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A Regional Static Model of the Dammam Aquifer as a Source of Injection Water, Southern Iraq

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Abstract

The Middle Eocene, shallow, dolomitic, high salinity aquifer has significant importance as the main source of injection water at the present time in order to maintain reservoir pressure above the bubble point in maturing oil fields in southern Iraq until other sources of injection water become available. Therefore, in this study, the Dammam aquifer was studied in detail by integrating all available data, including 3D seismic, well information, well logs, and core data.

A regional aquifer static model has been constructed to better understand subsurface geology and in order to be ready to be used in the construction of a sophisticated dynamic model to predict whether the Dammam aquifer can supply enough water for injection or not. More than 184 wells have been used in the present study. The structural framework was built according to 3D seismic cube and well tops. The average thickness is about 235 mm. In order to understand the lateral and vertical connectivity, a facies model was created in addition to the porosity and permeability models with input from the core and a Nuclear Magnetic Resonance (NMR) log.

According to the facies change, the Dammam aquifer has been divided from bottom to top into five units (MD50, MD100, MD200, MD300, and MD400). The top of the Dammam formation varies from 700m in the southeast to 1000m in the north-west. The porosity in the Dammam formation is very high and varies from 12 to 45 PU, with an average porosity of 29 PU. In order to reduce uncertainty, the study recommends that a new rock core have to be cut, in addition to a number of NMR and Formation Micro Imager (FMI) logs needing to be run into selected wells.

Keywords: Static Model, Aquifer, Injection water, Facies Model, well logging.

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الموديل الجيولوجي الاقليمي لخزان الدمام كمصدر لمياه الحقن في جنوب العراق

يتمتع خزان الأيوسين الوسط الضحل الدولومايتي عالي الملوحة بأهمية كبيرة كمصدر رئيسي لمياه الحقن في الوقت الحاضر من أجل الحفاظ على ضغط المكمن أعلى من ضغط الاشباع في حقول النفط الناضجة في جنوب العراق لحين توفر مصادر أخرى لمياه الحقن. لذلك، في هذه الدراسة، تمت دراسة خزان الدمام الجوفي بالتفصيل من خلال استخدام جميع البيانات المتوفرة، بما في ذلك البيانات الزلزالية ثلاثية الأبعاد ومعلومات الآبار ومجسات الآبار وبيانات اللباب الصخري.

تم بناء الموديل الجيولوجي الاقليمي ثلاثي الابعاد الخزان الدمام لفهم الجيولوجيا تحت السطحية بشكل أفضل ولكي يكون جاهزاً لاستخدامه في بناء الموديل المكمني المتكامل للتنبؤ فيما إذا كانت طبقة الدمام الجوفية قادرة على توفير كمية كافية من المياه للحقن مستقبلا أم لا. وقد تم استخدام أكثر من 184 بئرا في هذه الدراسة. تم بناء النموذج التركيبي بالاعتماد على المسح الزلزالي ثلاثي الأبعاد وقمم التكوين من الآبار، متوسط سمك حوالي 235 متر. ومن أجل فهم الامتدادات الجانبية والعمودية، تم إنشاء الموديل السحني بالإضافة إلى موديلات المسامية والنفاذية والتي تم تأكيد دقتها عن طريق مقارنتها مع اللباب الصخري والمجسات الرنين المغناطيسي النووي (NMR).

ووفقاً لتغير السحنات، تم تقسيم طبقة الدمام الجوفية إلى خمس وحدات من الأسفل إلى الأعلى (MD 50, MD 100, MD 200, Md 300, MD 400) تقع قمة تكوين الدمام على عمق يتراوح بين 700 متر في الجنوب الشرقي إلى 1000 متر في الشمال الغربي. المسامية في تكوين الدمام عالية جداً وتتراوح بين 12 الى 45. ومن اجل التقليل من عدم اليقين وزيادة الدقة توصي الدراسة بقطع لباب صخري جديد بالإضافة الى إنزال مجسات الرنين المغناطيسي النووي (NMR) ومجسات تصوير التكوين (FMI) في عدد من المختارة.

1. Introduction

Although there are many subsurface water aquifers within the study area, such as Dibbdiba, Ghar, Umm-Er-Radhuma, Tayarat, etc. The Middle Eocene aquifer (Dammam Formation) is considered the most important source of water used for injection for the purpose of supporting the reservoir pressure in oil fields in Basra province, especially in West Qurna 1 (WQ1) and West Qurna 2 (WQ2) oil fields, which have operated on pressure depletion since the commencement of production. Almost all of the production has been from the Mishrif formation (Middle Cretaceous), with minor oil production from the Upper Cretaceous Saadi and Lower Cretaceous Zubair formations [1]. The Dammam Formation is called after Saudi Arabia's Dammam Dome and Dammam Field, where the thickness of the Dammam Formation is approximately 180 to 275 meters. It consists mainly of porous, soft, chalky limestone and hard, crystalline dolomitioc limestone [7]. The Dammam Formation consists mainly of fossiliferous limestone, dolomites, and shales [4]. The Dammam Formation was studied for the first time in the provinces of Basra and Kuwait City by Owen and Nasir in 1958 [5]. The Dammam Formation has unconformable contact with the overlain Ghar formation, which consists of friable sand and gravel, and conformable contact with the underlain anhydriticritic Rus formation, as shown in Figure (1).

