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Tectonics of the western Tauern window

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With 2 Figures

Zusammenfassung

Im (westlichen) Tauernfenster unterscheidet sich die mittelpenninische Venedigerdecke mit ihrem variszisch geprägten Grundgebirge und geringmächtiger mesozoischer Bedeckung wesentlich von der südpenninischen Glocknerdecke, die nur postvariszische Formationen enthält. Die Basis der Glocknerdecke stellt eine tektonisch stark verschuppte Zone mit permotriadischen Sedimenten dar, die in der südlichen Venedigergruppe mit basalen Bündner Schiefern und Ophiolithen vermengt ist und das Aussehen einer ophiolithischen Mélange annimmt.

Das Grundgebirge der Venedigerdecke weist variszische Tektonik auf, die in einem Antiklinorien–Synklinorien-Bau und in der Überschiebung der vielfach migmatischen Riffldecke ihren Ausdruck findet. In altalpidischer Zeit unterlag die Venedigerdecke weiterer Einengung, wobei die paläozoischen Schiefermulden zwischen den starren Zentralgneiskuppeln besonders stark eingeengt und ihre mesozoischen Hüllen in Form von Abscherungsdecken nach Norden vorgetrieben wurden. An der Nordflanke der Tauernkuppel findet man vielfach Tauchstrukturen, die aus liegenden Falten hervorgegangen sind.

Summary

In the (western) Tauern window there are two quite different tectonic units, the Middle Penninic Venediger nappe with its Hercynian basement and thin Mesozoic cover; and the South Penninic Glockner nappe which contains only Alpidic formations and lacks older basement. The basal zone of the Glockner nappe is built up of highly contorted Permotriassic sedimentary rocks which, in the southern Venediger mountains, are intermingled with the basal Bündner Schiefer and ophiolites and attain the appearance of an ophiolitic mélange.

The basement of the Venediger nappe already shows Hercynian tectonic imprint resulting in synclinories and anticlinories, and a major thrust nappe. In old-Alpidic time the schistose synclinories between the Zentralgneiss cupolas suffered strongest compression, and their Mesozoic covers have been peeled off and thrusted northward in décollement nappes. On the northern flank of the Tauern arch, diving structures resulting from updomed recumbent folds, are common.

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Following the basic concepts of TERMIER (1903) and STAUB (1924), the *Penninic portion of the Tauern window can be divided into two tectonic units* (Fig. 1): the lower, Middle Penninic Venediger nappe (FRISCH, 1976) and the higher, South Penninic Glockner nappe (FRISCH, 1974). Of course, the boundary between, and the contacts of, the two units have been modified since the early authors. Most of the results discussed in the present paper are treated in more detail in FRISCH (1977) to which paper the reader is referred.

The **Venediger nappe** *is made up of a pre-Alpidic basement carrying a skin* of Mesozoic sediments. The basement consists of Carboniferous and Permian granitoid masses, the Zentralgneisses, which intruded Paleozoic sediments and metavolcanics; intrusive contacts and migmatitic zones are still preserved (e.g., FRASL, 1953). The Upper Paleozoic magmatic activity, metamorphism and tectonics bear witness to the efficacy of the Hercynian orogeny.

The H e r c y n i a n *tectonics affected the Zentralgneisses* as well, and with great probability even their Permian portions. Synclinoria filled with sedimentary and volcanic material, and anticlinoria with Zentralgneiss in their cores formed ample structures which became important for the tectonics of the Alpidic era.

A thrust nappe, the Riffl nappe (CORNELIUS, 1930) (Fig. 1), which brings Hercynian migmatitic formations in contact with weakly or (at Hercynian time) non-metamorphosed Lower Paleozoic sediments and volcanics, is considered to be of Hercynian age (FRASL & FRANK, 1966: Beil. 2; FRISCH, 1977). This is supported by the absence of Mesozoic strata involved as well as by the tectonic style which is not in accordance with the deformation of the basement during the Alpidic nappe-forming phase (see below). Near the hanging wall of the Riffl nappe, however, Alpidic tectonics is responsible for the formation of digitations of Mesozoic strata belonging to the Glockner nappe. This act is independent from the event responsible for the overthrusting of the Riffl nappe.

The Riffl nappe which is known from the Granatspitz area, is continuous with the Zillertaler and Venediger Zentralgneiss Kerne ("cores"). Hence this Hercynian structure can be traced over to the western end of the Tauern window; the thrust plane is probably situated within the Greiner synclinorium between the Furtschagl schists attributed to the Riffl nappe, and the Greiner formation s.str. (Fig. 1). Possibly up to Lower Permian sequences are involved in the Hercynian nappe tectonics within the Greiner synclinorium; however, this is not clearly to decide because of the uncertainty with the age of the sequences and the strong overprint by Alpidic tectonics which caused a general steepening of the sequences. Augen gneisses and migmatites which show intrusive contacts to the (Carboniferous?) Furtschagl schists (LAMMERER et al., 1976), were emplaced before thrusting. Therefore, the thrusting of the Riffl nappe is very likely to have occurred in late Hercynian time and may be seen in connexion with the Middle Permian radiometric event (FRANK, pers. commun.).

