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A Note on Stratigraphic Data and Geodynamic Evolution of Sistan Suture Zone (Neo-Tethyan Margin) in Eastern Iran

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ABSTRACT

The Sistan suture zone (Eastern Iran) belongs to the Tethian suture, which was formed during the Early Cretaceous to Paleogene. This suture zone is divided into two tectono-sedimentary provinces (Gazik and Sahlabad) that reflect different paleo-geographic domains. The zone was created as a marginal basin, which opened prior to the Early Aptian between the Lut block and Afghan margin as a consequence of northeastward subduction of the Neo-Tethys Ocean. The active margin accretionary facies accumulated in the eastern region of this suture (Gazik Province) during the Late Cretaceous (pre-Maastrichtian), whereas passive margin facies and deep basin facies were deposited in western region (Sahlabad Province) at this time. This narrow oceanic domain was closed in three steps with an east to west progradation, in the Maastrichtian to Late Eocene. This interpretation results from new microbio-stratigraphic data from the accretionary facies and Ophiolitic mélanges emplaced in this narrow mobile belt.

Keywords: Stratigraphy, Geodynamic evolution, Lut and Afghan margins, Sistan suture zone, Eastern Iran.

1. INTRODUCTION

The Sistan suture zone (Tirrul et al., 1983) belongs to Cenozoic Alpide suture of Sengor et al. (1988). This suture, previously called "East Iranian Flysch Trough" (Stocklin, 1974; Berberian and King, 1981) is one of the remnant basins (vestige of Waser ocean in Afghanistan) in Neo-Tethys, located between two micro-continental fragments that collided as a result of the tectonic migration of Lut block (west) towards Afghan block (East). The studied area is situated in the north-central part of this suture and is limited by the following coordination: 58° 30'to 60° 30' E and 32° to 33° N (Fig. 1). It is generally divided into two provinces: Gazik province in the east and Sahlabad province in the west (Babazadeh, 2003). It was interpreted as a basin (Sefidabeh basin) that was deposited in onlapping relationship with two ophiolitic complexes (Ratuk and Neh) (Tirrul et al., 1983). During Early Cretaceous-Eocene times, the Sistan suture zone was characterized by an autochtonous facies consisting of an ophiolite suite, a deep marine facies (pelagic limestones, radiolarian cherts), allochthonous elements containing the resedimented facies (passive and margin facies) in the foreslope (peripheral domain) and isolated platforms (shelf domain) including the patch reef, etc. No detailed stratigraphy has yet been worked out in this area. This paper aimed to relate the new stratigraphic data from the normal marine sediments, ophiolitic mélange and accretionary facies to paleogeodynamic and plate tectonic in this region.

2. METHODS

2. 1. NEW STRATIGRAPHIC DATA

2. 1. 1. EARLY CRETACEOUS (SECTIONS S & SH)

The best lower Cretaceous deposits crop out in the Soulabest area (section S) of the Gazik province and in the Shirshotor area of the Sahlabad province. This area is limited by 60° 17' to 60° 20' of longitude east and 32° 30' to 32 ° 33' of latitude north (Fig. 1). The Soulabest radiolarites consist of stratified basalts, radiolarian Cherts and red radiolarian argillaceous Cherts, pillow-lavas and patched limestones with the intercalation of the cherts. They are unconformably covered by Maastrichtian conglomerates and hippuritic limestone (Babazadeh, 2003; Babazadeh & Dewever, 2004). Two faunal assemblages were reported in the radiolarites.

Assemblage I consists of the following radiolarian association: Dictyomitra excellens (Tan, 1927); Archaeodictyomitra aff.

