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FABIJAN TRUBELJA and VESNA MARCHIG

PHASES OF INITIATION AND OPENING OF TETHYS AS OBSERVED IN MESOZOIC VOLCANIC ROCKS OF THE DINARIDES

SARAJEVO 1991

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Odjeljenje tehničkih nauka

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Abstract. Volcanic and some plutonic rocks from two magmatic complexes in the Dinarides of Bosnia and Herzegovina were investigated by petrological and geochemical methods. The Triassic magmatic rocks appear to have been produced during rifting of continental crust. The Jurassic volcanic rocks are extrusive ophiolite sequences. Ratios of hardly mobile trace elements show that both rock types were extrudet as mid-ocean ridge basalts (MORB). However, the Triassic rocks reveal additionally enrichment of Ba, Rb, and light rare earth elements (LREE). This suggests that during Triassic times the Dinaride part of Tethys was in the opening stage, with rifting of continental crust. This caused partial melting, uplift and eruptions of mantle-derived material, which, on its way through continental crust, was contaminated with large lithophile elements, including LREE. During the Jurassic the N-MORB type oceanic crust was formed, therefore spreading produced volcanic rocks which are not contaminated by continental crust. They are similar to present mid-ocean ridge basalts.

1. INTRODUCTION

We recognized two different magmatic-sedimentary complexes of the Mesozoic epoch in the central region of the Dinarides (the area of Bosnia and Herzegovina). The first of the two complexes is Triassic (mostly Ladinian basalt, andesite, dacite, spilite, keratophyre, quartz keratophyre, gabbro, diorite, granite). The second ophiolite complex is Jurassic and is characterised by the presence of large ultramafic massifs followed by gabbro, diabase, spilite and amphibolite (Fig. 1,and Fig. 2).

Triassic extrusive rocks are followed, here and there, by layers of pyroclastic breccias and tuffs. The occurrence of these magmatites in several parallel zones indicates that they have been formed as a consequence of rifting of continental crust

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during the initial opening of Tethys. Pillow lava and stratified tuff layers show that eruptions happened under shallow submarine conditions. The rocks reveal a large range of variability covering the differentiation from basalt over andesite to dacite for extrusive rocks, and adequate differentiation products from gabbro over diorite to granite for the intrusives. Low-albite containing extrusive rocks are wide-spread.

Jurassic magmatic rocks encountered are ophiolites which can be interpreted as products of spreading of oceanic crust. The upper layer is formed of pillow lavas, altered under very low grade metamorphism and hydrothermal activity. A sheeted dyke complex which usually is the next lower layer of ophiolites, is missing in our ophiolites. Layered gabbro, a filling of a fossil magma chamber, is present, as well as the mantle section, mostly represented by lherzolites.

Numerous papers have been published about Mesozoic igneous rocks of the central region of the Dinarides (Karamata, 1982, 1988; Lugović et al., 1991; Majer, 1962; Pamić, 1971, 1974; Trubelja, 1960, 1961, 1963; Trubelja and Marchig, 1990; Trubelja and Pamić, 1965; Trubelja et al., 1978). Their occurrrence and the relation-ship to the sedimentary and metamorphic rocks have been presented recently on the *Basic Geological Map of Bosnia and Herzegovina* (scale 1:100,000).

For comparison with the described magmatic rocks of the Dinarides, we used recent pillow lava from the southern part of the East Pacific Rise. The East Pacific Rise is a recent zone of divergence with accretion of newly formed oceanic crust which, in case of obduction would become an ophiolite, comparable with those which were obducted during the formation of the Jurassic Tethys.

In the southern part of the East Pacific Rise we could observe the cyclic development of spreading (Holler et al., 1990). The first phase of a cycle was characterised by eruptions of pillow lavas forming a steep and narrow volcanic ridge. The second phase revealed eruptions of sheet lava, forming a large and rounded ridge. The third and fourth phase were magmatically starved; in this period tectonic activity formed a central valley along the ridge crest. The sheet lava of the second phase was more evolved than the pillow lava formed in the first phase.

