The Biogeographic Relationships of the Carboniferous of Austria[5]

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with 4 figures

The Carboniferous Period of the Alps is generally subdivided into the final Variscan series representing a Lower Carboniferous pelagic development in the Tournaisian and succeeding flysch deposits of Visean and Namurian age, and the post-Variscan transgressive cover sediments of Late Carboniferous and Permian age. Both groups of rocks are separated by the Variscan unconformity. Based on new and revised data on conodonts and fusulinids in the Southern Alps the pre-Variscan strata were deformed between the late Namurian *Gastrioceras*-Zone and the Upper Miatchkovian of the late Middle Carboniferous in the Russian terminology (F.KAHLER 1983, H.P. SCHÖNLAUB, unpubl.), the latter corresponding to the West European Westfalian D Substage.

From the older cycle only few biogeographically relevant data are yet available which mostly comprise cosmopolitan groups like goniatites and some pelagic trilobites. According to D. KORN (in H.P. SCHÖNLAUB et al. 1988) and D. KORN 1992 across the Devonian/Carboniferous boundary a complete succession of ammonoids occur which indicate continuous pelagic sedimentation in an open marine pelagic environment comparable to many other places in the world, e.g., Rhenish Massif, Sauerland, Moravia, Southern France or South China. Similarly, trilobites are related to Cornwall and north Devon as well as to the Rhenish Massif, Frankenwald, Montagne Noire, the Sudetes, Poland, the Urals, Kazakhstan and southeast China (R. FEIST 1992). Some of these faunas are characterized by blind or reduced eyes indicating benthonic forms of moderately deep waters; some, however, represent fully blind trilobites yet not known from elsewhere in the Variscan basin (G. HAHN & R. KRATZ 1992). Nevertheless, loose relations do exist to Sauerland, Thuringia, Poland and England.

Floras from the Culmian Hochwipfel flysch of the Carnic Alps are of little biogeographic significance. According to H. W. J.van AMEROM et al. 1984 these new discoveries indicate similarities to the Erzgebirge (Chemnitz), Silesia, Thuringia, CZ, the Black Forest, France and Scotland.

In contrast to these reports and, hence, of special interest is the so-called "Carboniferous of Nötsch" from north of the Gail valley and west of Villach in Carinthia (Fig. 1). With regard to its lithology and the rich and diversified fossil content the Carboniferous of Nötsch has long been regarded as being unique and distinct for the whole Alps. The latest Visean or, more probably, Early Namurian fossil assemblage (H.P.SCHÖNLAUB 1985, G. SCHRAUT 1996) comprises brachiopods, trilobites, gastropods, bivalves, crinoids, corals, bryozoans, foraminifera, ostracods, plants and algae; yet, only a small part has been studied.

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5 Updated version of a chapter from the author's original paper of 1992 (Jb. Geol. B.-A., 135, 381 - 418).

According to G. & R. HAHN 1973 the trilobite fauna is characterized by its special Tethyan aspect with some similarity to coeval occurrences in the Veitsch Nappe of the Graywacke Zone of Styria. Subsequently this view was rejected by G. HAHN & R. HAHN 1987 when they recovered additional trilobites showing a strong relationship with the Kohlenkalk of Belgium. They then concluded a mixing of Asiatic-Australian, i.e., Tethyan and West-European trilobites. Based on additional rich material, however, G. SCHRAUT 1990, 1996 finally emphasized a strong affinity of trilobites to the Western European Kohlenkalk facies of Belgium and England ("European Province" of R. M. OWENS & G. HAHN 1993) and even to North America, and less close similarities to Russia, Asia and Australia. Even ostracods follow these suggested pathways and are closely related to the Kohlenkalk region and in particular to the north America Midcontinent. Different from trilobites, in eastern direction they show strong affinities to the Urals, Sibiria, China, Japan and Kazakhstan.