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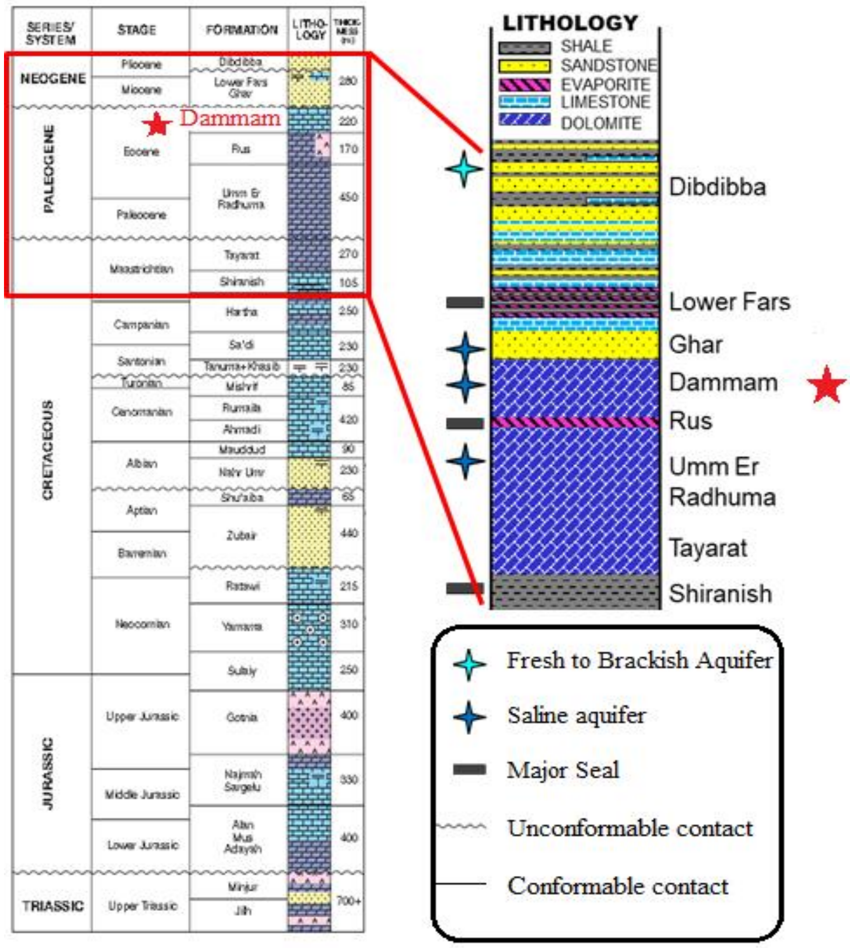

Fig. (1): Stratigraphic Column, Southern Iraq

The Dammam aquifer is laterally extensive over most of the Middle East. Dammam formation is exposed to surface in southwestern Iraq; therefore, the Dammam aquifer recharge is from the southwestern desert, 150km southwest of the West Qurna oilfield. Figure (2) shows the geological map of southern Iraq, including the Dammam outcrop inside Iraq.

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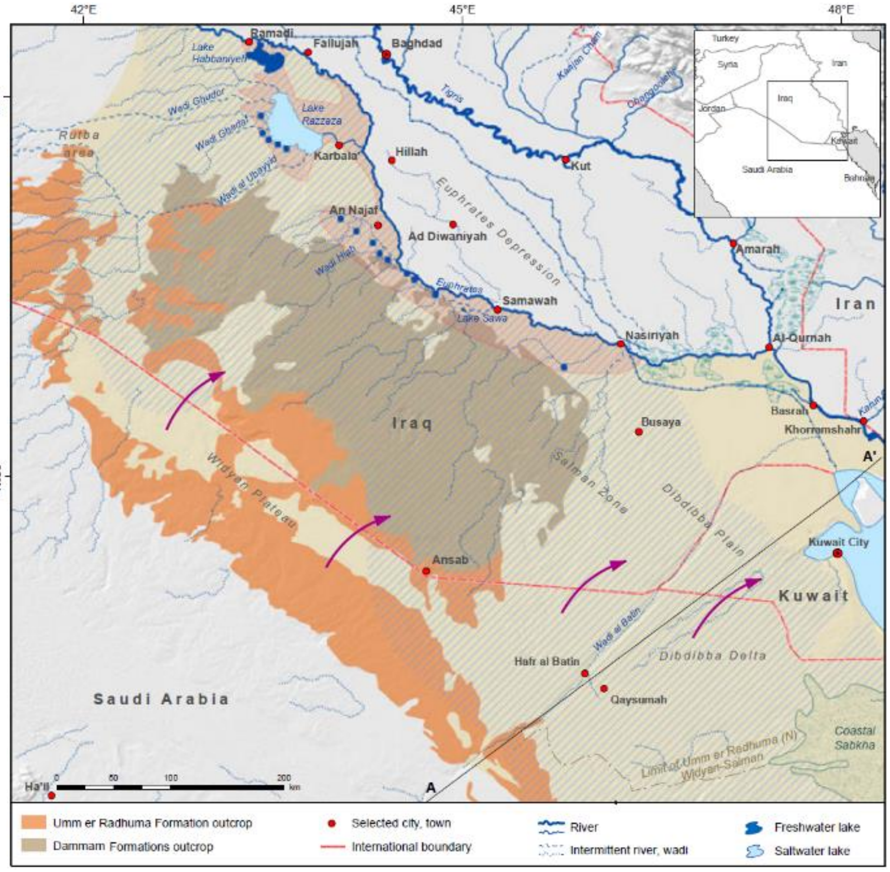

Fig. (2): Geological map of Southern Iraq [10].

2. Study Area:

Because the Dammam aquifer has wide lateral extensions, it was necessary to create the Dammam model on a wide area of southern Iraq in addition to parts of Kuwait and Saudi Arabia. The model was created on an area of 65,339 square kilometers, but the focus of this study was mainly on the West Qurna 1 oilfield because the Dammam aquifer is considered very important to provide water for the purpose of injection to maintain the reservoir pressure in the reservoirs of the West Qurna 1 field. West Qurna 1 surface area is approximately 500 square kilometers, and WQ1 lies approximately 50 km northwest of Basra city [2] [3]. Figure (3) shows the study area and the location of the West Qurna1 oilfield.

