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Variscan tectonic evolution in the Central Alps: a working hypothesis

by *Ivan Mercolli*[1] and *Roland Oberhänsli*[1]

Abstract

The Upper Paleozoic magmatic rock associations outcroping in four different tectonic units of the Central Alps (Aar massif, Lower Austroalpine, Austroalpine and Southern Alps) can be devided into three series: 1) calcalkaline volcanic and plutonic rocks, representing the more conspicuous member of this magmatism, 2) alkaline rocks, mainly plutonics and 3) G-type rhyolite. The correlation of the magmatic activities with their proper tectonic regimes as well as some sedimentological and tectonical observations provide an interpretation of the Variscan evolution in terms of plate tectonics. The proposed model presumes that the four studied areas were located at the southern margin of the European continent above the subducting Proto Tethys oceanic plate. The heterochronous development of the magmatism in the four different areas is interpreted as to be caused by the relative movement of the "Central Alps" continental block with respect to the subduction zone. This movement is related to the lateral acretion of continental material in front of the "Central Alps" block. The Mesozoic rifting is finally responsible for the separation of Aar massif, Lower Austroalpine, Austroalpine and Southern Alps in a way that could satisfy the Alpine paleogeography.

Keywords: magmatic activity, plate tectonics, Variscan evolution, Central Alps.

Introduction

Since the works of NICHOLAS (1972), BURRET (1972) and LAURENT (1973), use of the plate tectonic approach to interprete the evolution of the Variscan orogeny in Central Europe is common (for review see BARD et al. 1980, ZIEGLER, 1982-1986, LORENZ and NICHOLLS, 1984). Those studies are mainly based on the classical Variscan regions which were not affected by the Alpine orogeny (central and southern Germany, Massif Central, Spain, Sardinia, Corsica). Despite the fact that the Paleozoic basement is an important part of the Alpine chain, in all paleogeographic reconstructions references to the Central Alps are scarce or absent.

The aim of this contribution is to combine the results of several studies carried out at the University of Bern on Paleozoic sequences from the Central Alps and to propose a working hypothesis for the Variscan plate tectonic evolution of this area.

Observations on Upper Austroalpine magmatic rocks from four distinct tectonic units (Aar Massif, Lower Austroalpine, Austroalpine and Southern Alps), together with their relationships to regional Variscan metamorphism and deformation, have been chosen to develop a tectonic model.

Lithological and structural frame of the Upper Paleozoic magmatism

The studied units, except the Southern Alps, have undergone different degrees of Alpine metamorphism and deformation. As our attention is concentrated on the Variscan problem, the terms metamorphism and deformation always refer to pre-Alpine (mainly Variscan)

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orogenic events. Conversely we are constrained to utilize the Alpine terminology of the tectonic units (i.e. Lower Austroalpine) to achieve a maximum of clearness in our exposition. It would perhaps be more correct to use those terms with the prefix "proto" (proto-lower Austroalpine), because the relative position of the different units before the early Mesozoic rifting and subsequent Alpine overthrusting is yet to be established.

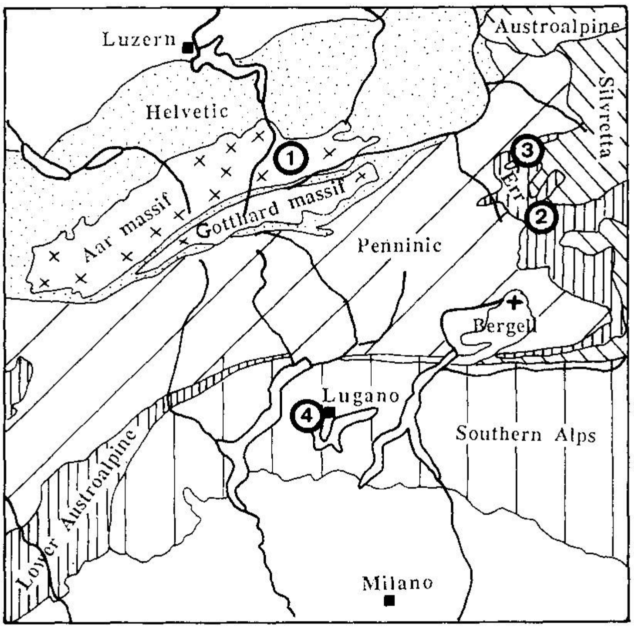


Fig. 1 Geographic and tectonic location of the four studied areas:
1. Aar massif - 2. Lower Austroalpine (Err and Julia-Bernina nappes) - 3. Austroalpine (Silvretta nappe) - 4. Southern Alps (Lugano area).