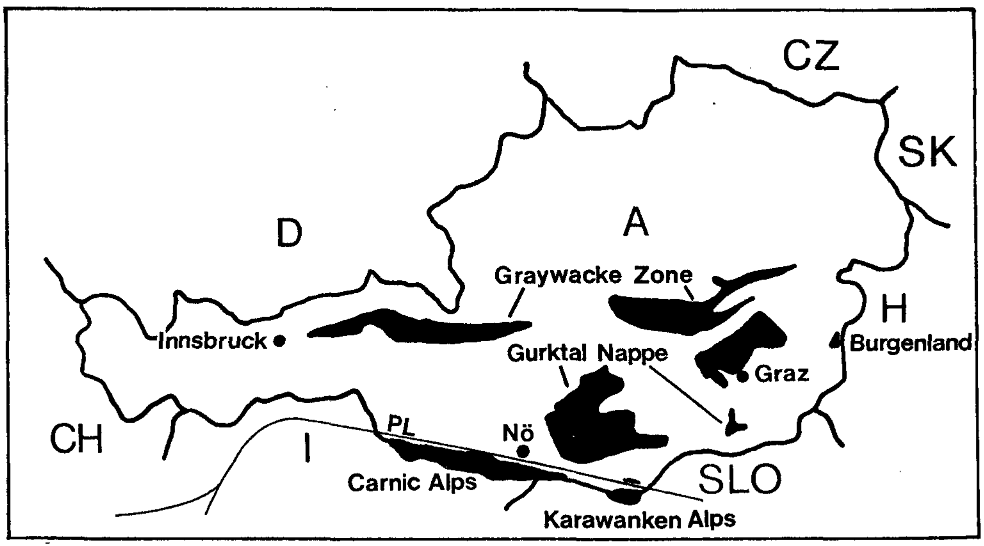

Fig. 1. Main regions with fossiliferous Paleozoic strata in the Eastern and Southern Alps (PL = Periadriatic Line, Nö = Nötsch).

The rich faunal and floral association of the Carboniferous of Nötsch represents a shallow water environment characterized by full marine conditions, agitated water, penetration of light and significant nutrient supply. Temporary, however, this environment was replaced by thick gravity flows named Badstub-Breccia which were formed as proximal inner fan or slope deposits along an active plate margin (H.P.SCHÖNLAUB 1985, K. KRAINER & A. MOGESSIE 1991, K. KRAINER 1992).

Such an inferred plate margin position seems strongly corroborated by other evidence. According to E.FLÜGEL & H.P.SCHÖNLAUB 1990 in the Carboniferous of Nötsch as well as in the Hochwipfel Formation of the Southern Alps (Carnic Alps) there occur exotic limestone clasts of varying microfacies-types. They indicate a shallow carbonate water setting of an open marine and restricted shelf environment during the Visean (Fig. 2). Presumably, this platform development existed north of the Gailtal Line and adjacent to a supposed land area. Yet, no relics of this platform have been preserved. The only records are some limestone clasts and paleoenvironmentally significant fossils such as the heterocoral *Hexaphyllia mirabilis* (DUNCAN), the algae *Pseudodonezella tenuissima* (BERCHENKO), the foraminifera