The hydrothermal activity of the first two magma-rich phases is adding to the sea water mostly volatile components of magma degasing like He and CH_4, and feeding numerous and populated hydrothermal biotops. In the third phase hydrothermal activity occurs as "black smokers" forming massive sulfide chimneys on the bottom of the central valley. The fourth phase is characterized by metal sulfide crusts and agglomerates covering the sea floor of the central valley. We assume that in this phase stockwork mineralisations were formed within the basalts of the central valley.

Thirty three samples of fresh glassy pillow lava were analysed for comparison, we additionally investigated fourteen samples of recent basalt which suffered severe hydrothermal leaching. These investigations are intended to serve as indicators for the mobility of different elements in the process of hydrothermal alteration.

2. RESULTS AND DISCUSSION

Microscopic determination of rocks supported with X-ray diffractometric determination of mineral content was performed on: 40 rocks of Triassic age (subdivided into 36 extrusive and 4 intrusive rocks) and 32 rocks of Jurassic age (subdivided into 22 extrusive rocks, 6 layered gabbros and 4 mantle samples).* On the same samples chemical analyses of major and trace elements were performed by means of X-ray fluorescence and a determination of rare earth elements (REE) was performed by means of inductively coupled plasma mass spectrometer (ICP-MS).

The preliminary results are presented below. The plot of V against Ti was suggested by Shervais (1982) to discriminate between diferent types of basaltic rocks. The ratio is formed during partial mantle melting, and this ratio does not change during processes of magma differentiation as both ions are similar in their behaviour during differentiation. Fig. 3 shows the V to Ti ratio of the samples discussed in this article; the average of the investigated samples plots in the range of mid-ocean ridge basalts i.e. the magma has its origin in partial melting of the mantle.

This is also valid for hydrothermally altered recent basalts; this shows that the V/Ti ratio doesn't change during hydrothermal alteration.

Fig. 4 shows the spider diagram (Thompson et al., 1984) not normalized for chondrite but for average pillow lava from the southern East Pacific Rise. The Jurassic volcanites reveal only insignificant differences to the recent pillow lava. Opposite to that, Triassic volcanites are strongly enriched in large ion lithophile elements. This shows that Jurassic volcanites have a similar genesis as modern mid-ocean ridge basalts. Triassic volcanites, opposite to the Jurassic ones, originated from the same source, but got contaminated with different components of continental crust which they had to pass through during their ascent.

The rare earth elements patterns normalized for chondrites which are shown in Fig. 5, lead us to the same conclusion. The pattern of REE in the Jurassic samples is very similar to the REE pattern of recent pillow lavas from the southern East Pacific Rise. The heavy REE of Triassic lavas also shows nearly identical patterns to the ones of Jurassic lavas and of recent pillow lavas from the East Pacific Rise. The light REE are, on the contrary, strongly enriched in Triassic lavas, showing again the addition of light REE by means of contamination with the material of the continental crust.

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* Locations of rocks sampling. Magmatic rocks of Triassic age: the northern flank of mount Kozara (western Bosnia); the valley of river Vrbas between Donji Vakuf and Jajce; the area of Bugojno and Kupres; the surroundings of Travnik and Komar; the large zone arround Konjic, Jablanica and Prozor; the surroundings of Sarajevo, Vareš and Kalinovik; in south-east Bosnia (Čajniče, Foča, Tjentište, Maglić). Ophiolites of Jurassic age: the large Krivaja-Konjuh peridotite massif; the surroundings of Višegrad in eastern Bosnia.

In Fig. 5 the average REE patterns are shown for 6 layered gabbros (filling of a magma chamber) and 4 mantle samples. Although the absolute amount of REE is very low, reaching partly the detection limit of our instrument, it is still obvious that the filling of the magma chamber reveals a large positive Eu- anomaly and the mantle material samples a large negative Eu- anomaly.

