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The pre-Alpine basement of the Tauern window area in the Alps: Link between extra- and intra-Alpine Variscides

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Abstract: Both in the extra-Alpine and intra-Alpine Variscides, nearly all tectonic units of the European Variscides represent continental units and all units are derived from Gondwana, exhibiting a broad Late Archean to Neoproterozoic U–Pb zircon memory and a lack of a detrital zircons with ages between 1.6 and 1.1 Ga. Ophiolites are scarce and magmatic arcs are subordinate and poorly characterized in both extra-Alpine and intra-Alpine Variscides. An apparent exception is the so-called Subpenninic basement exposed within the Tauern window of the Eastern Alps, where an ophiolite is well exposed in the Stubach Complex, and Neoproterozoic to Cambrian volcanic island arc rocks occur in the largely low-grade Habach Complex and in the high-grade metamorphic Storz Complex. Furthermore, poorly dated micaschists and migmatitic paragneiss ("Altkristallin") complete the basement lithologies, which also bear pre-Alpine eclogite lenses implying a subducted complex. After our knowledge, the Habach Complex is one of few island arc successions ever postulated in the Variscides, except, e.g., some recently identified arc successions in the Austroalpine and Southalpine units. The Habach and Storz complexes are intruded by Variscan granitoids, the so-called Central Gneisses, and these granitoids are considered to represent remolten arc rocks. The present model is that the Stubach and Habach complexes represent juvenile arc rocks formed between late Ediacaran and Cambrian times, and were located paleogeographically between the Moldanubian zone, which is part of the European Variscides, and the internal Austroalpine zone, which extends from the Eastern Alps via the Carpathians towards Turkey. Previous models discussed the juvenile nature of the Tauern basement, which sharply contrasts to adjacent Moldanubian and Austroalpine zones with their rich Gondwana-derived long history. With this review, we challenge this hypothesis although significantly more data are needed to constrain the age range of the arc complexes, as well as Hf isotopic data to constrain the juvenile character and sources of the arc complexes and Central Gneisses.

Keywords: Variscan orogeny, ophiolite, magmatic arc, paleogeography, accretionary orogeny

Introduction

The Variscan orogen is a double-vergent orogen, formed by oblique dextral convergence of Gondwana and Laurussia. It shows a wide range of tectonic units with distinct metamorphic overprint, extensive granitoid intrusions, preservation of rare ophiolitic sutures and high-pressure rocks (Franke et al. 2017; Schulmann et al. 2022, 2025). The extra-Alpine Variscides include external fold-and-thrust belts derived from Gondwana and Laurussia/Baltica passive margins and internal units which reached granulite facies and which are intruded by voluminous granitoids in the Moldanubian zone (Franke et al. 2017, 2021; Moyen et al. 2025). On the other hand, subduction-related magmatic arc successions are rare. The Variscan basement is also preserved in the Alps. Significant differences exist between the Europe-derived Helvetic and Penninic units and the Austroalpine and Southalpine basement, which are separated from the former by the Cenozoic Alpine Tethys (Piemontais–Ligurian) suture (Figs. 1, 2a) (Schmid et al. 2004). Because of the presence of abundant Variscan granitoids, the Subpenninic basement in the Tauern window of the Eastern Alps (Schmid et al. 2013) shows similarities to the Moldanubian zone, e.g., exposed in the Bohemian massif, although many other features are different, e.g., no granulites occur in the Variscan basement of Alps. The Subpenninic basement in the Tauern window shares abundant Variscan granitoids with the Penninic and Helvetic basement in the Central and Western Alps (von Raumer et al. 2013; Faure & Ferrière 2022). In the past, the Subpenninic Tauern basement was considered as a juvenile arc, later intruded by Variscan granitoids, which are in part explained to represent the melting products of the arc system, similar to Archean greenstone belts, which are intruded by late-stage K-granites (Frisch et al. 1993). This review aims to show the nature of various units of the Subpenninic basement of the Tauern window, to develop an updated geodynamic model for the Tauern basement and to put these into a regional paleogeographic framework within the Central European Variscides. Other important constraints like the presence of Early Devonian eclogites (von Quadt et al. 1997) associated with mélange-type meta-sedimentary and meta-magmatic lithologies (Miller et al. 2007) were never

