The Faunal Relationship of the Silurian of the Alps[1]

with 1 figure

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In the Alps the Silurian Period is characterized by a wide range of different lithofacies (H.P. SCHÖNLAUB 1979). The respective rocks are locally very fossiliferous and have long been known from the Carnic Alps of southern Carinthia and its eastern continuation, the Karawanken Alps, the Graywacke Zone of Styria, Salzburg and Tyrol, the surroundings of Graz, the Gurktal Nappe of Carinthia and Styria and from a few other places within the quartzphyllite complexes of the Eastern Alps.

Generally, three types of lithofacies, each with a distinct faunal assemblage, can be recognized :

1. Fossiliferous carbonate facies: The dominating lithologies are limestones and less frequently dolomites with a thickness of at most some 60 m. Although the equivalences of the Lower Llandovery are missing, for the remaining of the Silurian the fossil record from many sections of the Carnic Alps and the Graywacke Zone has indicated a complete but slightly condensed sequence. Fossil assemblages consist of varying abundances of nautiloids, trilobites, bivalves, brachiopods and scarce graptolites as well as of conodonts, foraminifera, acritarchs, chitinozoans, scolecodonts and ostracods. During the last decades most but by far not all groups have been revised or are being studied presently. This facies is best represented by the Plöcken and Wolayer Groups of the Silurian of the Carnic Alps.
2. Graptolitic facies: It is characterized by black siliceous shales, cherts (lydites) and alum shales which prevail over quartzitic sandstones and greenish mudstones at the base and in the basal Pridolian, respectively. The thickness approximates that in the pure limestone facies. A continuous record of graptolites starting with the name bearer of the *Akidograptus acuminatus*-Zone of the basalmost Llandovery and ending in the Upper Lockovian has indicated continuous sedimentation during the Silurian and across its boundary with the Devonian. In particular this is true for the Carnic Alps; in other areas, e,g., the Graywacke Zone such a continuous record has as yet not been demonstrated and it seems uncertain to assess it due to the bad preservation of all collections. During the last 25 years all graptolite faunas were revised by H.JAEGER and numerous new ones have been collected; the corresponding strata were named by him Bischofalm-Formation.
3. Transitional facies: It comprises a mixture of the above mentioned two main rock types, i.e. an alternation of black shales and marls with black or darkgrey limestone beds. Its faunal content is very poor and consists of grapolites and few conodonts and nautiloids. In the local stratigraphic scheme of the Carnic Alps this facies was named Findenig Facies.

All three main facies may intergrade to varying degrees depending on its setting in a distinct paleogeographical and paleotectonic environment with different amount of limestone production and fossil support. In particular this regards the region occupied

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by the Gurktal Nappe in Carinthia and parts of Styria with its dolomite and marble rich facies which is equivalent to a several 100 m thick clastic development in the same area (F.NEUBAUER 1979, F.NEUBAUER & J. PISTOTNIK 1984). Moreover, in some other fossiliferous sequences basic volcanics and tuffs are intercalated which indicate rifting associated with intracontinental volcanism at various times during the Silurian (for summary remarks see H.P.SCHÖNLAUB 1979, 1982, R. HÖLL 1970, F. EBNER 1975, M. F. BUCHROITHNER 1979, F. NEUBAUER 1979, F. NEUBAUER & J. PISTOTNIK 1984, U.GIESE 1988, H. FRITZ & F.NEUBAUER 1988, J.LOESCHKE 1989a,b).

Silurian faunas following the terminal-Ordovician mass extinction event are generally regarded as cosmopolitan and hence provide only little evidence to determine the latitudinal position of individual plates (D.JABLONSKI 1986). This evaluation, however, may change if a varied high diversified fossil association is considered together with lithic data from the host rock.

According to S.M. BERGSTRÖM 1990 most if not all post-Ordovician conodont localities ly between 40°S and 40°N paleolatitude. In the Wenlockian continental Europe was located at the margin of this belt consistent with our conclusions drawn for the Late Ordovician. For this time conodont evidence from the Carnic Alps and other areas of the Eastern Alps suggests close affinity to coeval faunas from central, southern and southwestern Europe. Comparable faunas from Britain and Gotland which occupied a more equatorial position seem, however, more diversified. These differences diminished towards the end of the Silurian. S.M.BERGSTRÖM 1990 concluded that the Pridolian was a time of minimal conodont provincialism during which coeval faunas from the Alps, Bohemia and Nevada showed striking similarities at the generic level.

