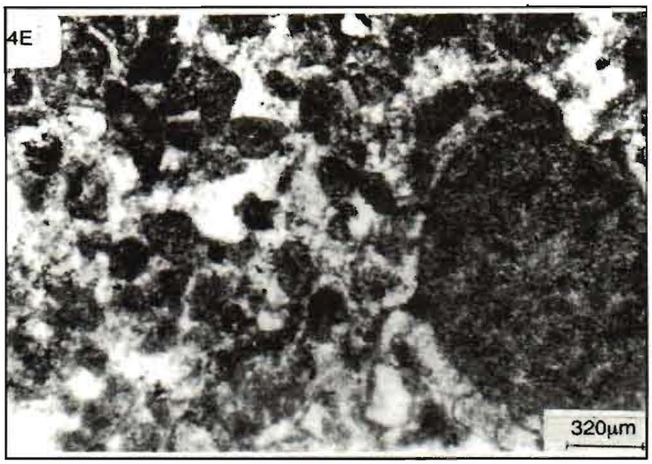


Fig. 4E. Structureless globular pseudo-oncoids. C.N.

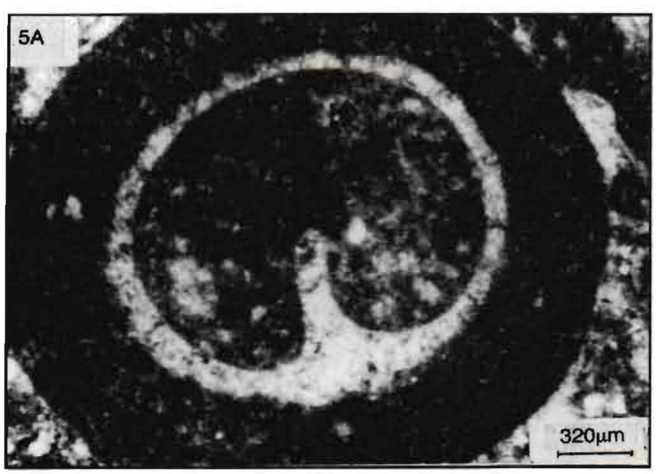


Fig. 5A. Compact dense micritic laminations surrounding gastropod shell. C.N.

which form lenses 200 to 250 μm in length (Fig. 5B). The sparite patches within the darker micrite form irregular "eyes" or "birdseyes" (Folk 1962) which was previously described as grumose texture by Cayeux (1935). The organodetrital and clastic bearing laminations are relatively less compact and sometimes porous (Fig. 5C). They are formed of micrite mostly showing grumose texture, but with a predominance of sparite patches and/or organic fragments and clastic grains.

The encrusting algae appear to participate directly in the construction of the studied oncoids. Algae occur as thalli reaching about 2 mm (Fig. 5B, and 5D) with

Fig. 5B. Compact dense micritic laminations with sparite patches (grumose laminations) surrounding shell fragment. C.N.

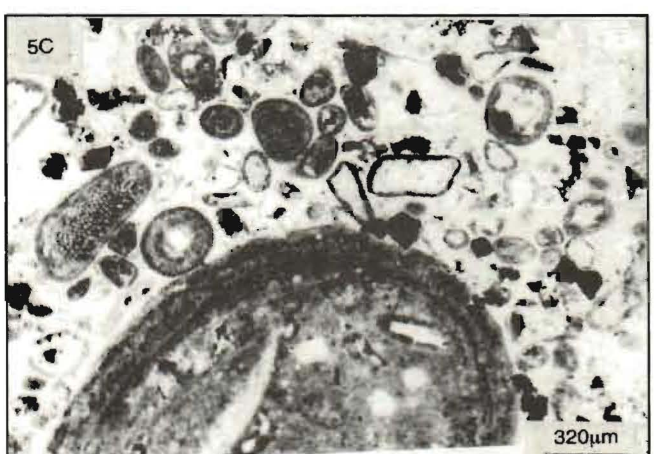


Fig. 5C. Porous organodetrital bearing laminations. C.N.