Fig. 1 shows the location of the four areas studied in detail:

1. Northeastern Aar massif (SCHALTEGGER, 1984; OBERHÄNSLI, 1986, 1987; SCHENKER, 1986, 1987; SCHENKER and ALBRECHT, 1987; BÖHM, 1986, 1988).
2. Lower Austroalpine, Err and Julier-Bernina nappes (BÜHLER, 1983; RAGETH, 1984; MERCOLLI, 1985).
3. Austroalpine, Silvretta nappe (FLISCH, 1987; ZAUGG, 1987; GRAF, 1987).
4. Southern Alps, Lugano area (BULETTI, 1985; STILLE and BULETTI, 1987; WENGER, 1987).

From these four areas it was possible to deduce some of the common characteristics of the Upper Paleozoic magmatism.

1. The plutonism can be divided into two series:
   a) A calc-alkaline series
   Diorite, small tonalitic intrusions, large granodioritic and granitic bodies represent the members of the magmatic sequence and are present, with variable proportions of the different lithologies, in all of the studied tectonic units. Only the Silvretta nappe lacks Variscan plutonics.
   b) An alkaline series
   This series (monzonite, syenite and alkali granites) well developed in the Lower Austroalpine (Julier Bernina nappe), is present in the Southern Alps as part of the Baveno granitoids (BONIN, 1987) and is absent in the Silvretta nappe. The syenitic rocks of the Aar massif seem to be older than Carboniferous and are therefore not included in this description.
2. The volcanism can be subdivided in:
   a) A calc-alkaline series.
   High-Al basalts, andesites, dacites and rhyolites are the typical members of this series. The different lithologies are well documented in the Southern Alps (Lugano area) and in the lower Austroalpine (Err nappe). In the Aar massif mainly rhyolite and related volcanoclastic sediments are preserved.
   b) Large masses of monotonous rhyolitic ignimbrites
   These rocks seem to fit some of the criteria for G-type rhyolites (IZETT, 1981). Typical outcrops can be found in the Southern Alps and in the Silvretta nappe. The rhyolite of the Sandpass formation (OBERHÄNSLI et al., 1988) could be assigned to this group.
   c) Rhyolitic ignimbrites with an alkaline tendency.
   These occur as a small body in the Julier Bernina nappe.
3. Mafic dikes (dolerites and lamprophyres), cutting the units mentioned above, are the latest magmatic products of the Variscan cycle.

Compositional change due to postmagmatic alterations and Alpine metamorphism, prevent in many cases a clear definition of the primary magmatic relations. Therefore, it is sometimes difficult to classify beyond a doubt the lithologies in the previous scheme.

The main magmatic activity can so be related to subduction processes, with the calcalkaline series (volcanics and plutonics) developing in an active continental margin while G-type rhyolite and the alkaline series reflect a cratonic environment.

Basic geological relations of the magmatic rocks in the different areas

AAR MASSIF

The following informations, in light of a paleotectonic reconstruction, can be derived from the Upper Paleozoic magmatic rocks and related sediments.

1. The volcanic and volcanoclastic rocks lie generally directly on the polymetamorphic basement. Later tectonic events often affected the contacts.
2. The subduction related volcanics (mainly of rhyolitic composition) and the associated molasse type sediments have been wedged into the basement during a pre-Alpine compressive tectonic phase (nappe structures, OBERHÄNSLI et al., this vol.).
3. The previously wedged volcanics were intruded by calcalkaline granitoids producing contact metamorphism, which is well documented by the growth of andalusite in the pelitic layers of the volcanoclastic members from the Diechter formation (SCHENKER, 1986, SCHENKER und ABRECHT, 1987).
4. The spatial distribution of the granitoids is subparallel to the wedging structures of the volcanics emphasizing the coherence between the wedging and the intrusion during a compressive tectonic phase.
5. The base of the Mesozoic units (Lower Triassic to Lower Jurassic) unconformably overlays the Paleozoic units.

LOWER AUSTROALPINE

Err and Julia Bernina nappes allow the characterization of some other important features of the Upper Paleozoic magmatism.