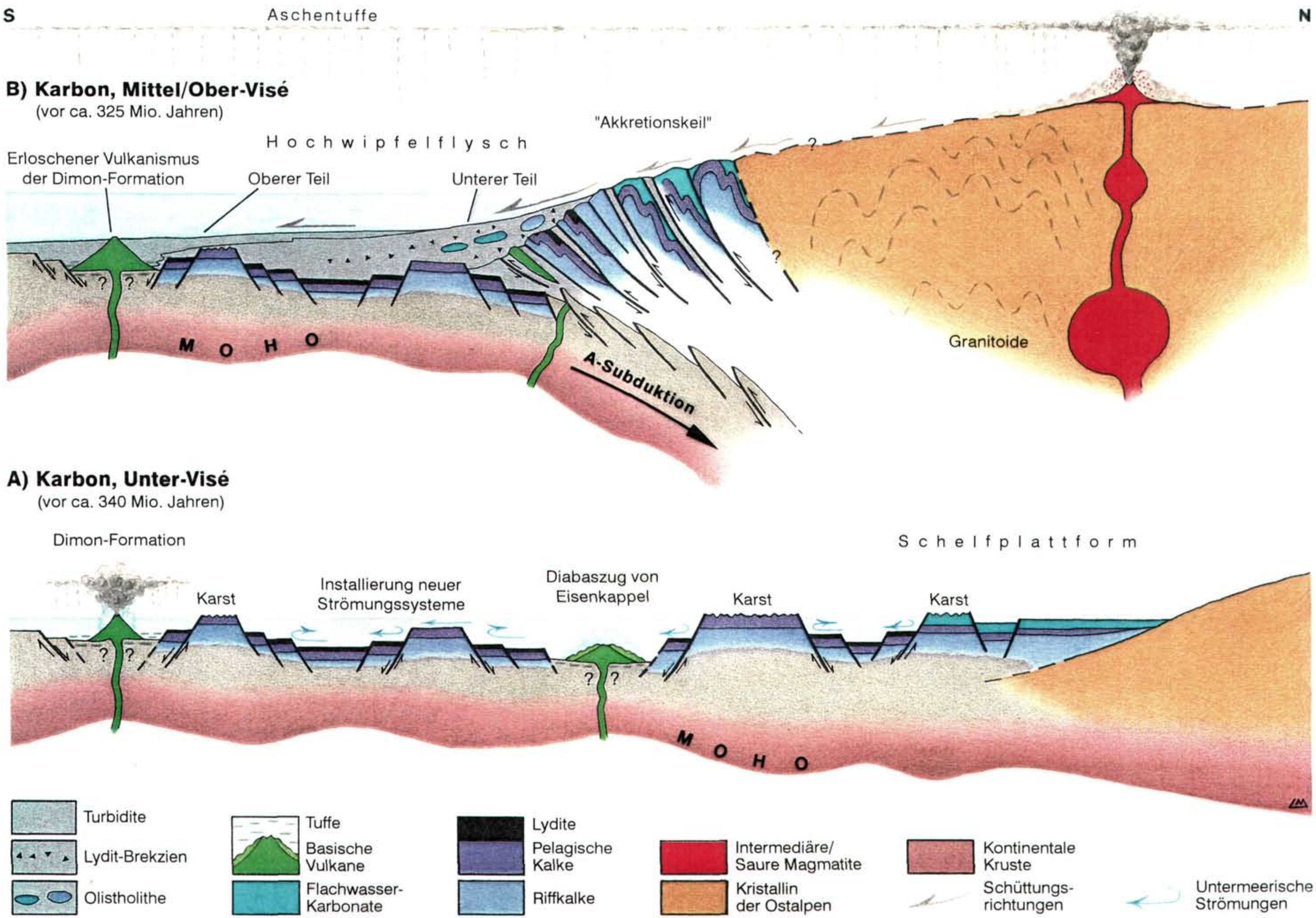

Fig. 2.
Geodynamic model of the tectonic and sedimentary history of the Southern and Central Alps in the Lower Carboniferous (after A. LÄUFER et al. 1993, modified).

Howchinia bradyana (HOWCHIN) and abundant conodont faunas corresponding to the *Eumorphoceras*-Stage E2 of the basal Namurian. Recently in other parts of Carinthia apparently coeval limestone clasts of boulder size were found (H.SCHLÖSER et al. 1990).

Litho- and biofacies of the forementioned exotic limestone clasts exhibit strong affinities to the Kohlenkalk Facies of various parts of Europe (Belgium, France, England, Poland), but also to Hungary, the eastern and southern Carpathians, the Pyrenees, southern Spain, northern Africa, the Donets Basin and the Urals (E. POTY 1981, H.-G.HERBIG 1986, E.FLÜGEL & H.-G.HERBIG 1988, F. EBNER 1990, D.HENNINGSEN & H.-G.HERBIG 1990, H. SCHLÖSER et al. 1990). Moreover, the *supposed setting on an active continental margin and its formation through successive* erosion of an accretionary wedge during a collision of two different plates reflect a remarkable coincidence between the Eastern Alps and the western part of the Mediterranean (see A. LÄUFER, J. LOESCHKE & B. VIANDEN 1993).

