Conclusion

The inner Mesozoic- early Paleogene ocean of Iran calls for further study as it is a neglected component of the Neo- Tethyan realm. The ophiolites representing this ocean are some of the best exposed in the World and are comparable with the Troodos in Cyprus. They are as yet unstudied in any detail. Both this inner ocean and the SSBD- Bitlis microcontinental block are major geological features, extending for thousands of kilometres. Their full lateral extent is unknown.

The history of deformation in the Makran from the late Paleocene to early Pliocene deserves further study, particularly in relation to studies by White (1982) of the offshore subduction zone of the Makran which suggest very early incipient small scale folding. The Iranian Makran is not only a perfect laboratory for detailed studies based on field work on ophiolites:the flysch sequences and neritic sequences are perfectly exposed,and the tectonic structures, of considerable apparent complexity apparently lacking the multiphase factor, should be investigated in detail by specialist structural geologists. The author is neither a specialist structural geologist or geotectonist, but has here recorded the conclusions based on integrated regional studies of the entire Iranian Makran, a unique programme

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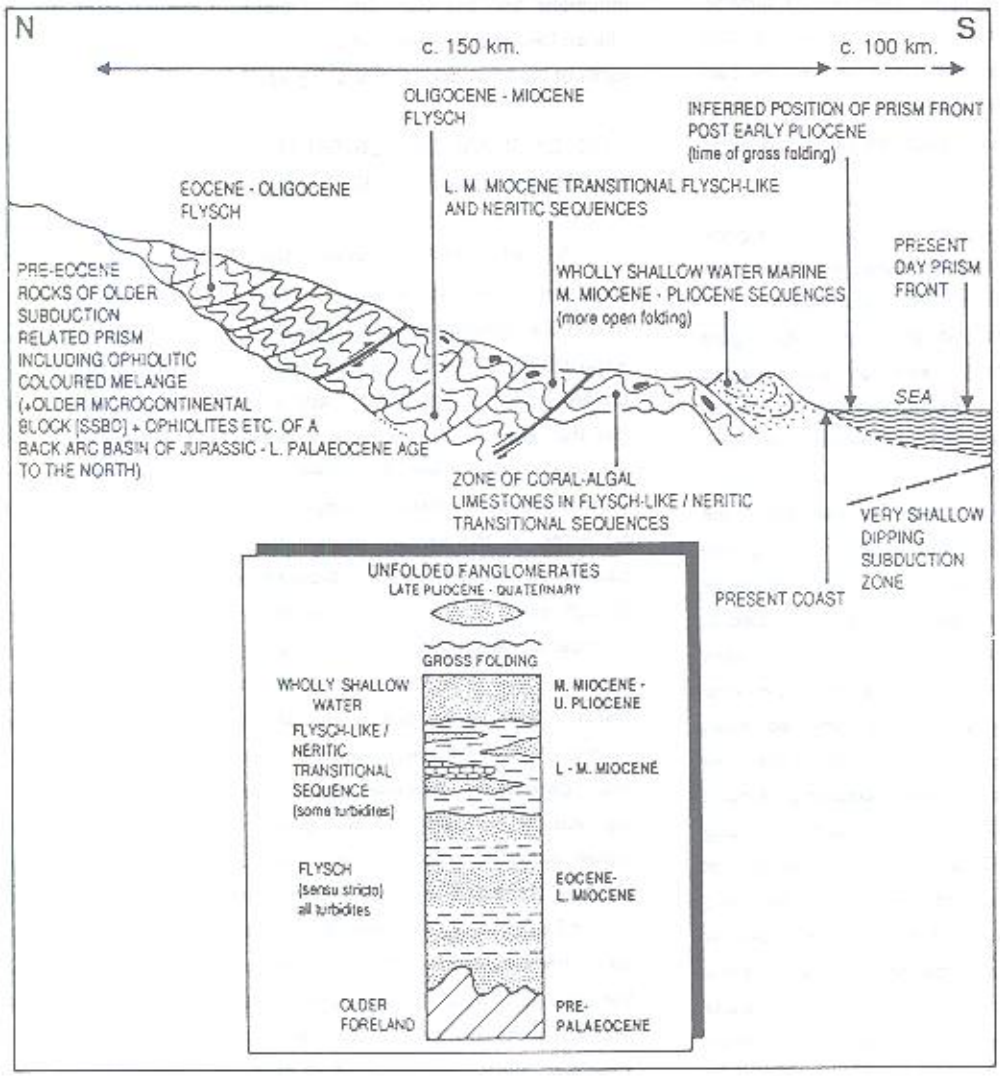


Figure 2: Cartoon section of the present relationships and cartoon geological column showing the relationships in the Cenozoic tract of the southern (outer) Makran.