1. In the Err nappe the calcalkaline volcanic suite includes a large rhyolitic member and former andesitic, dacitic to rhyodacitic rocks. Similar to the Aar massif this suite was wedged into the basement during pre-Alpine times.
2. The volcanics lay directly on the basement and are unconformably overlayed by the Mesozoic sediments.
3. In the Julier Bernina nappe the alkaline plutonics (syenites and alkali granites) are clearly intrusive into the calcalkaline series (diorites, granodiorites and granites) and therefore younger (BÜHLER, 1983 and RAGETH, 1984).
4. The slightly alkaline rhyolitic ignimbrites of the Julier Bernina nappe (Diavolezza region) can only be related geochemically to the alkaline plutonics (RAGETH, 1984). In composition they differ clearly from the calcalkali-rhyolites of the Err nappe.

SILVRETTA NAPPE

In the Silvretta nappe, relicts of Variscan magmatism are scarce. Plutonic rocks are absent and the volcanic rocks are restricted to the frontal part of the nappe. This volcanism is almost exclusively rhyolitic. In spite of lack of good information on the magmatism, the Silvretta nappe provides good data on the Variscan metamorphic evolution of the basement (FLISCH, 1987). The following points are important for our reconstruction:

1. The Silvretta basement has suffered a first peak of metamorphism in amphibolite facies with a strong penetrative deformation at about 350–360 ma. After an uplift phase, the same basement was affected by a second metamorphic event (greenschist to amphibolite facies) around 300–310 ma (FLISCH, 1987). The "Schlingen Bau" seems to be related to this second episode.
2. The volcanics can be classified as G-type rhyolites (IZETT, 1981) and have developed together with molasse type deposits which are intercalated with the rhyolitic ignimbrites. These series are confined by listric faults and pass without evident discordance into the Mesozoic sediments. The volcanics are always separated from the basement by a basal conglomerate and do not show any sign of Prealpine tectonic (ZAUGG, 1987, GRAF, 1987). Similar relations are described by DÖSSEGGER (1974) at the base of the Mesozoic sedimentary cover of the Silvretta nappe (Scarl unit). Recent work seems to indicate the presence of calcalkaline volcanics also in the Silvretta (GRAF, work in progress).

SOUTHERN ALPS

The Variscan magmatism is well represented in the Southern Alps and lacks Alpine metamorphism and deformation. Our studies are restricted to the area near Lugano where a volcanic sequence ranging from basaltic andesites through andesites, dacites, rhyodacites to rhyolites together with a large subvolcanic granophyric intrusion is exposed.

The following characteristics can be summarized for the Lugano volcanic suite (BULETTI, 1985):

1. Two volcanic series are present; the subduction related volcanics (basaltic andesites, andesites, dacites, rhyodacites, rhyolites) and the G-type rhyolites.
2. The subduction series seems to be older than the G-type rhyolites.
3. A polygenic conglomerate separates the volcanic series from the basement.
4. With the exception of a local fault tectonic no indications are present for a major postvolcanic tectonic event.

Similar characteristics are common in other classic localities of Upper Paleozoic volcanics of the Southern Alps: Val Trompia, Bolzano, Val Sesia (CASSINIS et al., 1984).

The plutonics of the Insubric zone are mainly calcalkaline but an alkaline tendency (part of the Baveno suite) seems also to be present (BONIN, 1987).

The age problem

The dating effort in this sector of the Alps was focused on the description of the Alpine orogeny so that the Variscan ages are scarce and disperse. This situation is not only a consequence of the tepid interest on the Variscan problem but also a technical problem in the sense that Alpine metamorphism has in many cases resetted the isotopic systems and obliterated fossil records. We will try to summarize here the relative and absolute age relationships of interest for the purposes of this note (this summary should not be interpreted as an exhaustive presentation of the Variscan ages in the Central Alps).

AAR MASSIF

WÜTHRICH (1965) reports a Rb-Sr age of 281 ± 11 ma for the Central Aar granite. Recent data from SCHALTEGGER (1986) seem to confirm an Uppermost Carboniferous age for the Central Aar granitoids.

Biotites from the basement give a 312 ± 12 ma Rb-Sr age (WÜTHRICH, 1965) and a 312 ± 12 ma K-Ar age (SCHALTEGGER, 1984). They were interpreted as cooling ages after the climax (undated) of the Variscan metamorphism.

