Late Triassic, Early and Middle Jurassic Radiolaria from ferromanganese-chert nodules (Angelokastron, Argolis, Greece): evidence for prolonged radiolarite sedimentation in the Vardar-Meliata Ocean

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In the Argolis, the Basal Sequence constituting the eastern Pelagonian margin which bordered the Vardar–Meliata oceanic domain, includes Late Triassic–Early Jurassic shallow-water carbonates, condensed pelagic limestones of Early–Middle Jurassic age, Late Jurassic radiolarian cherts, siliceous mudstones and sandstones rich in ophiolite fragments. Up-section, coarse breccias, also with clasts of boninites derived from a nearby ophiolite obducted onto the Pelagonian margin in Late Jurassic–Early Cretaceous times crop out.

Along the road from Angelokastron to Sofiko, about 2 km east of the village of Angelokastron, a small quarry exposes pervasively sheared dark reddish-brown, radiolarian-bearing cherty shales with disrupted fragments of chert and chert nodules impregnated by ferro-manganese oxides. These shales occur in the footwall of a thrust bringing them into contact with the Pantokrator Limestone of the Basal Sequence.

We collected more than 30 samples of the nodules and the shaly matrix. 13 nodules and one matrix sample yielded determinable radiolarians. 16 x-ray fluorescence analyses were carried out on 12 nodules that indicated a hydrothermal origin of the ferro-manganese mineralization.

The radiolarian taxa found indicate four age groups for the nodules that are embedded in the siliceous shale matrix that yielded a Middle Jurassic age (middle Bathonian). The first group includes nodules of Late Triassic age (late Norian–Rhaetian); the second group nodules of Early Jurassic age (early Pliensbachian and probably middle–late Toarcian); the third group nodules of early Middle Jurassic age (Aalenian–Bajocian); the last group finally includes nodules of late Middle Jurassic age (Bajocian–Bathonian).

The presence of Late Triassic to Early Jurassic Mn-impregnated chert nodules in a Middle Jurassic matrix indicates a deep oceanic environment prior to the tectonic emplacement of the succession onto the Pelagonian continental margin. We suggest that these nodules, more lithified than their matrix, were exhumed on the slope of an intra-oceanic accretionary wedge and were redeposited in the Middle Jurassic siliceous mudstones on the floor of the remnant Vardar–Meliata Ocean.

Radiolarian ages and geochemical data on the ophiolites from the Koziakas massif (Greece)

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The Koziakas massif, located at the western boundary of the Thessaly plain, consists of a stack of thrust units emplaced westward onto the Pelagonian (s.l.), which in turn thrusts

onto the Eocene Pindos Flysch. The dismembered units of the Koziakas are unconformably overlain by the Oligocene-Miocene molasse of the Mesohellenic trough.

In the Koziakas massif, at the top of the "Pelagonian" succession, three ophiolitic tectonic units crop out:

a) the "Mélange and Fourka Units". At the base of the Fourka Unit scattered outcrops of ophiolite-bearing mélange are exposed. The Fourka Unit consists of thrust sheets and blocks of pillow lavas locally covered by radiolarian cherts.

b) an "Ophiolite Unit", consists of slivers of sheared serpentinites, locally containing dunite bodies, plagiogranite and boninite dykes.

All volcanic rocks studied herein come from the "Fourka Unit" and consist of basalts and basaltic andesites. Six samples display a clear alkaline affinity and are similar to the alkaline within-oceanic plate (WPB) and are interpreted to have generated in a seamount setting. Two samples display similarities with enriched MORB (E-MORB) and are interpreted as formed from a N-MORB type mantle source slightly enriched in a plume component during the early stage of oceanic spreading or in an off-axis oceanic setting.

We examined 32 samples for radiolarian analyses. The assemblages of the samples collected near the WPBs indicate Middle and Late Triassic age, while the radiolarites collected near the E-MORBs indicate Late Triassic age.

The occurrence of Late Triassic WPBs and E-MORBs points to the existence of an oceanic setting in which the N-MORB asthenospheric source was influenced by a plume-type component and resulted in the off-axis eruption of enriched alkaline basalts and enriched MORB-type basalts. This conclusion is in agreement with similar results obtained from other sectors of the Hellenide ophiolites. During the post-Late Jurassic compressive tectonic phase, which affected the Internal Hellenides, the Mélange and Ophiolitic Units tectonically overthrusted the "Pelagonian" continental margin represented by the sedimentary units of the Koziakas Massif. During the post-Late Eocene compressive tectonic phase all these units were refolded and thrusted southwestwards onto the Eocene Pindos Flysch.

Water ages in thermal system of Podhale Basin, Inner Carpathians, southern Poland

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Fissured and karstified Eocene and Mesozoic carbonate formations of the Podhale Basin represent the largest reservoir of renewable thermal waters in Poland. They outcrop in the Tatra Mts. at altitudes of 1 000-1 800 m and deep to the north under the flysch formations of the basin. The main direction of flow is to the north for abt. 15 km where the impermeable formations of the Pieniny Klippen Belt divides it and diverts to the west and east, and next to the south to the Danube watershed in Slovakia. The temperatures range from abt. 20° C near the outcrops to abt. 85° C at the most northern wells. For a better understanding of the flow pattern, environmental isotopes ($\delta^{18}O$, $\delta^{2}H$, ^{3}H, ^{14}C, $\delta^{13}C$) have been used since early seventies and recently also gaseous tracers (He, Ne, Ar and SF_6) under the grant No N 525 402334 from the Ministry of Science and Education.

The C^{14} data of thermal waters change from 37 to 0 pmc with $\delta^{13}C$ from abt. –5 to 0‰; exhibiting the influence of isotopic exchange with carbonate minerals, which makes the quantitative dating difficult. The $\delta^{18}O$ and $\delta^{2}H$ are similar to those of modern waters in springs and wells with cold water, with several exceptions characterized by shift of $\delta^{18}O$ to heavier values, which are caused by isotopic exchange with carbonate minerals. The isotopic altitude effect was estimated form the data of springs and wells within the Tatras area. For $\delta^{2}H$, the mean altitude of recharge area reads: h_2 (m a.s.l.) = $–69.1 \cdot \delta^{2}H – 4054$, with the uncertainty of about 100-200 m. The most negative $\delta^{2}H$ values of thermal waters are similar to the values observed for large karstic springs in the Tatras, which may suggest their Holocene age. However, the spatial distribution of $\delta^{2}H$ values indicates that close to the recharge area, the thermal waters are similar to those of medium springs discharging at the