Besides the lowermost Carboniferous during which the end-Devonian climate prevailed, the available paleoclimatic data from the Southern Alps, the Carboniferous of Nötsch and the Veitsch Nappe of the Graywacke Zone suggest an increase of temperature and humidity during the Visean. Of particular significance is a widespread emersion that occurred in the lengthy *Scaliognathus anchoralis*-conodont-Zone, i.e., at the Tournaisian/Visean boundary prior to the deposition of transgressive cherts and the succeeding flysch deposits. It resulted in a variety of buried paleokarst features like an extensive relief and small-scale disconformities, mixed faunas, coated fissures, collapse breccias, caves with internal fillings and mineralizations which recently have been recognized in the Carnic Alps and most probably also occurred in the Graywacke Zone and the surroundings of Graz (H. P. SCHÖNLAUB et al. 1991, H. P. SCHÖNLAUB et al. 1980, F. EBNER 1976, see Fig. 3).

In the Southern Alps Late Paleozoic sediments unconformably overlie the Variscan flysch and other basement rocks of varying age, i.e., different Silurian and Devonian strata. According to F. KAHLER 1983 the oldest transgressive sediments are Middle Carboniferous in age and, more precisely, correspond to the *Fusulinella bocki*-Zone of the Upper Miatchkovo of the Moscow Basin. This Late Paleozoic cover comprises clastic and calcareous shallow marine sediments of the Auernig Formation in the Upper Carboniferous (Kasimovian and Ghzelian Stages) followed by various Lower Permian shelf and shelf edge deposits. They represent differentially subsiding platform and outer shelf settings and are characterized by transgressive-regressive cycles that lasted from the Westfalian to the Artinskian Stage of the Lower Permian.

Upper Permian sediments rest disconformably upon the Lower Permian and its equivalents in the Dolomites, or, farther west on phyllites of the Variscan basement. They indicate a transgressive regime starting with red beds of the Gröden Formation and followed by the Bellerophon Formation of the Late Permian. This formation represents a carbonate ramp which gently dips to the southeast, but is located far east from the Permian shoreline exposed in the Dolomites of Northern Italy in the west.

Even more restricted was the extent of the sea in the Late Carboniferous. In the Upper Miatchkovo the westernmost transgressive sediments were deposited near Lake Zollner in the central Carnic Alps. From there the transgression continuously

