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Glaciotectonic complexes in the central Anti-Atlas (Morocco): implications regarding the end-Ordovician ice-margin dynamics

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During the Upper Ordovician, the Moroccan Anti-Atlas was located in a marginal position regarding the ice domes centered farther southeast over the West Gondwana. Early glacial phases driven by glacio-eustatic transgressive-regressive cycles are recorded through a well-stratified alternation of sandstone and siltstone forming tens of meters sedimentary successions. During the glacial climax, the ice margin reached the Anti-Atlas area. This phase left behind typical deposits such as deformation till, outwash fans, glacimarine muds, tunnel-valley complexes and proglacial braided sandur but also paraglacial sandsheets, periglacial structures (palses) and tidal deposits.

Several glaciotectonic complexes were identified throughout the shelf. They typically comprise fold-and-thrust belts of more than one kilometer in width, which mainly involve fluviodeltaic and tidal sandstones. A progressive attenuation of the deformation in the fold vergence orientation is observed. Basal décollement surfaces are formed by fine-grained horizons either constituted by an underlying tillite (anterior glacial cycle) or corresponding to preglacial offshore facies. In some specific cases, several superimposed décollement surfaces were activated without however clear evidence of synchronicity. The lower décollement surface is characterized by small-scale fold-and-thrust while upper ones are associated with sedimentary dykes of different nature and orientations. In a single case, a syn-tectonic sedimentation was clearly evidenced. Local depocenters in syncline cores are filled by coarse conglomeratic facies recording the erosion of anticlinal topographic highs. Glaciotectonic deformations structures are commonly truncated and sealed by transgressive strata marking the termination of the glacial episode.

Based on field observation and the reconstruction of a numerical 3-D model of the different outcrops, we propose a scenario of the emplacement of these glaciotectonic complexes. Sediment bodies involved in the glaciotectonic deformation are interpreted as margino-glacial accretionary wedges with duplexes. They propagated on the décollement surfaces owing to fluid overpressure generated by sub- to proglacial meltwater flows. The fold vergence thus reflects the local ice flow direction. A strong coupling between basal ice and sedimentary substratum is also envisioned for the entrainment of thick sedimentary piles. Such a deformation mode may have required the presence of permafrost favoring overpressure development in sub- to proglacial aquifers. By comparison with Quaternary analogues, such deformation likely corresponds to periods of glacial stillstand or re-advances in continental or coastal domain in a context of general ice sheet margin recession at the end of the Upper Ordovician.