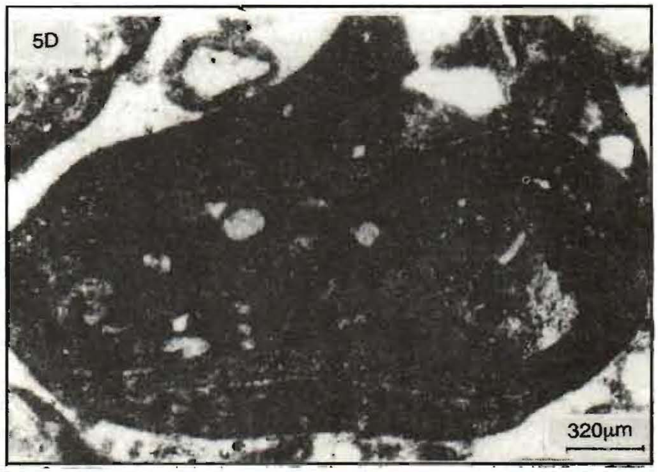


Fig. 5D. Discontinuous clastic bearing lamination showing growth of algae. C.N.

an average thickness of about 300 μm of irregular cell associations of different sizes. Some of these cells are filled with sparite giving the grumose texture. Most of the oncoids show continuous laminations resembling those of ooids. This suggests continued movements due to agitated conditions during their deposition. However, discontinuous laminations formed of organodetrital and/or clastic bearing laminae sometimes result in local growth (Figs. 5B and 5D). They reflect short periods of mild agitation or a calm environment which facilitated the growth of algae on relatively static oncoid grains.

Diagenesis

Porosity

The porosity in the studied carbonate facies ranges from zero to 20% (visual examination from thin sections). Voids include primary spaces between grains and fenestral vugs in the cement (Fig. 5C) as well as secondary spaces resulting from leaching of carbonate grains, open frctures (Fig. 6A) and selective dissolution of ooid and oncoid nuclei (Fig. 6B). Some of these voids and fractures are filled with equigranular sparry calcite (Figs. 6C and 6D). The irregular fenestral vugs indicate the effect of supratidal environment during lithification of sediments (Shinn 1983) whereas the secondary (moldic) pore spaces due to leaching of carbonate grains are characteristic features of rocks that have been exposed to meteoric water (Mathews 1968).

Cementation

Three types of calcite cement are dominant in the studied facies; microcrystal-

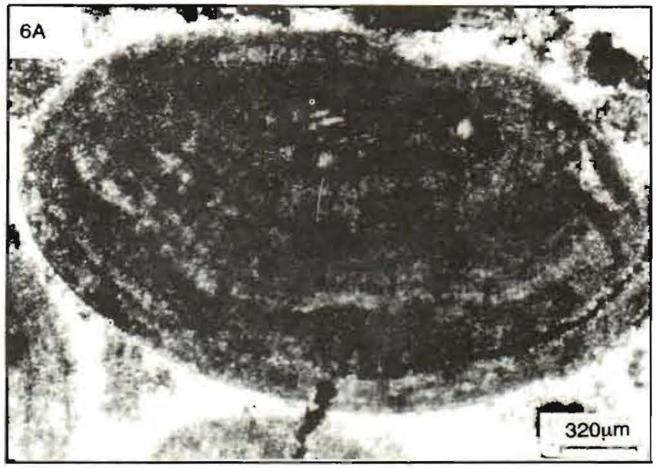


Fig. 6A. Secondary pore spaces in the form of open fractures. C.N.

Fig. 6B. Secondary pore spaces resulted from selective leaching of oncoid nuclei. C.N.

line calcite cement (Fig. 6C), granular equant sparry calcite cement (Fig. 6D) and circumgranular bladed-crust cement (Fig. 7A). The microcrystalline calcite cement (4-10 μm) represents the primary marine cementation while the circumgranular bladed (40 to 60 μm long) and equant "isopachous" sparry calcite (50 to 80 μm) represent the secondary cementation. The association of secondary cement with the moldic pore spaces (Fig. 6C) suggests a genetic relationship between them. The authors agree with Halley and Harris (1979) that the circumgranular bladed and equigranular calcite cements were precipitated in a

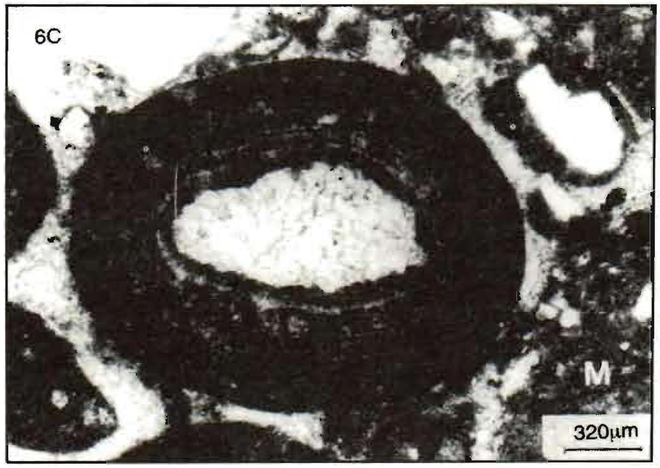


Fig. 6C. Oncoid grain with dissolved nucleus (shell fragment) which later filled with equigranular sparry calcite. M = microcrystalline calcite cement. C.N.