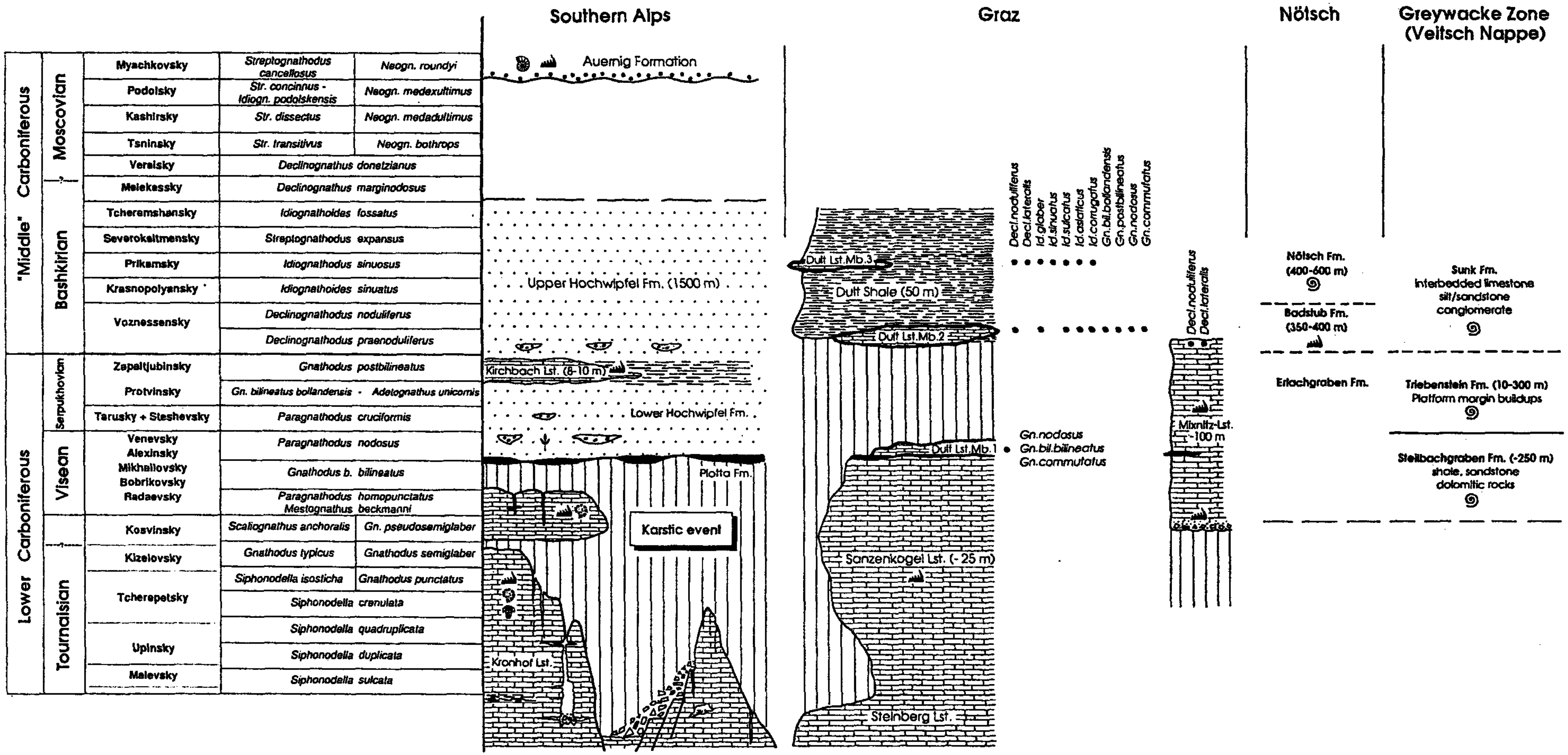

Fig. 3. Correlation of Lower Carboniferous sequences of the Southern and Central Alps.

progressed in western direction to reach Forni Avoltri and the region of the Seikofel north of the Sexten Dolomites during the Upper Carboniferous.

This whole area is very close to segments of the Periadriatic Fault Zone in the Lesach and Gail Valleys, immediately in the north. The prominent fault separates the predominantly marine post-Variscan sequences of the Southern Alps from clastic terrigenous Upper Carboniferous and Permian sediments of the Central Alps.

The marine post-Variscan sequences of the Southern Alps have long been famous for their abundant and highly diverse fossil groups. During the last few years the major part of the fauna and flora has been reinvestigated and new material was collected. Based upon these studies the following conclusions can be drawn: Fusulinids are of typical "Paleotethyan" and thus, apparently of cosmopolitan aspect showing similarities with coeval faunas in many other parts of the world, e.g., the Dinarides (Serbia, Velebit, Montenegro, Albania), the Bükk Mountains of Hungary, northern Africa (Tunis), Turkey (Anatolia), Iran (Elburs), Afghanistan, Indochina, South China, Japan as well as to the Moscow and Donets Basins, the Urals, Ferghana, Mongolia, Pamir, Greenland, northern California and Texas (F.KAHLER 1939, 1955, 1974, 1983, F. & G.KAHLER 1982); trilobites are closely related to the Karawanken Alps and the Cantabrian Mountains of northern Spain and less close to the Urals, the Moscow and Donets Basins (G. & R. HAHN 1987, G. HAHN & R. HAHN 1977, 1989); brachiopods are equally related to these regions as they have many species in common as opposed to the weak links with North America (K.L. GAURI 1965, A. RAMOVS 1972, C.F. WINKLER PRINS 1971, 1983, 1984); the ostracod fauna too suggests a close similarity with the Cantabrian Mountains of Asturia and reflects a shallow marine and low energy environment (G. RUGGIERI 1966, B. FOHRER 1990, 1991, G. BECKER 1978); sphinctozoans appear well comparable to those from New Mexico, Texas and the Cantabrian Mountains (H.-W. KÜGEL 1987); the rich coral faunas have yet not been revised but it appears that it is closely related to Russia, East Asia and China (F.HERITSCH 1936, 1943); in addition, Lower Permian faunas are of low diversity (W. HOMANN 1971); calcareous algae often occur as massive algal wackestones attributed to lense-shaped algal mud-mounds which consist of low diversity phylloid algae *(Epimastopora, Archaeolithophyllum, Eugonophyllum)* and the dasycladacean *Anthracoporella* and others (E. BUTTERSACK & K. BÖKKELMANN 1984, K. BÖCKELMANN 1985, K. KRAINER 1992) which appear of no biogeographic significance.

