

Aptian greenhouse climate and icehouse interludes – alpine Tethyan archives revisited

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In this study we revisit two Cretaceous archives in the Alps, and we test hypotheses of major sea level falls related to ice age interludes in the Aptian. The first of the two successions in focus was formed along the northern margin of the alpine Tethys and is today preserved as Garschella Formation in the Helvetic nappes of Switzerland. Aptian phosphorites of the Luitere Beds containing *Deshayites deshayesi* and *Dufreonia* are overlain by up to tens of meters of siliciclastic shales, the Gams Beds. Gams Beds with low carbonate content are poorly dated, according to available biostratigraphies they are of Late Aptian age (*nolani* ammonite zone). Gams Beds are covered by up to 15 m glauconitic bioclastic sandstones and limestones (Brisi sandstone and limestone).

The second locality we have revisited is Zürs in the Northern Calcareous Alps (NCA, Vorarlberg, Austria). There, a condensed succession of Jurassic-Cretaceous age records Southern Tethyan ocean history of a “submarine bank”. Jurassic radiolarian cherts are overlain by pelagic limestones of earliest Cretaceous age followed by an Aptian phosphorite hardground. These phosphorites are covered by an up to several meter thick succession of reworked crinoidal limestones and then by several tens of meters of “Kreideschiefer” (Lech Formation), which are of Albian to Cenomanian in age. Phosphorites at both localities record a time of hardground formation related to changes in Tethyan oceanography, triggered by a major perturbation of the global carbon cycle and by corresponding changes in climate and oceanography. Condensed sedimentation records intense

current activity on submarine highs and along the northern Tethyan shelf. Remarkable is the poorly understood change in sedimentation following hardground formation at both locations during Late Aptian time. The Helvetic Gams Beds (Garschella Fm.) record increased shedding of siliciclastics along the northern Tethys, either related to increased weathering or to a drop in sea level. We propose, that an eustatic drop of sea level explains observed northern Tethyan shifts in Late Aptian sedimentation. A corresponding drop in sea level is recorded at other localities as the Oman Mountains, along the Algarve coast in Portugal or in the Basque-Cantabrian Basin. There, most prominent “cold snaps” or “ice age interludes during Aptian greenhouse climate” are dated as martinoides to nolani ammonite zone, they coincide with the deposition of the Gams Beds.

Bioclastic limestones in the Helvetic succession and in the NCA record carbonate shedding at a time of renewed sea level rise following a major Aptian sea level drop. The Late Aptian prograding carbonate system of the NCA, considered as the source of crinoidal sands, was positioned along the northern margin of the evolving Eastern Alps while Brisi carbonate sands were shedded from a Northern Tethyan carbonate ramp. The Aptian condensed sediments of Helvetics and of NCA are indicators of extreme shifts in Aptian climate triggered by perturbations of the global carbon cycle. The Aptian-Albian Zürs succession provides additional information on the rapid transition of a passive continental margin with pelagic sediments into an Austroalpine foreland basin represented by “Kreideschiefer”.