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REVIEW ARTICLE

BASIN CLASSIFICATION OF SHOUSHAN BASIN, WESTERN DESERT, EGYPT

Jong E Cheng*

Sarawak Energy Resources, Sarawak Energy Berhad, 93050 Kuching, Sarawak
**Corresponding Author E-mail: echengjong@gmail.com*

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ABSTRACT

Several research works have been carried out on Shoushan Basin, Western Desert including the petroleum system in the Shoushan Basin. However, there is no proper classification was done on Shoushan Basin, Western Desert, Egypt using Global Basin Classification. The objective of this study is to classify Shoushan Basin using Global Basin Classification as proposed by Kingston et al. (1983a, b). The study which was done by integrating different types of data including geochemical, well log, seismic data from literature review provided a better understanding of the evolution and the hydrocarbon potential of Western Desert. Shoushan Basin consists of two basin types which included Margin Sag (MS) Cycle Basin and Wrench Cycle Basin (LL). The combination of these cycles, stages and tectonic event results in the formula being written from the youngest to the oldest as follows: LL - 2/LD/MS – 321321321.

KEYWORDS

Basin Classification, Shoushan Basin.

1. INTRODUCTION

The Western Desert (Figure 1) covers about 700,000 square kilometres which is equivalent to the size of Texas and is about two-thirds of Egypt's land area. Egypt borders the Mediterranean Sea to the north, the Red Sea to the east, Sudan to the south and Libya to the west. Western Desert consists of a few extensional coastal rift-basins included Alamein Basin, Abu Gharadig Basin and Matruh-Shushan Basin.

The aim of this study is to classify Shoushan Basin using Global Basin Classification [1,2]. The objectives were achieved by understanding the evolution of Shoushan basin, Western Desert. The integration of different type of data included geochemical, well log, seismic data from literature review provided a better understanding of the evolution and the hydrocarbon potential of Western Desert.

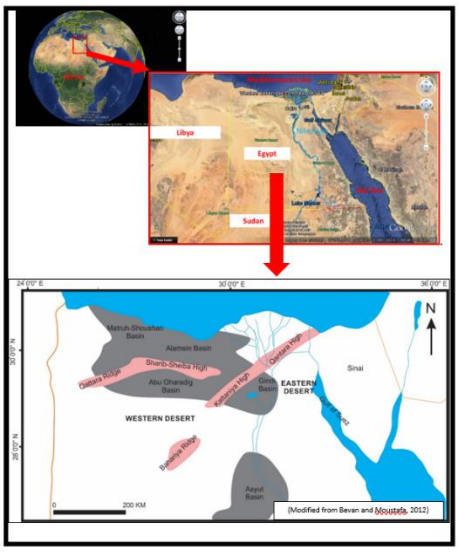


Figure 1: Location map showing significant sedimentary basins in Western Desert.

2. BASIN EVOLUTION AND BASIN CYCLES

2.1 Burial History of Shoushan Basin

The development of Shoushan Basin (rift basin) can be divided into Pre-rift (Paleozoic), Syn-rift (Jurassic- to Middle Cretaceous) and Post-rift (after Middle Cretaceous). During rifting phase or syn-rift stage, the crust was stretched, thinned, faulted followed by increased heat flow due to upwelling of the asthenosphere [3]. During syn-rift, the basin would have attained its highest heat flow [4]. Tectonic subsidence rate curves indicate rapid subsidence during the Middle and Late Jurassic which continued during the Early Cretaceous time. This subsidence due to changes in crustal thickness or stretching is represented by the steep part of the burial history diagram (Figure 2).

During post-rift stage, thermal cooling subsidence occurs due to thermal decay to re-establish the thermal equilibrium in the mantle lithosphere and asthenosphere [3]. During post-rift, the heat flow of basin will be declining [4]. The post-rift stage is represented by flatter slope of the burial history diagram (Figure 2) which indicates the dominance of thermal cooling subsidence during Albian- (113Ma) to Coniacian- age (88Ma).

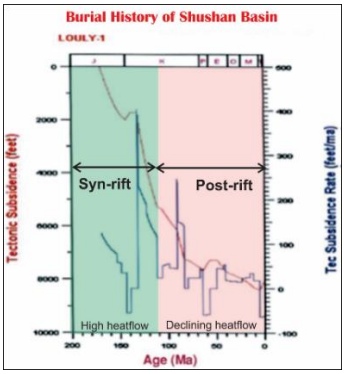


Figure 2: Tectonic subsidence rate curve for Louly-well, Shoushan Basin [4].

2.2 Cycles of Shoushan Basin

Shoushan Basin is polyhistory basin that initially evolved during the Middle Jurassic as a continental rift elastic basin, was overprinted by collision during the subsequent Late Cretaceous–Early Tertiary, becoming a convergent margin basin, and then viscoelastically thermally subsided up to the present as a divergent margin basin [4].