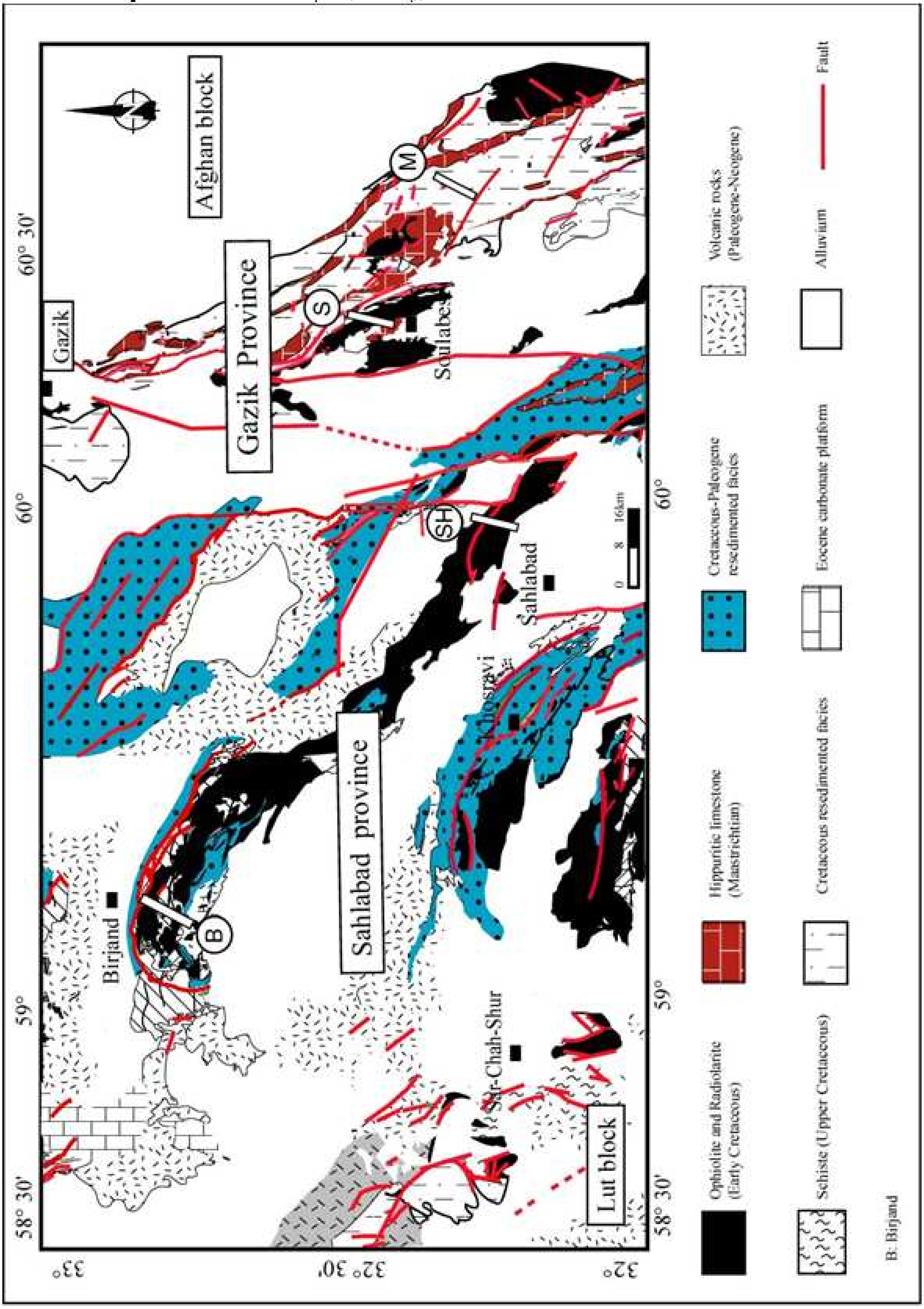

Fig. 1: Structural sketch map showing the Sistan suture zone containg Gazik and Sahlabad Provinces. Sections S , SH, M and B are assigned to Soulabest , Shirshotor , Mahirud and Birjand areas.

Vulgaris Pessagno, 1977; A. apiarium (Rüst, 1885); A. sp.; Podobursa aff. typica (Rüst, 1898); Stichomitra communis Squinabol, (1903); S. cf. japonica Nakaseko & Nishimura, (1979); S. sp., Thanarla pacifica Nakaseko & Nishimura, 1981; T. aff. brouweri (Tan, 1927); Xitus elegans (Squinabol, 1903); Dactyliodiscus cf. lenticulatus (Jud, 1994); Stichocapsa cf. robusta Matsuoka, 1984; Cryptamphorella cf. conara (Foreman, 1968); Hiscocapsa cf. asseni (Tan, 1927) and Parvicingula sp. This assemblage can be compared with Hiscocapsa asseni Zone and Turbocapsula verbeeki Zone of O'Dogherty (1994). This association allows assigning an early Aptian age.

