# PS Quantitative Subsidence Analysis of the Southeast of the Mesopotamian Basin, Southeastern Iraq: Implications for Basin Evolution Since the Middle Jurassic Period*

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## Abstract

The Mesopotamian Basin is a wide sedimentary basin and its evolution is poorly understood. In this study, subsidence analysis has been carried out to provide insights into the tectonic events that have influenced the basin's evolution, considering the controversy in the chronostratigraphy of the basin that can help to increase more realistic petroleum system modeling. Data constraints for the subsidence analysis have been provided from stratigraphic and wireline log data from 14 wells that penetrate the Cenozoic and Mesozoic successions down to Middle Jurassic strata.

Results from the subsidence analysis reveal distinct tectonic phases of extension in the early part of this basin's history. A main extensional event occurred at approximately 160 Ma with a lithospheric stretching factor of 1.38. There is a doubt whether this event extended to 130 Ma or was followed by another extension. A second extensional phase occurred about 130 Ma and lasted for approximately 20 Myr with a stretching factor from 1.08 to 1.15 across the study area. In about 100 Ma, the southeast part of the basin was subject to a flexural subsidence phase that was followed by two strike-slip related subsidence phases which initiated about 75 Ma to 60 Ma. The second phase was restricted to the northeast part of the study area. Further to the northeast, there is evidence of another strike-slip related subsidence phase during Eocene. During the Miocene, a rapid increase in subsidence highlights the last tectonic event.

Comparing these interpreted results to the geodynamic events shows that the first extensional phase may be caused by the late phase of Triassic-Jurassic rifting in the southern Neo-Tethys. Cretaceous extensional phase(s) should be attributed to the extensional phases during the subduction in the Neo-Tethys, while there is no evidence of a rift. The flexural event in the Late Cretaceous is consistent with the initiation of the ophiolite obduction, in more recent geodynamic studies, and it was followed by two transpressional phases of the ophiolite obduction, during the late part of the Late Cretaceous and Paleocene. Since the obduction did not span to Eocene, it should be related to the subduction in the Neo-Tethys. Eventually, the Arabia-Eurasia collision caused the rapid increasing in subsidence. These tectonic events should be considered in the petroleum system models and can be extended to cover the entire basin in the future.

# Quantitative subsidence analysis of the south-east of the Mesopotamian Basin, south-eastern Iraq

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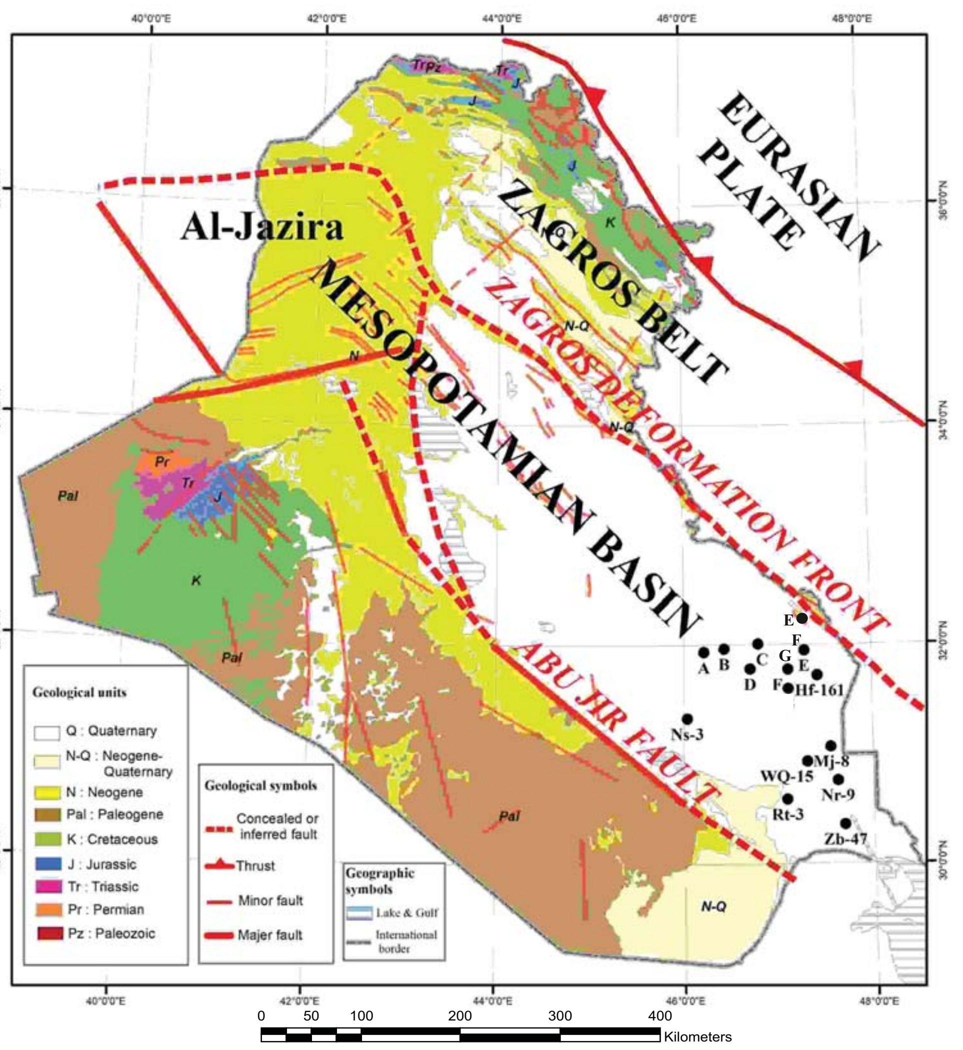
## 1 INTRODUCTION

