TECTONOGENESIS & EVOLUTION OF A SEGMENT OF THE CIMMERIDES: THE VOLCANO-SEDIMENTARY TRIASSIC OF AGHDARBAND (KOPET-DAGH, NORTH-EAST IRAN)

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ABSTRACT. During the late Palaeozoic, the area of the Kopet-Dagh had been accreted to the Turan plate and partly metamorphosed in greenschist facies, as were the Band-i-Turkestan, the North Hindu-Kush and the North Pamir. During Permian time, parts of these accreted terranes were uplifted, eroded and mainly the southern areas covered by red continental deposits. The Paleeotethys active margin migrated to the South and a new volcano-plutonic arc was emplaced South of the Hercynian collage, just to the North of the new Paleotethys subduction zone. During Triassic time, North of the plutonic arc and in a back arc setting, an arcuate deep subsiding volcano-sedimentary marine belt is recognised from the South Caucasus through the Kopet-Dagh to the North Pamir. A Cimmerian deformed segment of this back arc basin appears now in the erosional window of Aghdarband. From the study of the marine volcaniclastic facies and the Triassic events, a tentative model of the regional geodynamical evolution is presented.

1. INTRODUCTION AND GEOLOGICAL SETTING

In the Eastern Kopet-Dagh Range, the erosional window of Aghbarband has been discovered in 1956 and surveyed by several geologists during the last decades. A first general report has been presented by RUTTNER (1984) and a monograph on that area is now being finalised (RUTTNER ed., 1989).

The erosional window of Aghdarband shows the pre-Liassic basement of the Kopet-Dagh and is situated about 100 Km ESE of the holy town of Mashhad along the Kashaf Rud river (Fig.1).

Structurally, this pre-Liassic basement consists of North vergent

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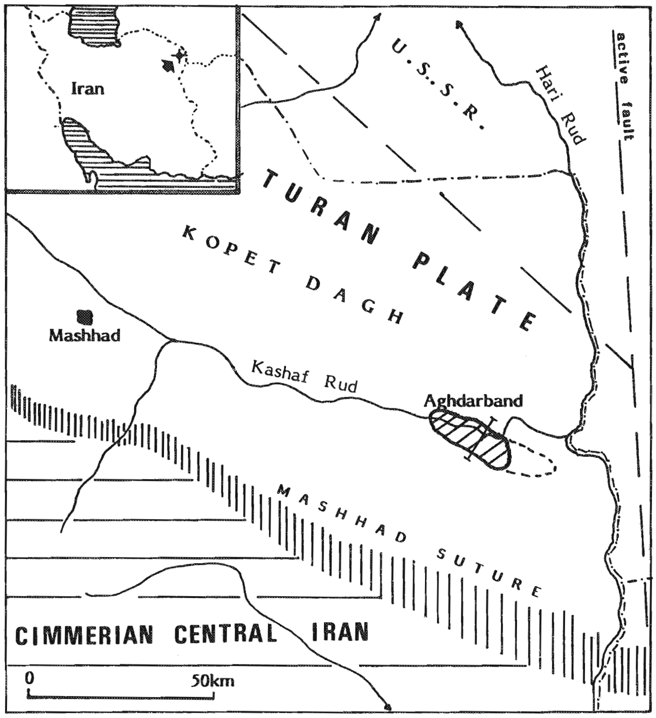

Fig.1: Location of the Aghdarband erosional window. The late Triassi/ early Jurassic Mashhad suture had been obliterated by later intraplate tectonism.

thrust slabs of Palaeozoic epimetamorphic metasediments over anchimetamorphic Triassic carbonates and volcaniclastics (RUTTNER, 1984). The Triassic rocks in 3 tectonic slices thrusted northward are folded and bounded to the NE by folded Devonian and early Paleozoic metasediments. The whole area is unconformably covered by late Liassic marine clastic and carbonate rocks (Fig.2).

Lithologically, the Triassic Aghdarband Group, 1.2 to 1.5 Km thick, is subdivided into 3 formations and shows a complete sedimentary cycle (Fig.3) from shallow water carbonate rocks (early Triassic) through deep water andesitic to trachytic volcaniclastics (middle to early late Triassic) to continental siltstones and sandstones with coal seams (late Triassic). An analysis of this sedimentary cycle is presented by BAUD et al. in RUTTNER (1986). Here, we explain and develop the main conclusions of that publication. A geodynamic model is presented, where the Aghdarband area is considered in a much wider geological context.