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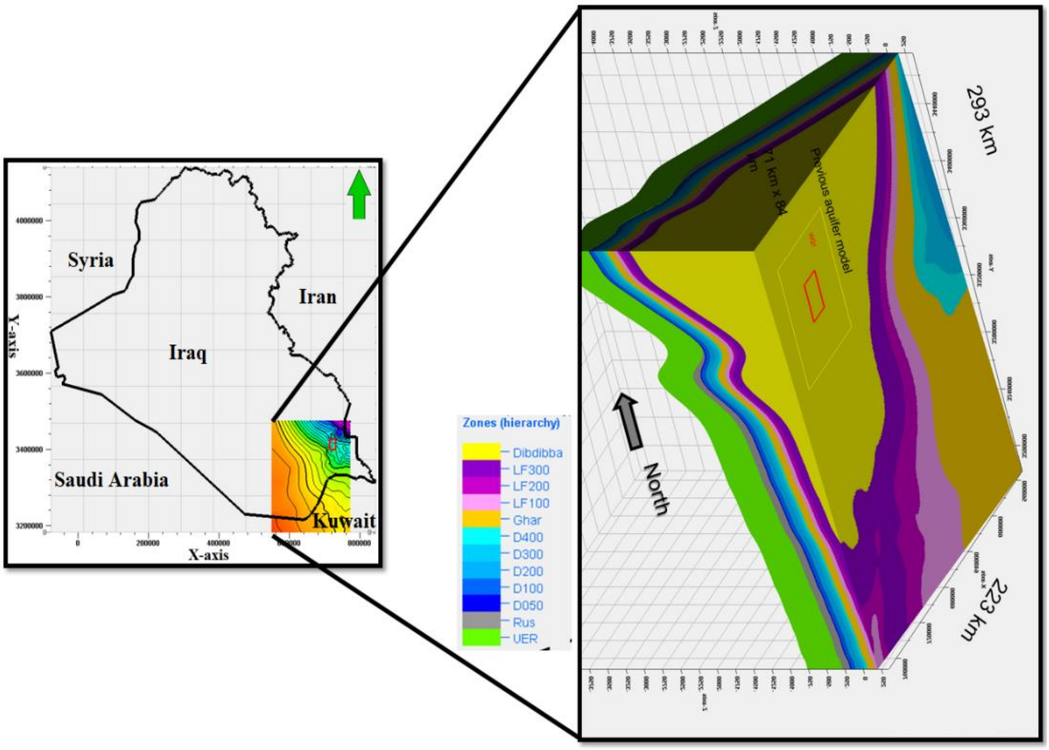

Fig. (3): Location map of study area.

3. Methodology and Results:

All available data has been integrated to build an accurate Dammam static model, including 3D seismic, well information, well logs, and core data. More than 184 wells have been used in the present study. Figure (4) illustrates the main steps used in this study to build the Dammam static model. Petrel software has been used to create a 3D static model for the Dammam aquifer. According to the rock properties, the Dammam formation has been subdivided into five units from bottom to top: (D 050, D 100, D 200, D 300, and D 400). Figure (5) shows the Dammam units.

3.1. Structural Framework

Successful static models are normally established with a 3D structure framework. The 3D structure framework includes gridding and structural contour maps not only for formation tops but for each unit within the Dammam aquifer in addition to isopach maps; it also includes making horizons, zones, and layering. Gridding is the process of creating a skeleton framework [8]. The top, mid, and base skeleton grids are connected to the top, middle, and base of the structure model [9].

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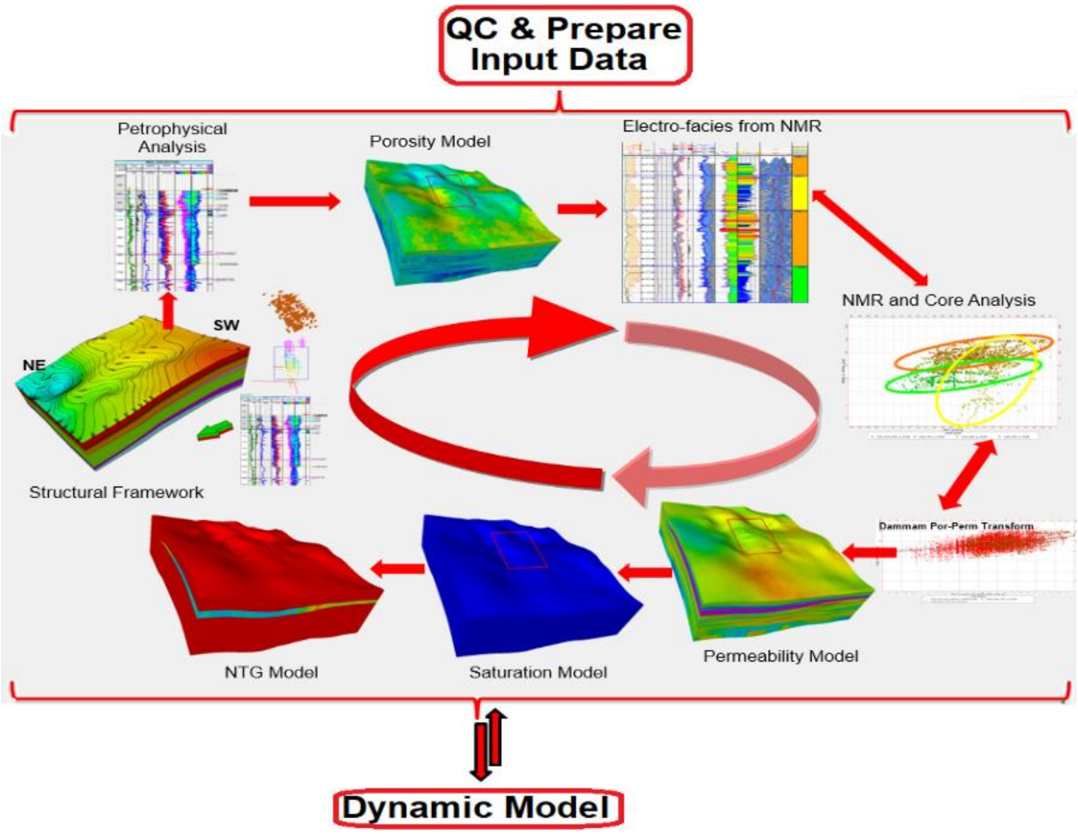

