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Perspective

The ophiolites of Khoy (NW Iran): their significance in the Tethyan ophiolite belts of the Middle-East

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1. Introduction

During the last 30 years, intensive studies on the Tethyan ophiolites have improved our comprehension of the various geodynamic environments in which these ophiolites were born, evolved and were finally accreted to the continents [7,10]. Among them, the so-called 'peri-Arabic ophiolites' [7,8] form a 3000-km long belt of Cretaceous ophiolites obducted during the Late Senonian over the Arabic–Tauric platform from Oman to northwestern Syria, Cyprus and Antalya (Fig. 1).

The degree of knowledge concerning these peri-Arabic ophiolites however is variable. In particular, the ophiolites from western Iran outcropping along the Zagros suture zone were not mapped in detail. This is why a French–Iranian cooperative programme was developed recently (1998–2002) in order to fill this gap, and obtain more structural and geochemical information on the Iranian part of the 'peri-Arabic ophiolitic crescent'.

Our programme included also the enigmatic ophiolites of Khoy, located in the extreme northwestern part of Iran, and clearly outside of the peri-Arabic ophiolite belt (Fig. 1). In their synthetic paper about the Tethyan ophiolites, Kniper et al. [7] classified them with a 'Van ophiolites' group (Fig. 1), in an area 'extensively covered by Quaternary basalts below which Tertiary flysches and molasses rest upon or are tectonically mixed with ophiolites' [7]. These authors remarked that these poorly known ophiolites "do not seem to rest [...] upon any continental basement and consequently were apparently not emplaced on continental crust by obduction". They interpreted them as "parts of the (Tethyan) oceanic crust simply crushed between colliding continents" [7].

2. Duality of the Khoy ophiolites

In his PhD defended at the 'Université de Bretagne occidentale' (Brest, France), as well as in a recently published synthetic paper [6], Morteza Khalatbari gave the first detailed and complete description of the ophiolites of Khoy and surrounding formations, in the northwestern part of the Iranian Azerbaijan Province [4]. Extending till the Turkish border, in a mountainous area of difficult access, these ophiolites strike NNW–SSE, at high angle with the curvature of the peri-Arabic 'ophiolitic crescent'.

The new field and laboratory studies, including a remarkable geological map at 1:50 000, lead Khalatbari to the conclusion that there are not one, but two ophiolitic complexes in the Khoy area [4–6].

(1) To the east, an older, metamorphic and pre-Cretaceous ophiolitic assemblage is tectonically included within a huge metamorphic complex (the eastern metamorphic zone), mainly composed of

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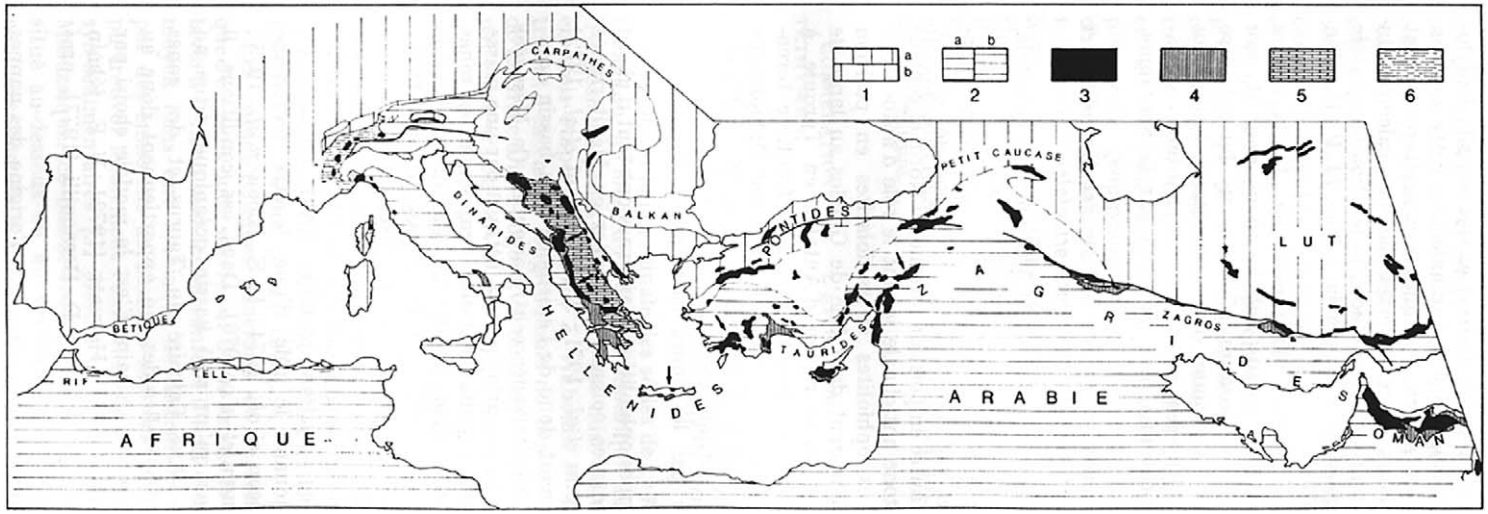