In this study, it is recognised that Shoushan Basin evolve through two cycles included Cycle 1: Margin Sag Basin (MS) and Cycle 2: Wrench Basin (LL) (Figure 3).

Cycle 1: Margin Sag Basin (MS) consists of Phase 1: Syn-rift (Early Jurassic – Aptian) and Phase 2: Post-rift Sag (Albian – Coniacian). During Phase 1: Syn-rift, rifting occurred followed by Phase 2: Post-rift Sag, subsidence due to thermal subsidence and sedimentary loading. Phase 1 and Phase 2 were resulted in formation of continental divergent cycle type basin [Cycle 1: Margin Sag Basin (MS)].

Cycle 2: Wrench Basin (LL) consists of Phase 3: Inversion (Campanian – Eocene) and Phase 4: Post-inversion Sag (Oligocene). During Phase 3: Inversion, basin was inverted due to Syrian-Arc Inversion followed by Phase 4: Post-inversion Sag, basin continue to subside due to thermal subsidence and sedimentary loading and resulted in formation of continental convergent cycle type basin [Cycle 2: Wrench Basin (LL)].

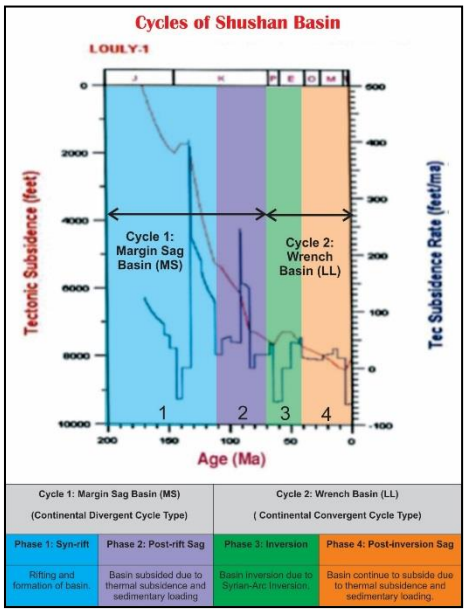


Figure 3: Cycles of Shushan Basin [5].

3. STRATIGRAPHIC SEQUENCE OF SHOUSHAN BASIN

The stratigraphic succession of the Western Desert was subdivided into four major regressive cycles and each regressive cycles were terminated by a marine transgression [6].

However, a more comprehensive stratigraphic column which defines the tectono-sequence was proposed in 2012. The stratigraphic succession of Western Desert into can be divided four tectono-sequence (Figure 4) included Tectono-sequence 1: Paleozoic; Tectono-sequence 2: Jurassic-Coniacian; Tectono-sequence 3: Santonian–Late Eocene and Tectono-sequence 4: Late Eocene-Pliocene [5].

The Paleozoic extends across the whole of northern Egypt with two exceptions; on the margins of the Gulf of Suez/ Red Sea (Red Sea Hills and Sinai), where the Paleozoic has been removed in part due to Cenozoic rift-related uplift. In Western Desert, Paleozoic succession exceeds 3000m in thickness.

Tectono-sequence 2 is defined on the basic of being syn-rift during the opening of the Tethys margin and the development of rift-basin on the greater Tethyan passive margin. There are three cycles of transgressive sedimentation included, (2a) Jurassic, (2b) Early Cretaceous and (2c) Late Cretaceous.

Tectono-sequence 2a consists of a transgressive sequence from non-marine clastic (Lower Jurassic Ras Qatarra Formation), shallow-marine mixed clastics and carbonates (middle Jurassic Khatatba Formation), and shallow marine carbonates (Upper Jurassic Masajid Formation). There is a major unconformity between the Masajid Formation and Alam El Bueib Formation [6].

A major regression at the beginning of the Early Creaceous marks the base of tectono-sequence 2b with deposition of the non-marine to shallow-marine clastic deposition (Alam El Bueib Formation). The transgression reached its maximum with the marine deposition of the Aptian-age Alamein Dolomite and Dahab Shale at the end of tectoono-sequence 2b. Jurassic and Lower Cretaceous sediments are commonly deposited in half-graben syn-rift wedge in the Western Desert. The Alamein Formation and Dahab Formation were deposited across the region and are only absent, through non-deposition or erosion (Figure 4).

The Albian- to Coniacian-aged tectono-sequence 2c could be a post- rift sequence to the earlier Jurassic and Early Cretaceous syn-rift sequences. Albian-aged regressive clastic sequences unconformably overlie the Dahab Shale and represent the base of another transgressive cycle. The fluvial to shallow-marine Kharita Formation marks the base of tectono-sequence 2c and is followed by the shallow-marine clastic of the Bahariya Formation, which are Early Cenomanian in age. The transgression continued into the Late Cenomanian, when carbonates of the basal Abu Roash Formation were deposited (the Abu Roash G Member).