In the Silurian the distribution of phyto- and zooplankton, i. e., acritarchs and chitinozoans displays a broad latitude-parallel-zonation. However, plotted on the new world maps of C.R.SCOTESE & W.S. McKERROW 1990 the old phytoplankton data of F.H.CRAMER 1971 seem to reflect local environmental conditions rather than a biogeographic pattern (G.K. COLBATH 1990).

Yet, from the Silurian of the Alps only few appropriate data are available (A. BACHMANN & M.E. SCHMID 1964, H. PRIEWALDER 1976, 1987, F. MARTIN 1978). Accordingly, acritarchs from the Cellon section of the Carnic Alps suggest an intermediate position between the high latitude *N.carminae* and the tropical *Domasia-Deunffia* biofacies (J.B. RICHARDSON et al. 1981, H. PRIEWALDER 1987). This paleolatitudinal setting is well constrained by other data presented here. On a worldwide scale F. PARIS (1981, 1989) concluded that the distribution of Silurian acritarcs is essentially cosmopolitan.

According to H. PRIEWALDER (pers. comm.) the chitinozoans of the Cellon section show close relationships to those from Bohemian deposits of the same age which is especially pronounced in the upper Ludlow to lower Lochkov sequence (DUFKA, 1992; KRIZ, 1992; KRIZ et al. 1986; PARIS & KRIZ, 1984; PARIS et al., 1981).

On the other hand in the Cellon section samples from the base of the Wenlock to the lower Ludlow yielded no chitinozoans whereas in Bohemia diverse faunas could be obtained from sediments of this period (KRIZ, 1992; KRIZ et al., 1993). This phenomenon might be caused by unfavorable conditions for preservation (e.g.oxidation) in the depositional environment of the Cellon section.

Silurian trilobites from the Carnic Alps are closely related to Bohemia and other central European regions (W.HAAS 1969, G.K.B.ALBERTI 1970). Affinities to Morocco may exist but are as yet not studied in detail. Interestingly, in the succeeding Devonian the apparent distinction with North Africa continued; instead, there appears a closer relationship with the Ural and Tienshan (G.K.B. ALBERTI 1969).

According to T. KOREN 1979 most if not all Silurian to Lower Devonian graptolites occur within paleolatitudes of some 30-40^{0}N and 30^{0}S. As noted by W.B.N. BERRY 1979 Silurian graptolites show only very little endemism suggesting that interplate dispersal was possible and apparently occurred during the Silurian and Lower Devonian. Presumably, its distribution was mainly controlled by the character of the surface water plus ocean currents that overlied the site at which graptolites are found. The distribution of graptolites may thus have very much depended on the size, shape and position of certain plates.

In 1962 C. ROMARIZ introduced the name "Mediterranean Province" for those graptolites which are characterized by large robust rhabdosoms and have been recorded from middle and late Wenlockian strata of Portugal, Spain, Sardinia and the Carnic Alps (see also M. GORTANI 1922 and C. ROMARIZ et al.1971). Many of these giant specimens are, however, tectonically deformed and did not represent a distinct biofacies (H. JAEGER 1968, 1975, H. JAEGER & D. MASSA 1965).

During the Ludlow and Pridoli an essentially uniform graptolite fauna developed in Europe. As pointed out by H. JAEGER 1976, 1989 the changing environment of this time is portrayed in strikingly similar and closely contemporaneous shifting lithofacies between northern Africa and Baltica which exhibit - with minor local modifications - a characteristic and continuous range from black graptolite shales to limestones, e.g., the well known "Ockerkalk" of Thuringia. According to H. JAEGER 1975 and G.K.B. ALBERTI 1980 this change in facies was controlled by simultaneous sea-level rise and fall that affected a hypothesized single block along its passive margins.

Distribution of extinct cephalopds corresponds widely to their living habitats (J.A. CHAMBERLAIN et al. 1981) and was limited by the same physical barriers as the recent *Nautilus*. In the absence of a planctonic larva stage (N.H. LANDMAN et al.1983) dispersal took place as part of the vagrant benthos on shallow shelfes or over shallow open marine environments and not as part of the oceanic nekton. Structural studies of the shell (R.E. CRICK 1988) have indicated that they were restricted to limits between 300 and 500 m water depths. This may explain why Ludlowian faunas from North Africa and Laurentia show such striking differences suggesting that an exchange across the wide mid-European ocean was largely impossible (R.E. CRICK 1990).