*West Asia showing the location of the Mesopotamian Basin.*

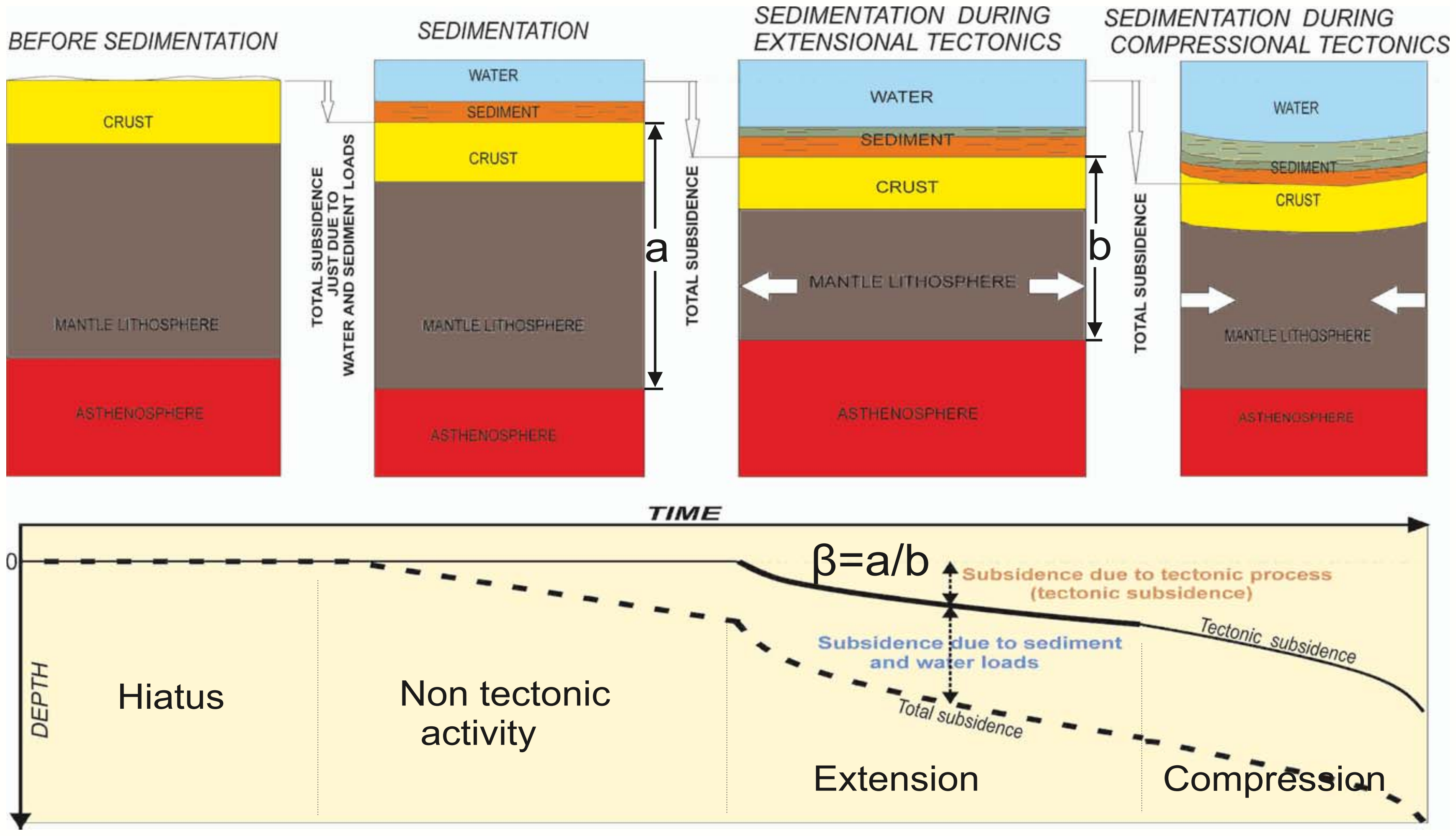


*Geology of the Mesopotamian Basin within Iraq [1, 2] that shows the wells used for this study.*

- The Mesopotamian Basin is a petroleum-rich sedimentary basin mostly located in Iraq (within west Asia) that began its main evolution with the opening of the Neo-Tethys Ocean during the Permian Period.
- In this study, subsidence analysis has been carried out to provide insights into the main tectonic events that have influenced the basin's evolution, particularly during the passive margin setting that lasted from the Permian to the Late Cretaceous periods and that covers a significant part of the basin petroleum system.

