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APPLICATION OF THE FORWARD MODELLING OF SEQUENCE STRATIGRAPHY & DIAGENESIS TO THE UPPER CRETACEOUS CARBONATES OF WESTERN IRAQ

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تطبيقات للنموذج المتقدم للتتابع الإستراتجرافيكي مع قياسات للكربونات العُليا في غرب العراق

علـــي كيـــــــــارة
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يعتمد الموديل الديناميكي المبكر لتحويرية الصخور الجيرية والطباقية التتابعية على فهم مختلف العوامل التي توفر الاستنتاجات الدقيقة للشكل الهندسي لأنطقة المسامية والنفاذية في المستودعات الجيرية، يمكن استنتاج العوامل الرئيسية أخذين بنظر الاعتبار التكتونية، والتغير في مستوى سطح البحر العالمي، والمناخ القديم، ويمثل تطبيق هذه الموديلات طريقة قليلة الكلفة لمعرفة خصائص صخور المستودعات النفطية.

تم بناء موديل باتجاهين لصخور الماسترختين الأعلى جيرية بالاعتماد على تسلسل العمليات التحويرية وتطور التتابع مما أدى إلى تحديد الأنطقة الدولوماتية العالية المسامية بالإضافة إلى الأنطقة القليلة المسامية الناتجة عن عملية التسميت المتأخر.

ABSTRACT

Dynamic forward modelling of carbonate diagenesis and sequence stratigraphy relies on the understanding of the different process which provide a high resolution prediction of the geometry of porous and permeable zones within carbonate reservoirs. The fundamental process can be derived from tetonics, eustasy, and climate. The application of such models can yield a rapid cost effective reservoir characterization.

A two dimensional model of the Upper Maastrichtian carbonates of Western Iraq was constructed. The model is based on the paragenesis of the different diagenetic processes and sequence development. As a result; highly porous dolomitized zones were determined as well as low porosity zones produced by the late diagenetic cementation.

INTRODUCTION

The advantage of dynamic forward modelling of carbonate diagenesis is to solve some of the problems of carbonate reservoir characterization, especially those of dolomite reservoirs. Such models can be useful in predicting or evaluating the distribution of dolomite within different depositional units i.e. the geometry, and the diagenetic overprint on these units. The one dimensional forward model is the tool of choice (Matthews and Frohlic, 1998) where it can be calibrated on few wells and we can contour the study area with regard to key input parameters/target variables.

This paper present a digenetic forward model which can be useful in evaluating dolomite reservoirs. This model is based on the interaction of eustasy and tectonics which provide the accommodation potential which together with climate affect the carbonate platform development (paleogeography and type of sediments), sea level fluctuations and climate have a great effect on diagenesis (Fig.1). The interaction of near surface diagenesis and mixing zone dolomitization (affected mainly by eustasy) controls the distribution, geometry, and characters of dolomite bodies, and consequently their petrophysical properties.

The study of the diagenetic development of the Tayarat Formation (Upper Maastrichtian) of western Iraq provided a good exmaple. Core sample from four subsurface sections and samples from one exposed section (Fig.2) were carefully examined. The detailed petrographic studies included the study of insolube residues and clay mineralogy. Thirty two selected samples were analysed for three trace elements (strontium, manganese, and iron).

Dolomite nonstoichiometry was determined using the euqation relating the calcium content and $d_{(104)}$ spacing and can be written in the form:

$$N_{CaCo_3} = Md + B$$

Where N_{CaCo_3} is the mole percent in the dolomite lattice,

d is the observed d spacing in Angstroms,

M is 333.33, and B is -911.99 (Lumsden, 1979).

The exact 2 – position of (104) x-ray reflection was determined relative to the (111) reflection of an internal standard Ceo (fluorite structure) where the specimen's poweder was mixed 10% standard by volume.