It is of interest that the Zentralgneisses of the lower Hercynian unit (autochthon to the Riffl nappe) consist mainly of granitic rocks whereas those of the overthrusted unit, the Riffl nappe, comprise great portions of tonalites and grano-

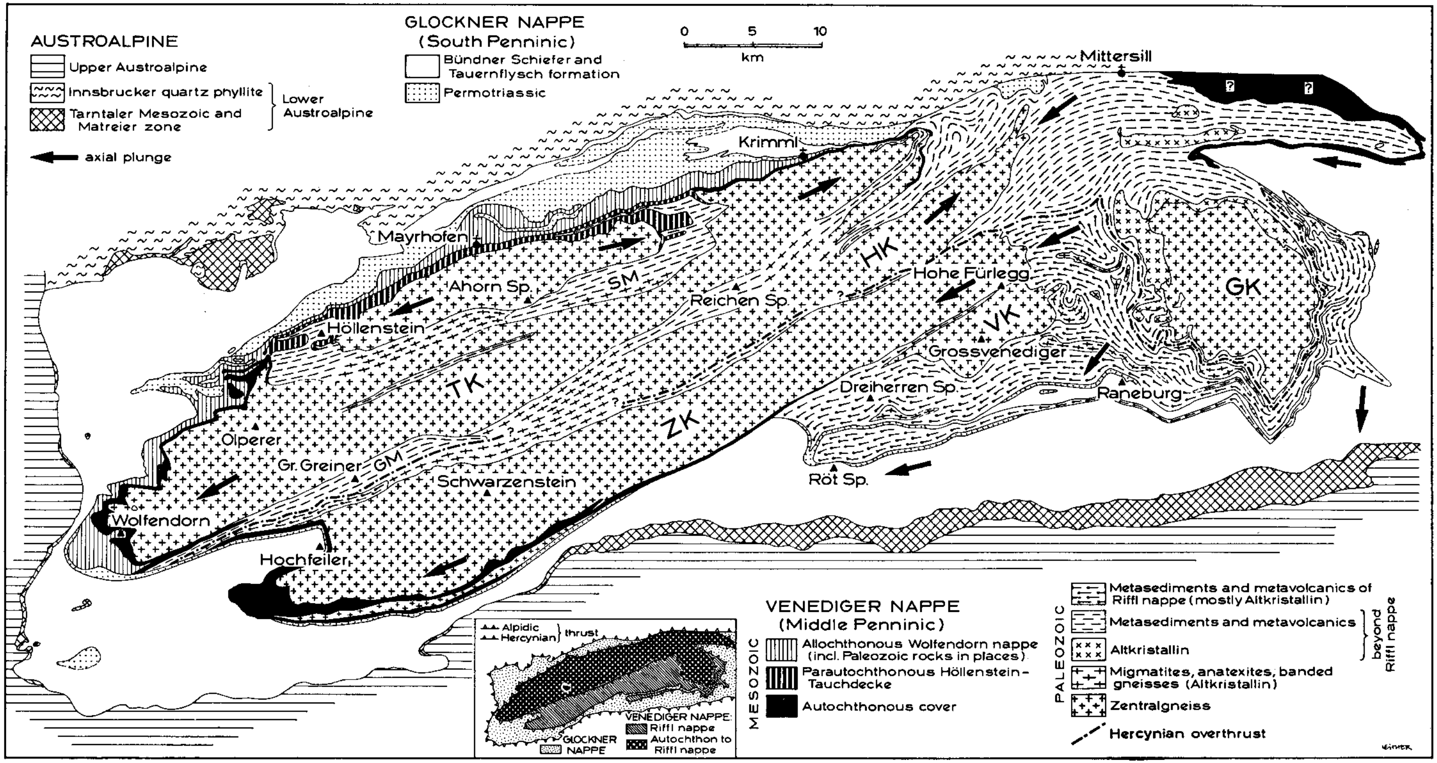

Fig. 1: Tectonic map of the western Tauern window.

diorites which is considered to be due to stronger melting with the anatectic process; this is in accordance with the broad migmatitic halos in the Venediger area.