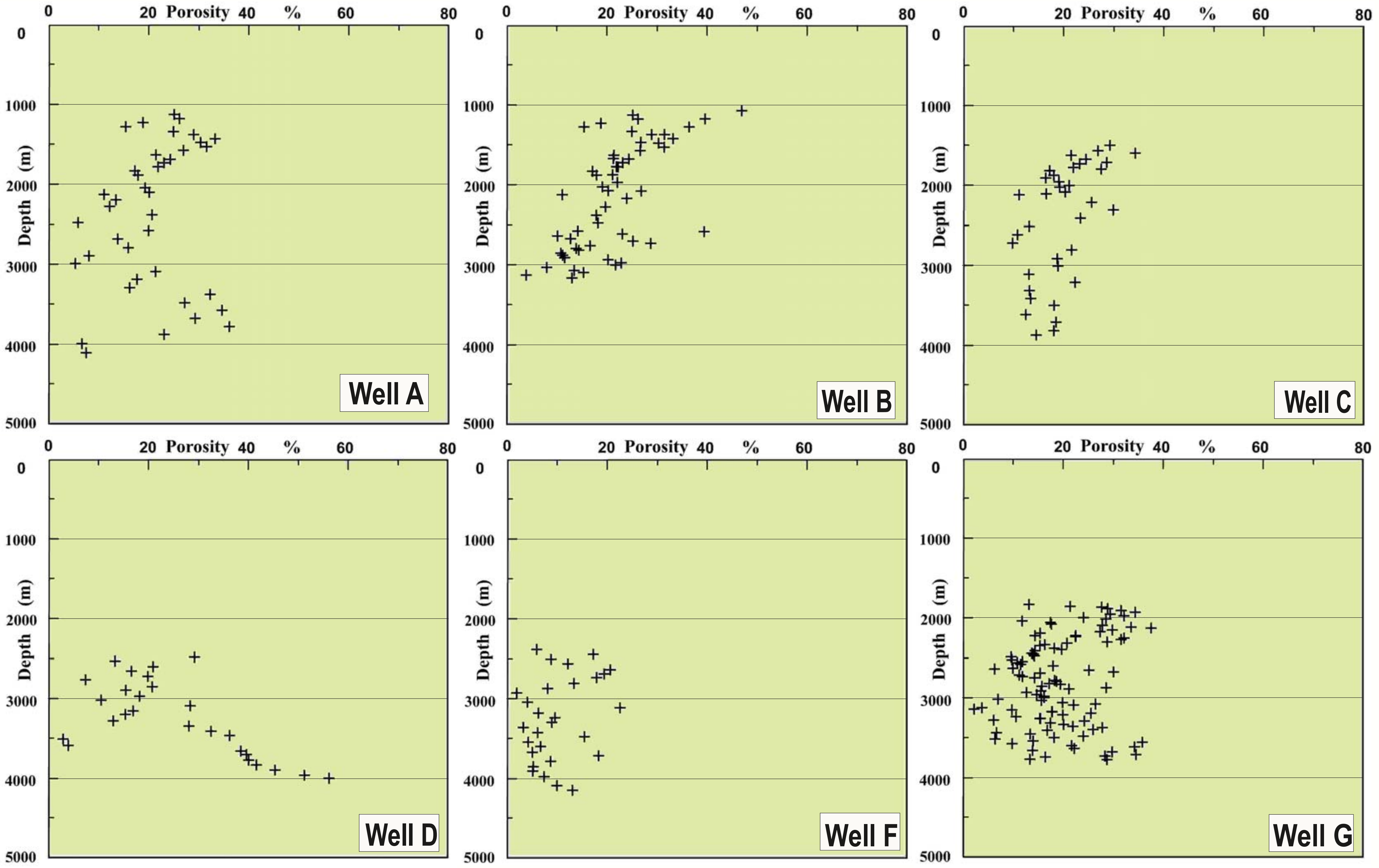
## 2 METHOD: Backstripping

The backstripping method is based on the concept of Airy isostasy. One-dimensional Genesis Zetaware basin modelling software has been used for backstripping. The input raw data is stratigraphical data of wells A to H (received from the Iraqi Ministry of Oil) and other wells,[3,4,5,6] palaeobathymetry (palaeo-water depth) [2] and eustatic sea-level estimate [7].

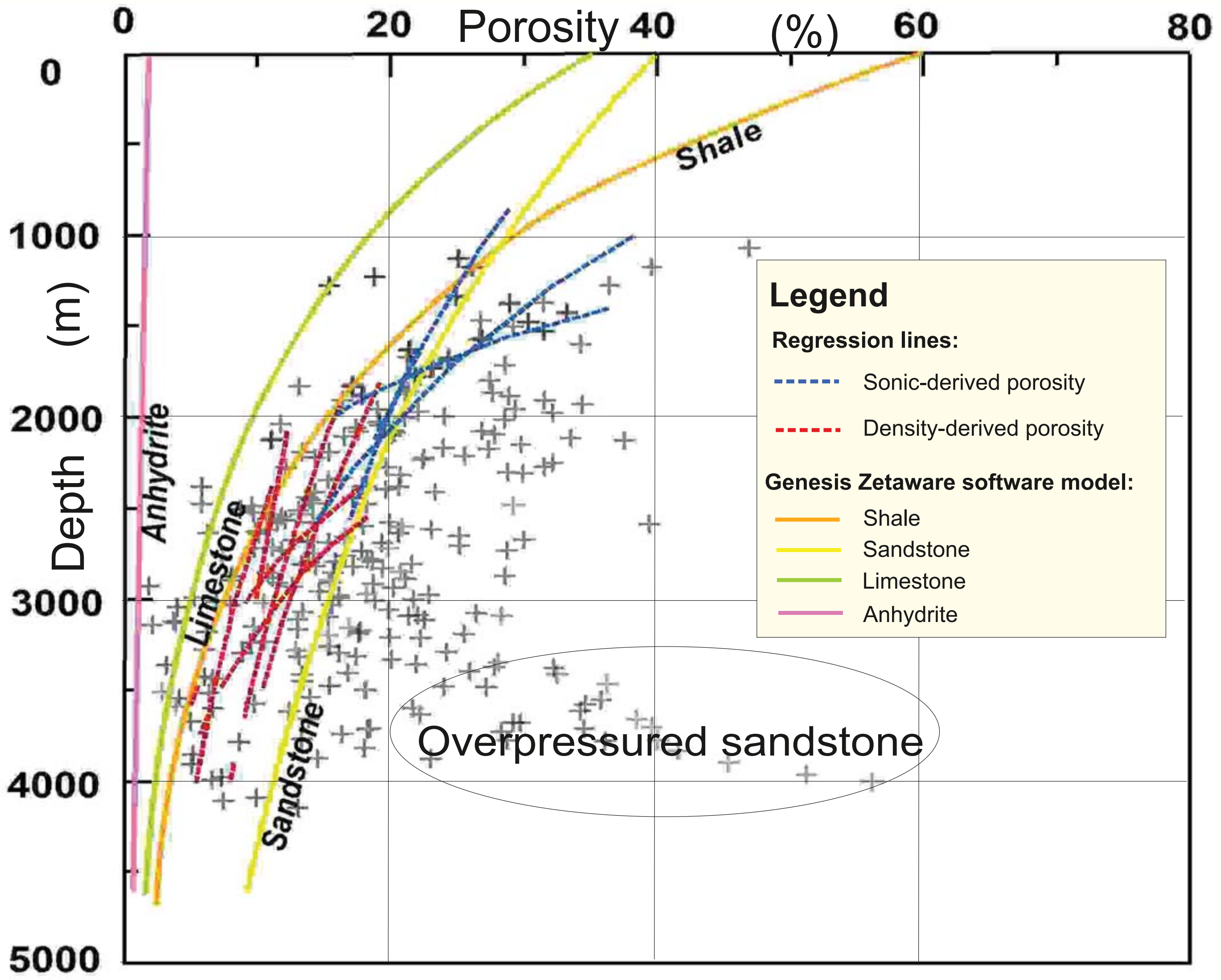


*On the top, schematic cross-sections of the lithosphere illustrate subsidence due to sedimentation within extensional and compressional tectonic regimes. On the bottom, burial history graph shows the tectonic and total subsidence in response to compression (represented by the concave curve) and extension (represented by the convex curve) with a uniform stretching factor (β) .*

## 3 DECOMPACTION: Depth-porosity relationship



Decompaction is the first step of backstripping, so the depth-porosity relationship has been determined from available wireline data of six wells that has be generalized for the whole southeast region of the Mesopotamian Basin.