Fig. (4): The main steps of geological (static) model.

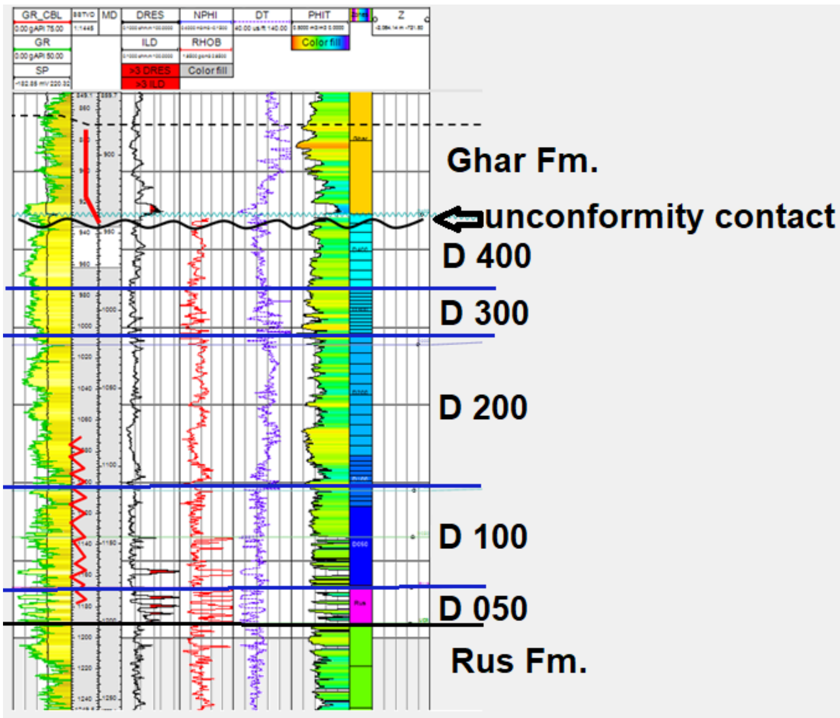

Fig. (5): Units of Dammam aquifer.

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Based on the 3D seismic interpretation report, the Dammam aquifer is an unfaulted formation; therefore, the simple grid process should be used instead of pillar gridding. The next steps are making horizons, zones, and layering. In this study, the grid cells (ni,nj,nk) are (200, 260, and 46), respectively, in West Qurna 1 and (800, 1000, 46) in the remaining area. Figure (6) illustrates the skeleton framework and grid size. For the purpose of completing the structure framework, the structural maps of the top of the Ghar Formation and Rus Formation In addition to tops of all Dammam units (D 400, D 300, D 200, D 100, D 050) have been created using well tops for all available wells within the study area. Figure (7) shows the all-structural maps used in this study. The next step was to select the proper number of layers for each zone. The Dammam model includes 46 layers. Figure (8) illustrates the number of layers for each zone.