The Alpidic tectonics of the Venediger nappe is characterized by a specific style (FRISCH, 1977) (Fig. 2). The basement is no more divided into far thrusted nappes, although internal tectonics cause compression and the formation of subordinate slices, décollement nappes of Mesozoic and schistose Paleozoic rocks, and upthrusts. The Paleozoic synclinoria filled with schistose rocks are strongly compressed between the more rigid Zentralgneiss cores, and the décollement nappes derive from these schistose zones; the Zentralgneiss cores, however, still carry their autochthonous Mesozoic cover. The behaviour of the basement rocks corresponds to that described by RAMSAY (1967) for an underlying competent layer (Zentralgneisses) covered by incompetent rocks: during compression, the competent layer forms cupolas with large wavelength and small amplitude; on the other hand, the schistose rocks form steep and narrow synclines with short wavelength and high amplitude.

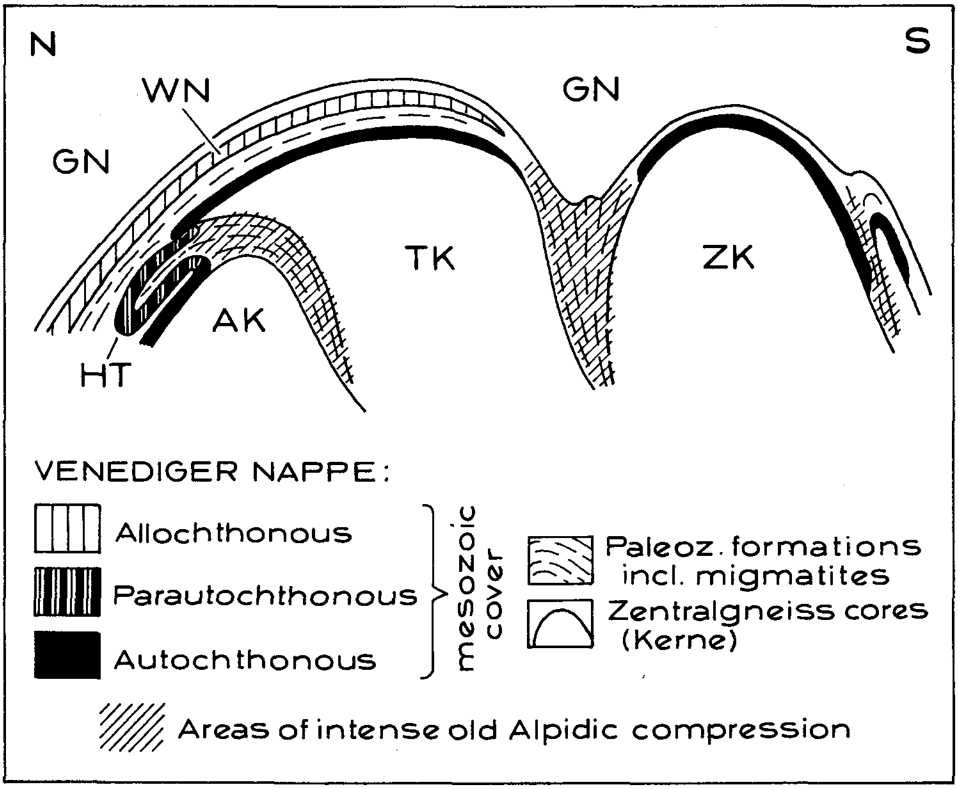

Fig. 2: Schematic section through the western end of the Tauern window (Tuxer Tal – Ahrntal) showing Alpidic structures of the Venediger nappe.
AK, Ahorn Kern (Zentralgneiss core). TK, Tuxer Kern. ZK, Zillertaler Kern. HT, Höllenstein-Tauchdecke (diving nappe). WN, Wolfendorn nappe. GN, Glockner nappe.

In the western Tauern window, the parautochthonous Höllenstein-Tauchdecke (diving nappe with an antiform as hinge and a synform at the front – see Fig. 2) derives from the Schönach synclinorium between Ahorn and Tuxer Kern (Fig. 1). The Wolfendorn nappe which has been thrust for at least 10 km, derives from the Greiner synclinorium between Tuxer and Zillertaler Kern. These décollement nappes of the Venediger nappe (unit) have local character and are not far-thrusted nappes mantling the Zentralgneisses domes all around. For this reason, the Wolfendorn nappe cannot be paralleled with, or seen as part of, TOLLMANN's (1962, 1975) "Lower Schieferhüll nappe".

The Höllenstein-Tauchdecke is not the only diving nappe in the Tauern window. In the northeastern corner of the window, the Silbereck-Tauchdecke forms the counterpart to the Höllenstein-Tauchdecke in a similar position. ALBER 1976 describes a large recumbent fold structure in the Sonnblick area which is diving at its front (synform), and BRAUMÜLLER & PREY (1943) describe synforms on the northern flank of the eastern part of the Tauern arch within the Glockner nappe. The core of another synform is represented by the Falkenbach-lappen (Fig. 1) which comprises Paleozoic schists with thin Mesozoic cover, and is part of the Venediger nappe; the Falkenbach synform which plunges to the west, is underlain by rocks of the (tectonically higher) Glockner nappe.