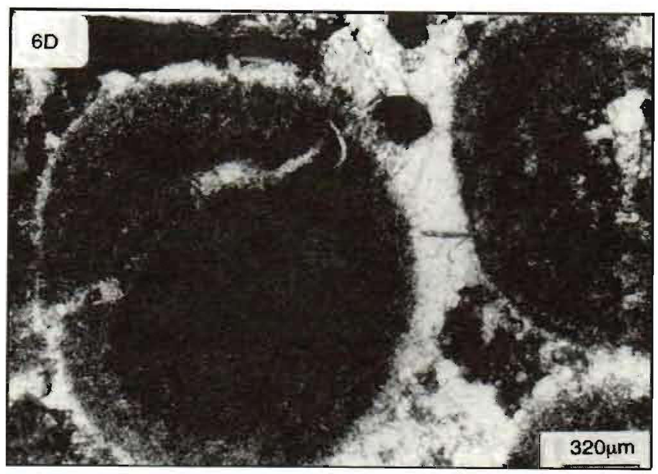


Fig. 6D. Fractured oncoid grains cemented with granular equant sparry calcite. Fracture filled with sparry calcite. C.N.

vadose fresh water environment due to dissolution of marine cement as well as carbonate grains and redeposition of calcium carbonate in these forms. Corrosion of quartz nuclei with the micrite envelope is also observed in the studied facies (Fig. 7B).

Compaction

Compaction of the studied carbonate facies is represented by two stages; (1)

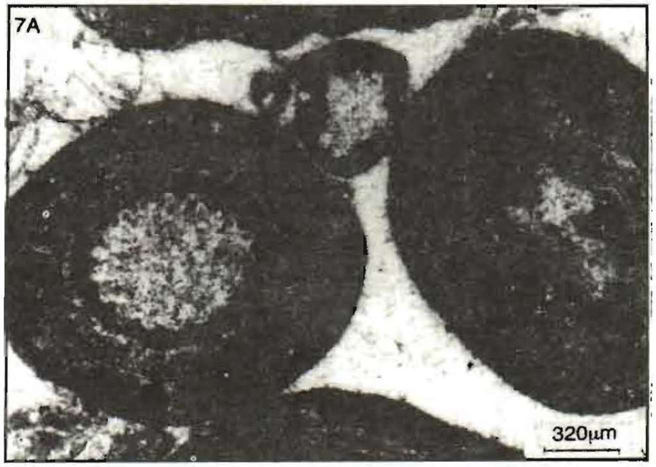


Fig. 7A. Oncoid grains cemented with circumgranular bladed-crust cement. C.N.

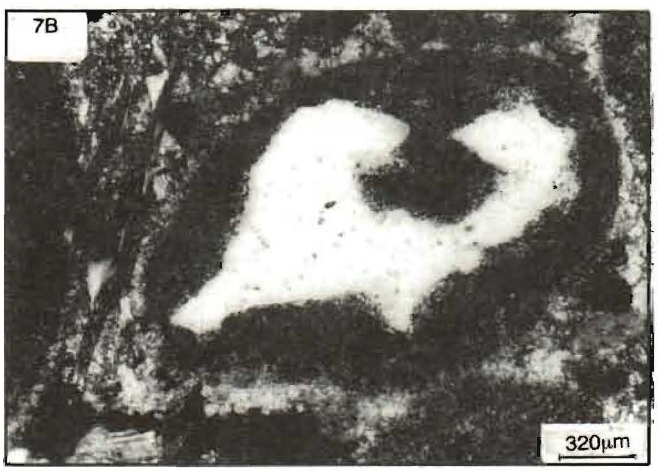


Fig. 7B. Corrosion of quartz nucleus with micrite envelope. C.N.