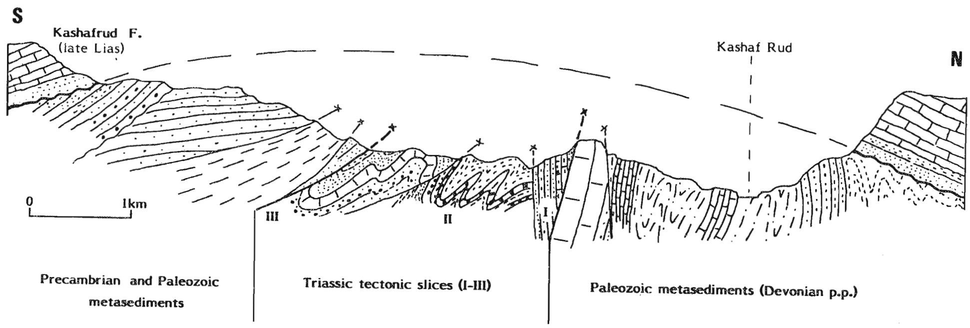

Fig.2: South-North Schematic crose-section through the Aghdarband erosional window, modified and completed from RUTTNER- 1984 & 1986.

2. TRIASSIC GEOLOGICAL EVENTS AND VOLCANO-SEDIMENTARY EVOLUTION

From the petrographical analysis and after comparisons with adjacent areas, ancient and recent models, we can assume that the detritic sedimentation of the Aghdarband Group originated from an active volcanic arc on a continental margin and we are interpreting the general depositional environment as a retro arc or Andean setting. In the Fig.3 we indicate the main characters of each of the formations of the Aghdarband Group and of the underlying red conglomerate.

During Triassic time, eight separate geological events have been recorded, delimited on the basis of tectonic movements, or abrupt lithological or environmental changes. At the base of the Aghdarband Group, within the late early Triassic, two events occured. The first was a major one with the superposition of non-metamorphic marine andesitic volcaniclastics on continental red conglomerates. This red conglomerate of late Palaeozoic age is considered as a late Palaeozoic molasse that drained mixed crystalline basement and epimetamorphic acidic rocks. The epimetamorphism is late Palaeozoic or older. The second event was the transgression of the shallow water shelf carbonates (Sefid Kuh Formation) on the volcaniclastics and this event is dated as early Spathian by DONOFRIO in BAUD et al. (1986b).

The next two events (third and fourth) occured during early Anisian. The third represents also a major break characterized by a tectonic phase consisting of strong vertical movements initiating the desintegration of the former early Triassic carbonate platform. Part of it was uplifted and eroded producing a thick limestone conglomerate. Other parts of the platform sunk rapidly into considerable water depths where turbidity currents became an important process of sediment transport. This event is dated by Ammonoids as Bithnynian (KRYSTYN et al. 1986). The same age is considered for the fourth event that corresponded with the replacement of the carbonate sedimentation by volcaniclastic supply probably in response to the effusion of juvenile andesitic volcanoes on the volcanic arc. During the Middle Triassic, this volcanism evolved to a more acidic composition.