In Alpidic time the Granatspitz Kern has the same tectonic position as the other gneiss cores, and not a deeper one as proposed by TOLLMANN (1975); with its northern margin, it lies in a line with the northern margin of the Zillertaler Kern (FRISCH, 1977). There are, however, differential movements of the Zentralgneiss cores (upthrusts to the north) due to the general northward overthrusting (southward underthrusting) during the main deformation period. These upthrusts are partly overprinted by later normal faulting (LAMMERER et al., 1976).

The Alpidic tectonics of the main deformation period resulting in ample cylindrical Zentralgneiss arches, narrow, strongly compressed synclinoria of incompetent rocks, and décollement nappes, has been overprinted by Lower Tertiary regional metamorphism and deformation (FRANK, 1969) and is therefore attributed to the old-Alpidic orogenic period. FRISCH (1977) showed that the tectonic style of the old-Alpidic structures favours elevated P/T conditions. The old-Alpidic orogeny gradually ceased with the "first continent-continent collision" (FRISCH, this vol., in press) in the Cretaceous. It was accompanied by a paired metamorphic belt (HAWKESWORTH et al., 1975), the high-pressure/low-temperature branch of which was effective in parts of the Tauern window, especially in the ophiolitic mélange of the basal Glockner nappe (see MILLER et al., this vol.).

The **Glockner nappe** comprises only post-Hercynian formations and therefore lacks Hercynian tectonic imprint. At the base of this unit there is a strongly tectonized zone of Permotriassic rocks and basal Bündner Schiefer (Schistes lustrés). In the southern part of the western Tauern window this tectonized zone comprises parts of ophiolites which are high-pressure metamorphosed (eclogites, blueschists; MILLER, 1974, MILLER et al., this vol.); this zone clearly attains the appearance of a tectonic mélange.

The formation of the mélange and the high-pressure metamorphism are related to the Cretaceous subduction process in the South Penninic basin resulting in the underthrusting of the Venediger nappe beneath the Glockner nappe. High-pressure metamorphics in the same position in the Western Alps yielded radiometric cooling ages crowding between 100 and 80 m.y. (early Upper Cretaceous). Recently, glaucophane from the southern Venediger mountains gave a K/Ar age of about 70 m.y. (ACKERMAND et al., 1978). It can be deduced that the Glockner nappe, like the Venediger nappe, received its dominant structural imprint during the old-Alpidic orogenic period.

The internal tectonics of the Glockner nappe is very difficult to unravel, and detailed mapping and subdivision of the Bündner Schiefer and Tauernflysch formation are still at the beginning (see FRISCH, this vol.). In the western Tauern window there is a horizon with Triassic rocks dividing the unit into two parts (l. c.). It is as well possible that there are several such horizons in different niveaus being discontinuous and relieving each other. Such a tectonic style resembles that in accreting wedges above subduction zones which may well turn out to be true for the Bündner Schiefer and Tauernflysch formation of the Glockner nappe.

Because the nappe-forming processes in the Tauern window were completed in the Upper Cretaceous by subduction and collision, Lower Tertiary regional metamorphism affected both Venediger and Glockner nappe as one unit. During this meso-Alpidic (TRÜMPY, 1973) orogenic period the process of arching or updoming of the Tauern cupola as a whole was initiated by continuous compression. The arching is responsible for the formation of south-vergent folds which prevail on a micro- to mesoscopic scale on the northern flanks of the cupola. This kind of minor folding to the Tauern cupola is again found on the southern flanks with opposite polarity; there, however, external rotation is responsible for steepening and even overturning of the axial planes. The axial planes of the south-vergent folds, on the other hand, dip gently to the north or are nearly horizontal; this gives evidence of that the arching of the Tauern cupola was carried out under south-vergent stress.

The arching of the Tauern units is also responsible for the overturning of old-Alpidic recumbent fold structures on the northern flanks of the cupola, thus making diving structures (Tauchdecken; see above) out of them.

Besides the well-known north-south striking B axes in the central Tauern window, there are also about meridional folds in the Bündner Schiefer and Tauernflysch formation in its westernmost part. They are strongly overprinted by south-vergent folding and therefore clearly older.

Lower Tertiary, meso-Alpidic orogeny was responsible for the Venediger unit becoming an allochthonous feature by subduction of the North Penninic ocean and underthrusting of the foreland beneath the Middle Penninic – Austroalpine block already welded together (FRISCH, 1976, 1978). The importance of the Upper Tertiary neo-Alpidic orogeny for the units of the Tauern window is still not well known. In any case, the raising process of the Hohe Tauern is to be seen in connection with this orogenic period, and possibly a thermal event is related to the underthrusting of the foreland.

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