This is in accordance with the observed presence of plagioclases in the filling of the magma chamber. Plagioclases are known to scavenge Eu by liquid/solid separation in the magma chamber. Mantle depletion on Eu is also in accordance with the observation that mantle material never contains any feldspar.

The described preliminary interpretation of mineralogical and chemical data shows that during Triassic age Tethys was an ocean in its initiation stage. Continental crust rifted together with overlaying sediments, partial mantle melt ascended, passed a quite strong differentiation and got contaminated with components of the continental crust.

During Jurassic the ocean basin was already well developed. At the diverging plate boundary lavas with oceanic basalt composition were erupted, which passed the same differentiation processes as recent basalts on the southern part of the East Pacific Rise. The question is, however, still open if the diverging plate boundary in Jurassic Tethys in the territory of Bosnia and Herzegovina was a mid- oceanic ridge or a back arc spreading ridge. The chemical composition does not give any hint to the influence of subducted material in Jurassic ophiolites, what would indicate a mid oceanic ridge situation. The back arc situation still cannot be excluded, as back-arc basins also produce pure mid oceanic ridge basalts if the position of the subduction zone is far enough away from the zone of spreading (L o o c k et al., 1990).

The question which also arises when comparing the East Pacific Rise basalt with the Jurassic Tethys basalt, is the reconstruction of spreading rates of fossil plate boundaries. H e k i n i a n (1982) suggested the change of chemical composition of basalt with spreading rate. That would indicate spreading rates of 12-16 cm/y for the Jurassic Tethys, because it produced basalts of a similar composition as recently erupted basalts of the southern part of the East Pacific Rise.

We cannot confirm these conclusions because we observed two different lava generations at the East Pacific Rise with a different chemical composition, although the average spreading rate did not change.

SAŽETAK

Istražili smo veći broj uzoraka efuzivnih, i samo nekoliko intruzivnih stijena sa područja centralnih Dinarida (Bosna i Hercegovina) uz primjenu petroloških i geokemijskih metoda. Stijene trijaske vulkanogeno-sedimentne serije nastale su kao posljedica riftovanja kontinentalne kore na početku otvaranja Tetisa. Bazične magmatske stijene (dijabaz-doleriti, spiliti) jurske starosti pripadaju završnoj efuzivnoj sekvenci centralne ofiolitne zone.

Odnosi imobilnih mikroelemenata određeni u ovim stijenama pokazuju, da i trijaski i jurski efuzivi imaju karakteristike bazalta srednjooceanskog hrpta (MORB). Međutim, trijaske magmatske stijene su naknadno obogaćene elementima Ba i Rb kao i laganim elementima rijetkih zemalja (LREE). To ukazuje da su Dinaridi za vrijeme trijasa bili dio Tetisa u fazi otvaranja, sa riftovanjem kontinentalne kore. Ovo je prouzrokovalo parcijalno talenje, kretanje magme istisnute iz plašta naviše, koja je na svom putu kroz kontinentalnu koru postala onečišćena sa velikim ionima litofilnih kemijskih elemenata, uključujući i lagane elemente rijetkih zemalja (LREE).

Za vrijeme jure formirana je bazaltna oceanska kora na mjestima širenja (spreading) oceanskog dna i tu nije bilo kontaminacije. Sastav tako nastale fosilne oceanske kore sličan je sastavu recentnog bazalta srednjo-oceanskog hrpta (N-MORB).

Istraženi uzorci kumulatnih gabra i peridotita predstavljaju dijelove ispunjenih magmatskih prostorija (magma chamber), dok tektonitni lercoliti pripadaju sekvenci plašta.