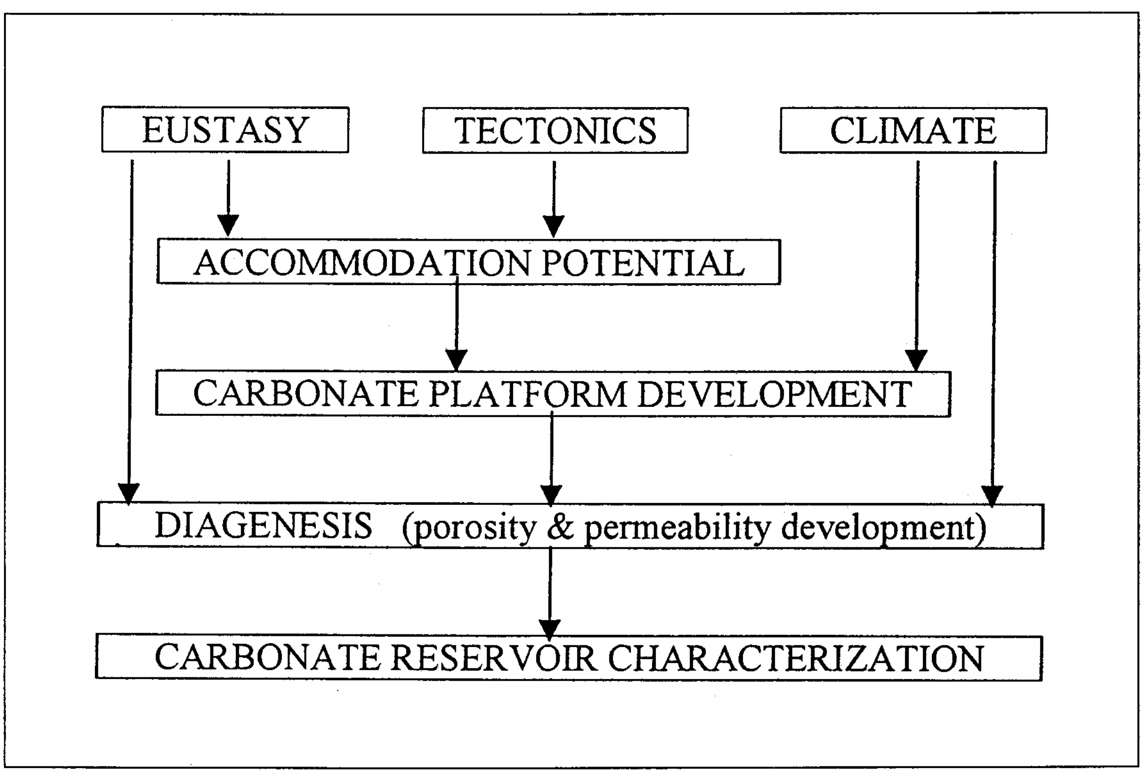

Fig. 1: Flow diagram showing relationships among variables in dynamic forward modelling of carbonate reservoir characterization (modified after Matthews and Frohlich, 1998).

STRATIGRAPHIC SETTING

The studied succession is an unconformity bounded sequence (Fig.2) which represent a shallow carbonate platform deposition on the stable shelf area of western Iraq. The very low rate of subsidence and the activated block movements during the Upper Maastrichtian affected platform development and facies stacking pattern. The eustatic componet is the dominant factor in this area. The succession consists of alternating restricted marine facies, open marine facies, deep marine facies, and shelf margin shoal facies (Fig.2). The western part near the paleoshoreline and Rutba uplift is characterized by clastic influx and prograding fluvial facies. The eastern part on the other hand intertoungs with the basinal Shiranish Formation on the border of the unstable shelf area. The succession reached its maximum thickness at location 7/7 (fig.2) where it represents a keep up phase of the platform which characterizes the Upper Maastrichtian during deposition of the Tayarat Formation.

The formation was affected by many diagenetic processes. These include, neomorphism, cementation, silicification, dolomitization, pressure solution, and dedolomitization. Dolomitization is the most effective process where three of the studied sections (5/8, the exposed section, and 7/7) were completely dolomitized.