Fig. 1. Location of the Khoy ophiolites and of the Tethyan ophiolite complexes along the Alpine-Mediterranean orogenic system. **1**: Eurasia and its alpine part; **2**: Arabian–African continent and its alpine part; **3**: Ophiolite complexes; **4**: Radiolarites (Pindos-Pichakun type); **5**: Intermediary platforms between (**3**) and (**4**); **6**: Ligurian radiolaritic association. Ophiolites cited in the text, from east to west: **Ka**, Kahnuj; **Es**, Esfandagheh; **Ne**, Neyriz; **Ke**, Kermanshah; **Gu**, Guleman; **Ha**, Hatay; **Tr**, Troodos; **An**, Antalya. The rectangle area includes the 'Van ophiolite group' of Kniper et al. [7]. After [10].

meta-sediments (micaschists, gneisses) and metavolcanics (amphibolites), and crosscut by calk-alkaline granitic plugs and veins. We think that this unit, underthrust eastward beneath the central Iranian Block margin, represents a subduction complex, developed during most of the Mesozoic times. Subduction began after the collision of the Central-Iran Block with Eurasia during Middle–Upper Trias [1,9], trapping and stacking the Early-Tethyan oceanic lithosphere in an accretionary subduction wedge, beneath the western margin of the central Iran Block.

(2) To the west, a younger, non-metamorphic and Upper Cretaceous ophiolitic complex (the Khoy ophiolite s.s.) represents the last oceanic ridge activity in the Khoy Basin. This ophiolite was obducted southwestwards over a 'western metamorphic complex', extending in the southwestern part of the mapped area till the Turkish border. It is mainly formed of metavolcanics, greenschists, very fine-grained amphibole schists, sericite schists, and locally massive marble beds. These metamorphic rocks, presently not dated, are overlain with disconformity by red conglomerates, sandstones and shales of Upper-Palaeocene to Lower-Eocene age. They are interpreted as representing the Arabian continental platform, or more probably a fragment of it, detached during Late Cretaceous.

This unit may represent an eastern extension of the Pütürge–Bitlis metamorphic belt of eastern Turkey, where similar metamorphic lithologies were described and dated from Middle Devonian to Upper Triassic. These formations, lying unconformably over pre-Devonian, highly metamorphosed gneisses, are interpreted as metamorphosed platform sediments and volcanics representing the margin of a Tethyan micro-continent, separated from the Arabian–African shield during Triassic, eventually the southern margin of the Anatolian micro-continent.

If this comparison is valid, the Turkish Late-Cretaceous Guleman ophiolites, thrust over the Bitlis metamorphics, and their Maden wildflysh cover of Late-Cretaceous–Early-Palaeocene age, would be the analogues of the Khoy ophiolite and of its turbiditic cover.

3. Geodynamic evolution of the Khoy area

Now the geodynamic evolution of the Khoy area can be reconstructed as follows (Fig. 2).