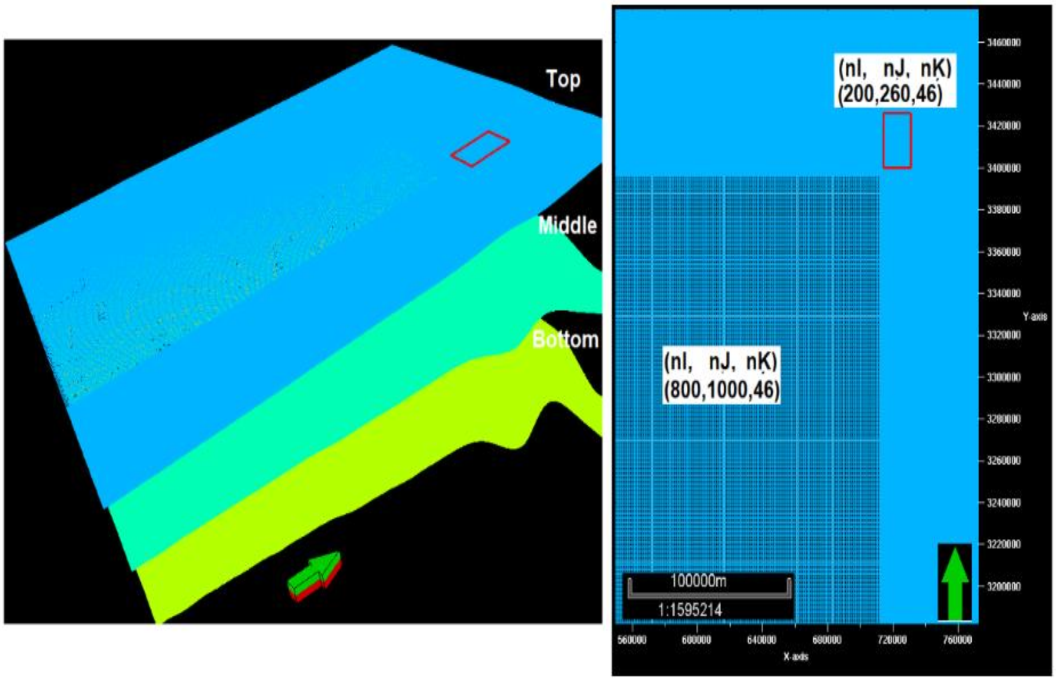

Fig. (6): Skeleton framework and grid size

3.2. Petrophysical Model.

After the structural model has been built and the grid cells have been generated, the next stage is to build the petrophysical model. The Petrophysical Model is the process of filling the grid cells with continuous properties (porosity and permeability). The Dammam formation was subdivided into five units according to its petrophysical properties. Figure (9) illustrates the properties of Dammam units. In this study, the main focus in preparing the petrophysical model was on the petrophysical changes within the West Qurna 1 oilfield, due to the availability of abundant

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information, and on the other hand, the dependence on the Dammam formation in the West Qurna field as a main source of water for the purpose of injection into the Mushrif and Zubair reservoirs at the present time in order to support reservoir pressure and the sustainability of oil production from these reservoirs.