*The sonic-derived porosity and density-derived porosity are calulated for the six wells. Although the calculated porosities show a wide range, their regression lines mostly follow a specific trend that is located between the sandstone and limestone curves within the Genesis Zetaware software. Overpressured sandstone has been excluded.*

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# Quantitative subsidence analysis of the south-east of the Mesopotamian Basin, south-eastern Iraq: Implications for basin evolution since the Middle Jurassic Period

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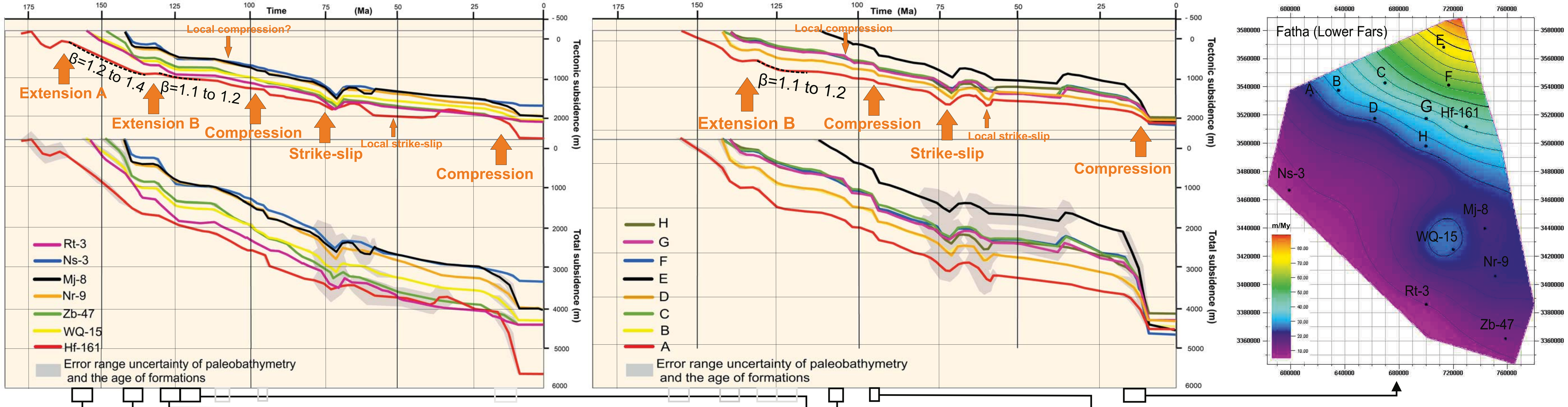
## 4 RESULTS & INTERPRETATIONS: 1-D & 2-D subsidence analysis

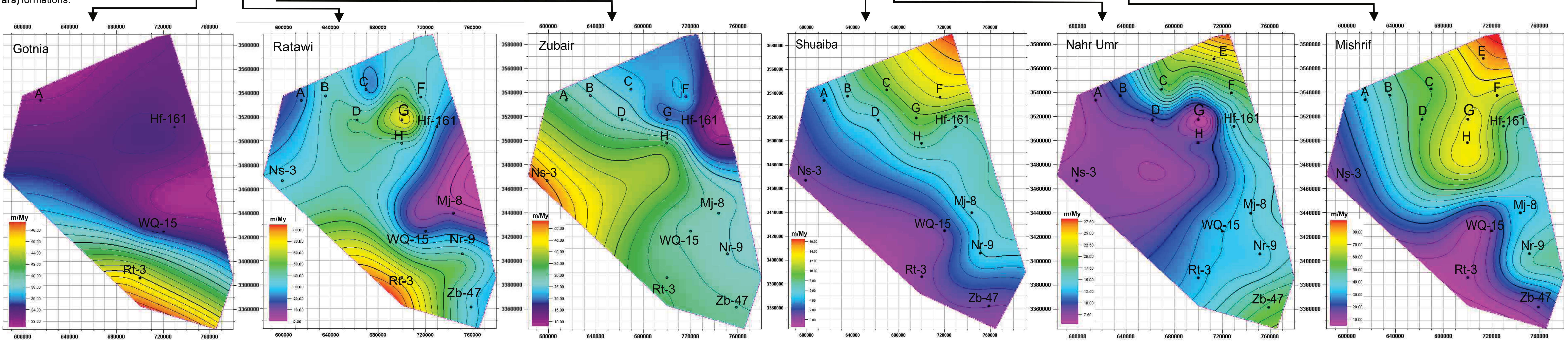
### 1-D subsidence analysis results:

- ***The Middl-Late Jurassic extension***: The first extensional (rifting?) phase (Extension A) occurred ~165 Ma and started with a high tectonic subsidence rate that decreased exponentially during the post-extension (rift?) thermal subsidence phase that deposited the **Najma** and **Qotnia** formations. This event stretched the lithosphere with a β factor of 1.2 to 1.4. After a hiatus, the tectonic subsidence rate decreased (the **Yamama** Formation) and then increased gradually (the **Sulaiy** Formation) in most of the study area that can be related to different processes[8]. During the deposition of the **Ratawi** Formation, the tectonic subsidence rate decreased to a trend similar to the previous post-extension subsidence that eventually ceased by ~135 Ma.
- ***The Early Cretaceous extension***: At around 130 Ma, another extensional (rift?) phase (Extension B) occurred that deposited the **Zubair** and **Shuaiba** formations. It was shorter and less intense than the previous extension and stretched the lithosphere with a β factor of 1.1 to 1.2 with post-extension (rift?) thermal subsidence finished by ~115 Ma.
- ***The local Albian compresional event*** deposited **Nahr Umr** and **Mauddud** formations.
- ***The Cenomanian compressional phase*** deposited the **Ahmadi, Rumaila** and **Mishrif** formations.
- The ***Campanian-Maastrichtian strike-slip phase*** deposited the **Hartha** and **Shiranish** formations.
- ***The local Paleogene strike-slip phase*** deposited the **Aaliji** and **Jaddala** formations.
- At the end of the Cenozoic, the severe ***Neogene compressional event*** deposited the **Fatha (Lower Fars)** and **Injana (Upper Fars)** formations.