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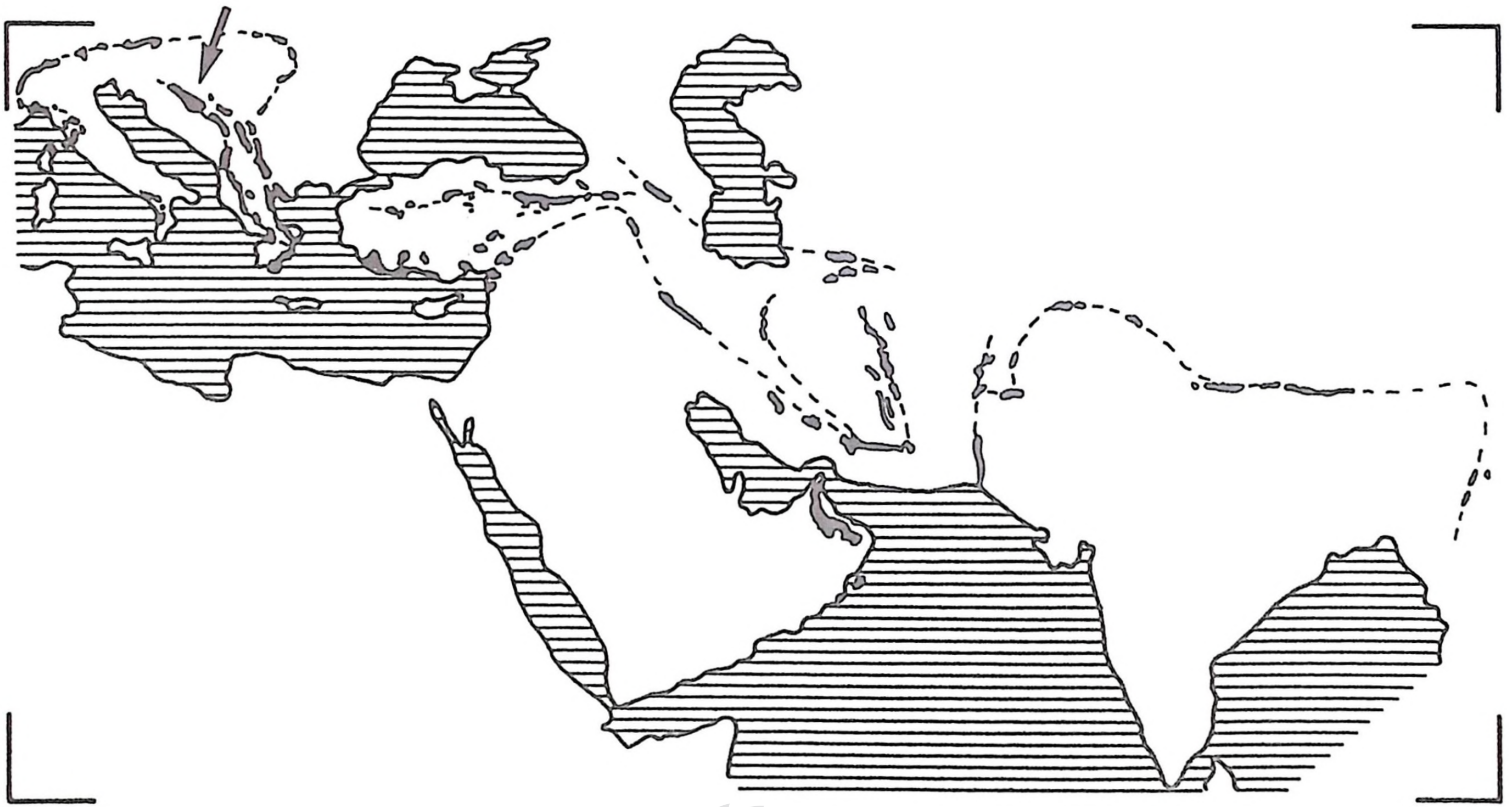


Fig. 1. Sketch of occurrrences of Tethys ophiolites. Arrow marks the area of investigation.