During the last twenty years in the Eastern Alps more than 60 localities with Upper Carboniferous and Early Permian plants were studied together with revisions of old collections (for summary see Y.G. TENCHOV 1980, A. FRITZ & M. BOERSMA 1986, 1990, M. BOERSMA & A. FRITZ 1990, A. FRITZ & K. KRAINER 1994). Besides implications for the paleoclimate and for the local facies development no distinct paleofloristic-biogeographic relationships can be inferred. Yet, its main importance is the potential for correlating West-European continental with Tethyan marine sequences which for a good deal has been demonstrated from floras of the Carnic Alps.

Conclusions

As a response to the Variscan Orogeny dramatic changes affected the Alps during the Carboniferous Period (see Fig. 2). In the Southern Alps the climax of deformation occurred between the Late Namurian and the Late Westphalian Stages, or, in the Russian terminology, between the Early Bashkirian and the Middle or Late Moscovian Stages.

In the Central Alps, however, deformation and metamorphism evidently occurred earlier. This conclusion seems well founded from radiomatric ages and from the transgressive molasse-type sediments within the Gurktal Nappe, the Carboniferous of Nötsch and the Veitsch Nappe of the Graywacke Zone. Moreover, we presented evidence that these scattered occurrences might represent the last remains of an originally vast shelf characterized by various platform sediments as opposed to the Southern Alps with contemporary flysch deposits.

During the Carboniferous this northern development was biogeographically more closely related to Western Europe and even to North America than to Eastern Europe or Asia. In particular, there appears a striking similarity with the Cantabrian Mountains, the western Mediterranean and to the "Kohlenkalk" regions of England, Belgium and Poland.

Consequently, we suspect that the Southern and Central Alps represented two different microplates during the Lower Carboniferous. This assumption confirms the suggested fragmentation of the predecessors of the Alps which has already been concluded elsewhere from the analysis of older rocks and faunas. If at all and how much they were separated is presently difficult to decide. Yet, it is worth mentioning that reworked amphibolite clasts in the Badstub Breccie of the Carboniferous of Nötsch are metamorphosed tholeiitic ocean floor basalts (T. TEICH 1982, K. KRAINER & A. MOGESSIE 1991) suggesting sometimes during the Paleozoic an enigmatic oceanic crust in this area of the Alps.

Soon after collision and amalgamation of the two plates the biogeographic patterns of the Southern Alps began to match those from the former settings in the Central Alps indicating migration of faunas and floras into the newly established Southern Alps domain where they found remarkably favourable environmental conditions. F. & G. KAHLER noted already 1982 that this new sedimentary cycle started approximately at the same time as sedimentation of the marine fusulinid-bearing strata of the Cantabrian Mountains ceased. In the light of new research, however, marine rocks of Stephanian age and *Triticites* bearing Late Kasimovian strata have been recognized there (E. MARTINEZ-GARCIA & R.H.WAGNER 1971, 1984, E. MARTINEZ -GARCIA 1984).

Most if not all suggested faunal and floral migration paths of fusulinids and other groups along the northern shelf margin of the Tethys Sea, the Ural Sea and the Arctic region to North America as well as to analogous occurrences on the southern shelf appear well constrained by the revised World Maps of C. R.SCOTESE & W. S. McKERROW for the Late Carboniferous. Possibly, dispersal of planctic groups was aided by warm subequatorial gyres which were blocked and deflected at the contact between Laurussia and Gondwana (A.M. ZIEGLER et al.1981, C.A. ROSS & J.R.P. ROSS 1985, P.H. KELLEY et al. 1990).