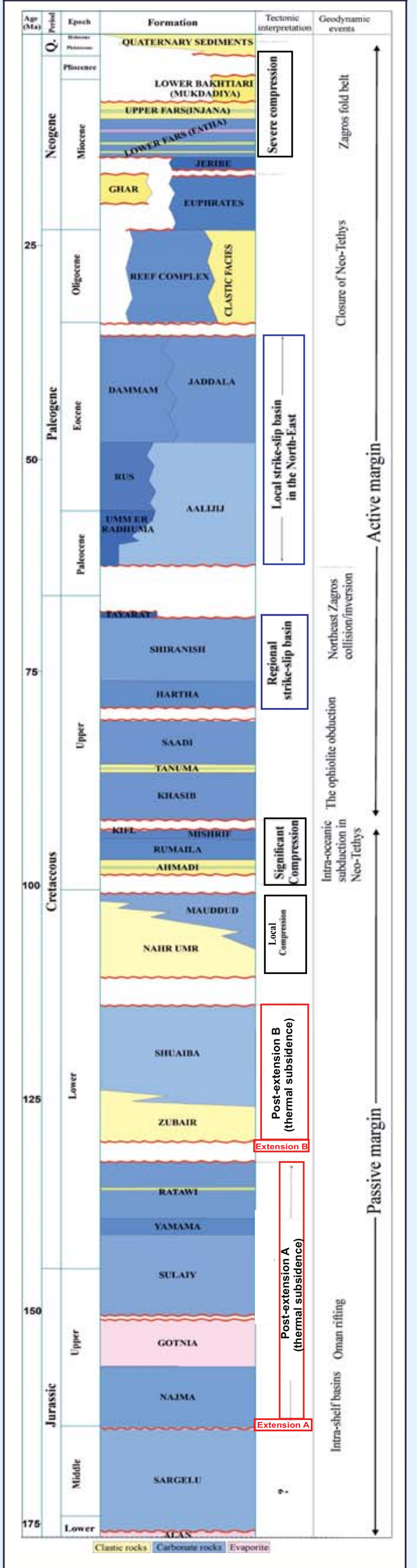
### 2-D subsidence analysis results:

The tectonic subsidence rate of each formation in the studied wells has been calculated from 1-D tectonic subsidence curves. The 2-D distribution maps of tectonic subsidence rate have been sketched using Petrel software 2013 for the study area. Each tectonic event deposited some formations that here just one of two of them are presented. Although all maps generally show the same NW-SE trend, the location of the high rate of tectonic subsidence is different. For example, the map of the Fatha Formation points out that the high rate of tectonic subsidence situated on the north-east where the margin of the Arabian Plate collided with the Eurasian Plate.



*The Gotnia and Ratawi formations deposited during the post extension A and the general trend were kept same. The post extension B deposited Zubair and Shuaiba formations, which followed the same trend, but the high tectonic subsidence rate migrated north-eastward. The maps of the Nahr Umr, Mishrif and Lower Fars formations, which represent the following compressional phases, show the same general trend and the high tectonic subsidence rate in the north-east that is probably proposed the tectonic influence of the northern east margin of the Arabian Plate*

## 5 TECTONIC EVENTS



*Tectonostratigraphic chart of the studied area showing the main interpreted tectonic events based on 1-D subsidence analysis. The geodynamic events of the Arabian Plate are presented for the comparison[2,9].*

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# Quantitative subsidence analysis of the south-east of the Mesopotamian Basin, south-eastern Iraq