The impression gained from the field mapping in the quadrangles to the south is that there was progressive upwarping as the zone of active flysch deposition moved rather jerkily southwards from the Eocene through the Oligocene to the early Miocene, each upwarp providing a source of detritus to be reworked in the new basin of deposition to the south, but there was no intense folding of the beds or associated major reverse faulting anywhere in the Makran until the end - Miocene- early Pliocene paroxysm. There is no evidence of multiphase folding, though faults certainly suffered some renewal of movement, once initiated. The possibility that the later movements obliterated the record of earlier folding has been considered, but appears to be untenable. The conclusion is reached that there was a single major paroxysmal episode throughout the entire Makran in the late Miocene to early Pliocene, when the Cenozoic rocks attained their present strongly folded, faulted and locally dislocated state, and that this was accompanied by strong uplift resulting in the spectacular Plio- Pleistocene piedmontane congomerates of the Palami, Tahtun and Nahang (Kech in Pakistan) units (the Tahtun fanglomerate system of the Tahruie Quadrangle (McCall, 1985b) is a remarkable example of such molassic fanglomerates and deserves more detailed study). The subduction front moved gradually southwards until this episode and then jumped out to its present position.

The Cenozoic- Early Pleistocene sequences of the Makran are summarised in a cartoon cross- section and stratigraphic column in Figure 2.

and basaltic volcanics), Dar Anar complex (basalts and basaltic dykes with limestones) and Band- e Zeyarat complex(a vast gabbro- dominated ophiolite complex with dykes beneath the Dar-Anar complex) represent this inner ocean: again the youngest microfossil dates are Paleocene, so the southern sector closed in the Paleocene.

It is clear from the regional mapping (e.g.the photointerpretative maps of Huber,1978,published by NOIC) that the ophiolites run north through Baft and Nain and approach the Sabzevar ophiolite tract from the west (McCall & Kidd, 1982, Figure 4).It seems probable also that this inner ocean may have extended northwestwards, between the SS/BD and Northwest Iran continental blocks into Turkey: it was probably a major component of the Neo-Tethyan realm and may have extended for thousands of kilometres. Southeast of the Sistan sector it is apparently represented by the Talkhab melange (McCall & Eftekhar- Nezad, 1993, in the press) which runs along the southern boundary of the Helmand block toward the Mashkel Quaternary depression.Senghor suggested to the author recently (pers. comm.) that the inner and outer oceans are likely to have merged here(i. e. the end of the microcontinenal sliver in south - east of Kuh- e Birk hyng out into a combined ocean in the Mesozoic): he believes that there is no evidence of the inner ocean and SSBD microcontinental sliver wrapping around northwards through the Chaman sector in Pakistan and continuing through the Himalayan sector, but such continuation is not disproven. There is strong evidence of the inner ocean and continental sliver continuing westwards through Turkey however (the SSBD is probably continuous with the Bitlis massif) and the existence of such an immensely long attenuated, Gondwana sourced microcontinent is surely remarkable. This pattern resembles some Pacific ocean geotectonic patterns. The SSBD microcontinental sliver was not emergent in the greater part of the Makran sector in the Mesozoic, but was only shallowly submerged, as is shown by the shelf facies of the rare Jurassic, and abundant Lower and Upper Cretaceous limestones of the Dur- Kan unit, which in the northwest mantled older shelf limestones of Carboniferous and Permian age, above metamorphic rocks (McCall, 1985c): and in the Cretaceous shelf limestones of the Birk unit in the east which mantle Permian shelf sediments. It separated two deep ocean basins.

In the extreme north of the Saravan quadrangle, there is a development of granodiorite (Shah- Kuh granodiorite: McCall & Eftekhar- Nezad, op. cit.) and this, probably late Eocene or Oligocene intrusion probably represents a last burst of calc- alkaline magmatism as the Sistan ocean closed. It forms part of a line of such intrusions running northwest through Zahedan. These intrusions and the Cenozoic intrusions to the north of the Jaz Murian Depression appear to cross- cut the lineaments of the older rocks of the inner ocean, producing apparent discontinuities.