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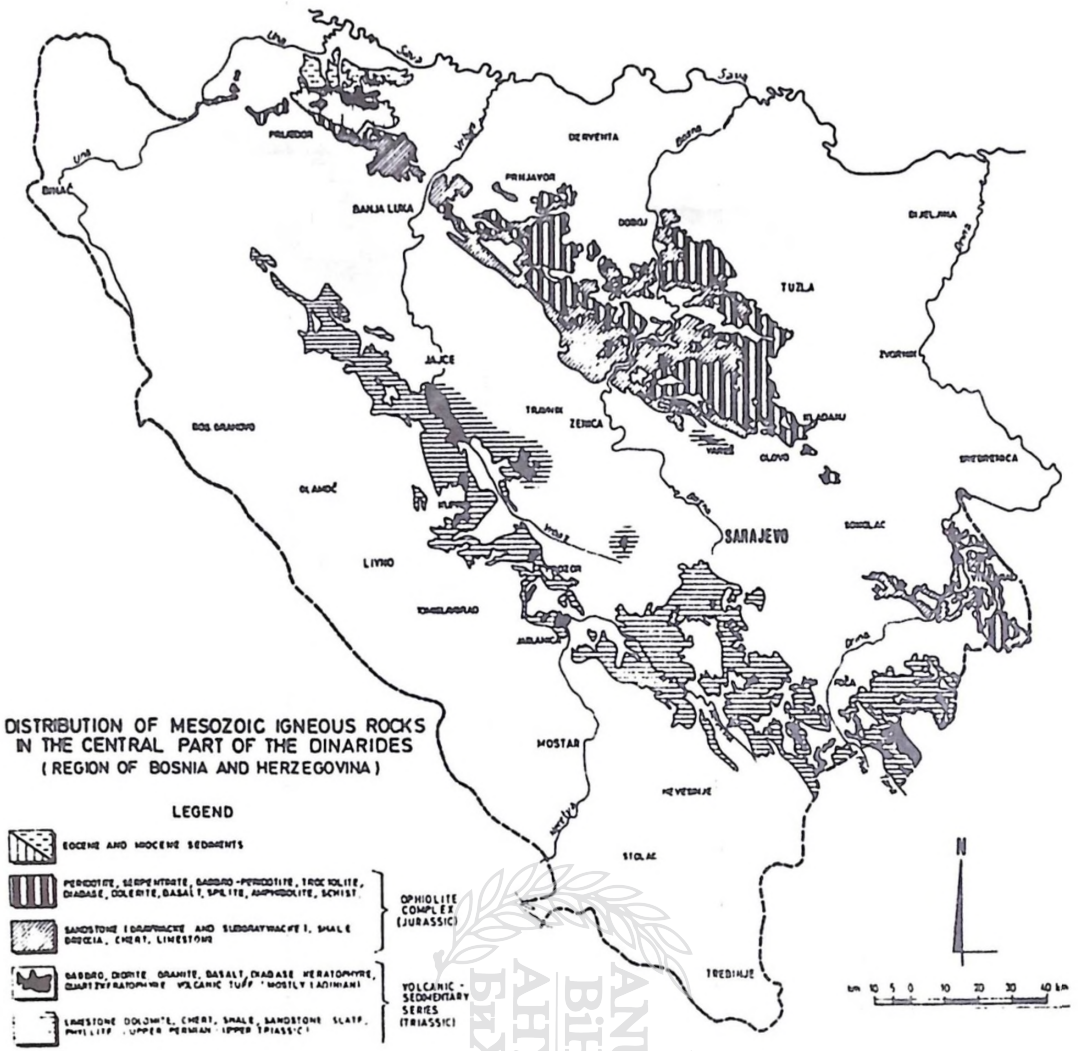


Fig. 2. Generalized geological map of area of investigation.