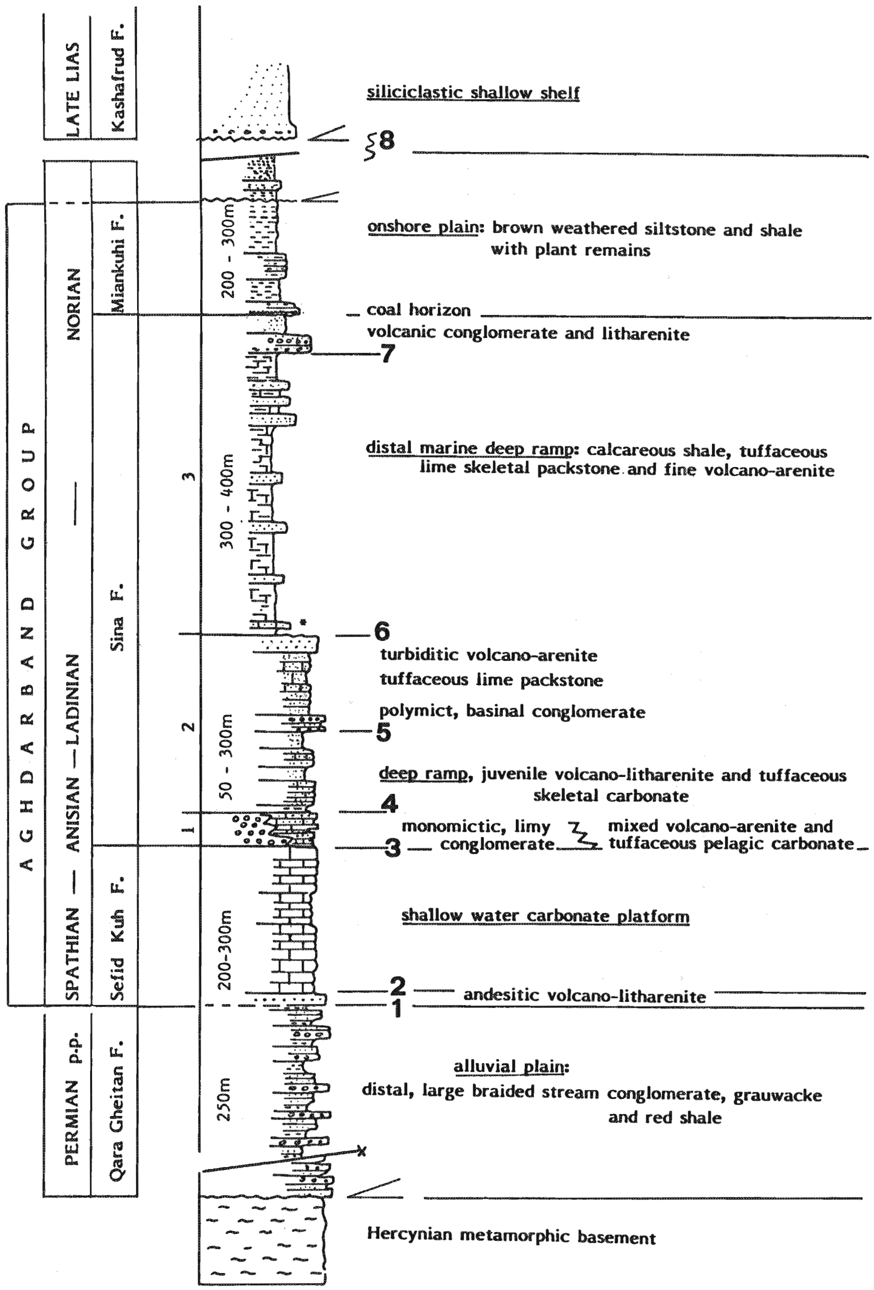

Fig.3: Generalized stratigraphical section of the Permian and Triassic of Aghdarband with interpretation of the environments of depositon (modified from BAUD & al., 1986, and RUTTNER, 1984).

The fifth event occured in the member 2 of the Sina Formation (early Ladinian ?) and is characterized by the deep marine deposition of mixed carbonate/crystalline conglomerate following the erosion of the crystalline basement and its late Palaeozoic sedimentary cover. The rapid erosion is interpreted as the result of a new tectonic phase of uplift (taphrogenesis). The sudden change from the mainly coarse detritic sedimentation of the member 2 to the fine detritic rocks and carbonate deposits of the member 3 of the Sina Formation forms the sixth event and is dated as late Ladinian (KRYSTYN et al, 1986). The evolution of the detritic sedimentation was characterized by an increase of felsic non-volcanic grains and the deep marine deposits (deep ramp) evolved to more distal turbidites and pelagic limestones.

The seventh event occured in the upper part of the member 3 of the Sina Formation and consisted of a sudden increase of the volcanic and tectonic activities as recorded by massive volcanic sandstone. The filling up and the closure of the marine retro arc basin and the rapid progradation of the continental fluviatile deposits characterize this event.

The latest event (eighth) corresponds to orogenic phases of the latest Triassic time recognised as the formation of the Cimmeride orogenic collage (ŞENGÖR 1984) that affect all the South Turan Plate. In the Aghdarband erosional window we can observe a general nothward thrusting and folding along WNW axes. The entire Paleozoic to Triassic sedimentary pile is involved in this cover deformation. Some particularities of this orogen and the collisional aspect would be examined in the fololwing section.

3. TENTATIVE PALEOGEOGRAPHIC AND GEODYNAMIC MODEL

Figure 4 is shown here to support the following text; it is a tentative model presenting some new ideas still to be confirmed by future field work. It presents an alternative interpretation to the one of ŞENGÖR & HSU (1984).