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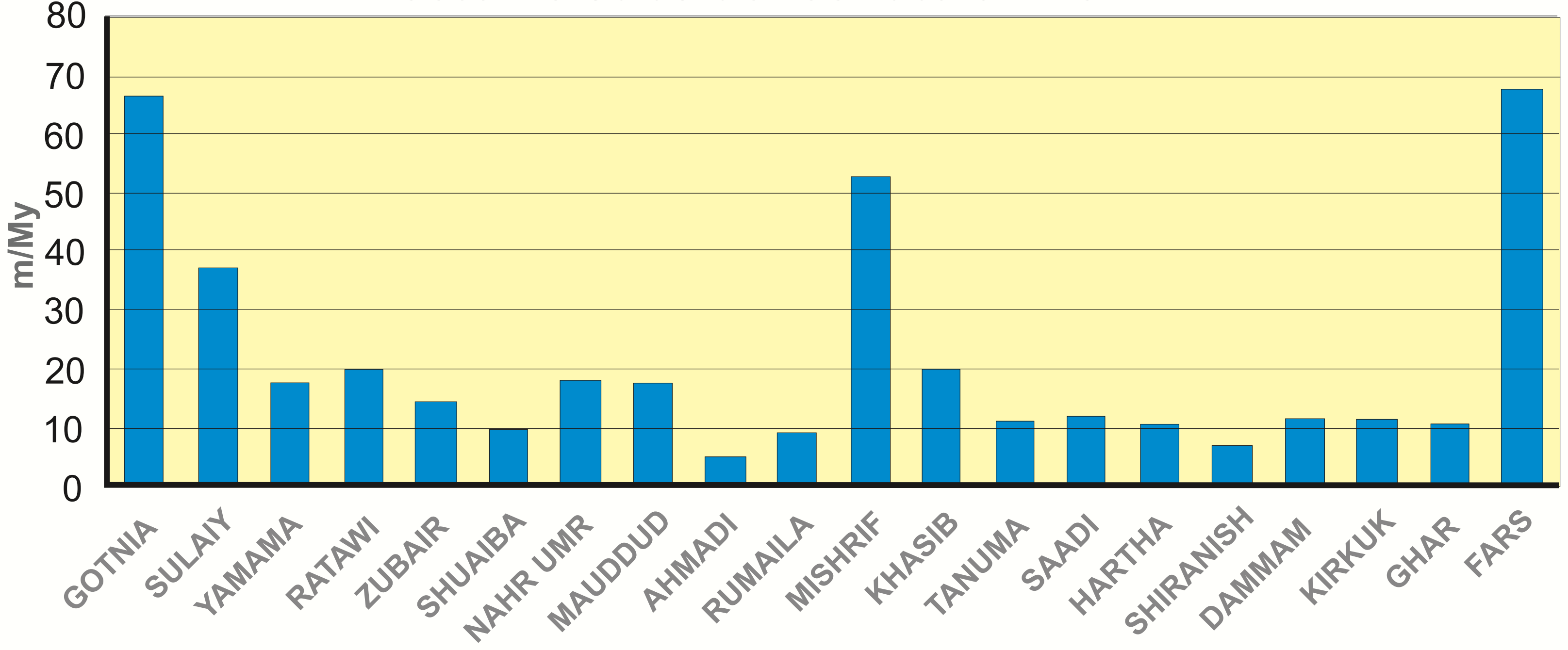
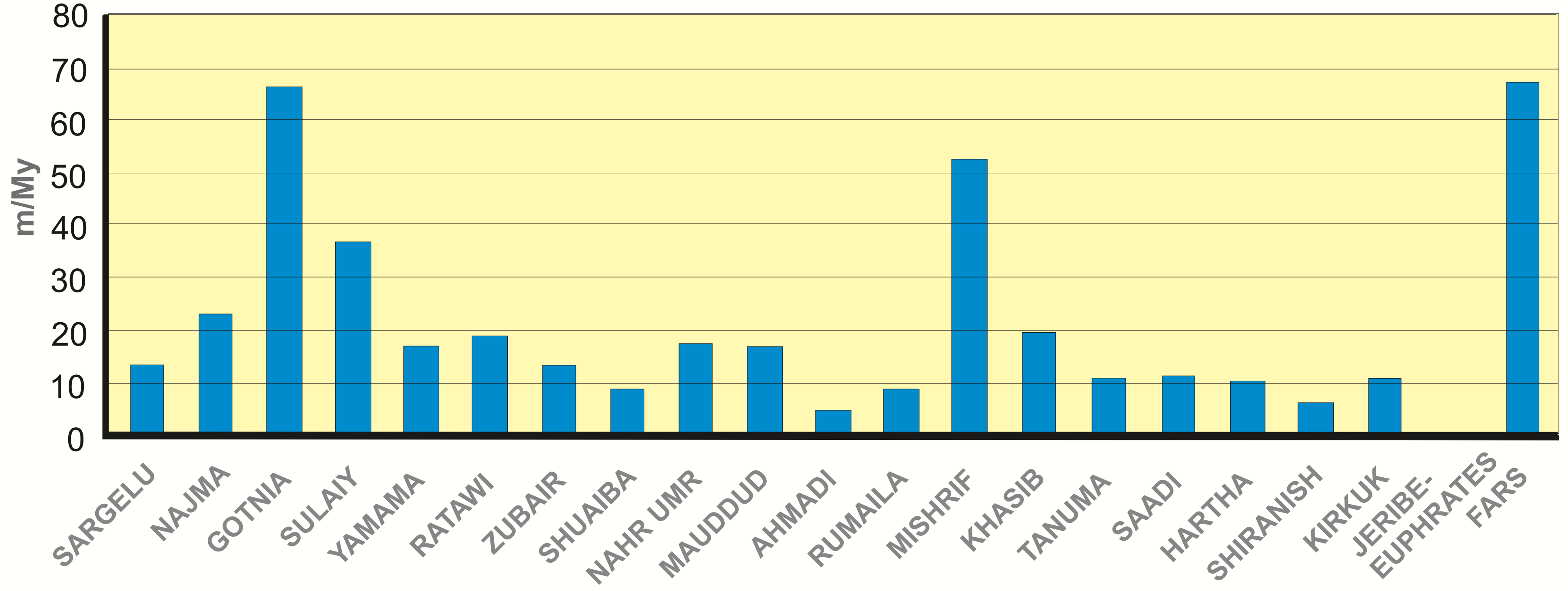
## 6 THE RELATION BETWEEN TECTONIC SUBSIDENCE RATE AND SEDIMENTATION RATE

Through the backstripping method, the decompaction correction provides the decompacted formation thickness during deposition. The decompacted formation thickness has been divided by the duration of sedimentation to calculate sedimentation rate which is compared with tectonic subsidence rate. It provides some insight into the tectonic influences on sedimentation that is generally straightforward but concerning all factors, which may effect on such relationship, it should say that this relationship is more complicated to be investigated easily in detail in such graphs.