The peculiar structural history of the Makran during the Cenozoic

McCall (in McCall, Rosen & Darrell, 1993, in the press) has observed that the structural history of the Makran fore - arc zone during the Cenozoic is quite different from the model of Moore & Karig (1980) for the Sunda fore- arc of Nias, northern Sumatra. As observed by platt and others (1985), working in a smaller area of the Pakistan Makran, the Miocene to early Pliocene slope and shelf sequences have been deposited virtually conformably and not markedly unconformably on abyssal plain sequences represented by flysch. In the Iranian Makran, the flysch ranges from latest paleocene, through Eocene, Oligocene to early Miocene age, but though there is some evidence of an unconformity within the Oligocene, detailed analysis of the structures (especially in the Nikshahr, pishin and Saravan quadrangles- McCall & Eftekhar-Nezad, 1993, in the press; McCall, 1985a; McCall & Eftekhar-Nezad, 1993, in the press) *provides no evidence at all that Eocene and Oligocene- Miocene flysch sequences were disturbed significantly by folding or faulting prior to the Miocene- Pliocene neritic sediment deposition and the culminating intense reverse faulting producing a duplex structure and the folding integrated with it.* Platt and others related this concordance to the very shallow dip of the subduction surface and invoked underplating to explain the obviously rapid shoaling, which is also evident in the Iranian Makran. Although distingushed geotectonists may dispute this structural history, this is evident from the field mapping, and geologists must not be carried to far by models: *it is clearly a fact that the Makran does not conform to Moore and Karig,s model.*

The Saravan quadrangle also, which represents the terminal stage of the Sistan ocean rather than the main ocean, does not reveal any obvious discordance between Eocene and Eocene-Oligocene sequences: though here there are no late Oligocene or Miocene sediments,other than restricted piedmontane conglomerates possibly of this age. The inference from the similarity of the structural patterns that the faulting and folding structures again represent the culminating late Miocene- Pliocene event. There is some evidence that the major Saravan fault may have been initiated earlier, at the same time as the Shah- Kuh granodiorite intrusion, but the suggested Oligocene- Miocene age of the piedmontane conglomerates at the foot of this fault scarp is by no means certain: they could even be Plio- Pleistocene.