During the Late Palaeozoic, the Turan Plate (Turanian and Karakum Microcontinents of SHEIN 1985) was accreted to the newly formed Eurasian Plate. During that period, due to continuing subduction of the Palaeotethys, the Turan Plate was subjected to important volcanism and pulotinsm. Most of its Palaeozoic sediments are metamorphosed. Several accretion events took place from the Devonian to the Triassic, marginal basins opened and closed, and the subduction migrated southward several hundred of kilometres, in a way similar to what happened along the West Coast of North America during the same time.

The Palaeozoic of the Turan Plate is only known from wells drilled by Soviet explorationists. The Siluro-Devonian rocks are metamorphosed up to granulite facies in some areas.

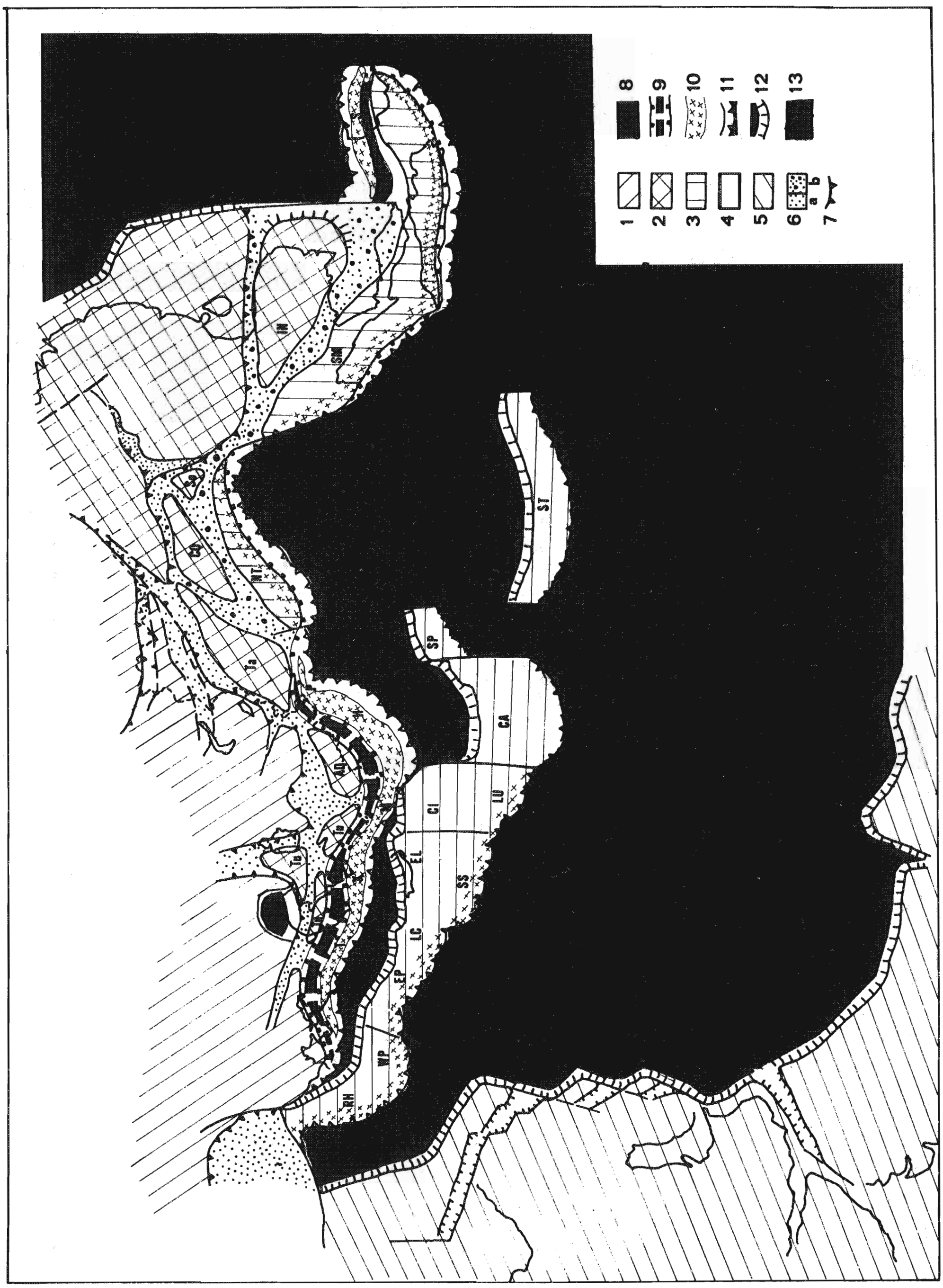
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Fig.4: Tentative palinspastic model for the late Triassic (modified from: DERCOURT & al., 1985, for the western part; STÄMPFLI, 1978 and BASSOULET & al., 1980 for the central part; HELMCKE, 1985 & 1986, and SENGOR & HSU, 1985 and SENGOR 1986 for the Eastern part). -1 Eurasia -2 Early late Palaeozoic collage microplates (Tu: Turan, AD: Amu-Daria, Ta: Tarım, CQ: Chaidam/Qilian, So: Songpan, IN: Indochina) -3 Late Palaeozoic microplates (NT: N-Tibet, SM: Shan-Thai/Malaysia) -4 Cimmerian collage (RH: Rhodope, WP: W-Pontides, EP: E-Pontides, LC: Lesser Caucasus, EL:Alborz, SS:Sanandaj/Sirjan, CI:central Iran, LU:Lut, CA:central Afghanistan, SP:S-Pamir, ST:S-Tibet). -5 Gondwana. -6 Mobile zones on a) late Palaeozoic or b) early Cimmerian sutures affected by Cimmerian/Indosinian movements (late Triassic/middle Jurassic) and post orogenic volcanism/magmatism. -7 Hercynian front. -8 Palaeotethyan oceanic crust (SC:S-Caspian, FR:Farah-Rud, TA:Tangula). -9 Back arc basin. -10 Volcanic/magmatic arc, island arc (T: Transcaucasia, K: Kara-Bogaz, M:Mashhad, H:Hindu-Kush, P:N-Pamir, S:Sarawak). -11 Subduction trough/fore arc basin. -12 Passive margin. -13 Oceanic ridge.