The flora from mudstones associated with volcanic and volcanoclastic rocks from the Bifertengrätli formation (FRANKS, 1968) can be assigned after JONGMANS (1960) at the boundary Westphalian D-Stephanian.

SCHENKER (1986) demonstrates that the Central Aar granite intrudes, with development of a contact aureole, the volcanoclastics of the Diechter formation.

LOWER AUSTROALPINE AND AUSTROALPINE

RAGETH (1984) reports, as a personal communication of Grünenfelder, an age of 305 ma (U-Pb on zircon) for the calcalkaline granitoids of the Julier Bernina nappe.

BÜHLER (1983) and RAGETH (1984) give field evidence in the Julier Bernina nappe for the intrusion of the alkaline rocks into the calcalkaline plutonics, which must therefore be older.

FLISCH (1987) dates a first Variscan metamorphic event in the basement of the Silvretta nappe around 360–350 ma and a second one around 310–300 ma (Rb-Sr, K-Ar).

SOUTHERN ALPS

HUNZIKER and ZINGG (1980) date the Baveno granitoid suite at 276 ± 5 ma (Rb-Sr whole rock).

HUNZIKER (1974) dates rhyolitic rocks from the Val Sesia and the Lugano area at 280 ± 5 ma (Rb-Sr whole rock).

STILLE and BULETTI (1987) obtained an age of 262 ± 1 ma (Rb-Sr mineral isochron) for the calcalkaline suite from the Lugano area.

JONGMANS (1960) assigns the flora of the Manno conglomerate (which seems to lay at the base of the volcanic suite of Lugano) to the Westphalian D-Stephanian boundary.

The tectonic model

Fig. 2 shows a tentative lithostratigraphical correlation between the four areas studied; this correlation is mainly based on the development of the magmatic activity and underlines the similarities and the differences of the evolution in the different areas. These can be summarized as follows:

All the studied terrains show an Upper Paleozoic magmatism that is related to subduction processes.

