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Artikel: Towards a better definition of the Anisian/Ladinian boundary : new biostratigraphic data and correlations of boundary sections from the Southern Alps

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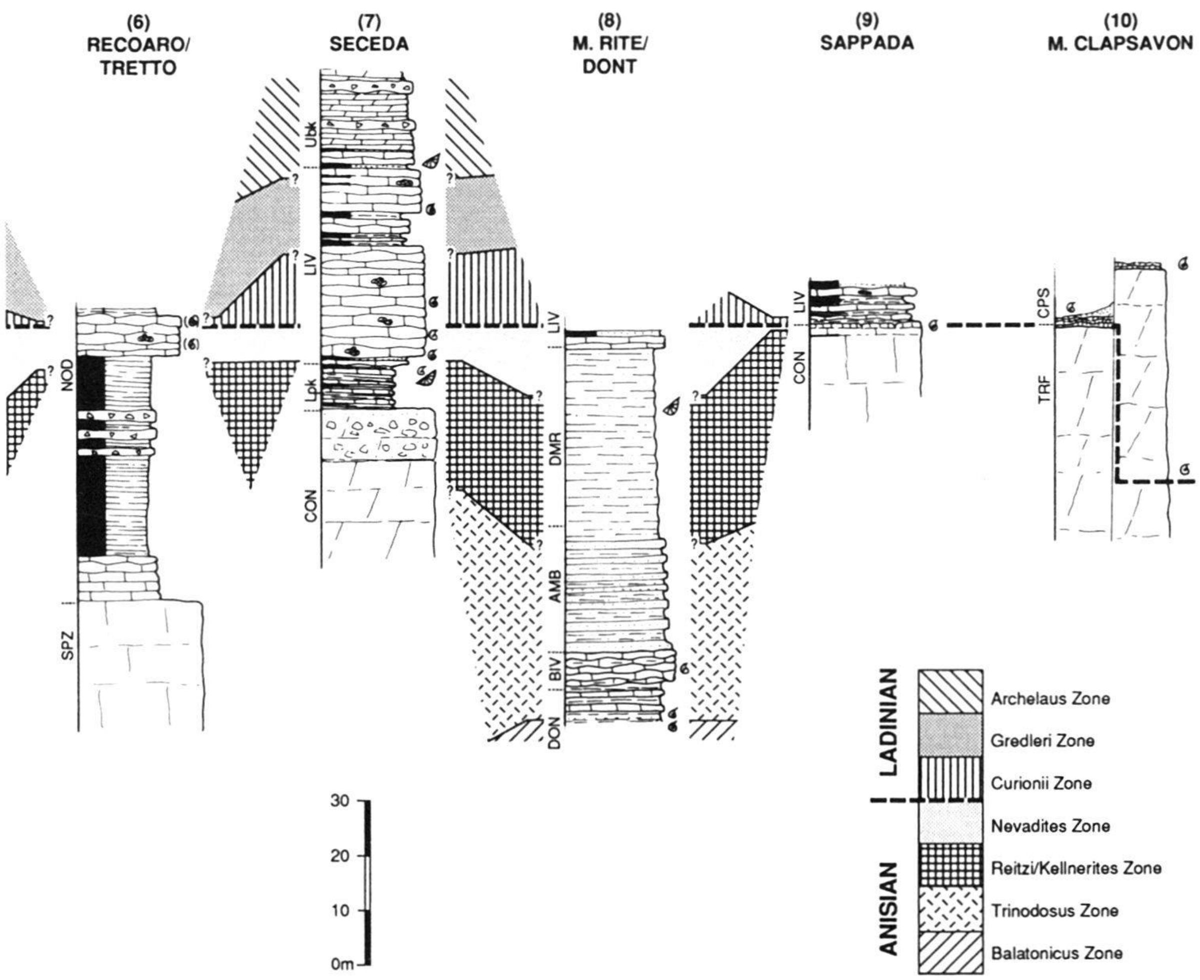

6. Additional Information on chronostratigraphy and time-scales

6.1. The calibration of the stratigraphic scheme (Fig. 2)

The calibration of the (chrono-)stratigraphic scheme of the South Alpine Middle Triassic (Fig. 2c) is based on age indications from ammonoids and Daonellas. The data coverage is obviously better for the basinal lithologies. We feel, however, that a careful integration of other stratigraphic tools including palynomorphs, conodonts, radiolarians and calcareous algae could improve the resolution in poorly constrained units. A prerequisite for this is a coherent calibration of the different scales against a common standard (e.g. the zonal scheme based on ammonoids).