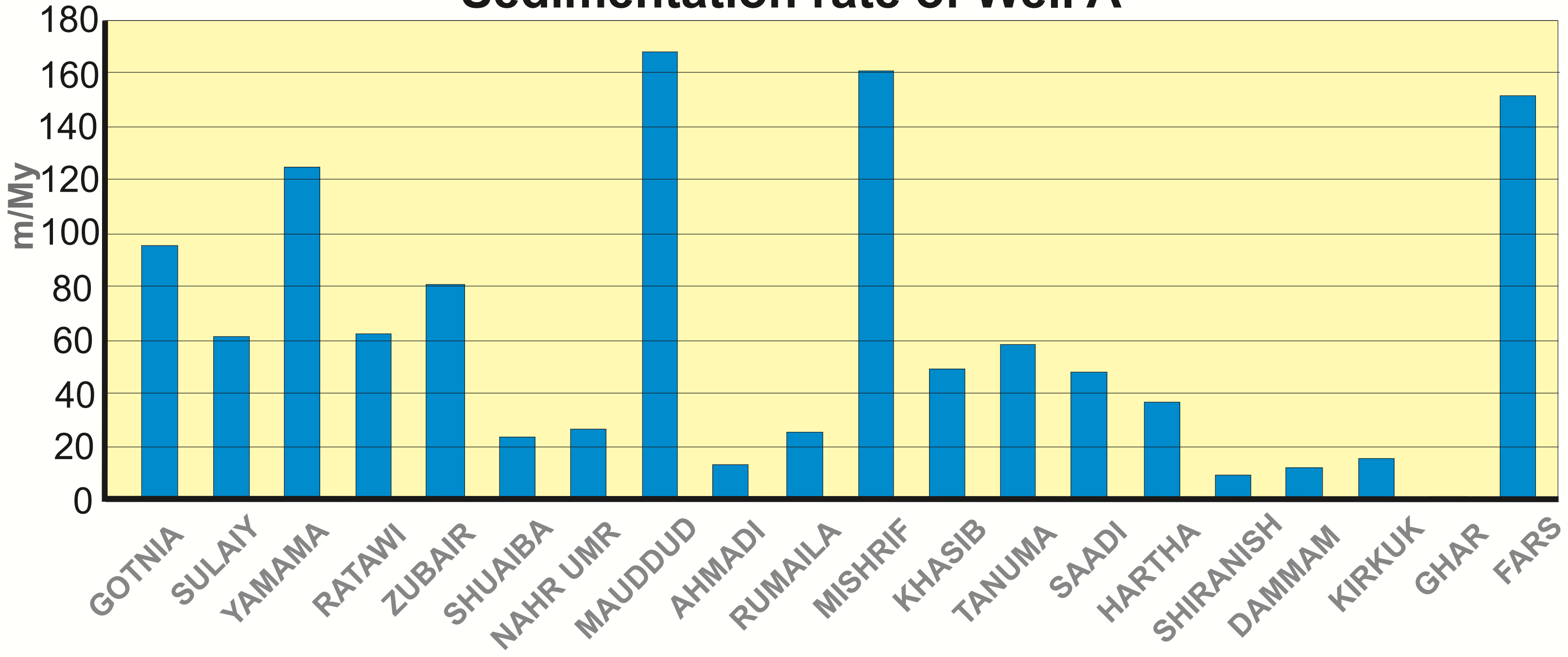
**Tectonic subsidence rate of Well A**



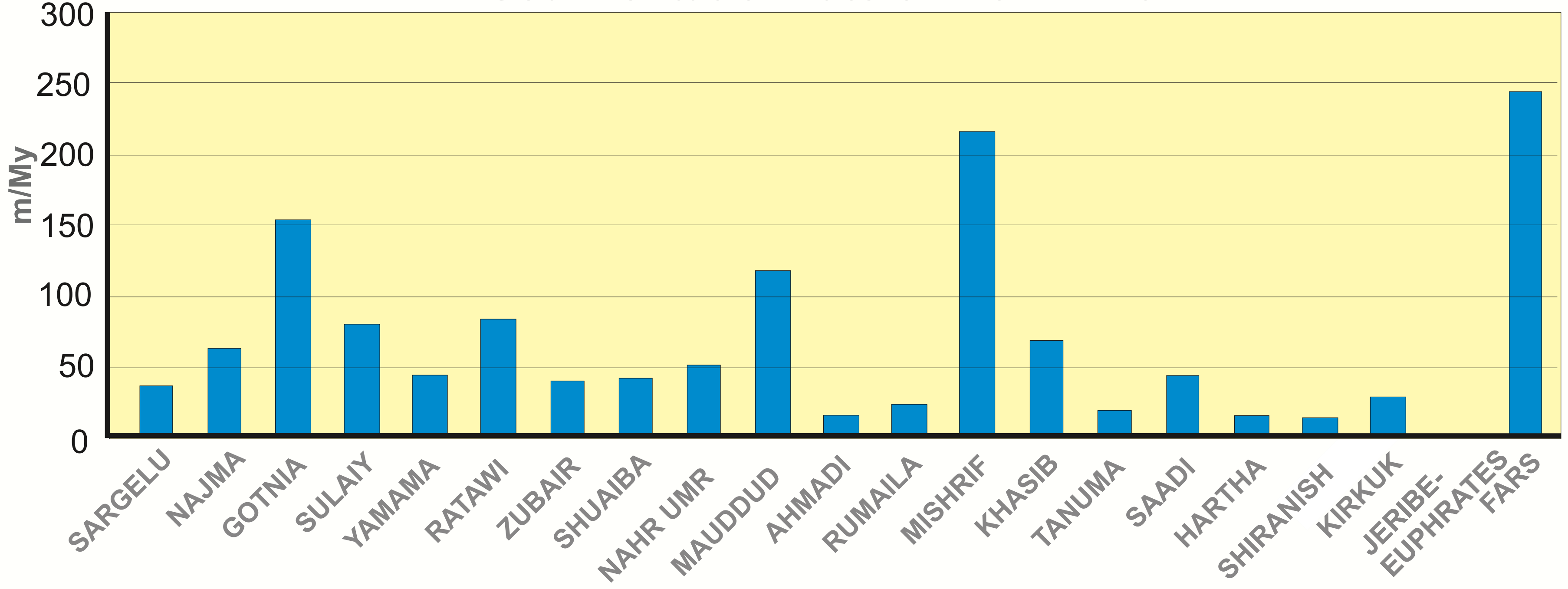
**Tectonic subsidence rate of Well Hf-161**



**Sedimentation rate of Well A**



**Sedimentation rate of Well Hf-161**



*The above graphs illustrate the relationship between sedimentation and tectonic subsidence rates of Wells A and Hf-161 , in the west and the east of the study area, respectively. Some formations such as the* ***Gotnia, Mishrif*** *and* ***Fars*** *formations has high rates of tectonic subsidence and sedimentation.Conversely, the relationship is not always straightforward as shown by the* ***Mauddud*** *and* ***Yamama*** *formations , where the high sedimentation rate appears to have been less affected by tectonic subsidence.*