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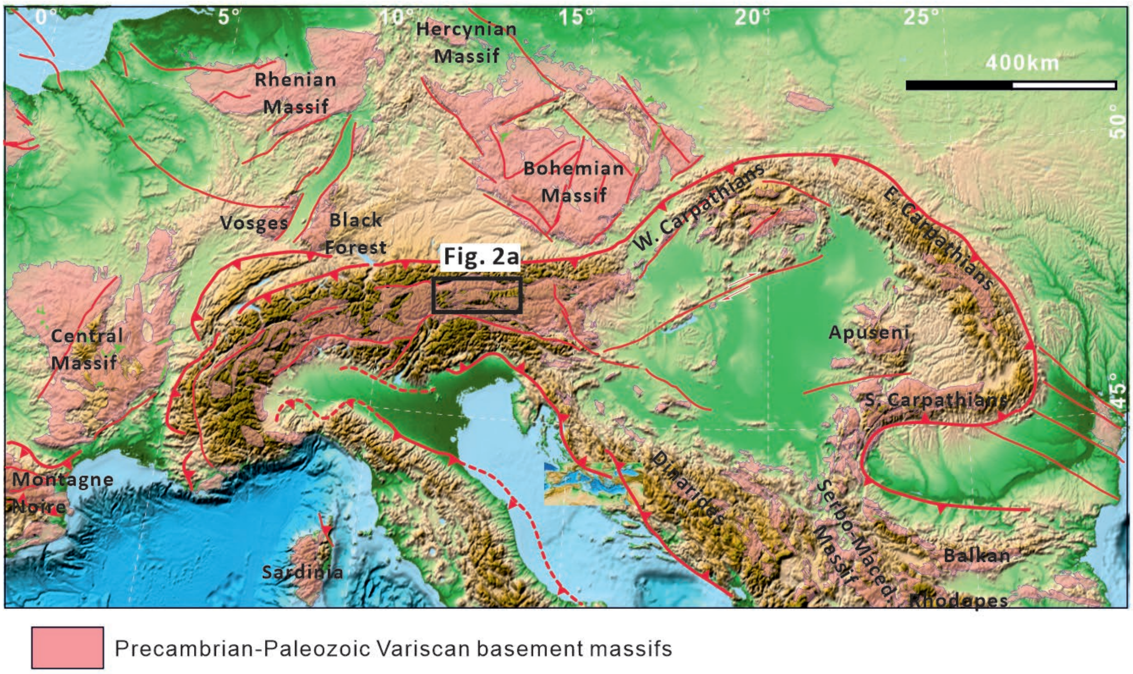

Fig. 1. The Tauern basement in the European Variscides.