Assemblage II yields the following radiolarian association: Thanarla pulchra (Squinabol, 1904); Thanarla sp. aff. brouweri; Thanarla aff. veneta (Squinabol, 1903); Archaeodictyomitra aff. vulgaris; A. sp.; Dictyomitra gracilis (Squinabol, 1903); D. montisserei (Squinabol, 1903); Pseudodictyomitra pseudomacrocephala (Squinabol, 1903); P. paronai (Aliev, 1965); Rhopalosyringium solivagum O'Dogherty, 1994; R. mosquense (Smirnova & Aliev, 1969); R. perforaculum O'Dogherty, 1994; R. adriaticum O'Dogherty, 1994; R. scissum O'Dogherty, 1994; R. hispidum O'Dogherty, 1994; R. sp. 1; R. sp. 2; Stichomitra communis.; Xitus mclaughlini (Pessagno, 1977); X. elegans; Dorypyle communis (Squinabol, 1903); Holocryptocanium barbui Dumitrica, 1970; Cryptamphorella cf. conara.; Protoxiphotractus sp.; Pseudoaulophacus cf. sculptus (Squinabol, 1904); Dactyliodiscus cf. lenticulatus; Diacanthocapsa cf. ovoidea Dumitrica, 1970; Crolanium aff. cuneatum (Smirnova & Aliev, 1969). This association can be similar to Pseudodictyomitra psedomacrocephala Zone of Vishnevskaya (1993) and Holocryptocanium barbui Zone of Bak (1999). The age of this association ranges from middle to late Albian.

In the Shirshotor area (section SH), the sedimentary series consists of bedded volcano-sedimentary rocks (green tuff) with underlying breccia and intercalations of red radiolarian Cherts. This area is located between 59° 56' to 59° 58' E longitude and 32° 14' to 32° 17' N latitude (Fig. 1). This sequence continues with gray limestones containing planktonic foraminifera. The radiolarian faunal assemblage is characterized by Psedodictyomitra lodogaensis, Psedodictyomitra cf. pentacolaensis, Psedodictyomitra aff. homatissima, Psedodictyomitra sp., Cryptamphorella conara, Cryptamphorella cf. sphaerica, Archeodictyomitra sp., Thanarla sp. 1, Thanarla sp. 2, Saitoum sp. The age is assigned to Aptian.

The top of sequence is overlain by a conglomerate horizon passing upward into a debris flow deposit (debrit) assigned to the Late Campanian (Babazadeh, 2005).

2.1. 2. LATE CRETACEOUS; CENOMANIAN-CAMPANIAN (SECTION M)

The section B is limited between 60° 32' to 60° 33' E longitude and 32° 17' to 32° 20' N latitude (Fig. 1). The Upper Cretaceous deposits are characterized by two types of sediment. The active margin accretionary facies containing sandstones, shale, limestone and basaltic blocks (olistostrome) accumulated in Mahirud-Lahnu region of the Gazik province (Fauvelet and Eftekhar-Nezhad, 1990; Babazadeh, 2003), whereas a passive facies showing a succession of pelites, micritic limestones, calcarenites (turbidite) and deep basin facies (pelagic limestones and radiolarian chert) deposited at Shirshotor area (section SH) in the Sahlabad province of this suture zone at this time (Babazadeh et al. 2007, Babazadeh, 2008).

The foraminiferal biostratigraphy of the section studied is based on planktonic forms examined in thin section. The sedimentary unit of Shirshotor area was deposited in deep marine environment and it is more accurately dated with the succession of index planktonic foraminiferal species. Five biozones have been identified on the occurrence of index planktonic foraminifera in this region.

Biozone A: Marginotruncana sigali Zone; Age: Late Turonian

Biozone B: Dicarinella concavata Zone; age: Latest Turonian to Early Santonian

Biozone C: Dicarinella asymetrica Zone; age: Santonian

Biozone D: Globotruncanita elevata Zone; age: Early Campanian

Biozone F: Globotruncanita calcarata Zone; age: early Late Campanian

Biozone E: Globotruncana ventricosa Zone; as the succession is truncated by an olistostrome this Biozone is lacking.