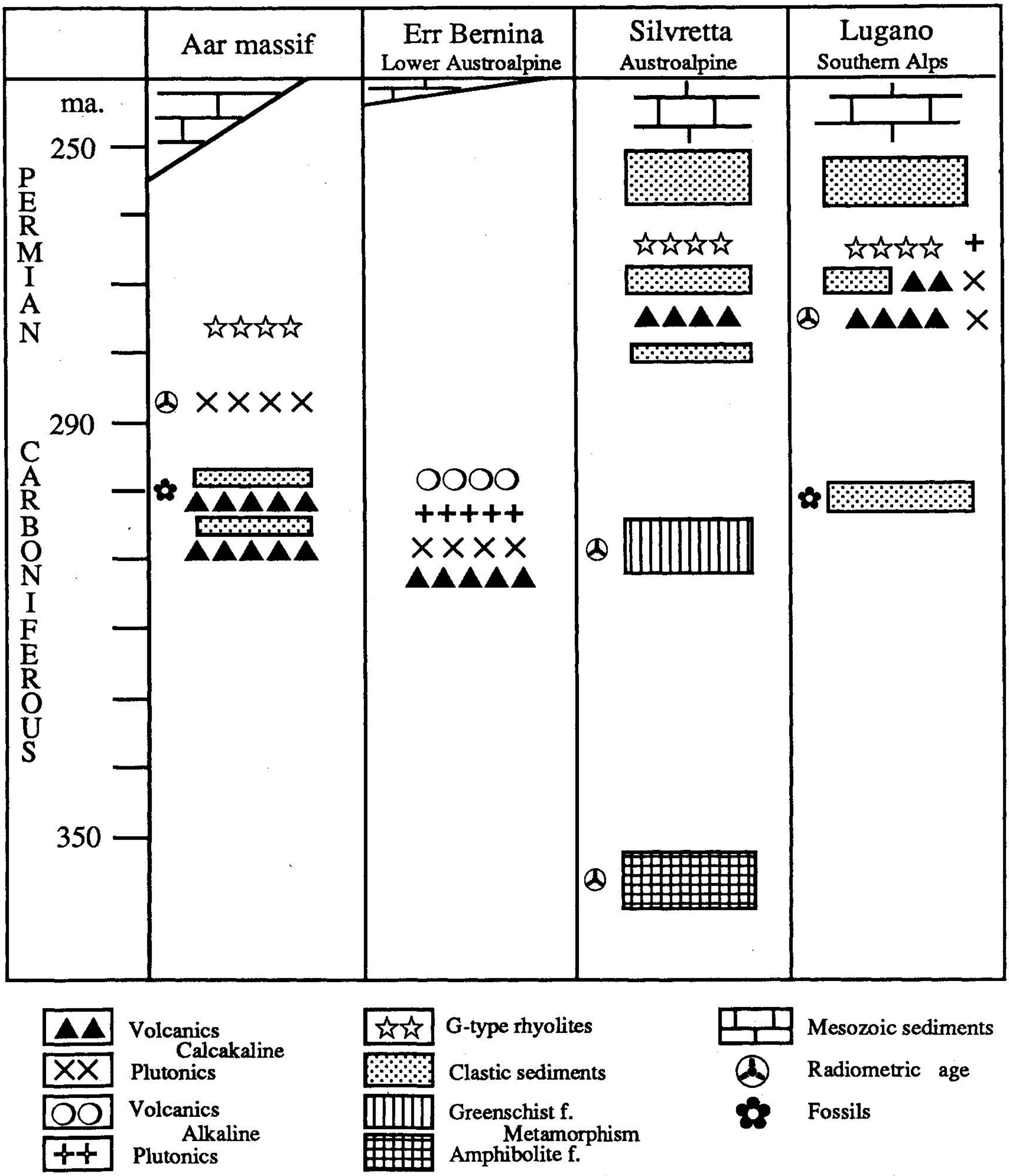


Fig. 2 Lithostratigraphical correlation between the four studied areas.

This magmatism occurs in the different areas at different times, Aar massif and lower Austroalpine seem to develop the subduction magmatism more or less simultaneously during the Westphalian, while the same type of magmatism in the Southern Alps and probably in the Silvretta is 30–40 ma younger (Early Permian).

A similar trend is displayed by the tectonic overprint of the volcanics and related sediments. In the Aar massif and Lower Austroalpine the volcanics are wedged together with the basement in Upper Carboniferous-Lower Permian time. The equivalent units in the Silvretta and in the Southern Alps do not show any latest Paleozoic tectonic overprint.

The alkali magmatism and the G-type rhyolites are not dated. It is therefore impossible to say whether they developed in the different regions at the same time or not.

Based on this observations we have tried to construct a plate tectonic model for the Central Alps during the Upper Paleozoic.

Some important external constraints must be fulfilled by the model:

The initial configuration of the plates should fit a general paleogeographic reconstruction. We have chosen the reconstruction of ZIEGLER (1986) for the Lower Carboniferous in Europe.

The final configuration should fit the initial paleogeographic situation of the Alpine orogenic cycle. In this case we have adopted the Lower Jurassic reconstruction of TRÜMPY (1980).

The coarse geometrical relations between the different environments of a subduction zone (i. e. trench, forearc basin, volcanic arc intra-arc basin, fault and thrust belt, backarc basin) must be respected.