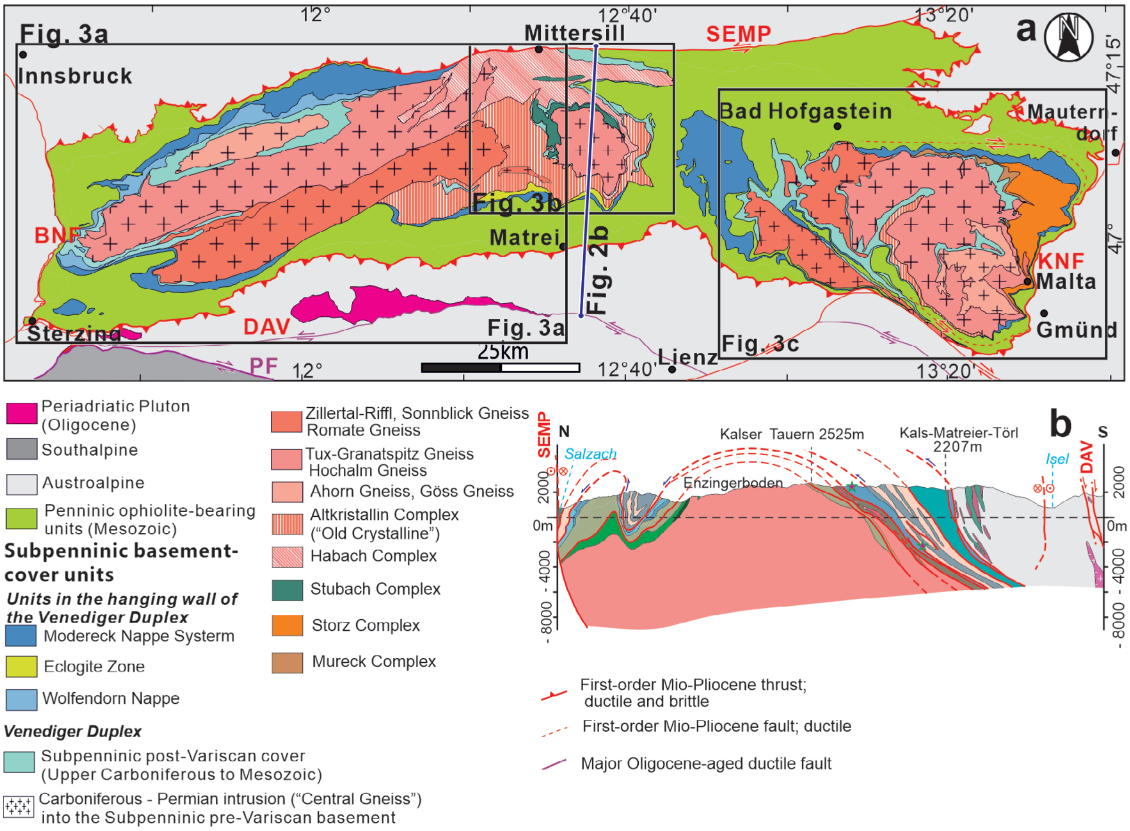

Fig. 2. **(a)** Simplified geological map of basement units exposed in the Tauern window (base map after Schmid et al. 2013). **(b)** N–S cross-section across the central Tauern window showing the main tectonic units (modified after Ordosch et al. 2019). Abbreviations: BNF – Brenner normal fault; DAV – Defreggen–Antholz–Valles fault; KNF – Katschberg normal fault; PF – Periadriatic fault; SEMP – Salzach–Enns–Mariazell–Puchberg fault.

considered in any tectonic model. We show that the Subpenninic Tauern basement comprises an arc system, which developed during Ediacaran to Cambrian times. Parts of it were subducted and affected by high-pressure metamorphism (Miller et al. 2007) in Silurian to Early Devonian times (von Quadt et al. 1997), and the arc system underwent melting during the Variscan orogeny when it was attached to extra-Alpine Variscides by underplating through Ediacaran to Cambrian aged crust, tentatively assumed to be represented by the Austroalpine mega-unit.

Characterization of Tauern basement units

The Tauern window was metamorphosed during Cenozoic times (Hoinkes et al. 1999 and references therein; Rosenberg et al. 2018). Metamorphism reached amphibolite facies in the central part, where most basement units are exposed, and upper greenschist facies conditions along the periphery. The overall structure of the Tauern window includes a series of elongated domes, with the Variscan Central Gneiss in the center (Fig. 2a, b), which intruded into pre-Carboniferous, Ediacaran to Cambrian, basement units. The intrusions and their host rocks form together the Subpenninic basement. The pre-Central-Gneiss basement is generally closer to the periphery, especially in the central northern part (Fig. 2a, b). The basement units are overlain by their Upper Carboniferous to Mesozoic cover forming together the Venediger Duplex, and by basement-cover nappes (e.g., the Modereck nappe), and are structurally overthrusted by the Glockner nappe system, which comprises Jurassic to Cretaceous ophiolites (Fig. 2a, b).

In the following, the main basement units are shortly described mainly in a N–S section along the Felbertal transect, the main road connection across the otherwise difficult to access Hohe Tauern, where the diversity of basement units is highest (Fig. 2a, b). The basement units along this section include a succession of basement and basement-cover nappes (e.g., Modereck, Wolfendorn nappes), previously also called Lower Schieferhülle (meaning “Lower Schist Mantle”), which mantel the voluminous Variscan Central Gneiss domes along the central, ca. E–W trending axis of the Tauern window (Venediger Duplex). The basement-cover nappes (e.g., Modereck, Wolfendorn nappes) are structurally overlain by the Jurassic–Cretaceous Penninic ophiolites of the Alpine Tethys (Glockner Nappe) and associated metasediments (Schmid et al. 2013), previously also called Upper Schieferhülle. In the south, along the boundary between the Modereck Nappe and the Glockner Nappe, the Eclogite zone is exposed with Eocene to Oligocene eclogites (Nagel et al. 2013). Both the Subpenninic units and the ophiolite-bearing Glockner Nappe are overprinted by the Cenozoic regional metamorphism (Tauern crystallization).

Available protolith ages (mostly U–Pb zircon) from basement units within the Tauern window are compiled in Table 1 and available U–Pb zircon ages of Central Gneiss from the western, central and eastern Tauern window are shown in Fig. 3a, b, c.