Potentially useful climate-sensitive sediments of Carboniferous age comprise in the Veitsch Nappe of the Graywacke Zone several tens of metres of graphite and related rocks as well as limestones and dolomites which supposedly formed in a

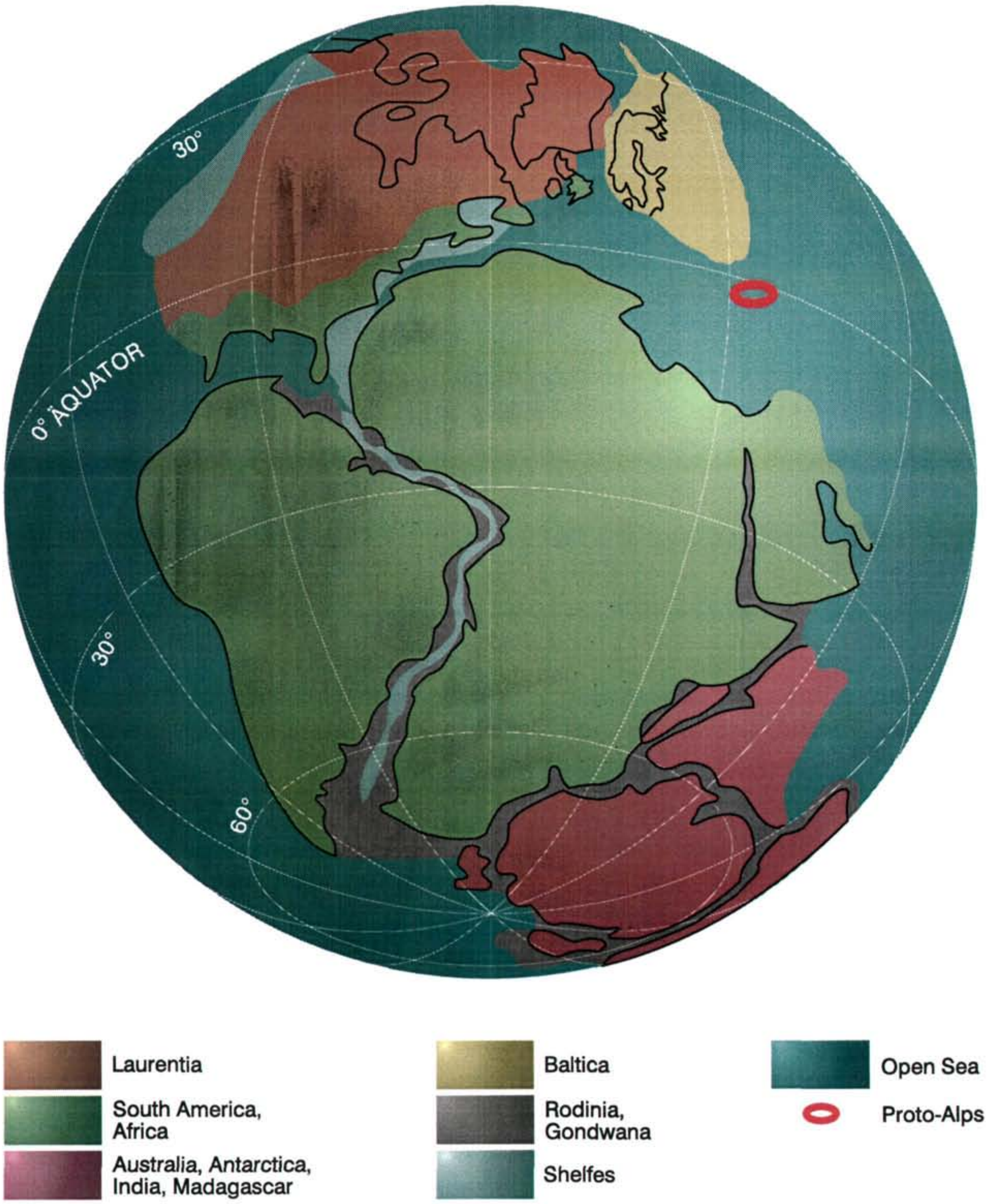

Fig. 4.
Paleogeographic reconstruction of the supercontinent Pangea in the Upper Permian at c. 260 Ma (after I. W. D. DALZIEL 1995, position of European plate strongly modified).