Gabboric intrusions and local serpentinites have been reported together with basic to intermediate volcanism starting in late Devonian. Flyschoid sequences form the major part of the sedimentary record. Fossiliferous marble is also present (oral communication from Soviet Geologists). A major diastrophism took place between the late Carboniferous and the Permian molassic deposits which cover the whole Turan Plate. This event can be related to the main late Palaeozoic folding in the Ural and surrounding areas. After the late Palaeozoic collage, the subduction migrated southward once more and a new volcanic arc was formed all along the southern border of Eurasia (STÄMPFLI, 1978).

Associated with that event, extensive metamorphism took place as reported in Band-i-Turkestan, North Hindu-Kush and North Pamir (BAZHENOV et al, 1982). The Kopet-Dagh area is part of the magmatic belt associated with the renewed subduction. The metamorphic Paleozoic of Mashhad with its Devonian ophiolites and radiolarites forms the southernmost extension of it (LAMMERER et al., 1984). The Hindu-Kush granodiorite (BOULIN, 1981) can be regarded as the eastern extension of the Mashhad complex.

During the Permo-Triassic, a marginal basin developed along the new Palaeotethyan active margin. This basin has been regarded by some authors as an intracontinental rift (BASSOULLET et al., 1980, BAZHENOV et al., 1982, SHEIN, 1985), but others recognise it as a back arc basin (BOULIN, 1981, for the Hindu-Kush, KHAIN, 1984, for the Caucasus, present authors for the Kopet-Dagh area). The mode of emplacement in time and space, the geometry and the nature and composition of the marine clastic infilling of this subsiding zone speak in favour of a back arc setting (BAUD et al. 1986).

In the back arc sequence of Aghdarband, the first volcanic activity appeared in the late Scythian marine sediments and became preponderant in the early Anisian (event four), it ceased in late Norian. A very similar evolution is reported eastward by SLAVIN (1974) in Band-i-Turkestan and by BOULIN (1972) in the North Hindu-Kush. Between Aghdarband and the Band-i-Turkestan, middle to late TRiassic marine volcaniclastics are also reported by Soviet Geologists in the West Murghab River area (well information).