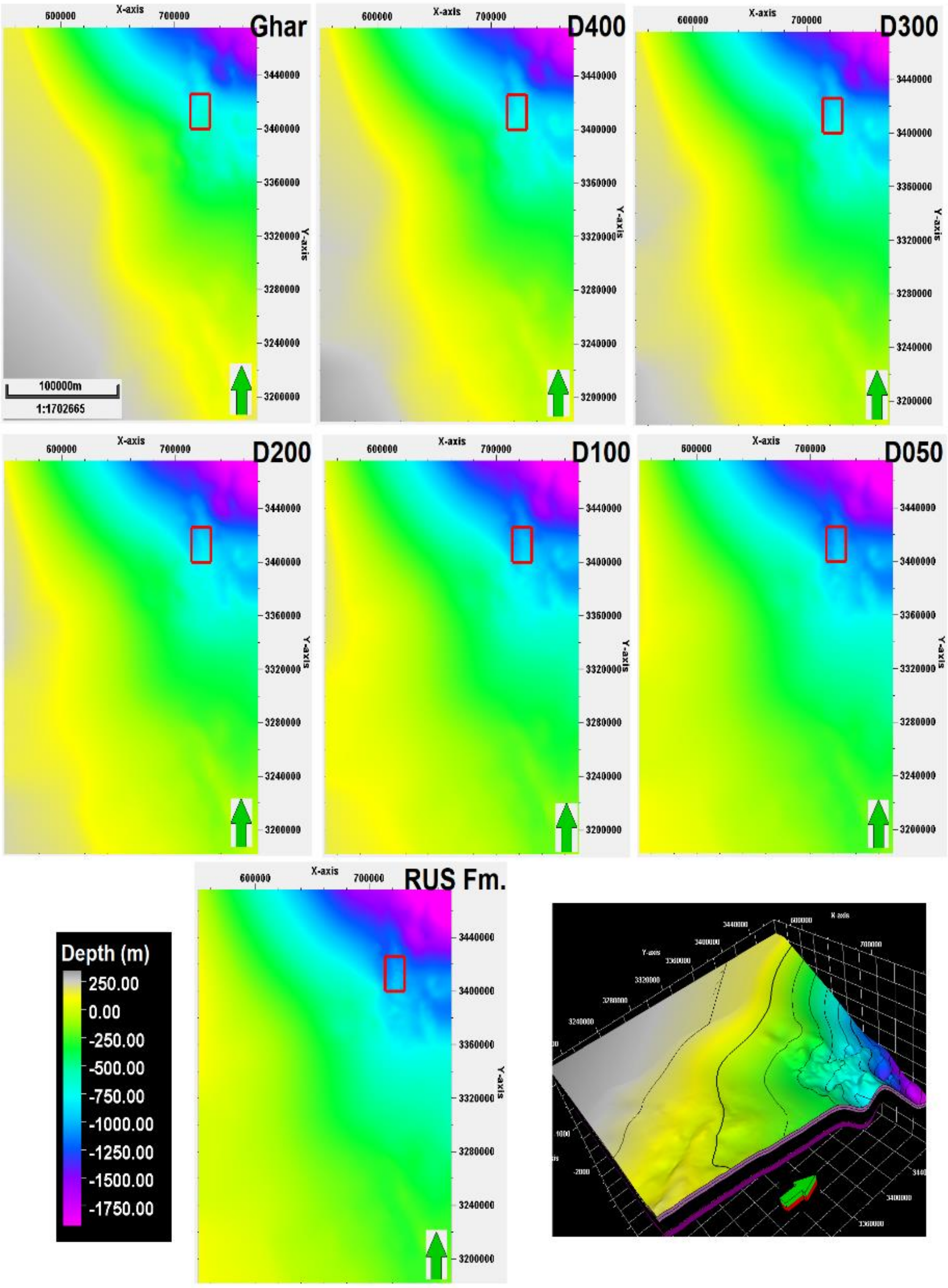

Fig. (7): Structural Maps

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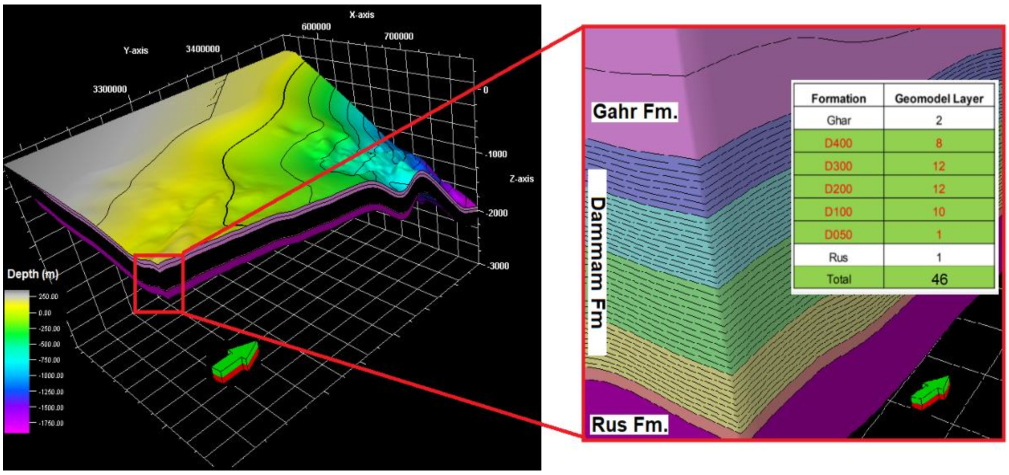

Fig. (8): Zones and layers of Dammam Model

3.2.1. Porosity Model.

In this study, density porosity was used to create a porosity model for the Dammam aquifer. If the wellbore shape is good, the density method provides the most reliable porosity (Φ) [6]. Wyllie's equation is used to calculate density porosity with a suitable matrix and fluid density. Geolog software was used to calculate Dammam porosity in all wells, then the results were used to upscale porosity and then create the porosity model by Petrel software using the stochastic method (Sequential Gaussian Simulation SGS). The Nuclear Magnetic Resonance (NMR) method in selected wells is used to validate the porosity driven by density logs. Figure (10) shows the porosity map for each of the Dammam units in addition to the full porosity model. Whereas Figure (11) shows a very good match between the well log porosity, the upscaled porosity, and the model porosity for each zone.

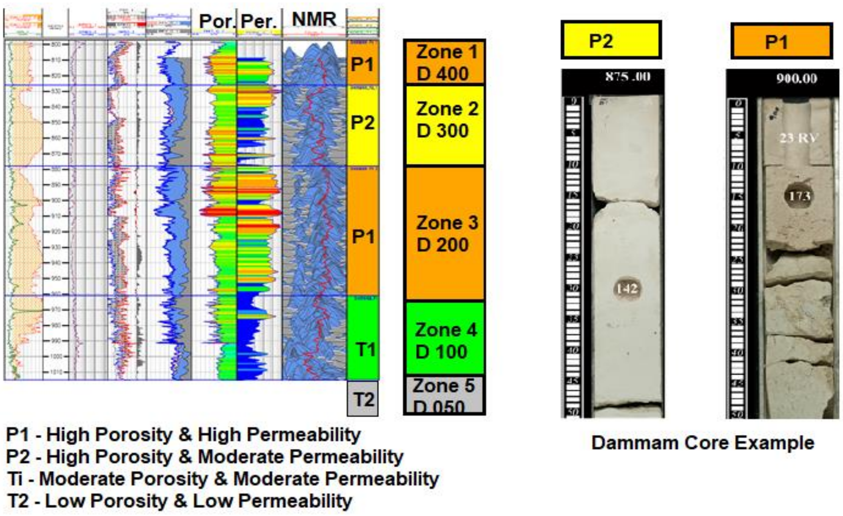

Fig. (9): Properties of Dammam units.

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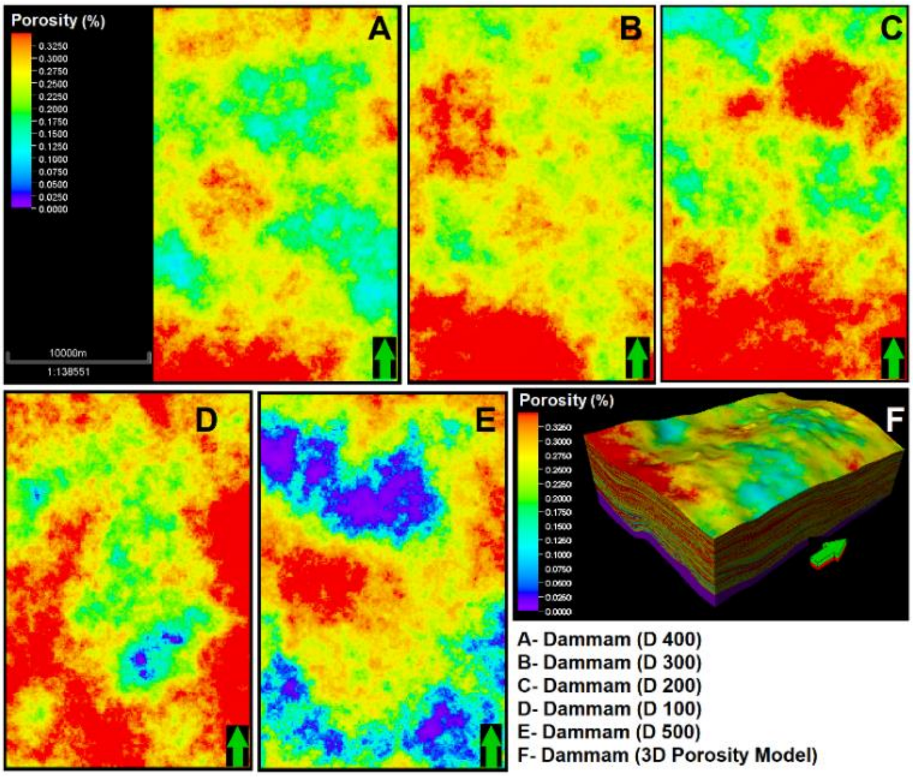

Fig. (10): Porosity Maps of Dammam Formation.