In addition to the fossil data already discussed in this paper, calibration points for the western sector (Lombardy, western Trentino) include mainly ammonoids and Daonellas from the Prezzo Limestone (Trinodosus Zone), the "Wengen Beds" (Archelaus- & Regoledanus Zones) and the Esino Limestone. Daonellas (*Daonella pichleri*) have been found in the lower part of the Pratotondo Limestone (Brack 1984) and a ammonoid fauna is known from Carnian platform carbonates (Aonoides Zone; Allasinaz 1968). The biostratigraphic control on Lower/Middle Anisian and Upper Ladinian – Lower Carnian units is as yet unsatisfactory. Particularly difficult to assess are the positions, correlations and durations of time gaps documented by prominent and widespread exposure surfaces in platform carbonates (e.g. Assereto et al. 1977b; Gnaccolini & Jadoul 1990).

The age of the Middle to Upper Anisian pelagic sediments in the eastern Dolomites (Dont Fm., Bivera Fm., Ambata Fm.) is constrained by ammonoids, conodonts and Daonellas (see Assereto 1971; Farabegoli et al. 1984). The calibration of Upper Ladinian to Lower Carnian units in the Dolomites is based on ammonoids and Daonellas from formations of the Wengen Group (mainly Archelaus to Lower Regoledanus Zone; e.g. Viel 1979; Blendinger et al. 1982) and the basinal San Cassian Fm. (uppermost Archelaus to Aonoides Zone; Urlichs 1974, 1977). The stratigraphic scheme (Fig. 2c) is compatible with palynostratigraphical results (mainly van der Eem 1983; see also data in Brugman 1986, Blendinger 1988).

Physical relationships between platform carbonates and basinal successions in this sector have largely been adapted from Bosellini (1984) and Doglioni et al. (1990). However some units have been repositioned with respect to the biostratigraphical scale.

At present it is difficult to judge how this affects the correlations of the stratigraphic pattern with eustatic-cycle charts for the Triassic as indicated by Sarg (1988) and Doglioni et al. (1990). According to Haq et al. (1988) this chart is partly based on the Dolomites for the Anisian to Carnian time interval but no details were released on a biostratigraphic calibration. Thus it is not clear whether our modifications imply equivalent shifts in the chart or, alternatively, they require new correlations between the stratigraphy and a fixed chart. The latter would apply if the cycle chart is demonstrably tied to biostratigraphic scales in areas independent of the Southern Alps (e.g. the Arctic Triassic). Moreover, the significance of tectonic noise is in our opinion not yet sufficiently well established in the analysis of South Alpine sequences and it is unclear to what degree it obscures their straightforward interpretation in eustatic terms.

In view of these unsolved problems we refrain from correlating our stratigraphic scheme with published cycle charts even though this may eventually improve the calibrations. Nevertheless, a few striking and apparently synchronous changes in the South Alpine stratigraphic patterns (Fig. 2) shall be briefly emphasized. Particularly evident are distinct drowning events of carbonate platforms, several of which have also been recognized in the Triassic of the Eastern Alps. In both areas drowning affected in some cases only parts of larger platforms while carbonate growth was unimpeded or could quickly enough resume in other platform portions.

The pelagic cover (Prezzo Lst.) on top of Anisian platforms in eastern Lombardy (Dosso dei Morti and equivalent Limestones) is analogous to similar basinal strata (Reifling Beds) above the Steinalm platform in the Eastern Alps (e.g. near Saalbach, Brandner 1984). A relationship between this sudden transition in eastern Lombardy and prominent tectonic events in the Middle/Late Anisian cannot be ruled out. These movements resulted in, amongst other effects, a prominent uplift and tilting of the realm of the western Dolomites. Near surface-water carbonate production may have dropped in adjacent areas due to a suddenly increased input of clastic fines. In western Lombardy a clastic succession was submerged at approximately the same time. Its eastern margin was transgressed by basinal strata (Prezzo Lst.) and a vast carbonate platform nucleated in adjacent areas. Portions of large platforms in western Lombardy (Albiga and equivalent dolomites) and in the Dolomites possibly drowned within a short time span in the

Late Anisian (Reitzi/Kellnerites Zone). Time-equivalent pelagic sediments ("Buchenstein Beds") in eastern Lombardy document a roughly coeval lowering in sedimentation rate (at 58 m-level on Bagolino section; Figs. 7, 10, 11) due mainly to a reduction in the supply of fine clastic detritus to the basin. In the easternmost portion of the Southern Alps this event could correlate with a stage in the drowning of a depply eroded ridge (the "Dorsale Palaeocarnica" of Farabegoli et al. 1985). In the Eastern Alps this same event may have submerged the "Zwischendolomit"-platform in the Drau range and at Dobratsch (Bechstädt et al. 1976; Tollmann 1977). This in turn presumably corresponds to the abrupt changes in the stratigraphical patterns which were termed the "Reiflinger Wende" by Schlager & Schöllnberger (1974). Even further afield in Hungary (Balaton Highland), the Megyehegy Dolomite platform drowned in places during the same time interval.