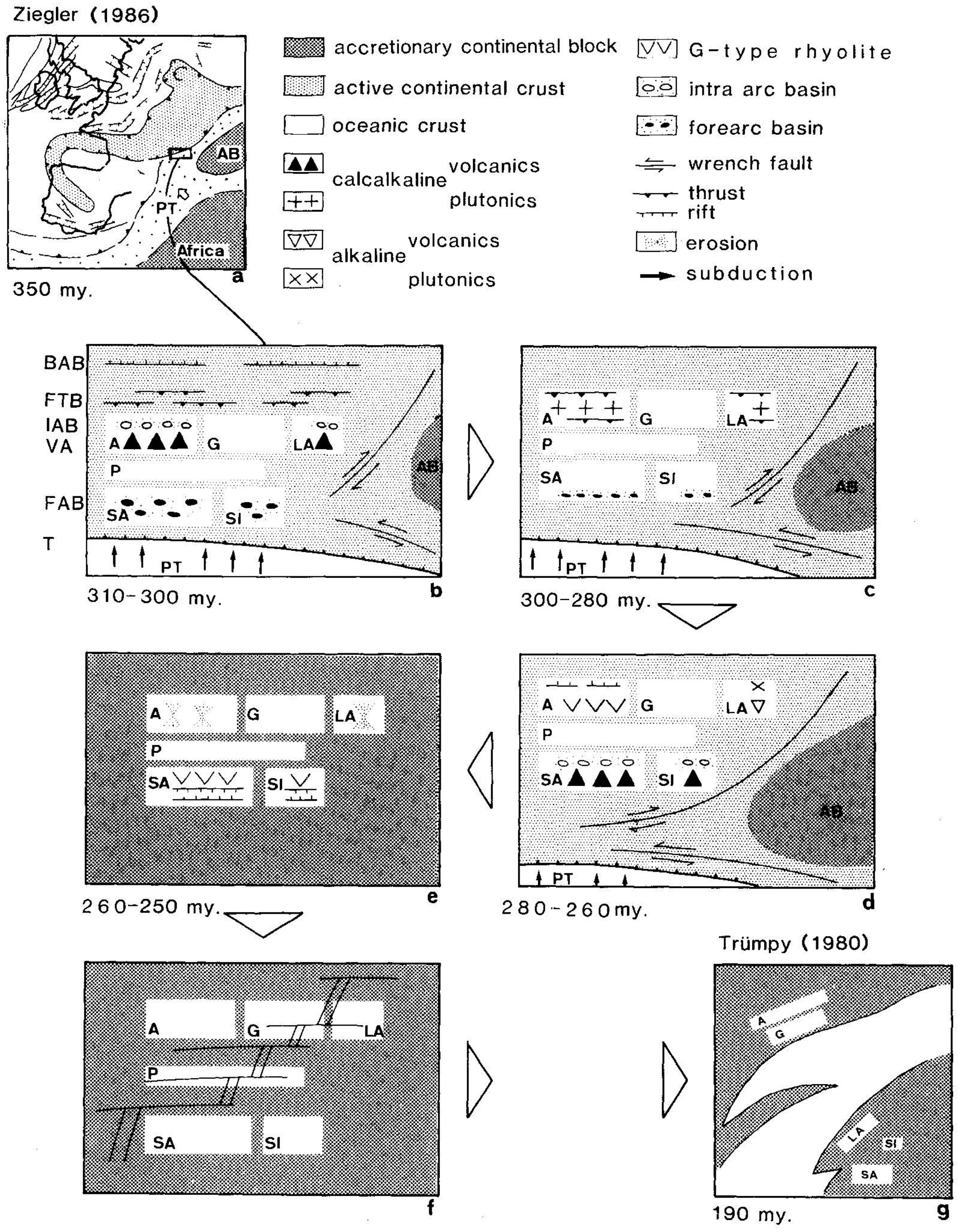
Finally the major geological constraint to the model is the apparent absence of Upper Paleozoic oceanic sediments and/or oceanic crust lying between the studied domains. The consequence is that we assume that the four areas (Aar massif, Lower Austroalpine, Austroalpine and Southern Alps) belonged in Upper Paleozoic times to the same continental block, the European continent.

Fig. 3 illustrates in an extremely schematic way our hypothesis. In the construction of the sketches we kept the relative positions of the subduction related environments constant (i. e. trench, forearc basin, volcanic arc infra-arc basin, fault and thrust belt, backarc basin) and located the volcanic arc about 200 km away from the trench. We further assumed that the relative position of the domains (Aar massif, Lower Australpine, Austroalpine and Southern Alps) did not substantially change during the times of interest. These positions have been deduced from the lithostratigraphical relations summarized in Fig. 2. The boxes, representing the different domains, contain a schematic representation of the geological processes going on in the region at the time. We have added to the four areas studied, the Gotthard massif and the Penninic domain as extrapolations of our model, but the respective boxes have been keep void to emphasize the fact that we have not studied these regions.

The central idea of this model is based on the assumption of a constant position of the subduction zone. The active volcanic zone is allowed to migrate due to lateral accretion of continental material by wrench tectonics. With this mechanism the block with the areas of interest is moved through different environments. Therefore the four studied areas reached a similar position relative to the subduction at different times and underwent the same type of magmatism, tectonic and depositional environment.