In the Alps the oldest yet not described nautiloids occur in the Ashgillian Uggwa Lst. of the Carnic Alps. From the Late Llandovery onwards nautiloids became the dominating organisms in the carbonate facies of the Southern Alps with rich abundances of orthocerids in the Late Wenlock and Early Ludlow (H.RISTEDT 1968, 1969). The diversified fauna seems closely related to Bohemia and Sardinia. With decreased numbers nautiloids continue into the Pridolian and Lower Devonian.

According to O.K. BOGOLEPOVA (pers. comm. 1994) the Silurian cephalopod biofacies of the Carnic Alps reflects a close relationship with coeval deposits from Bohemia and the Tajmyr Peninsula of northern Siberia. The affinities between these faunas and supposedly with those from other localities in southern Europe may have resulted from the South Equatorial Current that operated during the Silurian and Devonian along the southern margin of Siberia and Laurussia.

In contrast to the Carnic Alps in the Graywacke Zone and in the Gurktal Nappe of Carinthia very few nautiloids have been found despite the occurrences of very similar lithologies. This remarkable feature is yet difficult to explain.

The distribution of other molluscs, in particular bivalves corresponds grossly to that of orthoconic nautiloids. According to J. KRIZ 1979 the Silurian cardiolids from the Southern Alps and the Graywacke Zone inhabited the warm equatorial zone or were dispersed through south equatorial currents. However, plotted on the modified base maps proposed by C.R.SCOTESE & W.S.McKERROW 1990 the central and southern European faunas must either have occurred in slightly higher southern latitudes or the position of the respective plates is too high. In our opinion a position around 35°S would be the best estimate for the Silurian occurrences in the Alps.

This view is strongly supported from other evidence: In the Silurian corals were prominent constituents of the shallow water environment in the tropical belt. After a crises at the end of the Ordovician several order among the Tabulata and the Rugosa diversified in the early Silurian. During this time only weak provincialism is apparent at the generic level (J.W.PICKETT, 1975, R.A.McLEAN 1977, 1985, D.L.KALJO & E.KLAAMANN 1973, W.A.OLIVER 1977). An explanation might be the assumed larval life-style of rugose corals so that long-living teleplanic larvae were capable of being transported by ocean currents 1000 km or more (R.S. SCHELTEMA 1968, 1971, 1972, A.E.H.PEDDER & W.A.OLIVER 1990).

Remarkably, rugose and tabulate corals abundantly occur in the Late Llandovery of Middle Carinthia (E.STREHL 1962, M.F. BUCHROITHNER 1979), in the Upper Silurian (Ludlowian) of Graz (H.MENSINK 1953, H.W.FLÜGEL & H.P.SCHÖNLAUB 1972, F.EBNER 1976) and very rare in shallow water and locally superficial ooid bearing limestones in the Late Llandovery of the Graywacke Zone of Tyrol (H.MOSTLER 1966, N. AL-HASANI & H. MOSTLER 1969), but apparently are missing in coeval strata of the Southern Alps. The inferred Silurian age of F. HERITSCH 1929 is actually Lower Devonian (Lochkovian).

We hardly believe that these coral bearing bioclastic limestones represent the fossil counterpart of modern cold-water coral reefs such as the common *Lophelia* reefs found presently as far north as beyond the Polar Circle, in the Barents Sea and on the shelf off Mid-Norway at depths between 250 and 300 m and at water temperatures of 6°C (T.STROMGREN 1971, N. MIKKELSEN et al.1982). Rather they display excellent environmental indicators controlled by such physical factors like light, temperature, suspended sediment, salinity, water agitation and other agents (D.J.J.KINSMAN 1964, T.P.SCOFFIN et al.1989 and others). Modern and ancient builtups cannot exist beyond the "Darwin Point" of about 35°-latitude (R.GRIEG 1982), which is also the northernmost limit of corals in the present-day Pacific (G.W.TRIBBLE & R.H. RANDALL 1986) and, more generally, carbonate production is light-limited to within 35° latitudes (R.A.ZIEGLER et al.1984). There is no objective reason against the consideration that the Silurian of the Central Alps was positioned within these limits. This conclusion was already drawn by A.J. BOUCOT 1975 and lately 1990 who subdivided the Silurian World into two main realms. The Carnic Alps correspond to the warm water North Silurian Realm characterized by limestones and rich shelly faunas in contrast to the cool and cold water high southern latitude Malvinokaffric Realm.

