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# Tectonically-induced start of Early Permian carbonate shelf deposition, Zweikofel-Trogkofel area, Carnic Alps (Austria).

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In the area of the central Carnic Alps, Austria, a Late Carboniferous (early Kasimovian) to Early Permian (Artinskian pro parte) interval about 21 Ma in duration of cyclothemic, inner-shelfal mixed siliciclastic-carbonate deposition was followed, during the early Artinskian, by establishment of a carbonate shelf margin.
The Late Carboniferous to Early Permian icehouse Earth was subject to waxing and waning of polar ice sheets on Gondwana. During the Early Permian, the area of the Carnic Alps was situated along the northeastern passive margin of Gondwana facing into Palaeotethys. Along this margin, following Variscan orogenic deformation (Westphalian), a mixed siliciclastic-carbonate cyclothemic succession 2000 m thick accumulated under moderate to low rates of subsidence. The cyclothems are interpreted as the preserved landward tracts of glacio-eustatic depositional sequences.
At Zweikofel, the lower part of the section is represented by a package of decameter-scale, mixed siliciclastic-carbonate cyclothems. The cyclothemic succession is capped by a surface of erosion. Above the surface, two intervals of unbedded and very thick-bedded limestones are present that are vertically separated by an intercalated package of marls and lithic rudstones. The lower interval of unbedded limestone is about 40 m in thickness, and consists mainly of bioclastic limestones and microbial boundstones. Within the lower interval of unbedded limestone, emersion surfaces are present that, however, can be identified only in polished slabs and thin sections. In addition, within the lower interval of unbedded limestone, a lense of lithic rudstones to stylorudstones composed of shallow-water limestones is intercalated. The rudstone clasts are similar in facies to the limestones of the lower unbedded interval; furthermore, clasts of phylloid-algal limestones are present that may be derived from more distant locations outside the outcrop area.
The lower interval of unbedded limestone is sharply overlain by a succession of marls with intercalated, faintly graded beds of lithic rudstones. Up-section, no clear-cut trend in bed packaging, bed thickness and mean grain size of rudstones is discerned. The lithoclasts are derived from erosion of penecontemporaneous carbonate shelf deposits. Subaerial exposure and, perhaps, also subaerial erosion of at least some of the carbonate clasts is recorded by karstic vugs and veins filled by red internal sediments. The marl/rudstone package is sharply overlain by the upper, very thick-bedded limestone interval about 40 m thick of shallow neritic limestones; unfortunately, this upper interval is accessible only along its base. Boulders toppled down from the upper interval, however, indicate that it also consists of shallow-neritic bioclastic limestones, microbial boundstones, and ŕeefalćementstones rich in Archaeolithoporella and Tubiphytes. With respect to facies, each of the thick limestone intervals is different from the neritic carbonates (e. g. ooids, phylloid algal limestones, oncoid limestones) of the underlying cyclothemic succession. In addition, both limestone intervals are cross-cut by karstic veins and dykes filled by collapse breccias with a matrix of lime mudstone (locally dolomitized).
We interpret the change in depositional style across the top of the underlying, cyclothemic succession as a result of tectonically-induced backstep of the shelf margin. Subsequent to subaerial exposure and erosion, after reflooding of the shelf, deposition of microbial mounds and bioclastic limestones prevailed (lower interval of unbedded limestone). Following subaerial exposure of the lower interval of unbedded limestone, the considered sector of the shelf became more deeply submerged during the next transgression. As a result, carbonate shelf limestones, previously exposed at unknown (unpreserved) locations, became eroded upon transgressive shoreface reworking, and redeposited in rudstone event-beds within neritic marls. The sequence-stratigraphic significance of the upper interval of shallow neritic limestones is uncertain. Directly to the south of the Zweikofel area, but separated by a fault zone with strike-slip component, an Artinskian platform succession about 550 m in thickness is present

(Trogkofel Limestone; see our other contribution). The observations in the Zweikofel-Trogkofel area support the concept that the termination of cyclothemic deposition and establishment of a carbonate platform margin was induced by tectonism along this sector of the shelf.