The early shallow compaction in which syndepositional plastic flow of some ooid and oncoid grains was the result of stress accumulation and (2) The late deep compaction in which pressure solution of lithified oncolitc and oolitic carbonates predominate. The shallow burial compaction is represented by fractured and flattened grains (Figs. 8A and 8B) whereas the deep burial compaction resulted in the formation of concavo-convex and sutured grain contacts (Fig. 8C). Some grains resistant to compaction developed microstylolitic contacts (Fig. 8D). Druckman and Moore (1985) showed that much, if not most of the compaction,

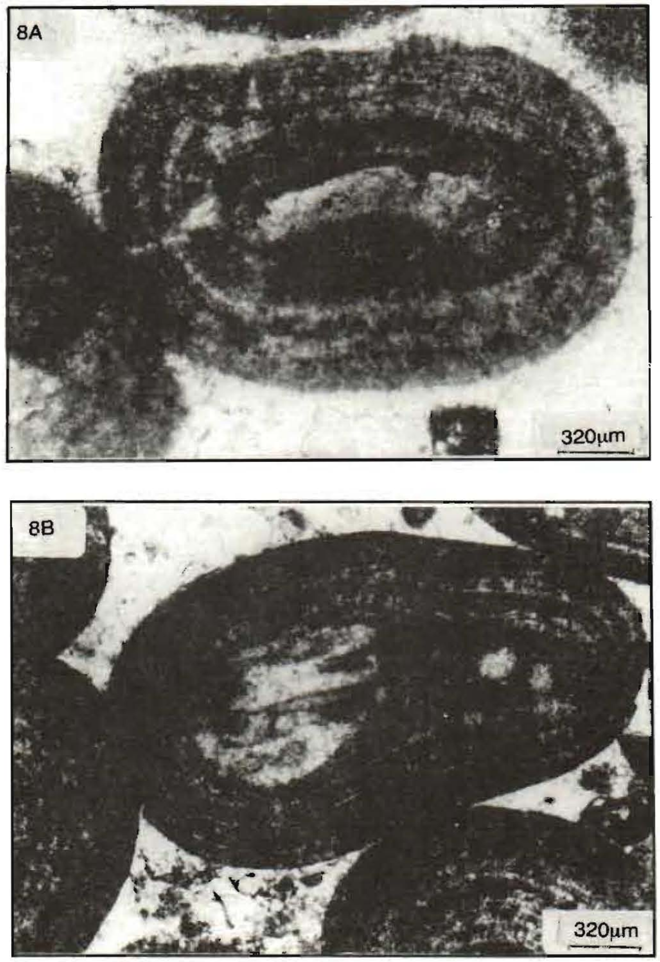
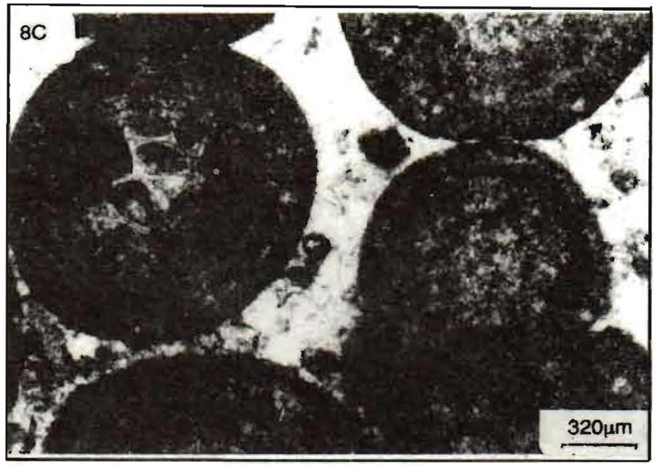


Fig. 8A and 8B. Oncoid grains showing distorted and flattened shape which resulted from shallow burial compaction. C.N.

both mechanical (deformation and crushing of grains) and chemical (microstylolites) appear to have taken place within the first 1100 m of burial.

The observation that the fractures in carbonate grains extend through the cement (Fig. 6A) indicates that compaction followed cementation. Some of these fractures are filled with sparry calcite (Fig. 6D) suggesting that the calcum carbonate which dissolved due to pressure solution could be the source for the late stage of calcite cementation. It has been stated that early cementation prevents compaction (Bacher and Moore 1976, Purser 1978 and others). This statement is