Slightly younger but apparently not synchronous (Nevadites to Curionii Zones) drowning events affected portions of carbonate platforms in Cadore/western Carnia and in the eastern Dolomites (e.g. Cemera).

The products of the prominent Late Ladinian transpressional tectonic movements and magmatism (peak activity in the Archelaus Zone) in the Dolomites have no obvious counterparts in Lombardy. We suspect, however, that the sudden influx of siliciclastic detritus into the previously starved Buchenstein basins (i.e. the Lombardian "Wengen Beds") was a result of the simultaneous reworking of clastic shelves or exposed (? basement) areas. Moreover, the rapid and apparently local subsidence of the northernmost Esino Limestone platforms in Lombardy could be related to transtensional zones within the same Late Ladinian tectonic system.

Uppermost Ladinian and Lower Carnian exposure surfaces in the Lombardian platforms document higher amplitude sea-level fluctuations similar to features observed in the Dolomites. The age of individual events is, however, not yet sufficiently well constrained for precise correlation.

6.2. The numerical time-scale and duration of the Ladinian

Assessments of the durations of intervals and the correlation of relative and numerical time-scales are still problematic for the Triassic.

In the Southern Alps radiometric age data exist for a number of stratigraphically constrained Middle Triassic intrusive and volcaniclastic rocks (Borsi & Ferrara 1967 [22]); Borsi et al. 1968; Hellmann & Lippolt 1981; Cassinis & Zezza 1982; Crisci et al. 1984).

The K/Ar and Ar/Ar ages of alkali feldspars from bentonite layers in the "Grenzbitumenzone" at Monte San Giorgio (Hellmann & Lippolt 1981) are the best documented tie between Triassic biostratigraphical and chronometric time-scales. Based on our correlations these data can finally be pinpointed in a wider stratigraphic context. Forster & Warrington (1985; p. 106) call it "the most precise data available for any level within the Triassic" and according to a recent database (Harland et al. 1989) no significant additional data have been published recently for levels within this period. New age values are available for magmatic products close to the upper and lower boundary of the Triassic Period (Dunning & Hodych 1990; Claoué-Long et al. 1991).

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[22]) See Forster & Warrington (1985) and Harland et al. (1989) for recalculated values.

The numerical scale in Fig. 2c is largely tied to the radiometric ages of the above mentioned bentonites as well as to selected data from shallow intrusives and "Pietra verde" deposits in eastern Lombardy (see Brack & Rieber 1986). The radiometric ages of the Upper Ladinian Monzoni and Predazzo intrusives and their metamorphosed host rocks were not considered here for reasons given in Forster & Warrington (1985).

Despite the disagreement with most other current scales our time-scale is largely compatible with an inferred age of 223 Ma for the Middle/Late Carnian boundary. This age can be estimated from the time span represented by Upper Carnian to top Triassic orbitally induced cycles in lacustrine sediments of the Newark Group in NE-America (around 23 My; Olsen 1986, Olsen et al. 1989) and high-quality U/Pb data (201 $\pm$ 1 Ma; Dunning & Hodych 1990) of igneous rocks that are probably correlative with the Triassic/Jurassic boundary.

Based on the presently available age information we assume a duration of 7 My for the Ladinian Stage. However, this is in conflict with other estimates. The application of Milankovitch frequencies to the stacking patterns of the allocyclic platform carbonates at Latemar (Goldhammer et al. 1990) suggests a minimum duration of 11 My for the Ladinian platform portion alone (i.e. 20 ky times 550 cycles). According to our ammonoid based calibration this portion includes the uppermost part of the "Lower Cyclic Facies," the "Tepee Facies" and the "Upper Cyclic Facies". Biostratigraphically this corresponds to the Curionii and parts of the Gredleri Zones i.e. the lower two out of four Tethyan ammonoid zones of the Ladinian. Assuming all four ammonoid zones to be of similar duration this would indicate a time span longer than 20 My for the Ladinian Stage. In the Southern Alps it is difficult to estimate the relative length of the Early and Late Ladinian. However, more homogeneous sedimentary successions in other areas suggest that the duration of the younger two Ladinian ammonoid zones is in the same order of magnitude as the older ones.