2. 1.3. MAASTRICHTIAN

- CONGLOMERATIC UNIT (SECTION S)

This unit shows a succession of conglomerates, sandstones, limestones and gray conglomerates at the Soulabest area (Gazik province). The conglomeratic layers are composed of basaltic fragments, radiolarian cherts and limestone containing Maastrichtian benthic foraminifera such as Orbitoides media, Siderolites calcitrapoides, Omphalocyclus macroporus and Hippurites (Osculigera sp.).

It covers unconformably pre-Maastrichtian ophiolitic mélange and accretionary facies. Its outcrops are fairly continuous and can be observed throughout this province. This unit changes laterally into reef limestones containing Maastrichtian Hippurites. It shows two interdigitated facies such as conglomerate and reef in the Gazik province.

Remarks: No resedimented facies showing the peripheral domain are observed in the Gazik province during Maastrichtian.

- TURBIDITIC FACIES

Turbidites are only observed in the Sahlabad province during Maastrichtian time. They are composed of a succession of gray limestones containing Maastrichtian planktonic foraminifera, fine grained sandy limestones and Calcarenites Calcisphaerulids. These facies correspond to distal Turbidites, deposited in the fore-slope basin (peripheral domain).

Remark: No conglomeratic facies are observed in the Sahlabad province during this period.

2. 1. 4. PALEOCENE

During the Paleocene, the Hippuritic reefs and the conglomerates are replaced by carbonate turbidites (allodapic limestones). The resedimented facies consists of pelagic debrites and turbidites were mainly deposited in Sahlabad province. They are characterized by turbidity current and debrit flows at the foreslope in the peripheral domain.

2. 1. 5. EOCENE (SECTION B)

This section is limited by 59° 15' to 59° 17' of longitude east and 32° 42' to 32° 43' of latitude north (Fig. 1). The shallow water carbonate terrigenous deposits are containing algal limestones, benthic foraminiferal calcarenites and reefal limestone facies (bindstone and grainstone) including opertorbitolites douvillei Nuttall, Alveolina aragonensis Hottinger, Alveolina avellana Hottinger, Alveolina pasticillata Schawager, Nummulites globulus Leymerie, Lockhartia conditi (Nuttall) and Miliolids, overly Paleocene deep marine resedimented facies at some places in Sahlabad province.

This succession is attributed to forearc basin deposits (Dickinson & Seely, 1979). However, the Early Eocene transgressive conglomerates containing basalt fragments, cherts and sandy limestone fragments unconformably cover the ophiolitic mélange south of Birjand (section B) in the Sahlabad province. The Early-Middle Eocene deep resedimented facies, containing a succession of sandstones, shales, pelagic limestones with exotic blocks of basalt were deposited in other places. A late Eocene reefal unit with the basal conglomerates unconformably covered the early Eocene resedimented facies in the Sahlabad province.

3. RESULT AND DISCUSSION

3. 1 GEODYNAMIC EVOLUTION

The Ophiolitic sequence, the accretionary prism and the passive and active margin facies make up the essential tectonic units in the Sistan suture zone (Fig. 2).

In Jurassic time, the subduction producing the andesite rocks commenced under Sanandaj-Sirjan zone in the Neo-Tethys (south of central Iran) (Berberian & King, 1981; McCall & Kidd, 1982; Sengor et al., 1988). The Arabian plate was located at a great distance. There is no evidence of any subduction in Makran at this time, although Jurassic pelagic deposits in the inner Makran indicate the development of a rift (McCall & Kidd, 1982).

During the Early Cretaceous, the Eurasiatic active margin was fragmented and the back arc oceanic basins separated Tabas block from Lut block, as well as Lut block from Afghan margin (Masse et al., 1993; Babazadeh, 2003). The later basin corresponds to Sistan Ocean. This event is confirmed by the presence of Aptian radiolarites (Babazadeh & De Wever, 2004). The Sanandaj-Sirjan Zone was separated from Tabas block by Baft-Nain Rift.