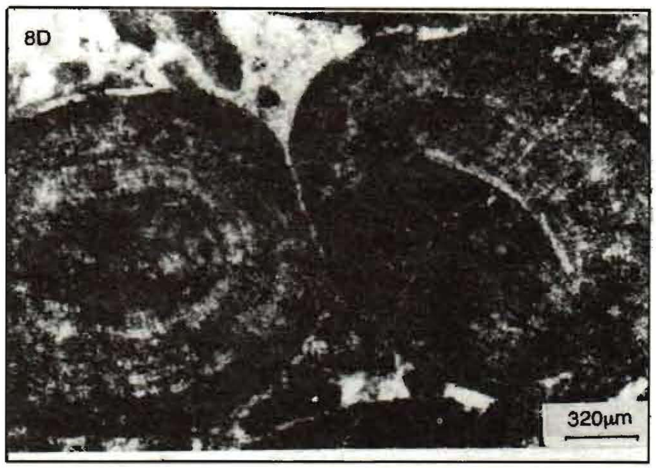


Fig. 8C and 8D. Oncoid grains showing microstylolite, concavo-convex and sutured contacts which resulted from deep burial compaction. C.N.

evidenced in the studied facies by the observation that most of the highly compacted carbonate facies lacks early (primary marine) cementation.

Conclusion

Regionally, during the Jurassic time, the Tethys was a broad shallow sea, depositing carbonates, from central Arabian Peninsula east to Iran and Oman and south across Yemen, where it was in continuity with the East African Sea (Powers *et al.* 1966). Moreover, the Upper Jurassic beds in Somalia and Ethiopia have identical facies as those of central Arabia. This similarity is explained by the link across the Yemen (Saint-Marc, 1978). Al-Thour (1988) concluded that the Jurassic carbonates (Amran Group) in Yemen Arab Republic (Y.A.R.) represent the depositional connection between the Tethys and the East African Sea. The studied oncolitic carbonate is one of the main facies in these Jurassic carbonates (Amran Group).

The textural and compositional characteristics of the studied facies show that they were deposited in a shallow intertidal environment subjected to energy conditions ranging between high and low during their deposition. Remnant algal laminites are observed in the envelope of oncoid grains. The sparite patches (birdseye filled with sparite) in the grumose laminae are regarded as the earlier cells in the algae structure. This may shows the role of algae in the formation of the studied sediments.

The diagenetic history of the oncolitic carbonate could be outlined as follows:

(1) Cementation of the carbonate grains took place in the marine environment. The marine cement and internal sediments were important in reducing the primary interparticle porosity. However, the lack of marine cement in some facies increased its susptability to compaction during burial.

(2) Exposure to meteoric water, in a vadose fresh water environment, caused leaching of some crbonate grains and increased porosity. However, subsequent precipitation of the dissolved carbonates as secondary equigranular and circumgranular bladed calcite cements tended to low the porosity.

(3) Compaction during early shallow burial stage resulted in fracturing and syndepositional plastic flow of some carbonate grains, whereas the late deep burial compaction resulted in the formation of concavo-convex and sutured grain contacts. The compaction appears to have been the main porosity destructive digenetic phases.

References

Abou Khadrah, A.M. (1982) Sedimentological evolution of the Y.A.R., *Bull. Fac. Sci., Sana'a,* **2:** 39-55.

Abou Khadrah, A.M., Khalifa, M.A. and **Mahfouz, S.A.** (1984) Sedimentological studies on the Upper Jurassic in northeast of Sana'a, Yemen. *Teacher's College Bull.,* Kuwait, **6:** 9-21.

Al-Thour, K.A.. (1988) Geological and sedimentological studies on Jabel Al-Balaq area, Marib, Yemen Arab Republic. Faculty of Science, Sana'a University, Sana'a, Y.A.R., 214 pp.

Becher, J.W. and **Moore, C.H.** (1976) The Walker Creek fields: Smackover diagenetic trap. *Gulf. Coast Assoc. Geol. Soc. Trans.* **26:** 34-56.

Beydoun, Z.R. (1966) Geology of the Arabian Peninsula Eastern Aden Protectorate and part of Dhufar U.S. *Geol. Survey Prof.* Paper 560-H.: H_{17}-H_{33}.

Cayeux, L. (1935) Les roches sedimentaires de France, Roches carbonatees calcaires et dolomies, Masson, Paris, 463 p.

Dahanayake, K. (1977) Classification of oncoids from the Upper Jurassic carbonates of the French Jura. *Sedimentary Geology*, **18:** 337-353.

Druckman, Y. and **Moore, Jr. C.H.** (1985) Late subsurface secondary porosity in a Jurassic grainstone reservoir, Smackover Formation, Mt. Vernon field, southern Arkansas. In **Roehl, P.O.** and **Choquette, P.W.** (Eds.), carbonate petroleum reservoirs. Springer-Verlag, New York, Berlin, Heidelberg, Tokyo, 371-383.