The history of this marginal basin became relatively complex as it evolved in time and its closure was only completed in some areas during Cretaceous time. The closure was induced by the collision of the drifting Gondwanian fragments with Eurasia (Cimmeride orogenic collage of ŞENGÖR, 1984, or Indosinian orogenesis of STÖKLIN, 1977, 1980). These deformations affected the whole back arc area forming the Asian Cimmeride front of ŞENGÖR (1985). The first area affected by that collage was the Kopet-Dagh on the active margin side, the Eastern Alborz and the North Central Iran on the Gondwanian passive margin. The main events are very well correlatable between the Aghdarband area and the Alborz. Major tectonic inversions affected the passine margin (STAMPFLI, 1978) as well as certain mobile areas within the Irano-Afghan plate (BERBERIAN and KING, 1981). From that time, the subduction of the Palaeotethys under the Eurasian plate ceased and the closure of the marginal basin ended. The magmatic activity starting at the same time along the South margin of the Iranian plate (BERBERIAN and KING, 1981, DAVOUDZADEH and SCHMIDT, 1984) shows that the subduction once more shifted southward.

A major reorientation of the sea-floor spreading occured during the Jurassic (opening of the Neotethys and the Central Atlantic). It is possible that szome active margins like South Iran became transform margins at that time.

The major transcurrent forces associated with this plate reorganization ended up with the closure of the remnant Paleotethyan Ocean between Central Afghanistan and the Hindu-Kush during mid-Cretaceous time (BOULIN, 1981) and between North-West Iran/Lesser Caucasus and Caucasus in late Cretaceous/Paleocene (BERBERIAN, 1983, KHAIN, 1984).

The change in horizontal compressional stress is very well examplified in the whole Alborz area where, after the inversion in late Triassic/Liassic, the inverted basement blocks regained their initial collapsed position and the passive continental margin sedimentation resumed. A continuous carbonate platform progradation took place from Callovo-Oxfordian until the Paleocene all around the South Caspian Basin which thus should be garded as a Palaeotethyan ocanic remnant (STÄMPFLI 1978).

From this rapid account of the geodynamic evolution of that part of the Cimmeride front, it can be seen that outcrops like those of Aghdarband represent key-points for the understanding of the geology of the whole North Iran. It certainly shows by comparison with similar sequences in Afghanistan and Caucasus that the history of the Cimmerides is polphased.

If the formation of magmatic arcs and associated back arc subsidence can be regarded as relatively synchronous along great portions of an active margin, collision and subsequent closure of the marginal basin is likely to be diachronous. This is shown by many past and present examples, e.g. the collision between Australia and the Indonesian magmatic arc where the geometry of the colliding blocks is the major intervening factor which can also be greatly affected by rapid shifts of the sea-floor spreading (also sohwn in the South Pacific area and related collages in New Zealand).

In the case of the Cimmerian front considered here, both factors played an important role. This is further exemplified by the more recent evolution of the Irano-Afghan plate during the Alpide orogeny. Major transcurrent movements took place again in late Cretaceous (South Atlantic opening) after the closure of Palaeotethyan oceanic remnants. Intracontinental rifting affected the Irano-Afghan plate at that time and closure of the rifts took place during the Paleogene due again to a main plate motion rearrangement. The final closure of the Neotethys around the Irano-Afghan plate was also diachronous due to the geometry of the continental margins. Continent/continent collision did not even occur all along the suture areas as in Baluchistan, the Neotethyan oceanic remnant there (Arabian Sea) can be a good example for what happened in the South Caspian area during late Triassic and Jurassic periods (the obduction of ophiolites on the Oman passive margin in Late Cretaceous being somewhat more drastic than the inversion affecting the Alborz passive margin in Late Triassic).

REFERENCES

Bassoulet,J.P., Boulin,J., Colchen,M., Marcoux,J., Mascle,G. & Montenat,C. (1980). L'évolution des domaines téthysiens au pourtour du Bouclier indien, du Carbonifère au Crétacé. In: Colloque "Chaînes alpines issues de la Téthys", 26ème Congr.géol.int., Paris 1980.

Baud,A., Brandner,R. & Donofrio,D.A. (1986). The Sefid Kuh Formation (Triassic Aghdarband Group, Kopet Dagh, Iran). In: RUTTNER ed., Geology of the Aghdarband area (Kopet Dagh, NE Iran). Abh.Geol.B.-A., Wien, 40, in press.

Baud,A., Stampfli,G. & Steen,D. (1986). The Triassic Aghdarband Group, volcanism and geological evolution. In: Rutnner ed., Geology of the AGhdarbandarea (Kopet Dagh, NE IRan). Abh.Geol.B.-A., Wien, 40, in press.