temporary hypersaline environment (R. RATSCHBACHER 1984). Furthermore, at many localities plants occur in rich abundances and diversity; up to a few metres thick coal seams, however, are mainly restricted to the Carnic Alps and the Gurktal Nappe. In the former they are interbedded with locally rich occurrences of corals, fusulinids, algal mud-mounds and oncoid limestones consistent with the inferred low latitudinal position close to the equator and humid climatic conditions for the Middle and Late Carboniferous of the Alps. Nonetheless, it should be kept in mind that the O_2-concentration of the Carboniferous atmosphere is still unsettled and may have varied between 13 and 35% of the present 21% level (H.D. HOLLAND 1990). Other major perturbations concern its anomalous carbon, oxygen and sulfur isotopic composition and the low CO_2 content (see T. J. ALGEO et al. 1995, H. P. SCHÖNLAUB 1996, R. A. BERNER 1997). The latter reached almost present-day values. Moreover, nutrients levels varied considerably during the Carboniferous with significant implications for the marine and terrestrial biosphere (R. MARTIN 1996).

According to J. C. CROWELL 1978, M. J. HAMBREY & W. B.HARLAND 1981, M. V. CAPUTO 1985, M. V.CAPUTO & J. C. CROWELL 1985, J. J.VEEVERS & C. Mc POWELL 1987, J. N. J. VISSER 1990, J. LANG et al. 1991, A. BOUROZ et al.1978 T. J. CROWLEY & S. K. BAUM 1991, G. GONZALEZ-BONORINO & N. EYLES 1995, N. EYLES et al. 1995, R. A. GASTALDO et al. 1996 and others the continental glaciation in the Southern Hemisphere started diachronously in the Tournaisian and Visean[6]. With varying intensities this climatic alteration caused high-latitude cooling and contemporary equatorial warming episodes which lasted until the Lower Permian. According to P. H. KELLEY et al.1990 the cooling event resulted in changes of latitudinal diversity patterns coupled with migration of different organisms, for example brachiopods. The well known "Auernig-cyclicity" in the Upper Carboniferous of the Carnic Alps may certainly be explained as a glacial rebound (K. KRAINER 1991) although alternative proposal have also been made (e.g., G.M. FRIEDMAN 1989); evidently, it was of no consequence to the biogeographic distribution of faunas and floras of that region.

At the beginning of the Carboniferous the apparent polar wander path (APWP) shows a change in the drift direction from a Devonian southward movement to a continuous and rapid northward drift of Gondwana with minimum drift rates of 10 cm a^{-1} (R. VAN DER VOO 1988, D.E. KENT & R.VAN DER VOO 1990, V.BACHTADSE & J.C. BRIDEN 1990). This rapid movement of Africa over the South Pole is hold responsible for the final disappearance of the Mid-European or Rheic Ocean besides several other oceans and the collision between Gondwana and Laurussia in the Namurian (e.g., W. S. McKERROW & A. M. ZIEGLER 1972, J. NEUGEBAUER 1988, C. R.SCOTESE & W. S.McKERROW 1990). As mentioned above the collision of the Southern Alps with the central part of the Eastern Alps can also be related to this motion; it occurred, however, slightly later at the end of the Namurian or at the beginning of the Westfalian Stage, i.e. in the Bashkirian or early Moscovian.

Fig. 4 illustrates the paleogeography of the supercontinent Pangea in the Upper Permian at c. 260 Ma. The organisation of plates resembles that from the Upper Carboniferous.

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6 However, according to M. V. CAPUTO (pers. comm. at the James Hall Symp. Rochester, N. Y., 1996), tillites occur already in pre-expansa-Zone old deposits, i. e. in the Famennian in the Amazonas and Parnaiba Basins of Brasil; older tilltes may even be assigned to the Frasne/Famenne boundary but are as yet not dated.

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