El-Anbaawy, M.i. (1984) Contribution to the lithostratigraphic subdivisions of the Amran sequence in the Y.A.R. *Bull. Fac. Sci.*, Sana'a Univ., **4:** 65-84.

El-Anbaawy, M.I. (1985) Geology of Yemen Arab Republic. El-Topgy Press, Cairo, Lazoghly, 303 p.

Folk, R.L. (1962) Spectral subdivision of limestone types. In **Ham, W.E.** (Ed.) Classification of Carbonate Rocks, *Am. Assoc. Petrol. Geol. Memoir* **1:** 62-84.

Geukens, F.P. (1966) Geology of the Arabian Peninsula, (Yemen) *U.S. Geol. Survey Prof.* Paper, **560-B:** B_1-B_{23}.

Halley, R.B. and **Harris, P.M.** (1979) Fresh water cementation of a 1000-year-old oolite. *Jour. Sedim. Petrology*, **49**(3): 969-988.

Logan, B.W., Rezak, R. and **Ginsburg, R.N.** (1964) Classification and environmental significance of algal stromatolites. *Jour. Geology*, **72:** 68-83.

Mathews, R.K. (1968) Carbonate diagenesis, equilibration of sedimentary mineralogy to the subaerial environment; Coral Cap of Barbados, *West Indies. Ramirez, Jour. Sedim. Petrology*, **38:** 1110-1119.

Powers, R.W., Ramirez, L.F., Redmond, C.D. and **Elberg, J.E.L.** (1966) Geology of the Arabian Peninsula (Sedimentary Geology of Saudi Arabia). *U.S. Geol. Survey Prof.* Paper, **560-D:** 1-147.

Purser, B.H. (1978) Early diagenesis and the preservation of porosity in Jurassic Limestones, *Jour. Petroleum Geology*, **1:** 83-94.

Saint-Marc, P. (1978) Arabian Peninsula. *In:* **Moullade, M.** and **Nairn, A.E.M.** (Eds.), *The Phanerozoic Geology of the World*, No. 2. *The Mesozoic, A.* Elsevier Publishing Company, Amsterdam: 435-462.

Shaalan, M.B. (1986) Pb-Zn mineralization in the dolomitized Amran Limestone, Nehm area, Yemen Arab Republic. *Bull. Fac. Sci.*, Cairo Univ. **54:** 677-708.

Shinn, E.A. (1983) Birdseyes, fenestrae, shrinkage pores and loferites: A reevaluation. *Jour. Sedim. Petrology*, **52**(2): 619-628.

Wolf, K.H. (1965a) Petrogenesis and paleoenvironment of Devonian algal limestones of New South Wales. *Sedimentology*, **4:** 113-178.

Wolf, K.H. (1965b) Gradational sedimentary products of clacareous algae. *Sedimentology*, **5:** 1-38.

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بتروجرافية وتغيرات ما بعد الترسيب للحجر الجيري الجوراسي الأونكوليتي بالجمهورية العربية اليمنية

السيد عبدالعزيز علي يوسف و محمد إبراهيم حسن الانبعاوى

قسم الجيولوجيا - كلية العلوم - جامعة القاهرة - القاهرة - مصر

يهدف هذا البحث إلى دراسة طبقات الحجر الجيري الأونكوليتي الذي يميز مجموعة عمران الجوراسية بالجمهورية العربية اليمنية والتي تتميز بخصائص وتراكيب ترسيبية وبعد ترسيبية.

وهناك أربعة أنواع من رقائق حبيبات الأونكويد هي :

١ - النوع الميكربتي.
٢ - النوع الجراموزي.
٣ - النوع الحامل للمواد العضوية الفتاتية.
٤ - الرقائق الحاملة للمواد الفتاتية.

ومعظم هذه الرقائق دائرية ومتصلة مما يدل على استمرارية حركة المياه أثناء الترسيب ومع هذا فهناك بعض الرقائق غير متصلة في أماكن محدودة مما يدل على هدوء البحر نسبياً أثناء ترسيبها.

وتعتبر المسامية للسحنات تحت الدراسة كنتيجة لتاريخ الظروف البيئية التي مرت على الرواسب بعد ترسيبها.

وتشمل هذه المسامية على فراغات أولية ممثلة بنوافذ مثقوبة وأخرى ثانوية كنتيجة لذوبان حبيبات الكربونات والمادة اللاصقة.

هذا ويعتبر التلاصق والتضاغط من أهم العوامل المسببة لنقص المسامية.