## 7 CONCLUSION

Facilitated by subsidence analysis, the tectonic events that have influenced the evolution of the southeast of the Mesopotamian Basin have been studied. The following tectonic events, since the Middle Jurassic, have been identified:

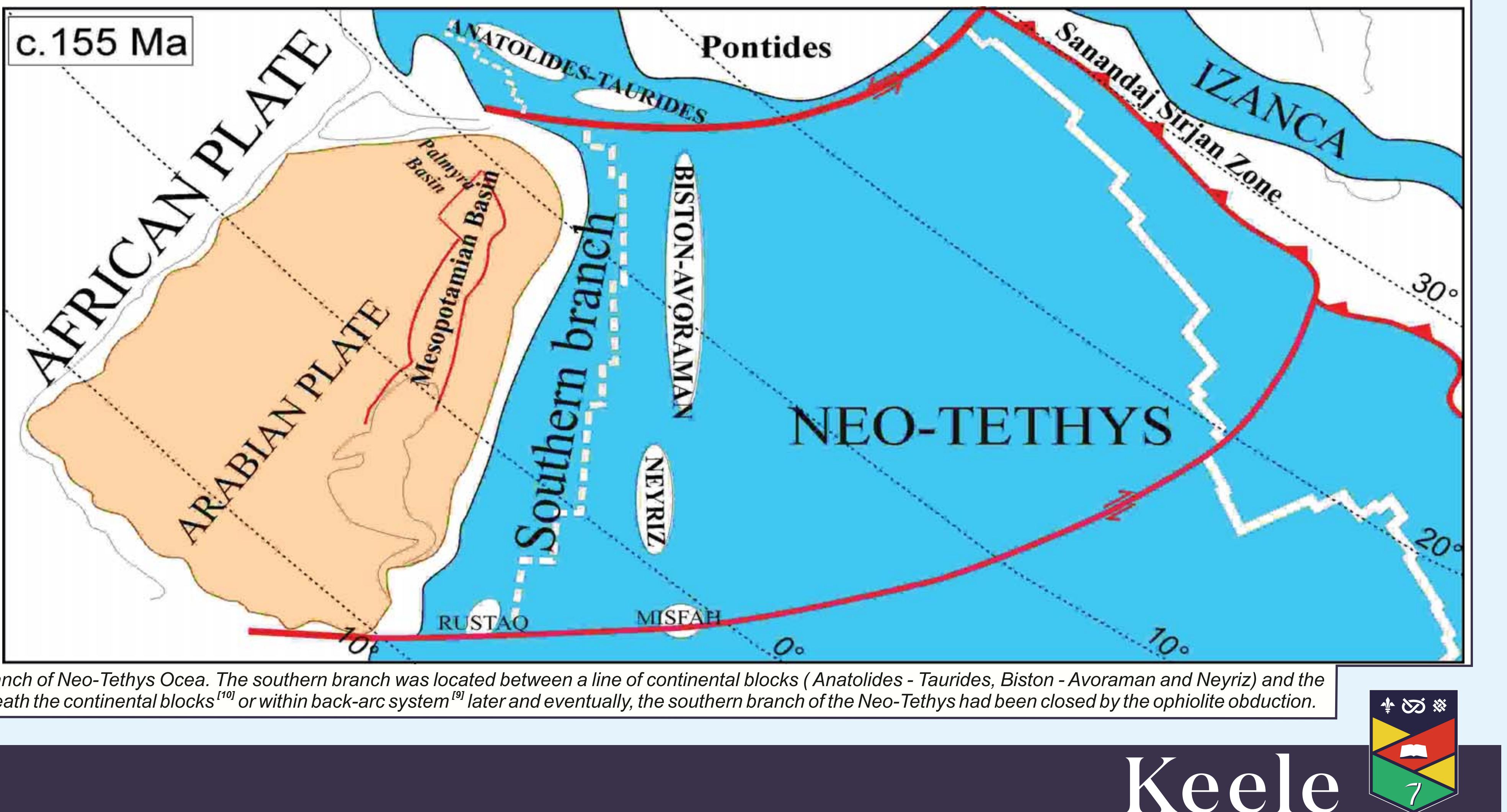
1- The Middle-Late Jurassic and the Early Cretaceous extensional phases caused significant thermal subsidence. The lithospheric stretching factor (ß) for the first extension phase was 1.2 to 1.4, depending on the chronostratigraphic models as well as the density of infill assumed. The stretching factor (ß) related to the second extension phase ranged between 1.1 and 1.2 over the different wells. These extension phases most likely represent the post-extension (rift?) episodes associated with the development of the southern branch of Neo-Tethys Ocean. They were the last main extensional phases experienced by the southeast of the Mesopotamian Basin.

2- Cenomanian compression dominated the region that deposited the Mishrif Formation, which shows the highest rates of tectonic subsidence and sedimentation. This event could represent the first stage of the ophiolite obduction.

3- The previous event was followed by dominantly strike-slip deformation during the Late Cretaceous to Paleogene that were marked by a deep sedimentary environment.

4- The last compression occurred during the Neogene representing the closure of the Neo-Tethys Ocean.

In addition to these main tectonic phases, a less dominant compressional subsidence phase occurred during the Albian and led to the deposition of the Nahr Umr formation. Testing the relationship between tectonic subsidence and sedimentation provides a general view about the tectonic influence on sedimentation.



*Tectonic reconstruction of the Late Jurassic, Kimmeridgain (155 Ma) that depicts the possible location of the mid-oceanic ridge of the southern branch of Neo-Tethys Ocea. The southern branch was located between a line of continental blocks ( Anatolides - Taurides, Biston - Avoraman and Neyriz) and the north-east margin of the Arabian Plate [2,9,10]. The Arabian Plate (coloured by pale brown) was attached to the African Plate. This ridge subducted beneath the continental blocks [10] or within back-arc system [9] later and eventually, the southern branch of the Neo-Tethys had been closed by the ophiolite obduction.*

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