PETROGRAPHY

The early effect of the fresh water phreatic zone caused the recrystallization of the matrix and the formation of syntaxial rim cement around echinoderm fragments, such type of calcite cement may represent an early diagenetic process (Koch and Schorr, 1986). Drusy mosaic cement is also common filling both interparticle and intraparticle pores and may also represent an early process. Late meteoric diagenesis can be related to exposure surfaces where basinward shift of the meteoric lens effected the exposed section in the vicinity of the Rutba uplift and the lower part of well 18/7. This was represented by the formation of late granular calcite cement, silicification, and dedolomitization (calcitization). The section at 1/7 was highly affected by early and late meteoric diagenesis.

Different dolomite textures were recognized. They include the crystalline mimetic (CM) which is hard crystalline mimetically preserving the precursor fabric, the crystalline non-mimetic where there is no preservation of the precursor fabcric, and the medium to coarse crystalline mosaic dolomite (100 to 200 μm) interpreted to represet an intermediate to late dolomitization characterized by cloudy-center clear rim (CCCR) texture and non mimetic replacement of the allochems. Coarse crystalline subhedral dolomite cement is also present lining voids and fractures. This type of cement usually occurs late in the diagenetic history (Amthor and Friedman, 1991). Late diagenetic dolomite and dolomite cement may represent a late burial local source dolomitization (Sibly, 1982).

Mixing zone dolomitization of the Tayarat Formation is characterized by non-ferroan massive permeable and porous (up to 40%) dolomite. Moldic porosity, cloudy-center clear rim texture, and dolomite cement reflect local source dolomitization. Increasing of dolomite percentage towards shale units within well 1/7 and association with minor silicification may indicate a clay-derived source. Such dolomite is characterized by the increase of illite on the expense of smectite which form in a temperature suitable for the formation of indegenous oil as in the present case where oil shows are common.

DOLOMITE NONSTOICKIOMETRY

Due to the compositional changes in dolomitizing fluids; dolomite compositions changes and rarely achieves its stoichiometric composition (Lumsden and Chimahusky, 1980). It can be expressed in terms of mole percent $CaCO_3$ in the dolomite lattice. In the studied dolomite samples of the Tayrat Formation it usually ranges between 49.967 and 51.8. Very few with up to 55.467 mole percent $CaCO_3$ (Table.1). It has a positive relationship with the strontium concentration (correlation coefficient = 0.899). Dolomitized shallow open marine facies are almost stoichiometric (Fig.3). This may suggest that a relationship between dolomite composition and depositional facies does exist. Such a relation may reflect the effect of fluctuating relative sea level on the different diagenetic environments.

TRACE ELEMENTS

Strontium concentration ranges from 62 to 229 ppm for the dolomite samples (Table. 1). It is generally low in the dolomitized transgressive shallow open marine facies. This may indicate the influence of Sr impoverished meteoric lens on the freshwater-seawater mixing zone during early shallow burial dolomitization.