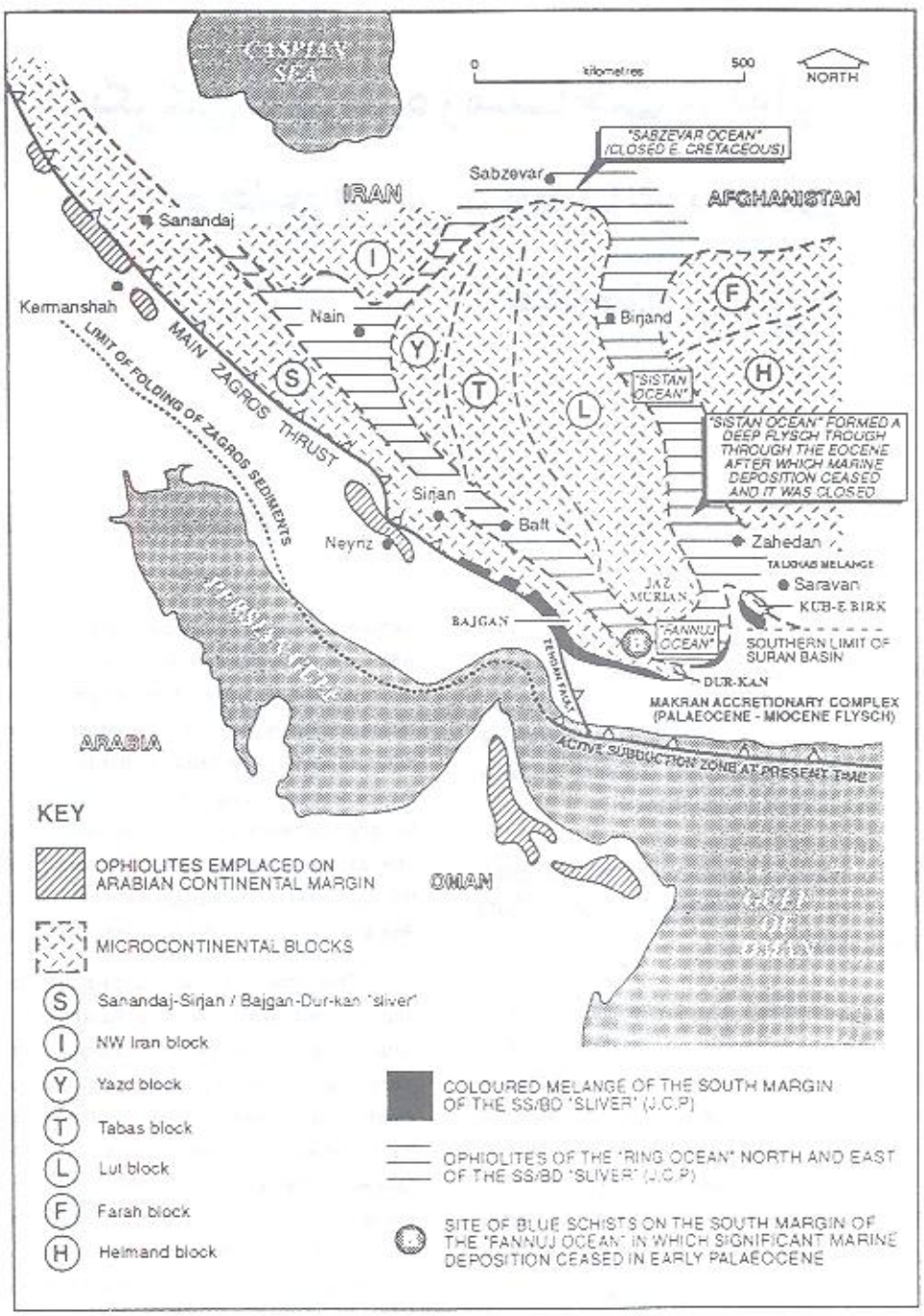


Figure 1: The principal geotectonic elements of southern and central Iran and adjacent parts of Arabia, Afghanistan and Pakistan, showing the postulated Jurassic/ Cretaceous/ early Paleogene inner ocean which includes the "Sabzevar" and "Sistan" oceans postulated by Senghor and others (1988) and the "Fannuj" ocean postulated here, all being picked out by Cretaceous ophiolite tracts. This ring ocean is quite distinct from the ocean south of the SSBD microcontinental sliver and was separated from it by a shallow sea over this ridge. The main ocean to the south is represented by the Coloured Melange complex (ophiolitic). The several microcontinents were fused as the ocean closed at various times into the now rigid continental mass.

نگرشی نو درباره زمینساخت ورقه‌ای جنوب ایران وخلیج فارس برپایه نتایج به‌دست آمده از تهیه نقشه‌های زمین‌شناسی مکران

نوشته: ج.، ملک کال

Introduction

The results of the regional mapping of Makran (East Iran Project, Area No.1) have now been fully compiled and the last two reports on the Nikshahr and Saravan quadrangles (1: 250,000) are in the press. It is now possible to amplify the review of McCall & Kidd (1982) and that of Senghor and others (1988).

The Mesozoic to early Paleogene Inner Sea inside the Sanandaj- Sirjan/Bajgan - Dur- Kan microcontinental sliver

During the recent completion of the Saravan report in particular (McCall & Eftekhar - Nezad, in the press, 1993), considerable further insight was obtained into the manner of assemblage of the Gondwana- derived microcontinental plates and their enveloping oceans which came to together to form the now more or less rigid continental mass of southern Iran, Afghanistan and Pakistan.Among the most important revelations of the Makran mapping in 1976- 1978 was the recognition that the Sanandaj- Sirjan microcontinental sliver continues right through the Makran, terminating close to the Pakistan frontier in the Kuh- e Birk range. This was coupled with the recognition of an inner ocean, including very deep ocean deposits and bordered by the south by blue schists, representing subduction (? and obduction). Senghor and others (1988) attempted reconstructions allowing for this new data, but his reconstructions did not reveal the complete story: it is now evident that there was an extensive inner ocean: the three components of the "Lut Block" (Yazd, Tabas, Lut), separated by fracture zones and rearranged from their original relative positions, were apparently surrounded by an inner ocean, quite distinct from the main Indian Ocean represented by the renowned Coloured Melange (Figure 1). This inner ocean closed at different times in different sectors, the Sistan sector being in existence to the end of the Eocene and being filled with immensely thick flysch deposits of Eocene age (those of the Saravan quadrangle and adjacent areas). The last Eocene- Oligocene flysch lapped over the eastern end of the Sanandaj- Sirjan/Bajgan- Dur- Kan block (SSBD) east of Kuh- e Birk and merged with the deposits of the southern ocean.