Bazhenov,M.L. & Burtman,V.S. (1982). 'The kinematics of the Pamir arc'. Geotectonics, vol.16/4, 288-301.

Berberian,M. (1983). 'The southern Caspian: a compressional depression floored by a traped modified oceanic crust'. Can.J.Earth Sci., 20, 163-183.

Berberian,M. & King,G.C. (1981). 'Towards a paleogeography and tectonic evolution of Iran'. Can.J.Earth Sci., 18, 210-265.

Boulßing,J. (1972). 'L'évolution stratigraphique et structurale de l'Hindu-Kouch central en Afghanistan d'après la traversale du Salang'. Rev.Geogr.phys.Géol.dyn. (2), XIV/4, 371-382.

Boulin,J. (1981). Afghanistan structure, greater India concept and eastern Tethys evolution'. Tectonophysics, 72, 261-287.

Davoudzadeh,M. & Schmidt,K. (1984). 'A review of the Mesozoic paleogeography and paleotectonic evolution of Iran'. N.Jb.Geol.Paläont.Abh., 168, 182-207.

Dercourt,J., Zonenshain,L.P. & 15 authors (1985). 'Présentation de 9 cartes paléogéographiques au 1/20.000.000e s'étendant de la l'Atlantique au Pamir pour la période du Lias à l'actuel'. Bull.Soc.Géol.France, (8), 1/5, 637-652.

Helmcke,D. (1985). 'The Permo-Triassic "Paleotethys" in mainland of SE-Asia and adjacent part of China'. Geol.Runschau, 74/2, 215-228.

\- (1986). 'Die Alpiden und die Kimmeriden: Die verdoppelte Geschichte der Tethys'-Discussion. Geol.Rundschau 75/2, 495-499.

Khain,V.E. (1984). 'The Alpine-Mediterranean fold belt of the USSR'. Episodes, 7/3, 20-30.

Krystyn,L. & Tatzreiter,F. (1986). 'Ammonoids from the Triassic Aghdarband Group'. In: RUTTNER ed., Gology of the Aghdarband area (Kopet Dagh, NE-IRan). Abh.Geol.B.-A., Wien, 40, in press.

Lammerer,B., Langhenrich,G. & Manutchehr-Danai,M. (1984). 'Geological investigation in the Binalud mountains (NE-Iran)'. N.Jb.Geol.Paläont.Abh., 168, 269-277.

Ruttner,A.W. (1984). 'The pre-Liassic basement of the eastern Kopet-Dagh Range'. N.Jb.Geol.Paläont.Abh., 168/2-3, 256-268.

Ruttner,A.W. (1986). 'Geology of the Aghdarband area (Kopet-Dagh, NE-Iran). Abh.Geol.B.-A., Wien, 40, in press.

Şengör,A.M.C. (1984). 'The Cimmeride orgenic system and the tectonic of Eurasia'. Geol.Soc.Am., Sp.paper, 195, 82p.

Şengör,A.M.C. (1985). 'The story of Tethys: how many Wives did Okeanos have?'. Episodes, 8/1, 3-12.

Şengör,A.M.C. (1986). 'Die Alpiden und die Kimmeriden: die verdoppelte Geschichte der Tethys'-Reply. Geol.Rundschau, 75/2, 501-510.

Şengör,A.M.C. & Hsu,K.J. (1984). 'The Cimmerides of eastern Asia: History of the eastern End of the Paleotethys'. Mém.Soc.Geol.France, N.S., 147, 138-167.

Shein,V.S. (1985). 'A geodynamic model forthe petroliferous Regions of the southern USSR'. Sovietskaya Geeologiya, Moscow, 1985/2, 64-77, in russian.

Slavin,V.I. (1974). 'The Triassic Deposits of the Afghan part of the Tethys and their correlation with those in neighbouring regions'. Vestnik Moskovskogo Univ.Geol., 29/2, 22-31, in Russian.

Stampfli,G. (1978). 'Etude géologique générale de l'Elburz oriental au Sud de Gonbad-e-Qabus, Iran NE'. Thèse Université Genève.

Stöckling,J. (1977). 'Structural correlation of the Alpine Ranges between Iran and central Asia'. Soc.Geol.France, Mém.h.sér., 8, 333-353.
Stöcklin,J. (1980). Geology of Nepal and its reginola frame., J.Geol.Soc.London, 137/1, 1-34.