In the Upper Cretaceous (Cenomanian- Campanian), The Arabian plate was brought closer by the NE dipping subduction zone, and for the first time Semail Ophiolites in Oman were obducted (McCall & Kidd, 1982; Sengor et al., 1988). The Hawasina thrust slice of Oman was stacked up in this subduction zone. In Campanian time, the collision is completed with the Semail ophiolite being emplaced on top of the stacked Hawasina continental margin sequence (McCall & Kidd, 1982). A passive margin facies and a deep marine basin facies were deposited in the western part of the Sistan ocean (Sahlabad province) and an accretionary facies formed in the eastern part of this ocean (Gazik province) in reason of NE dipping subduction zone during the Late Cretaceous (Babazadeh, 2003). The Sanandaj-Sirjan zone was still separated from the Tabas block by the Baft-Nain marginal basin. During the Maastrichtian, the Semail ophiolite was emplaced and unconformably overlain by a conglomerate. There was an ocean to the NE of the Zagros, between Sanandaj-Sirjan, Tabas-Lut and the Sistan (McCall & Kidd, 1982; Camoin et al., 1993). No collision of the Arabian plate with the Makran region occurred during this period. The Ophiolitic mélange and the accretionary facies are unconformably covered by maastrichtian conglomerates in the Gazik province, whereas a passive marginal facies was formed in the Sahlabad province. The interruption of convergence in the

Gazik province may have been caused by the presence of coloured mélange uplift in the central part of the Sistan suture zone. The hypothetical presence of this uplift led to the deposition of passive margin facies in the Maastrichtian and an active Paleocene-Eocene margin facies in the Sahlabad province. However, there were no Maastrichtian reworked conglomerates in this province.