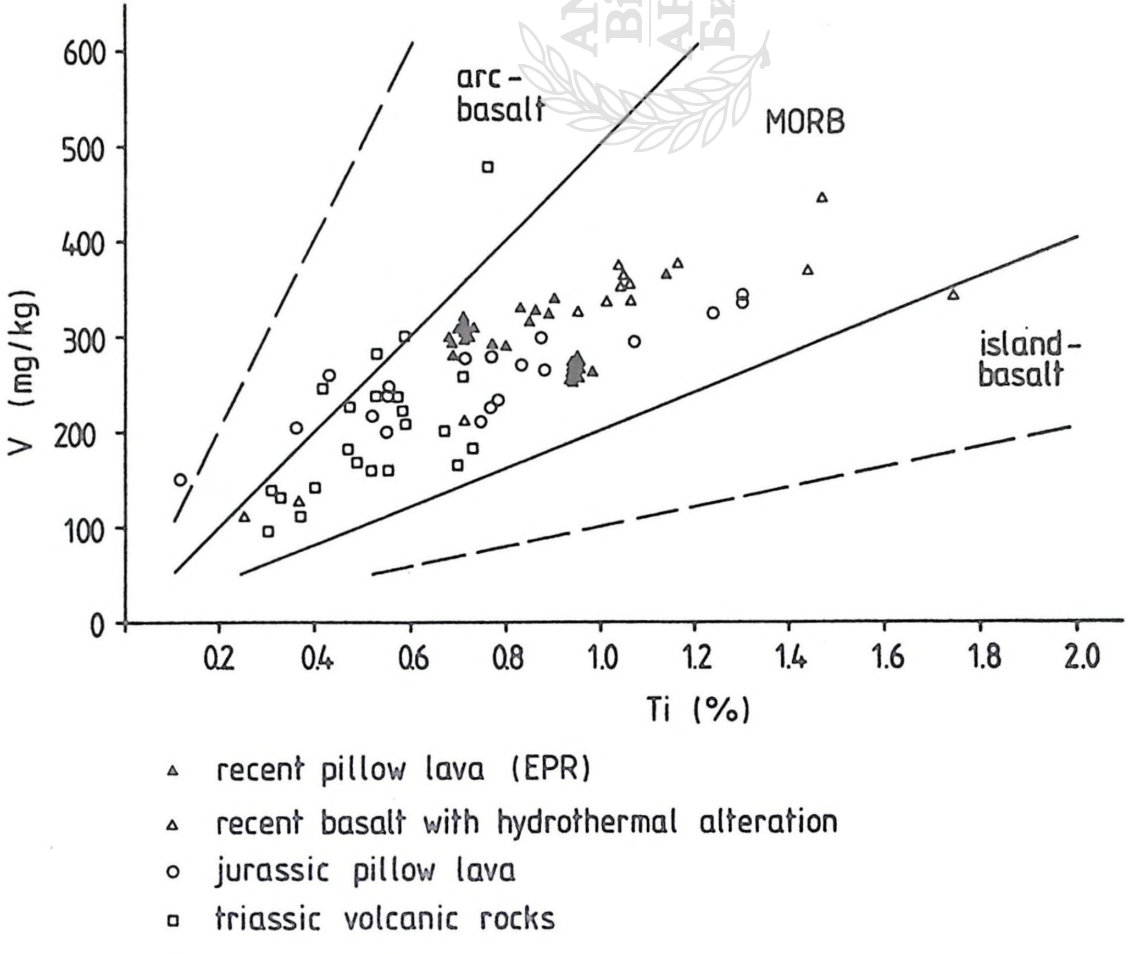


Fig. 3. Ti-V plots as suggested from Shervais (1982).