(1) After opening of the Neo-Tethys Ocean during Upper Permian, the Khoy oceanic basin developed by seafloor spreading.
(2) From Upper Triassic to Upper Cretaceous, the Khoy oceanic basin was simultaneously opening by seafloor spreading, and subducting along its eastern margin beneath the Central Iran Block.
(3) The last oceanic lithosphere was produced during Upper Cretaceous in a closing oceanic basin. This oceanic lithosphere was never subducted and remained unmetamorphosed, giving the Upper Cretaceous ophiolite complex of Khoy. Volcanoclastic turbidites accumulated in the subduction trench, and unmetamorphosed igneous bodies (gabbros, granites) intruded the subduction metamorphic complex.
(4) Somewhat later (Lower Palaeocene), the western margin of the basin began to be underthrust beneath the Upper Cretaceous oceanic lithosphere, with production of late swarms of isolated calk-alkaline diabase dikes, crosscutting the whole ophiolite of Khoy. Just before collision, the ophiolite of Khoy was obducted over the western metamorphic complex, probably representing a fragment of the Arabian–African shield.
(5) After collision and folding, calk-alkaline monzonitic subvolcanic intrusions were intruded during Upper Miocene in the Khoy ophiolite and its Palaeocene–Eocene cover, leading to the present-day situation.

4. Conclusion: from Khoy to the Makran area, the western margin of the Central-Iran Block was active during most of the Mesozoic times

In conclusion, the data collected in the Khoy area suggest that the western margin of the Central-Iran Block was active during the Mesozoic times along its whole length till the latitude of Khoy to the north. Recent studies of other ophiolites from western Iran, realized in the frame of our cooperative programme, have confirmed the reality of subduction processes during most of the Mesozoic times all along the western mar-

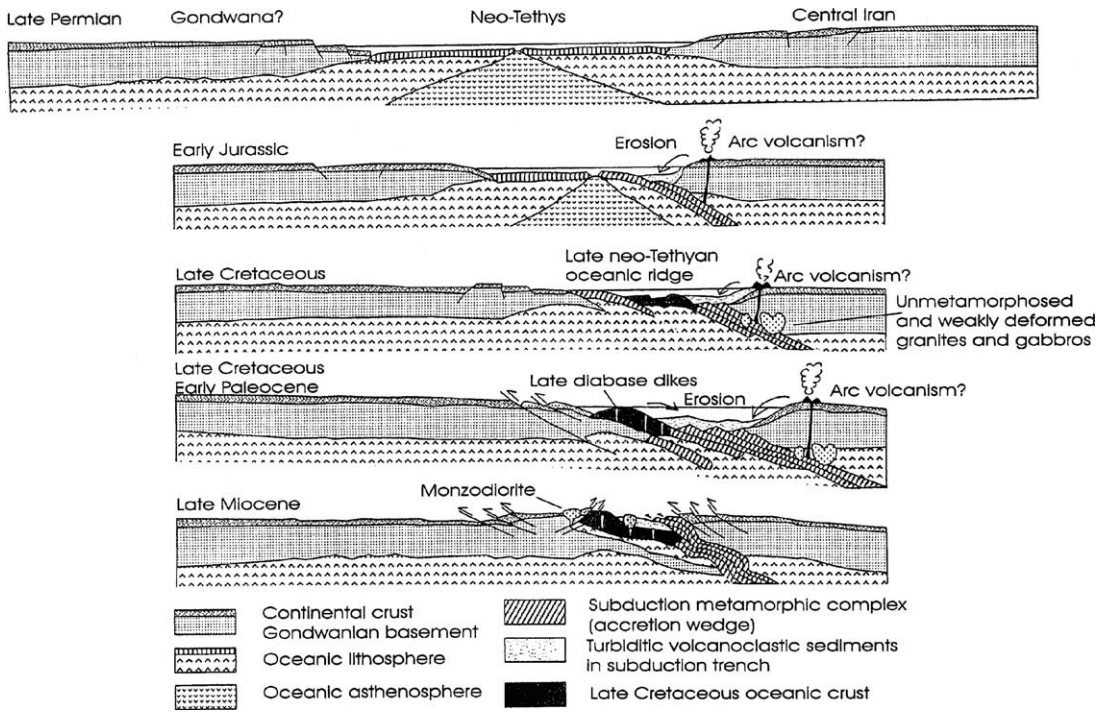

Fig. 2. Proposed scenario for the geodynamic evolution of the region of Khoy (after [4,6]). Explanations in the text.

gin of the Central-Iran Block till the Makran area to the south: development of back-arc basins of Jurassic–Cretaceous age in the Esfandagheh region [2], development of a back-arc basin of Cretaceous age in the Kahnuj ophiolitic region [3], interpretation of the polymetamorphic complex of Sanandaj–Sirjan in the region of Neyriz as a subduction complex developed during Mesozoic times [11].

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