The base of Tectono-sequence 3 is marked by a regressive phase of deposition in the Santonian. The Khoman B Member shale were deposited in relatively restricted basins which were previously tectonically active [7]. The major phase of transgression, starting in the Campanian, led to increased sea levels in the latest Cretaceous to Eocene, followed by the deposition of the chalks and limestones of the Khoman A and Apollonia Formations in the Western Desert.

The Late Eocene-Oligocene Dabaa and Miocene Moghra marine clastic unconformably overlie the Apollonia Formation. In the vicinity if the inversion folds, this has an angular relationship. The Marmarica Formation represents the Middle Miocene part of this sequence.

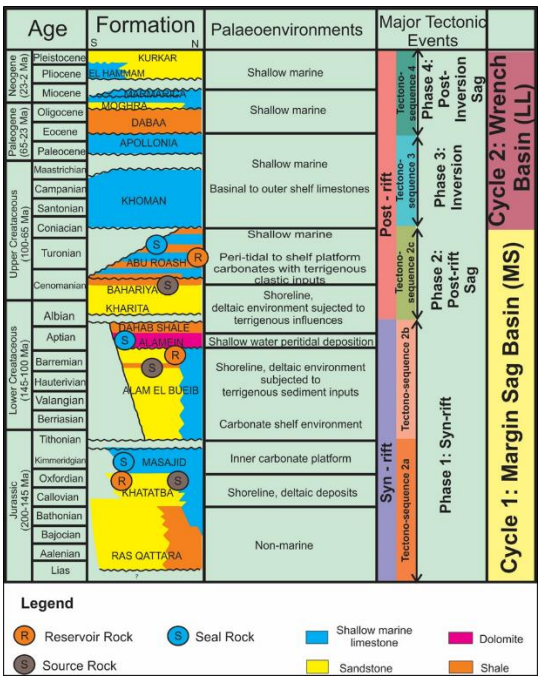


Figure 4: Phases and cycles of Shushan Basin on Stratigraphic Column [5,8]

4. STRATIGRAPHY OF JURASSIC SEDIMENT AT SHOUSHAN BASIN

The stratigraphy of Jurassic sediment at Shoushan Basin as the Khatatba Formation underlies the Masajid Formation [9,10]. The stratigraphy of Jurassic sediment at Shoushan Basin as the Khatatba Formation overlies the Ras Qattara Formation and underlies the Masajid Formation (Figure 5) [4,11].

The Khatatba Formation at Shoushan Basin was divided into Zahra

Member and Safa Member [13]. The stratigraphic scheme for the Jurassic sediment of the western Desert, which can be more or less correlated to the rock succession at Shoushan Basin [13]. Khataba Formation was divided into four member included Lower Safa Member, Karbit Member, Upper Safa Member and Zahar Member by a researcher [13].

Safa Member is characterised by sandstones, alternating with siltstones and coals, although shale and limestone are important secondary constituents with the age of Bathonian [13]. The member is often split into two (Upper Safa Member & Lower Safa Member) by the carbonate-dominated Kabrit Member. Kabrit Member is dominated by thin and thickly-bedded limestones, with subordinate shales, sandstones and coals with the age of early Bathonian. However, Kabrit Member cannot be recognised in the Shushan and Clysmic Basins [13]. Safa Member was deposited at fluvial coastal plain which comprises meander-belt facies [12] and braided-stream facies sandstone interbedded with coastal-swamp coals and carbonaceous shales [11].

Zahar Member is characterised by roughly-equal proportions of thinly bedded shale and limestone aged from mid-Bathonian to early Callovian which act as transitional unit between the Masajid Formation and the Safa Member, the Zahra Member does constitute a clearly-recognizable interval [13]. Jurassic succession was separate by an unconformity due to period of uplift, tilting, partial erosion and karstification during Late Jurassic [12,13].

Khatatba Formation at Shoushan Basin was divided into Unit 1: Marine Shelf and Unit 2: Fluvial Coastal Plain [11]. The Khatatba Formation in the Shoushan Basin into lower units: Fluvial Coastal Plain and upper units: Marine Shelf [12]. The Middle Jurassic Khatatba Formation is formed by fluvial-deltaic clastic grading upwards into marine shales and limestones [12].