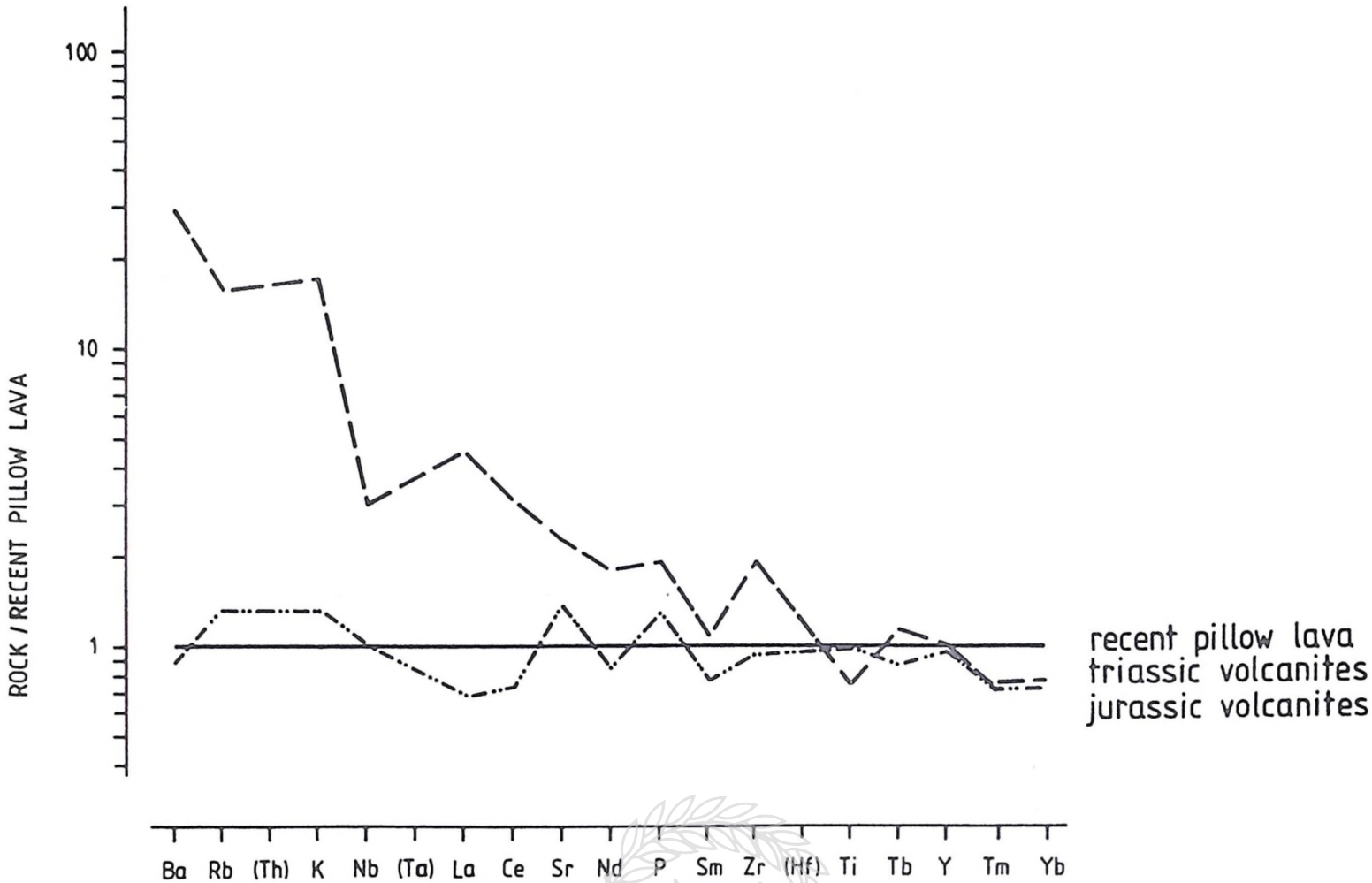


Fig. 4. Spider diagram on basis of recent pillow lava from southern part of East Pacific Rise (full line at 1. Triassic volcanites - dashed line; Jurassic volcanites-dashed/stippled linep