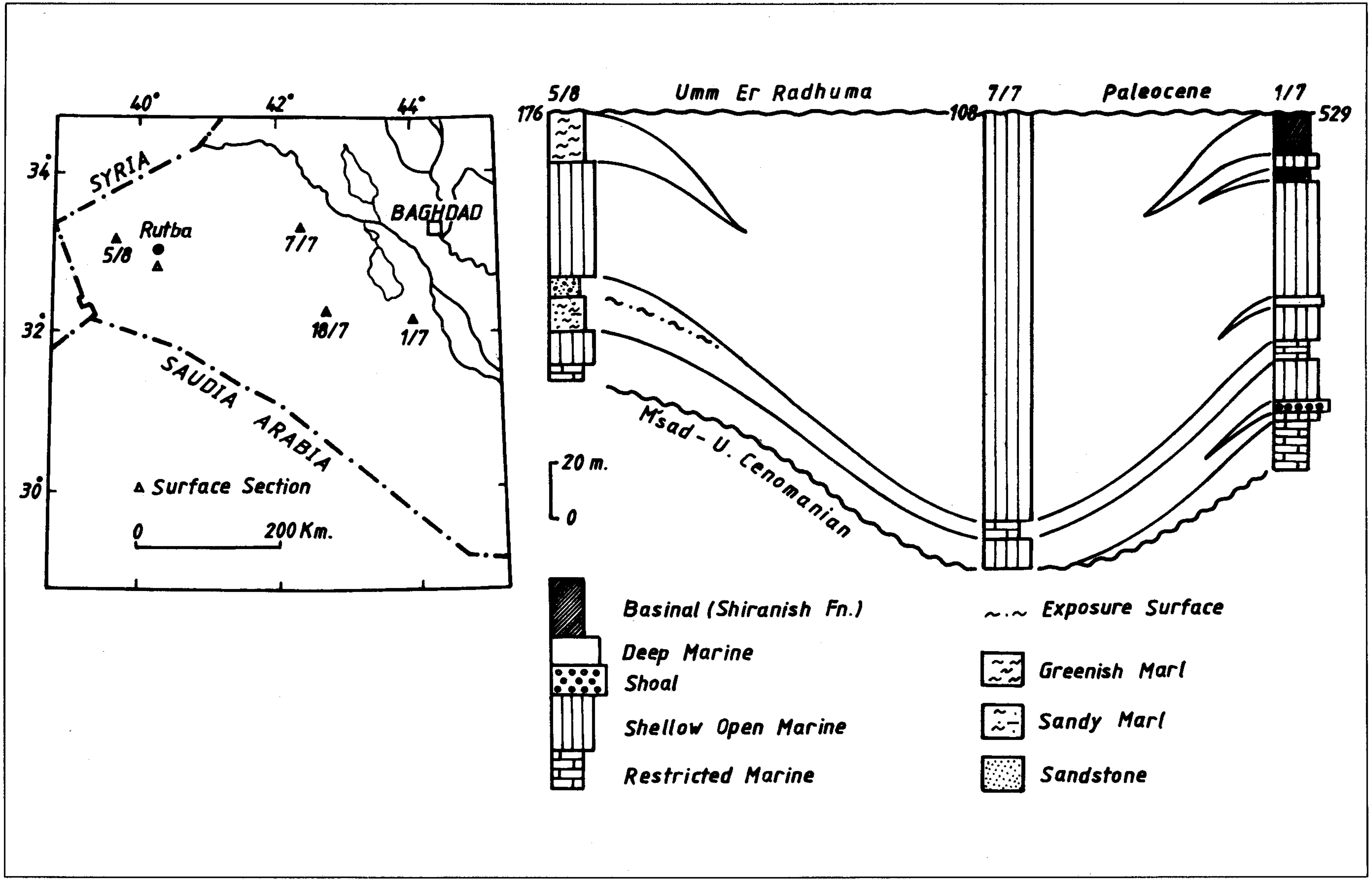

Fig. 2: Index map showing location of the studied sections and stratigraphic section of the Upper Maastrichtian in western Iraq.

Table 1: Geochemical data of dolomite samples in the present study.

Well No.	Depth (m.)	Mole % $CaCo_3$	Sr ppm	Fe ppm	Mn ppm
5/8	193.5	50.567	111	1328	103
	205.0	51.167	115	1022	87
	216.6	49.967	113	4755	241
	221.3	49.967	111	6393	232
	251.7	49.367	62	8003	489
	253.5	49.967	92	16031	374
	260.5	49.967	97	3074	300
7/7	112	49.967	126	890	45
	126.4	49.967	135	1854	61
	140	49.367	118	241	32
	150	49.967	97	606	31
	165	49.967	96	371	26
	181	49.367	67	305	31
	194	49.367	89	277	36
	211	49.967	63	447	36
	226	50.567	94	258	55
	240.5	49.967	104	785	68
	249.5	49.967	107	789	59
18/7	204	49.967	73	138	14
	209	49.967	69	268	16
	240	49.967	67	503	23
	257	50.567	65	332	23
	258	54.833	106	262	22
	364	54.833	229	167	11
1/7	584.5	55.467	184	5612	166
	595.5	54.833	171	1736	64
Surface Section	1	53.60	189	3680	371
	3	51.80	161	1035	209
	11	49.967	133	2118	113
	18	49.967	148	2087	37
	25	50.567	172	919	36
	28	50.567	182	610	47

Manganese concentration ranges from 11 to 489 ppm (Table.1). The relatively higher values in dolomite samples at well 5/8 may be attributed to its association with clays which constitute a major part of the insoluble residue. Dolomites of well 7/7 which lies away from the paleoshoreline are generally with lower Mn concentrations. (Fig. 3).