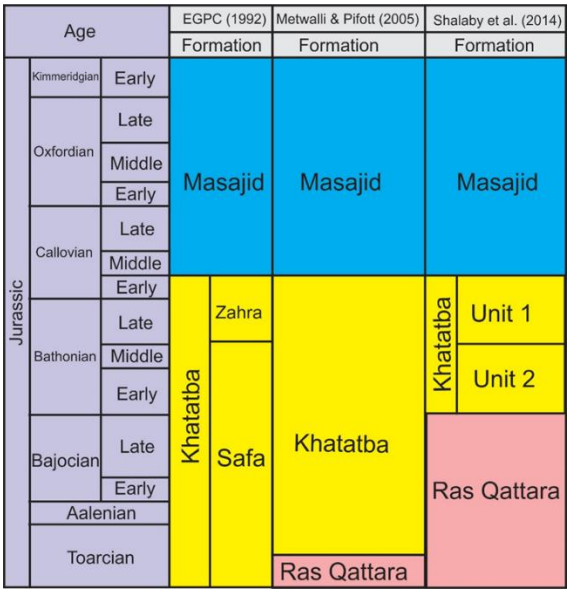


Figure 5: Several stratigraphy of Jurassic sediment at Shoushan Basin considered by different authors.

5. Global Basin Classification of Shoushan Basin

Shoushan Basin was classified based on global basin classification system and combine the structural and stratigraphic elements to make a formula [1,2]. Formula summarized the important points included structural and depositional history of Shoushan Basin. In this classification of basin and writing its formula, only main events in the basin history were outlined.

Shoushan Basin was classified by comparing basin parameter included cycles, depositional stages, and tectonic event of a polyhistory basin combine to create the basin formula (Figure 7). Figure 6 is a cross-section of a basin to be formulated and Figure 7 translates the cross-section events into the formula.

Shoushan Basin consists of two basin types included Margin Sag (MS) Cycle Basin and Wrench Cycle Basin (LL). The top or youngest cycle of Shoushan Basin is a Wrench Cycle (LL) with wedge middle (2) overlies with an unconformity. This unconformity corresponds to an episoidic wrench with moderate to strong magnitude (fold and flower structure can be recognized on seismic section) which known as Ld event. This Ld event occurred during Late Cretaceous. The Wrench Cycle (LL) was ended by basin-modifying tectonic or Ld event. The next older event is Margin Sag (MS) Cycle with wedge top, wedge middle and wedge base (3,2,1). Combination of these cycles, stages and tectonic event results in the formula being written youngest to oldest as follows: LL - 2/LD/MS – 321321321. The formula with the abbreviated ages of each cycle written above the formula was shown in Figure 7.

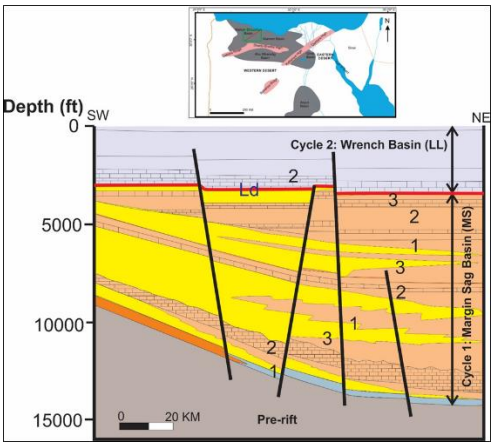


Figure 6: Cross-section of Shoushan Basin shows it is polyhistory basin which consists of two cycles included Cycle 1: Margin Sag Basin (MS) and Cycle 2: Wrench Basin (LL) [10].

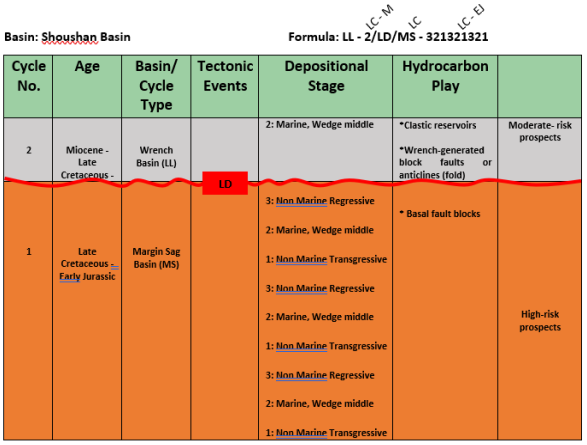
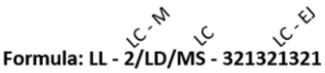


Figure 7: Comparison of basin parameters of Shoushan Basin.

6. CONCLUSION AND RECOMMENDATION

Shoushan Basin consists of two basin types which included Margin Sag (MS) Cycle Basin and Wrench Cycle Basin (LL). The combination of these cycles, stages and tectonic event results in the formula being written from the youngest to the oldest as follows:



After Shoushan Basin was classified, the favourable plays and risks for each basin type can be evaluated. The potential play of Margin Sag (MS) Cycle Basin is Basal fault blocks and it is classified as high-risk prospects [2]. The potential play of Wrench Cycle Basin (LL) is clastic reservoirs and wrench-generated block faults or anticlines (fold). Wrench Cycle Basin (LL) is classified as moderate- risk prospects.

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