Upper Ordovician diamictites from the Balkan Terrane, Western Bulgaria: a glaciomarine record of the Gondwana Hirnantian glaciation

Горноордовишки диамиктити от Балканския Терен, Западна България: глациално-морски отложения, свързани с хирнантското заледяване в Гондвана

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Hirnantian diamictites are exposed in the Paleozoic Balkan Terrane (Western Stara Planina Mts) which was an integral part of the Armorican Terrane Assemblage (s.l.). In terms of lithostratigraphy the rocks are referred to as Sirman Fm having thickness of 7–10 m (Fig. 1). This unit overlies non-fossiliferous argillites of the Tseretsel Fm (Katian stage) and is covered by lydites and graptolite-bearing argillites of the Saltar Fm (Hirnantian–Telychian). The dark grey, massive, sandy diamictites contain single pebble-sized extra-clasts derived from the Ordovician basement. The main microfabric constituents include quartz grains (≥80%), lithic fragments, intrabasinal shale clasts and silty-clayey matrix.

The combination of several rock characteristics indicates glaciomarine origin of the Hirnantian sediments: distinct stratification, poor sorting, presence of lonestones (well preserved unstable lithic fragments), random arrangement of the clasts, lower gradational boundary and intercalation with dark marine shales, lack of evidence for glacial terrestrial deposition (e.g. abraded bed surfaces, faceted, striated or bullet-shaped clasts, specific landforms such as moraines, etc.). Moreover, these laterally persistent deposits show uniformity in thickness, colour, structures, composition, and texture. Another diagnostic feature is the occurrence of till pellets, e.g. unsorted debris identical to the rock matrix, but having diffuse boundaries, flattened shape, and subparallel orientation to bedding. The ice-distal origin of the diamictites is emphasized by their relatively small thickness, common laminations, pronounced sandy (e.g. gravel-poor) character, homogeneous lithology of the extrabasinal clasts, and lack of ice-proximal and ice-contact facies (fining-up and coarsening-up units, rapid lateral facies changes, etc.).

Fig. 1. Simplified log of the study interval
The primary diamicts originated through rain-out settling of clay-sized to sand-sized particles from turbid meltwater plumes and ice-rafted debris (IRD) reaching pebble size. The turbid plumes were emanated from the front of a distant grounded or floating glacier while the IRD were derived from seasonal ice or icebergs. Although distinction of those two sources for IRD is difficult in ancient successions, the heterogeneous particle size and shape, as well as the extra-basinal provenance of many clasts, imply far-travelled iceberg-related transport (Fig. 2). The balance between transported material by meltwater plumes and IRD may have varied but the siliciclastic supply ultimately resulted in a regionally extensive, blanket-like diamict facies. The occurrence of slumps and load casts reflects high sedimentation rates and/or local steep slope with unstable substrate. The lack of high-energy depositional/erosional structures and the low degree of grain sorting suggest deposition in a weakly agitated, mid-shelf to outer shelf environment. Marine currents may have assisted in the distribution of clastic material across the shelf whereas intermittent reworking of semi-consolidated sediments is inferred from the commonly abundant intrabasinalclasts (Fig. 3). While the glaciomarine sedimentation occurred mostly during glacier retreat forming a deglaciation sequence, the intercalated shales represent products of suspension settling during relatively short periods of interglacial highstand.

The abundant quartz grains and the ZTR heavy mineral association imply a low relief, granitoid-dominated sourceland with warm and humid climate. Extreme chemical weathering and erosion of the Gondwana interior related to intensive volcanic activity (e.g. a CO₂-rich atmosphere) took place during the late Neoproterozoic and early Cambrian providing large volumes of mature quartz sands. The latter were transported by rivers and deposited as first-cycle sediments in Cambrian–Ordovician time on a vast shallow shelf along the northern continental margin. After a long-term coastal reworking the extensive ice-sheet growth over part of Gondwana in the Hirnantian resulted in incorporation of those mature clastics and their subsequent release during the ice-sheet decay.

The regional geographic distribution of similar Upper Ordovician glaciogenic rocks in South/Central Europe (Portugal, Spain, France, Italy, Germany, Czech Republic, Austria), Turkey and Iran is consistent with the existence of a broad belt of glaciomarine sedimentation along the north Peri-Gondwana nonglaciated shelf, e.g. beyond the outer ice-sheet limit, during the Hirnantian age.