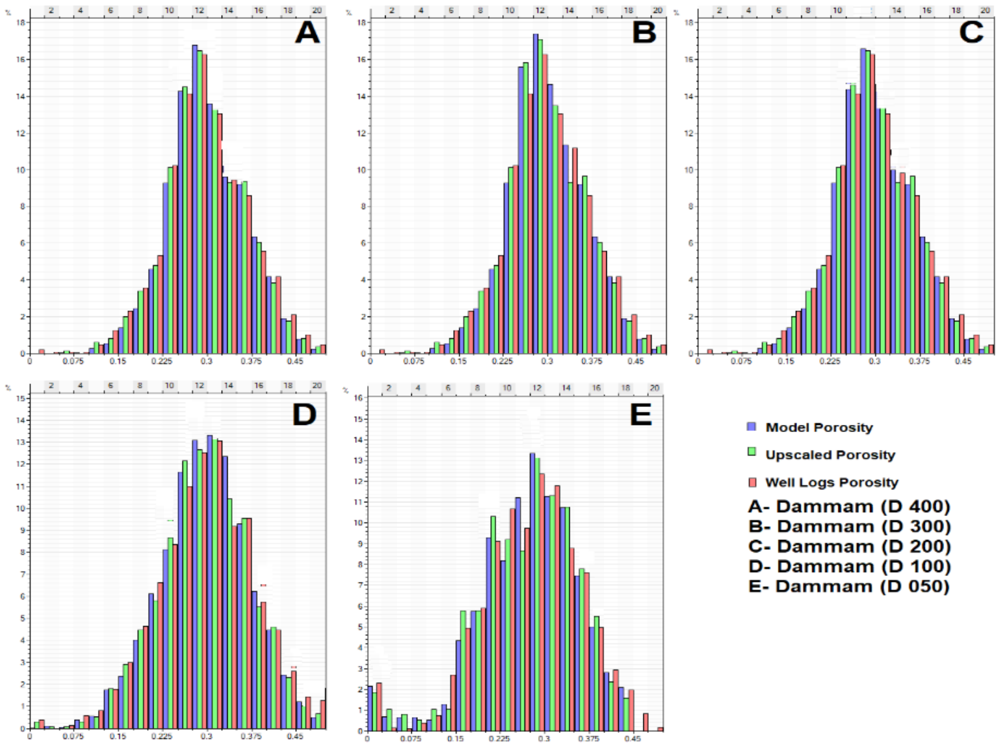

Fig. (11): Porosity Histogram for each Dammam Units.

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3.2.2. Permeability Model.

Permeability (K) is a very important property in dynamic and static models as it relates to the rate of fluid recovery. The permeability in the static model normally has higher uncertainty than the other properties, especially since there is limited data in this case. Only one core of Dammam is available, with limited coverage. Therefore, the Nuclear Magnatic Resonance (NMR) permeability has been calculated using the mufti recreation method, and then the permeability-porosity transform by zone was created using NMR data. Figure (12) shows the porosity-permeability relationship based on NMR for all Dammam units. It is obvious that there is no relationship between NMR permeability and porosity, as shown in Figure (12A). When dividing the NMR data according to zones, it is clear that there is an acceptable correlation between the NMR permeability and NMR porosity for each zone (D400-D 300, D 200, D 100, and D 050) as shown in Figure (12 B, C, D, and E).

This permeability-porosity relationship is required to create upscale permeability directly from upscale porosity for each zone within the Dammam aquifer, and then the permeability model was created by Petrel software. Figure (13) shows the permeability model for each zone within Dammam formation by Petrel software using the stochastic method (Sequential Gaussian Simulation SGS).