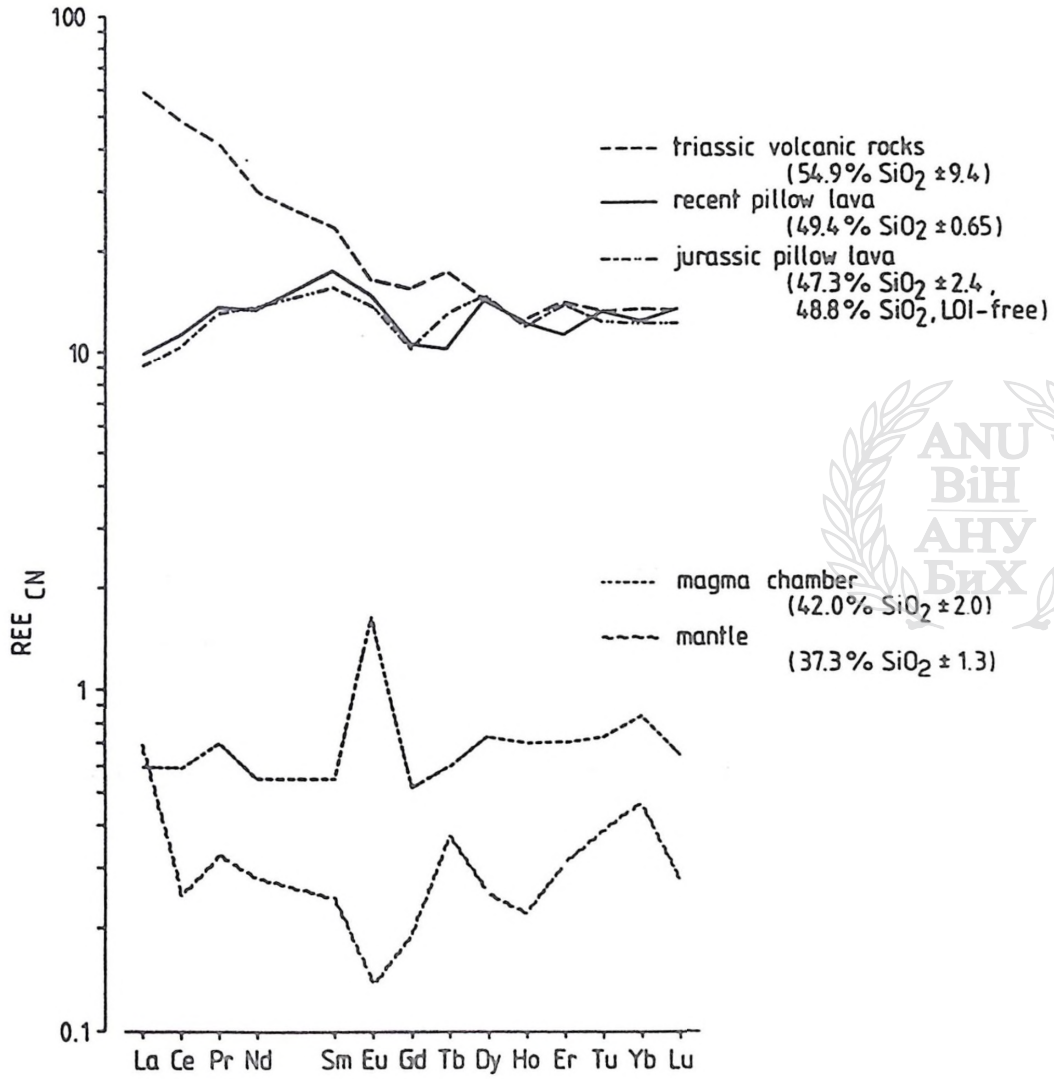


Fig. 5. Chondrite-normalized REE, average values for group of rocks. Values for chondrite after Wakita et al. (1971).