Following the sketches in Fig. 3 we start with the main tectonic frame for Europe in Lower–Middle Carboniferous (ZIEGLER, 1986). The major feature at this time is the north vergent subduction of the Proto Tethys oceanic crust beneath the Southern margin of the European continent. In the area of interest this continent is characterized by an active belt and an already consolidated block (the Austroalpine micro continent of ZIEGLER, 1986). Restricting the view to the Central Alps (Fig. 3b to 3g) the Upper Paleozoic evolution can be described as follows:

Fig. 3b: In the Upper Carboniferous (310–300 my) the subduction of the Proto Tethys is still active and causes the formation of a cordillera at the Southern margin of the European continent. At this time the Aar massif and the Lower Austroalpine are in volcanic arc position and develop the typical calcalkaline volcanism and the related clastic sedimentation in intra arc basins. It is possible that the volcanic activity is not strictly synchronous in the two areas, but this would only imply a relatively weak shift of the corresponding boxes in



A:Aar massif
G:Gotthard massif
LA:Lower Austroalpin
P:Penninic
SA:Southern Alps
SI:Silvretta nappe

AB:Austroalpine block
PT:Proto Tethis

VA:volcanic arc
IAB:intra arc basin
FTB:fault thrust belt
BAB:backarc basin
FAB:forearc basin
T:trench

Fig. 3 Schematic representation of the proposed evolution model for the Central Alps in the Upper Paleozoic (explanation of the figure in text).

Fig. 3b. Contemporaneously the Southern Alps and the Silvretta nappe are located in forearc situation and show only clastic sedimentation.

Fig. 3c: During the Stephanian (300–280 my) the Austroalpine block moves laterally (to the West?) along wrench faults and wedges itself in front of the block representing the Central Alps. This process causes the consequent movement (to the North ?) of the Central Alps, increasing the distance of our areas from the trench. As consequence, the Aar massif and the Lower Austroalpine pass from the volcanic arc situation in a fault-thrust belt resulting in the wedging of the volcanic and sedimentary sequences into the basement and in the simultaneous emplacement of the calcalkaline plutonics. At this time the Southern Alps lack magmatism and sedimentation. This indicates a probable uplift consistent with the transition from the forearc to the volcanic arc situation.

Fig. 3d: During Lower Permian (280–260 my) the continous lateral accretion of the craton further shifts the Central Alps, so that the Southern Alps and the Silvretta reach the volcanic arc position and the calcalkali volcanism begins. Consequently, the Aar massif and the Lower Austroalpine also move. It is difficult to recognize the geological processes going on in these areas during this time. Probably, these blocks become more and more stable changing the type of magmatism. In this period G-type rhyolites extruded in the Aar massif and indications of an alkaline magmatism in the Lower Austroalpine can be found.

Fig. 3e: It seems that in Middle to upper Permian time (270–250 my) the subduction stops. No evidence of younger calcalkaline magmatism have been described in the studied areas.

In the Central Alps no arguments for the complete closure of the Proto Tethys are found. Speculation for a shift of the subduction zone to the south due to renewed accretion are supported by the description of calcalkaline volcanism up to the Middle Triassic in the Dolomite area (CASSINIS and ZEZZA, 1982; BARBIERI et al., 1982; BOSELLINI et al., 1982).

In the Aar massif and Lower Austroalpine, geological records of this time are practically absent. The Southern Alps and the Silvretta nappe developed instead conspicuous clastic sedimentation in presumably extensional basins often associated with acid volcanism.

Fig. 3f: The rifting related to the opening of the Tethys separates the Variscan craton along new boundaries. In this way the Lower Austroalpine, related in Variscan times to the Aar and Gotthard massifs, became part of the Insubric block. Relative motion along transform faults seems a plausible mechanism to fit the proposed setting of the Variscan units in the Central Alps into the paleogeographic reconstruction for the Lower Mesozoic (Fig. 3g, after TRÜMPY, 1980).

Conclusions

Without overrating the arguments suggested in this note, which are in many aspects affected by simplifications and generalizations, it seems important to formulate some statements which can help to develop a discussion of these problems.

The first encouraging result is the quantity and quality of the data that could be collected in the so called Alpine fold belt in order to understand the Variscan evolution. In spite of the Alpine alteration of the original relationship, the Paleozoic rocks are in many cases abundantly and continuously exposed, permitting a fruitful field approach.

It seems evident that at least in the studied areas, the tectonic activity persisted during Early Permian times, producing magmatism, deformation and perhaps metamorphism.

Deformation and type of magmatism are compatible with the Early Permian Post Variscan wrench faulting evident in the Alpine foreland (ZIEGLER, 1982).

Against the established point of view we have located the Southern Alps and the Silvretta at the Southern margin of the European continent (not at the northern edge of Gondwana) and the Lower Austroalpine in the same position as Aar and Gotthard massifs. This topology is fundamental for the proposed model, but will surely be a point of discussion.

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