Accepting a Ladinian Stage of 7 My, net average sediment accumulation rates for the (non decompacted) pelagic carbonate fraction of the "Knollenkalke" ("Buchenstein Beds") range between 4.5 and 10 m/My. This compares well with average sediment accumulation rates of ancient pelagic sediments (e.g. Scholle et al. 1983). The rates of correlative Hallstatt-type limestone intervals at Epidhavros (Greece; Krystyn 1983) are approximately one order of magnitude smaller (i.e. around 0.5 m/My). Lower values (1–2.2 m/My for the "Knollenkalke" and 0.11 m/My for the Hallstatt facies) are obtained if the 20 ky-cycle based time span is applied, however, these values appear to be unrealistically small. This is especially true for the "Buchenstein Beds" which were deposited in narrow inter-platform depressions in the northwestern Dolomites.

Provided the above mentioned duration for the Late Triassic (Olsen 1986, Olsen et al. 1989) is correct, the sum of the cycle-based time spans from the base of the Ladinian to the end of the Triassic would approach or even exceed time-spans that are generally assumed for the entire Triassic Period (40–50 My on current time-scales). Some of the estimates based on the application of astronomical frequencies to sedimentary cycles are therefore either too high or the duration of the Triassic is seriously underestimated. In the Southern Alps the problem cannot be solved by simply shifting well dated Upper Ladinian units into the Carnian as suggested by Goldhammer et al. (1990, Fig. 8). Although the allocyclic interpretation of the Latemar cycles is plausible we suspect that the smallest recorded cycle generation has not a 20 ky period but one of hitherto unrecognized shorter duration (around 5000–8000 y).

Additional high-quality age determinations are clearly required to resolve the discrepancies. Stratigraphically controlled rocks which are potentially suitable for radiometric age dating occur at various levels throughout the Anisian to Carnian stratigraphy of the Southern Alps! Our future efforts shall therefore address these problems.

7. Conclusions

South Alpine Anisian/Ladinian boundary sections in basinal and platform settings are correlatable in detail by means of macrofossils and characteristic volcaniclastic layers. The projections are the basis for the following conclusions of bio- and chronostratigraphical interest:

(1) Clear relative positions are ascertained for ammonoids and Daonellas in the Anisian/Ladinian boundary interval. Key ammonoids include species of *Judicarites, Paraceratites, Kellnerites, Hungarites, Reitziites, Parakellnerites, Aplococeras, Ticinites, Halilucites, Stoppaniceras, Nevadites, Chieseiceras, Eoprotrachyceras, Arpadites* and *Protrachyceras*. In the Southern Alps most of the recognized ammonoid levels are documented in the Bagolino section.

(2) The ammonoid succession between the Trinodosus and the Curionii Zones is split into two zones of presumably similar duration. The terms "Reitzi/Kellnerites Zone" and "Nevadites Zone" are suggested for the older and younger interval respectively.

(3) Within this zonal scheme the Anisian/Ladinian boundary can be suitably located at the boundary between the Nevadites and Curionii Zones. This is equivalent to the top of the "Chiesense groove" in the continuous pelagic successions of the Brescian Prealps and Giudicarie. This time marker can be pinpointed or approximated in a number of sections in the Southern Alps and further afield. Moreover it corresponds most closely to the widely accepted position of the stage boundary in North America.

(4) Radiometric age data of stratigraphically controlled Middle Triassic magmatic rocks in the Southern Alps suggest an age of some 232 Ma for the base of the Ladinian Stage. However, this age and the duration of 7 My for this stage (Curionii to Regoledanus Zone) is in conflict with other recent estimates.

(5) The time scale and resulting rates of sedimentation suggest that the smallest recorded cycle generation of the Latemar platform interior facies has a period that is significantly shorter than 20 ky. A corroboration of this conclusion has to await more high quality radiometric age data, however.

Clear geometrical relationships and the positions of equivalent macrofossils (ammonoids and Daonellas) in basinal sediments and adjacent carbonate platforms in the Dolomites constrain the timing and reconstruction of the platform to basin evolution:

(6) In the western Dolomites, a long lasting phase (Reitzi/Kellnerites- to Gredleri Zone) of platform up- and equivalent outbuilding (Latemar, Rosengarten) was followed by a short period of rapid lateral accretion (Rosengarten). The latter stage corresponds to only a small stratigraphic interval of the uppermost "Buchenstein Beds."

(7) At Latemar and Cernera, platform aggradation was fastest during parts of the Reizi/Kellnerites- and Nevadites Zones. However, the net carbonate accumulation