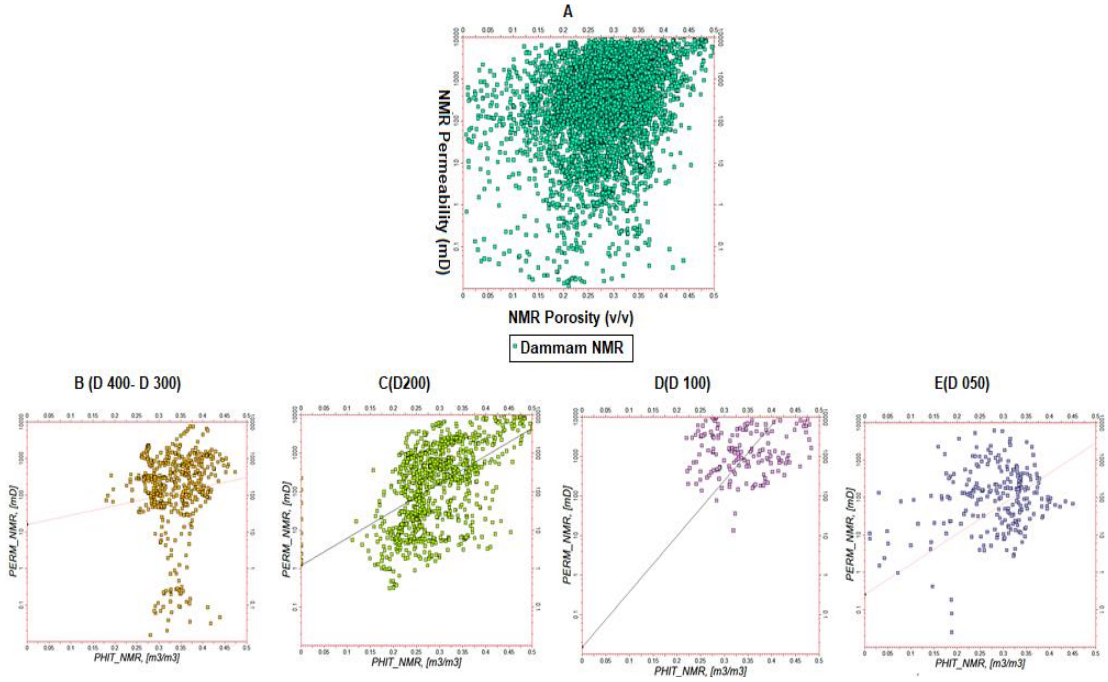

Fig. (12): NMR Porosity – Permeability Relationship

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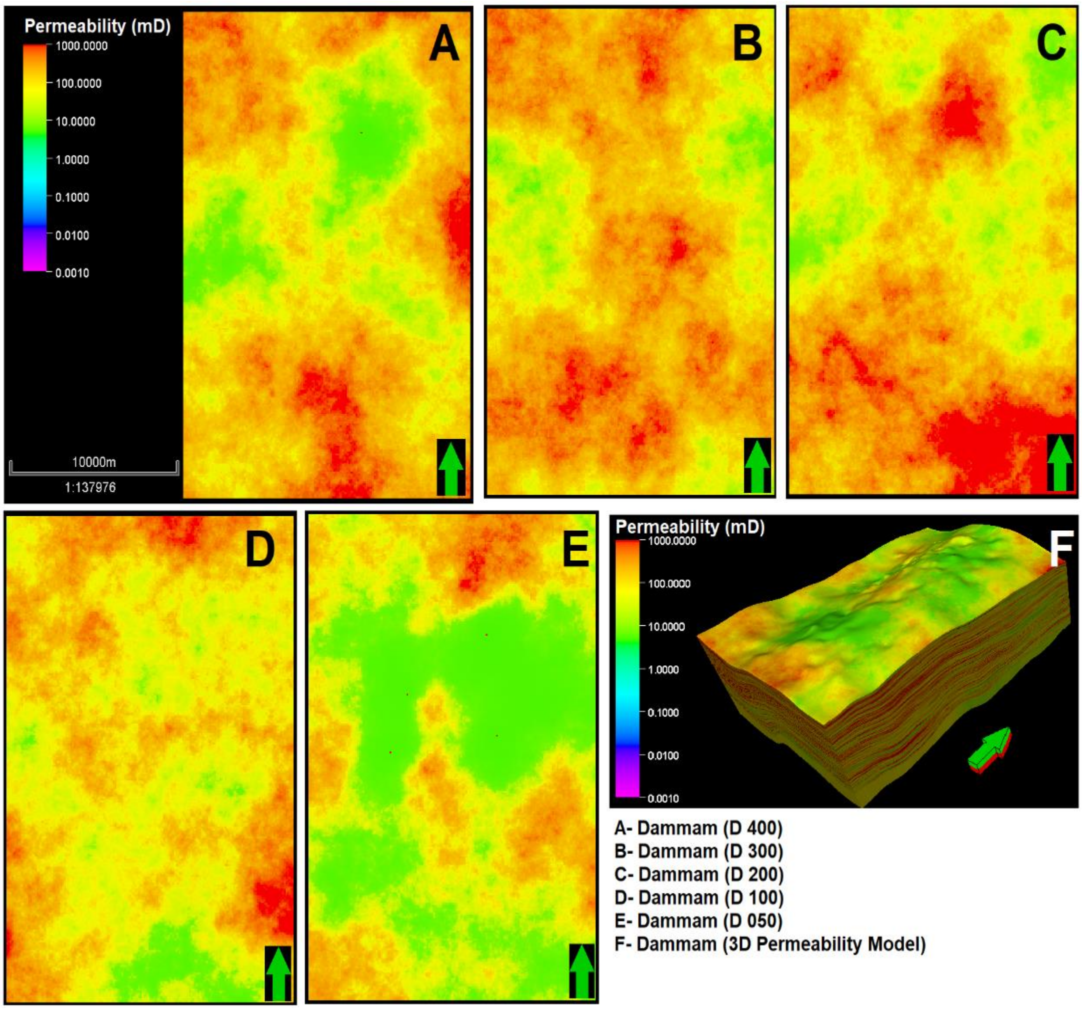

Fig. (13): **Permeability Maps of Dammam Formation.**

4. Conclusions

This study delivers a coherent 3D geological model for the Dammam aquifer in southern Iraq that honors the available data. The model is used to investigate the geometry of the aquifers. The main geological structures are mapped in 3D. The top of the Dammam formation varies from 700m in the southeast to 1000m in the north-west of the Westqurna1 area, and it is exposed to the surface in southwestern Iraq. This static model is used to evaluate the aquifer according to its petrophysical properties (porosity and permeability) and water storage. This study concluded that the Dammam porosity varies from 12 to 45 PU. The originally water in place is approximately 190 billion barrels within West Qurna 1 only. The best Dammam units in terms of porosity and permeability are D 400 and D 200, while the worst unit is D 050. D 300 and D 100 have moderate quality; therefore, in water source wells, it is preferable to produce from the upper part of Dammam (D 400, D 300, and D 200). Finally, this static model is ready to build an azurite dynamic model to predict the

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future performance of the Dammam aquifer in terms of determining the volumes of water that can be extracted from the Dammam.

Abbreviations and acronyms

FMI - Formation Micro Imager log

K- Permeability

NMR - Nuclear Magnetic Resonance Log

Φ - Porosity

PHIT - Total Porosity

SGS - Sequential Gaussian Simulation

WQ1 – West Qurna 1 oilfield.

WQ2 – West Qurna 2 oilfield.

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