Iron concentration ranges from 138 to 16031 ppm (Table.1). It may reflect the terrigeneous contribution of Fe during deposition. Ti positive relationship with Mn concentration (correlation coefficient=0.98), and the higher concentration at well 5/8 may support that suggestion.

EUSTATIC CONTROL ON NEAR SURFACE DIAGENESIS

The nature of sea level fluctuations had a great affect on the rates of processes within each diagenetic environment especially on near surface meteoric diagenesis and mixing dolomitization (Gayara and Taha, 1995). In an area of very low rate of subsidence as in the case of this study; it has affected the extent of each diagenetic environment. A two-dimensional model (Fig.4) can be constructed in order to show the extent of porous permeable dolomitized zone. This zone lies within the central part of the study area where a relatively higher rate of subsidence was caused by activated longitudinal block movements during the Maastrichtian. As a result; a relatively thicker transgressive open marine succession was developed. It was highly affected by early mixing dolomitization and later by late burial dolomitization, only its top was affected by the zone of active meteoric waters related to the overlying unconformity.

Late meteoric diagenesis can be related to the basinward migration of the meteoric lens due to the major regression at the end of Masstrichtian. This together with the activity of the Rubta Uplift to the west; produced highly cemented and dedolomitized zones in the west and at well 1/7 near the shelf margin (Fig.4).