This inner ocean surrounded the Yazd- Tabas- Lut nucleus and included Senghor et al.'s "Sistan" and "Sabzevar oceans", the latter closed by the early Cretaceous. The former separated the Yazd- Tabas- Lut microcontinental nucleus from the Helmand- Farah microcontinental nucleus. The sector to the south of the Yazd- Tabas- Lut nucleus (largely obscured by the Jaz Murian Quaternary depression) has been named the "Fannuj ocean": this is the sector bordered to the south by blueschists and it is represented by immense tracts of largely intact ophiolites (layered intrusions of the Remeshk complex,minor basaltic sheeted dykes and basaltic volcanics of the Mokhtarabad complex, associated with radiolarites and Globotruncana limestones). The earliest microfossil ages obtained on these deep- sea sediments were Jurassic and the youngest Paleocene, so this sector apparently closed by the Eocene, which is represented here by only very localised developments of shallow- water clastic sediments, conglomerates, sandstones, siltstones and limestones. Further west, the Ganj complex (largely composed of intermediate to acid sheeted dykes

New Insight into the Plate Tectonics of Southern Iran and the Persian Gulf Region, Arising from the Mapping of the Iranian Makran

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چکیده

نتایج به دست آمده از برداشت‌های مربوط به تهیه نقشه‌های زمین‌شناسی مکران ایران که بخش عمده آن منتشر گردیده و یا در شرف انتشار می‌باشد، دو مسئله مهم ژئوتکتونیکی را از دیدگاه انگاره زمین ساخت جهانی روشن ساخته است. اولین آن در ارتباط با دریای درونی مزوزوئیک (Mesozoic inner Sea ؛ که به طور محلی تا پالئوسن و یا ائوسن تداوم می‌یابد) بخش جنوبی ایران مرکزی است که در حال حاضر برونزد سنگ‌های افیولیتی، به همراه رسوبات دریای ژرف و تهشته‌های فلیشی آن را مشخص می‌سازد. براهمیت این دریا و خرده قاره سنندج - سیرجان/ باجگان - اورکان تاکید شده است. مورد دوم، در ارتباط با نتایج به دست آمده از بررسی تاریخچه ساختاری پیچیده ساختمان‌های رسوبات فلیش و نریتیک (Neritic) سنوزوئیک مکران و عدم انطباق آن با مدل پیشنهادی Moore and Karig (1980) است که در آن به ظاهر تنها یک دوره از تغییرات ناگهانی شامل گسلش، چین‌خوردگی و جابه‌جایی رویداده و با نهشتگی رسوبات مولاس کوهپایه‌ای (Piedmontane) همراه بوده است. در همین مقطع زمانی نیز بالا آمدگی بخش پیش فرورانش در موقعیت فعلی یا اقیانوس هند شکل گرفته است. با آنکه ردیف‌های رسوبی فلیش که دارای سنی از پالئوسن پایانی تا اوایل میوسن بوده به شدت چین‌خورده و گسلیده‌اند، ولی جا به جایی قبل از ظهور این بالا آمدگی، ابتدا با دگر شکلی کم‌تری در تهشته‌های اولیه همراه بوده است.

Abstract

Two major geotectonic problems related to the New Global Tectonics are considered here in the light of the regional mapping of the Iranian Makran, now complete and published or in the press. The first concerns the Mesozoic (locally extending to the Paleocene or Eocene) inner sea of southern and central Iran, now represented by ophiolites and associated deep- sea sediments or flysch deposits. The importance of this inner ocean and the Sanandaj- Sirjan/Bajgan- Dur- Kan microcontinental block is stressed. The second concerns the peculiar structural history evident from analysis of structures in the Cenozoic flysch and neritic sediments of the Makran: this does not conform to the model of Moore & Karig (1980) in that there was apparently only a single cataclysimic episode of reverse faulting, folding and dislocation, dated as late Miocene to early Pliocene, accompanied by uplift leading to molassic piedmontane deposition: this episode was accompanied by a jump of the subduction front out into its Present position in the Indian Ocean. Though the flysch sequences range from late paleocene to early Miocene, and are all strongly folded, faulted and locally dislocated, the progressive move south of the locus of flysch deposition before this jump appears to have been accompanied only by quite minor deformation, mainly upwarping of the earlier deposits.