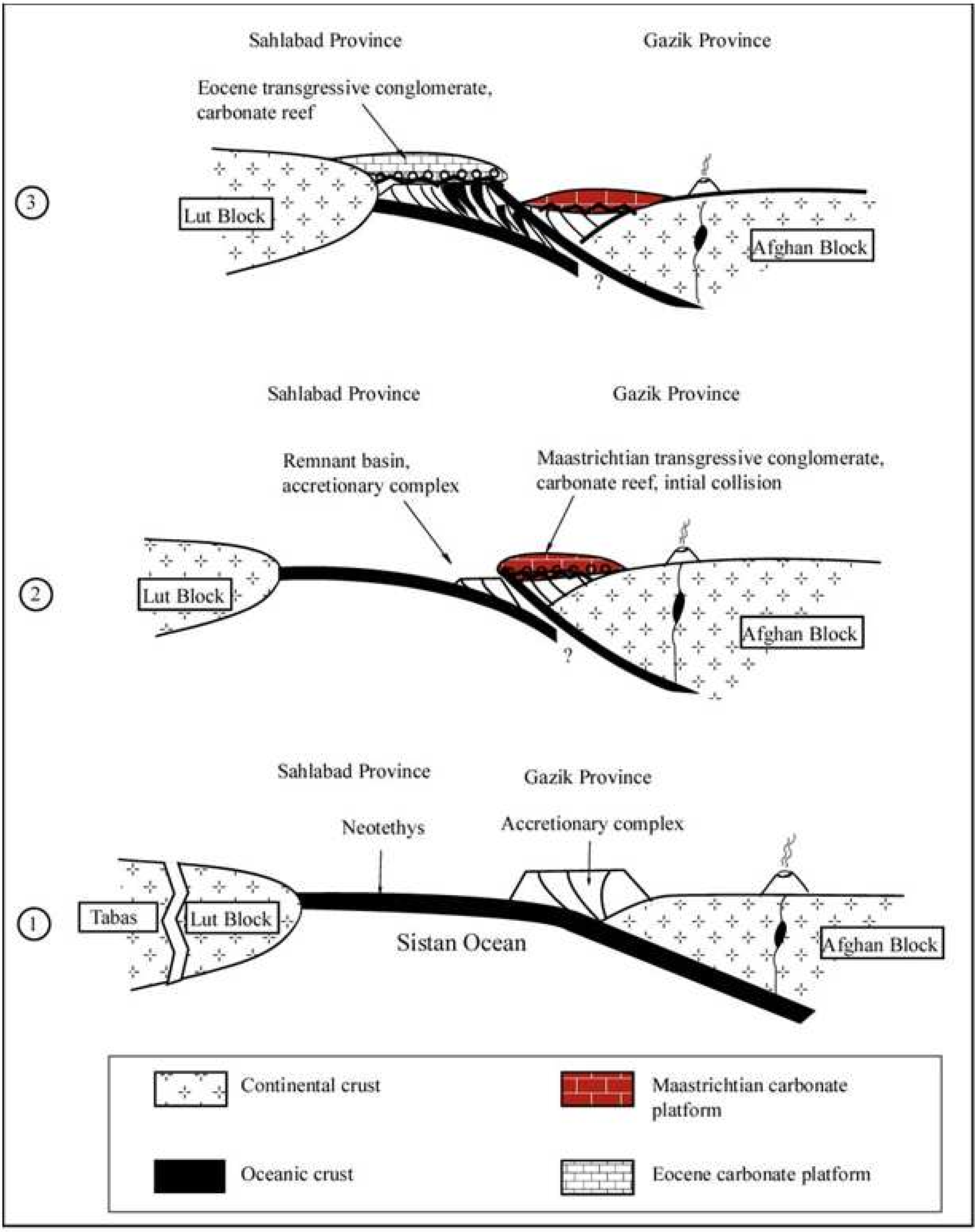

Fig. 2: Schematic model showing the geodynamic evolution of the Sistan suture zone. 2-1) Early to Late Cretaceous: the passive margin facies and a deep marine basin facies were deposited in the western part of the Sistan ocean (Sahlabad province) and an accretionary facies formed in the eastern part of this ocean (Gazik province). 2-2) Maastrichtian: The ophiolitic mélange and the accretionary facies are unconformity covered by maastrichtian conglomerates in the Gazik province, whereas a passive marginal facies formed in the Sahlabad province. 2-3) Eocene: the Sahlabad province was unconformably covered by conglomeratic layers and a reefal facies.

The paleogeographic history of the two provinces changed during the Early Eocene. No early-middle Eocene resedimented facies are observed in the Gazik area. Two different types of facies (reefal and resedimented facies) are observed in the Sahlabad province. A shallow water reefal facies with early Eocene basal conglomerates formed unconformably on the ophiolitic mélanges (e.g. Birjand area) whereas, the early-middle Eocene pelagic resedimented facies, indicating the continuity of subduction, formed in the foreslope basin (peripheral domain) (e.g. Khosravi area). During the Late Eocene, the Sahlabad province was unconformably covered by conglomeratic layers and a reefal facies.

4. CONCLUSION

1- The opening age of the Sistan Ocean is attributed to pre-Aptian time.

2- The subduction beneath the Afghan block led to the first collision between Lut and the Afghan blocks in the Gazik province during the Maastrichtian due to the blocking of subduction stopped in this province and the convergence continued in the western part of the Sistan Ocean (Sahlabad province). The Sistan Ocean was not completely closed since the accretionary facies were still being deposited in the sahlabad province.

3- The existence of a maastrichtian passive margin resedimented facies (in western part of the Sistan ocean), the lack of reworked maastrichtian conglomerates and, especially, the occurrence of ophiolitic elements in the Paleocene-Eocene accretionary facies, imply the persistence of an oceanic basin between Lut block and the pre-maastrichtian accretionary prism. The blocking of subduction is suggested by the existence of the coloured mélange uplift in the central part of Sistan basin.

4- The early Eocene transgression corresponds to the second closing of the Sistan ocean. It is characterized by a conglomeratic facies deposited unconformably over the ophiolitic mélanges.

5- The age of the ophiolite emplacement in the Gazik province is assigned to the pre-Maastrichtian, whereas in the Sahlabad, it is attributed to before the Early Eocene.

6- The terminal collision containing the transgressive conglomerates took place in the Late Eocene period.

7- The polarity age of the accretionary facies indicates that the direction of subduction is towards the East or North-East. In fact, the eocene accretionary facies occurs in the western part (Sahlabad province) in remnant basin, whereas the Cretaceous active margin facies were formed in the eastern part (Gazik province) in forearc basin.

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