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Dinaric Glaciation - new perception of glaciation in the Mediterranean based on sedimentological evidence of Early/Middle Pleistocene glaciation of the Croatian Dinarides

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The Quaternary sediments have been studied for the past 20 years in the area of Croatian Dinarides, specifically northeast Adriatic coast and islands, the Velebit Mt. and northern Dalmatia. The sedimentological research yielded glacigenic origin of studied sediments, as follows:
1) Glacial sediments are diamicts (tills or tillites) interpreted as ground, medial and lateral moraines. The main characteristics of glacial origin are clasts with glacial striae, ice-shaped (faceted, bullet-shape and conical) and ice-shattered clasts. The ground moraines are identified as Rujno, Paklenica and Novigrad Members in terms of litho-, allo- and morphostratigraphy. The Paklenica Member, found also on Krk and Rab Islands, documents the furthest extent of glaciation. Another characteristic landform of ice-contact zone are kame-terraces, well preserved on the Krk and Pag Islands.
2) Glacifluvial sediments comprise both glacial outwash deposits of braided streams and flood plains, and fluvial deposits of meandering rivers, represented with sand and gravel deposits. Their glacigenic origin is based on facies association, since they occur with tills or tillites, and contain glacially-derived boulders and blocks, sometimes also lithologically exotic debris. The proglacial glacifluvial sediments are found on Krk and Pag Islands (as kame-terraces) and are widespread in Northern Dalmatia.
3) Glacilacustrine sediments comprise a) clay-silt sediments with classic varves, and b) varve-like calcisiltites with drop-stones, being the main diagnostic feature for their proglacial character. Varved sediments with abundant plant macrofossils, ostracods and small bivalves are found at Žrilo coast. Varved-like sediments with dropstones are exposed at Novigrad Sea and Seline coastal sections.
4) Glacideltaic sediments are represented by conglomerates, calcarenites and calcisiltites in alternation. Significant characteristics for glacial attribution are ice-striated clasts that were found in conglomerates, and their association with glacilacustrine sediments, all exposed along the Seline coast and named Starigrad Unit.
Sedimentological research showed that glacigenic sediments are widespread in the north Adriatic region and Northern Dalmatia, which proves far seawards extension of the Dinaric glaciation. The occurrence of ice-wedge casts and kettle-forms at Novigrad Sea coastal section documents the most southwards periglacial palaeoenvironment. Sedimentary successions indicate at least three ice advances and retreats.
The U-series dating of calcite cements in moraines yielded 350ky minimum age of Paklenica Member, thus it is attributed to the Middle Pleistocene Elsterian (Mindel) glaciation. Regionally, it correlates with Ninkovići Member in Montenegro and Skamnelian stage in Greece (MIS12). Dating of calcite from an ice-wedge cast yielded age between 146ky and 110ky, thus we assume that some of them mark the end of the Elsterian glaciation, and that the Novigrad Member was deposited during the Saalian (Riss) glaciation. This tentative chronostratigraphic correlation and superposition of the defined allostratigraphic units implies that the Starigrad Unit is the oldest, indicating even older glaciation than Elsterian.
On account of all data about sediments, their position of occurrence and tentative chronostratigraphy, it is presumable that Middle Pleistocene glaciation (MIS12) was the most extensive one in the Eastern Mediterranean. Further, more precise chronostratigraphic correlation of scattered glacigenic sediments of the Dinarides is expected in future research.