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Evolution of the Late Paleozoic platform from a ramp into a rimmed shelf (Karavanke Mts., Slovenia)

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Facies association and (micro)facies characteristics indicate that in the entire Karavanke Mts. area Upper Carboniferous beds were deposited on a platform with a gently steeping ramp configuration. The siliciclastic-carbonate sedimentary succession exhibits a clear cyclic transgressive-regressive depositional pattern. Coarse-grained fluvial, coastal and/or fan-deltaic conglomerates alternate with finer-grained sandstones and bioturbated siltstones, deposited under the strong influence of storm events in the lower shoreface setting and with limestone horizons mainly related to algal mound buildups in the offshore setting below the storm wave base (NOVAK 2007).
Both high frequency and high amplitudes of sea-level changes reflected in a cyclic depositional pattern are recorded in the Late Paleozoic sedimentary successions also on a global scale. They are related to glacio-eustatic control associated with waxing and waning of the Gondwanan ice sheet. Because of the flat topography and the gentle angle of ramp inclination even the slightest change of sea-level caused a considerable shift of the coastal line (MASSARI & VENTURINI 1990, SAMANKASSOU 1997).
In the Early Permian, a prominent differentiation of the platform morphology is recorded in the Karavanke Mts. It is marked by the formation, drowning, reestablishment and a final subaerial exposure of a larger reef mound in the Dovžanova soteska area, while in other parts of the Karavanke Mts. predominantly siliciclastic sedimentation continued.
The lowermost part of Permian beds of the Dovžanova soteska Formation (BUSER & FORKE 1996, FORKE 2002) reflects a rapid transgression with progressive increase of carbonate content within the clastic sequence. It is followed by the gradual transition from dark bedded limestones to light-grey to pale-red massive Dovžanova soteska Limestone body.
Since it is grossly built of postmortally segmented skeletal fragments of crinoids, bryozoans, green calcareous algae and brachiopods in a micritic matrix, bounded only with encrusting *Tubiphytes*, algae, bryozoans and small sessile foraminifers, while the true reef-building metazoans and the "reefal cementation" are almost absent, we can refer to it as a reef (or skeletal) mound (FLÜGEL 2004).
The bioclastic packstone to microbreccia composed of fragmented allochthonous reef mound derived debris in the upper part of Dovžanova soteska Limestone represents the reef-flank facies. It was deposited in the forereef facies belt and suggests a substantial topographic relief and the rigidity of the reef mound body. Further evidence of this are neptunian dikes in the uppermost part of the complex. Taking into consideration the inherited instability of poorly cemented reef mounds, we can explain fissure opening as a result of oversteepened depositional relief that leads to passive gravitational movements and fracturing (READING 1996, FLÜGEL 2004, STANTON & PRAY 2004).
The following horizon, composed of deeper-water calcareous siltstones, marlstones and thin-bedded marly limestones with deeper-water biotic association speak for the short-term drowning of the reef complex prior to the deposition of red bedded crinoidal limestones with a rich and diverse shallow-water biotic association. Red stained silty crusts capping almost every limestone bed represent omission surfaces of the hardground type. Increased slope angle shifted the activity of sediment gravity flows from deposition and accretion to erosion. This change favours seafloor lithification by exposing sediment on the sea floor for extended periods. Winnowing and erosion by turbidity currents create hardgrounds on the slope (SCHLAGER 1989). Increased water agitation resulted in submarine cementation of calcareous ground and an impregnation with Fe and Mn oxides (BRETT 1998). This bare

surfaces prevent turbidity currents to become saturated with sediment, leading to more erosion. The result of this feedback loop are extensive crusts on the steep upper slope, which is too hard and too steep to alow much sediment accumulation, but it is not easily eroded either (SCHLAGER 1989). The uppermost part of the Dovžanova soteska Formation is marked by a reestablishment of reef growth, this time with strong marine cementation, suggesting a steep slope inclination.

The described development of the Dovžanova soteska Formation with drowning event, restored reefal sedimentation and intermediate tongue of deeper-water and upper-slope facies fits the description of a back-stepping reef with the landwards shift of carbonate production during the episode of relative sea-level rise (READING 1996).

Basal quartz conglomerates of the Born Formation cut into uppermost beds of red limestone with erosional unconformity. A clear erosional surface and features like calcareous pisoids and infillings of vadose silt in the topmost limestones of the Dovžanova soteska Formation suggest that the reef sedimentation was terminated as a result of subaerial exposure (FORKE 2002).

During the following transgression, sedimentary depocentre migrated towards the open-marine inner platform. The alternation of black bedded bioclastic grain- to packstones, biocalcarenites, oolites, sandy limestones and quartz sandstones with shallow-water benthos in the Born Formation indicates deposition in an open lagoonal setting repeatedly affected by the sedimentary influx from platform-margin oolitic and sand shoals. Some of the mixed carbonate-siliciclastic rocks (e.g. paraconglomerates) have characters of the debris flow deposits (NOVAK 2007). One of the rocky pyramids is built of massive light grey micritic limestone with the rugose corals forming an isolated patch-reef.

The youngest Lower Permian succession of the Rigelj beds indicates gradual shift of the facies belts from high energy coast through open-marine lagoon towards the shallow-marine, and shelf edge. In the transitional coastal belt, conglomerates, sandstones and oolitic limestones were deposited. Black bedded algal limestones with clayshale intercalations were formed in the inner-shelf environment. There, in the restricted marine shoals limestones with low diversity algal association were deposited, while in the open lagoon with normal water circulation near to platform edge, sedimentation of limestones with high diversity algal association took place (FLÜGEL 2004). Reef limestones and limestone breccias mark shelf edge setting. Development of the upper part of Rigelj beds suggests a shift of facies belts back into the open-marine lagoon, where black limestones with high-diversity biota and *Osagia*-type oncoids were formed (FLÜGEL 2004). Substantial content of fine-grained, well-rounded quartz pebbles in several limestone beds indicates periodical terrigenous influx from a distant hinterland. Regressive trend continues with the deposition of sandstones and calcitic siltstones in high-energy shoreface setting.

Based on facies relationships in the succession of Upper Paleozoic rocks in the Karavanke Mts., a change in platform morphology can be suggested. In the Dovžanova soteska area, a gently steeping ramp without both, the marginal barrier and the shelf break in the basinward direction developed into a rimmed shelf with steeper slope as a result of lateral and vertical accretion in response to numerous relative sea-level changes. During periods of sea-level stillstands or slow rises the reef mound on the platform margin rapidly prograded, while as a response to periods of rapid sea-level rises the initial drowning and back-stepping event caused vertical accretion and steeper slope angle (READING 1996). Similar platform evolution had been suggested in many sedimentary basins in different geologic periods.

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