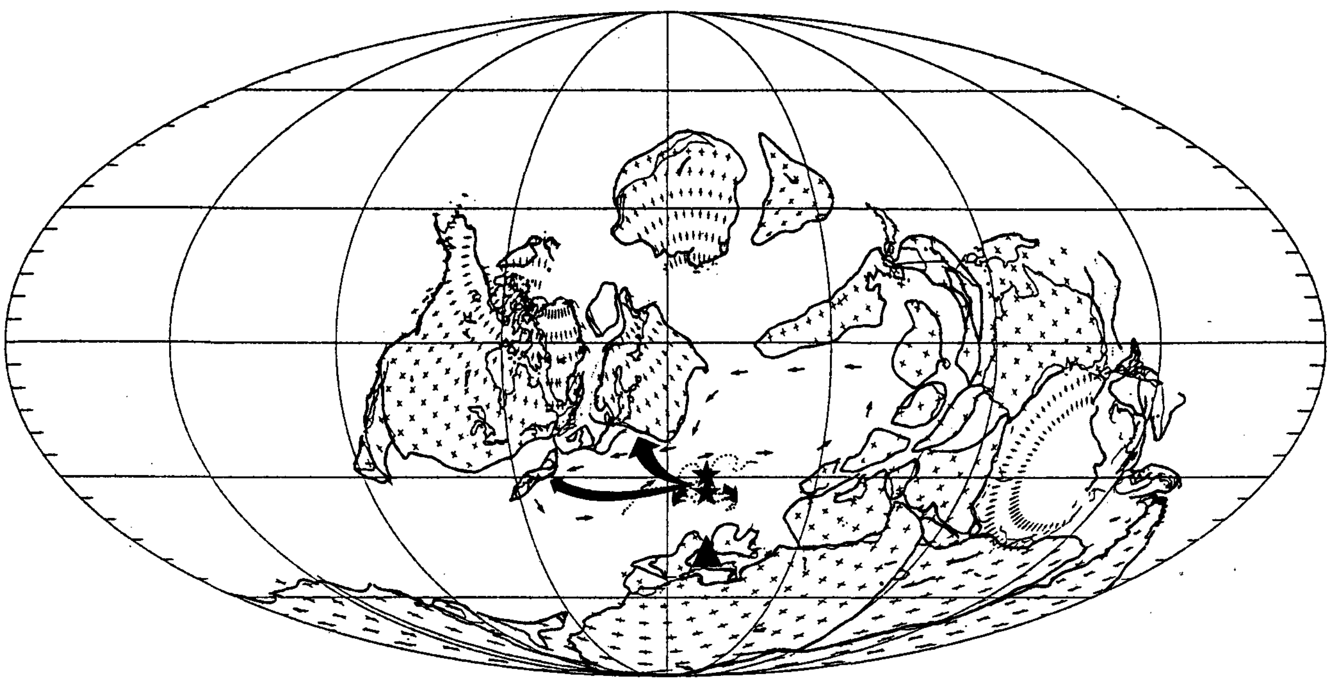

Fig. 1
Middle Silurian (Wenlockian) paleogeography.
Triangle indicates position of the Alpine Silurian as suggested by C.R. SCOTESE & W.S. MCKERROW (1990). The author's latitudinal setting is shown by two stars for the Silurian of the Southern and Central Alps, respectively. Faunal relationships are shown by heavy arrows, the oceanic current system in the mid-European ocean by small arrows.
Modified from C.R. SCOTESE & W.S. MCKERROW (1990).

Conclusions

During the Silurian Period the Alpine occurrences of Silurian strata continued to shift into lower latitudes. Based on the evidences presented above the best position is estimated at approximate 30-35° southern latitude. Faunal relationships existed to southern Europe but apparently were closer to northern Europe. The affinities to southwestern Europe and northern Africa, however, decreased.

Paleomagnetic data from Gondwana seem to support the assumption of a rapid northward movement. It is associated with rifting-related volcanism through much of the Silurian. Interestingly, the Southern and Central Alps differ in two main aspects: The Silurian of the Central Alps, i.e., the development north of the Gailtal Fault, is characterized by warm water occurrences of rugose and tabulate corals in an environment which locally also contains superficial ooids, but these sequences yield only few cephalopods as opposed to the Southern Alps with the opposite relationship suggesting most plausibly a farther south and slightly cooler environment. These differences may indicate two separate terranes or microcontinents prior to the Variscan deformation in the Alps.

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