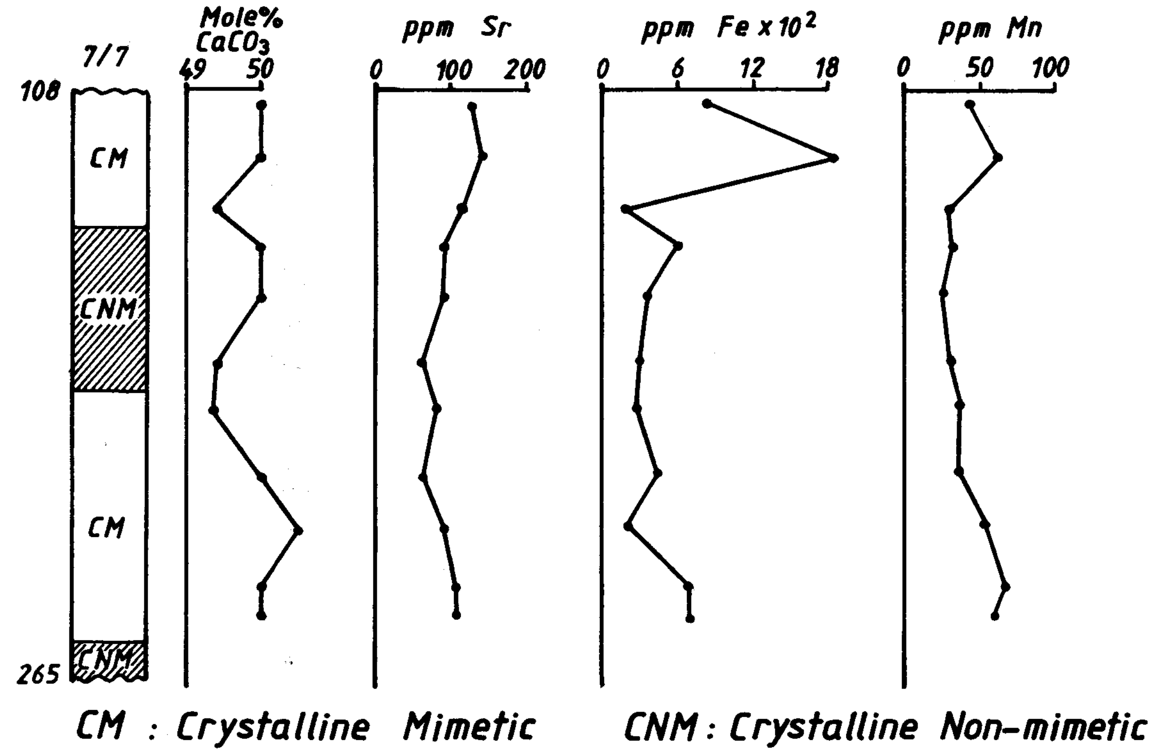

Fig. 3: Vertical variations in dolomite textural types, Mole % CaCo₃, and trace elements at well 7/7.

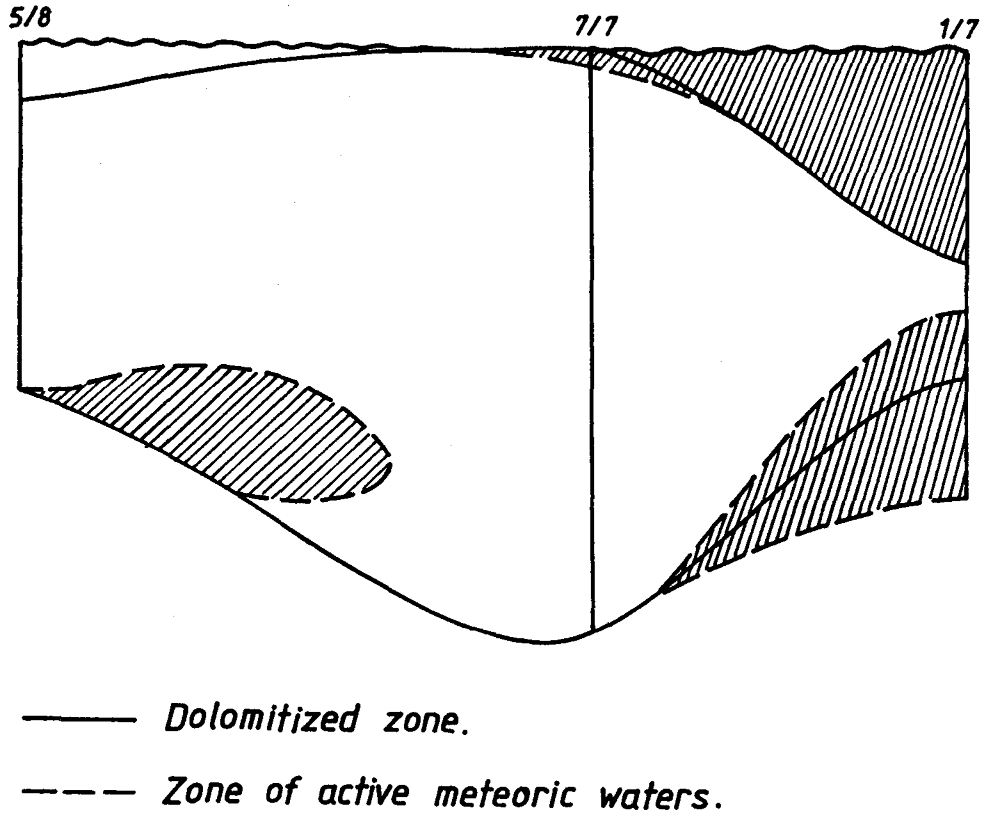

Fig. 4: Two dimensional model showing distribution of the porous and permeable dolomitized zone and the highly cemented low porosity zone formed due to the effect of active meteoric waters.

CONCLUSIONS

A two-dimenstional forward model based on the paragenesis of the different diagenetic processes and development of the Upper Masstrichtian succession was constructed. The application of the model relied mainly on the understanding of the effect of eustasy on the major diagenetic environments.

The diagenetic development of the Upper Masstrichtian carbonate succession of western Iraq provide an excellent example where highly porous and permeable dolomitized zones can be determined with reasonable accuracy. This will lead to the construction of a three dimensional model and mapping the different key variables.

Such type of models can yield a rapid, cost effective dolomite reservoir characterization.

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