Stubach Complex

The Basal Amphibolite (“Basisamphibolit”) unit is also called Stubach Complex and comprises banded amphibolites, meta-gabbros, and some ultramafic rocks (Petrakakis 1977, 1978; Neubauer et al. 1989; von Quadt 1992). The protolith age is debated. Conventional U–Pb zircon ages of 657+14/−15 Ma and a Sm–Nd age of 664±12 Ma were reported for a banded amphibolite (von Quadt 1985, 1992); a metagabbro yielded a U–Pb zircon age of 539+10/−9 Ma (von Quadt 1992), which roughly coincides with the SHRIMP U–Pb zircon age of 551±9 Ma reported for a hornblende–plagioclase gneiss (Eichhorn et al. 2001). Loth et al. (1997) reported ages of 486±5 and 535±12 Ma for a banded amphibolite. In contrast, Kebede et al. (2005) published much younger in situ U–Pb zircon ages of 351–343 Ma for the Basal Amphibolite and therefore grouped it contemporaneous with the Variscan Central Gneisses. A closer look at the few reported cathodoluminescence images of zircons reveals that the dated zircons exhibit a smooth and homogeneous pattern, and these zircons could potentially reflect a high-grade thermal overprint and represent not necessarily protolith ages. However, this interpretation needs further constraints by future studies. In terms of geochemistry, the amphibolites show (enriched) MORB-like geochemical signatures typical of back-arc magmas (Frisch & Raab 1987; Vavra & Frisch 1989; von Quadt 1992; Höck 1993; Ordosch et al. 2019).

The overlying metavolcanic-sedimentary sequence is referred to as the Basal Schist (Basisschiefer; synonymous with the Eiser Complex; Pestal et al. 2009). It was considered to form the basal unit of the Habach Complex (Höck 1993) and includes metasedimentary rocks: micaschist, paragneiss, graphitic quartzite, and metaconglomerate (Frasl 1958; Fuchs 1958; Pestal et al. 2009). Detrital zircons from the Basal Schist yielded a U–Pb age of 362±6 Ma of the dominant population beside few older grains (Kebede et al. 2005), and the Basal Schist is, therefore, been interpreted as a Lower Carboniferous metamorphosed flysch sequence (Draxel Complex; Pestal et al. 2009; Schuster et al. 2006). Again, the exclusively young zircons are close to metamorphic ages elsewhere (see below). Consequently, further investigations of all lithological types of the Habach Complex and Basal Schists are needed for clarification.

Habach Complex

The Habach Complex itself represents the largest exposure of pre-Mesozoic volcano-sedimentary basement rocks in the central Tauern Window (Frasl 1958; Höll 1975; Höck 1993). In the southern area, it is in tectonic contact with the underlying Basal Amphibolite. Further to the north (e.g., around the Felbertal scheelite mine), its base is formed by the Basal Schist with its biotite schists. There, the contact was interpreted

Table 1: U–Pb zircon geochronology of the Subpenninic basement in the Tauern window. Abbreviations: ICP-MS – inductively coupled plasma mass spectrometry, ID-TIMS – isotope dilution thermal ionization mass spectrometry, LA – laser ablation, SHRIMP: sensitive high-resolution ion micro-probe.

Name, unit	Method	Crystallization age ± error (Ma)	Reference
Western Tauern window			
Zillertal granodiorite, ultramafic cumulate	SHRIMP	(309±5) 298±7	Cesare et al. 2002
Zillertal granodiorite	SHRIMP	295±3	Cesare et al. 2002
Ahorn durbachitic gneiss	LA ICP-MS	347±3	Veselá et al. 2011
Ahorn gneiss (biotite porphyric augen gneiss)	LA ICP-MS	347.4±1.6	Veselá et al. 2011
Ahorn gneiss (biotite porphyric augen gneiss): “granulitic” zircons	LA ICP-MS	349.5±2.2	Veselá et al. 2011
Ahorn gneiss (biotite porphyric augen gneiss)	LA ICP-MS	335.4±1.5	Veselá et al. 2011
Tux augengneiss	U–Pb ion probe	306.8±3.8	Langthaler et al. 2004
Tux leucocratic orthogneiss	U–Pb ion probe	305.0±6.6	Langthaler et al. 2004
Tux Core, Alpeiner Scharte molybdenite vein	Re–Os molybdenite	306.8±3.1	Langthaler et al. 2004
Tux granodiorite gneiss	LA ICP-MS	292±2	Veselá et al. 2011
Tux gneiss (augen flaser gneiss)	LA ICP-MS	292.1±1.9	Veselá et al. 2011
Tux gneiss (augen flaser gneiss): inherited cores of zircons	LA ICP-MS	556	Veselá et al. 2011
Tux gneiss (augen flaser gneiss): magmatic cores	LA ICP-MS	314±10	Veselá et al. 2011
Grierkar meta-rhyodacite, magmatic cores	LA ICP-MS	320.9±2.9	Veselá et al. 2011
Grierkar meta-rhyodacite	LA ICP-MS	309.8±1.5	Veselá et al. 2011
Pfitscher Joch meta-rhyolite	LA ICP-MS	280.5±2.6	Veselá et al. 2011
Pfitscher Joch meta-rhyolite, initial magmatic zircons	LA ICP-MS	303.1±2.9	Veselá et al. 2011
Pfitscher Joch meta-rhyolite, second stage magmatic zircons	LA ICP-MS	286.7±2.9	Veselá et al. 2011
Tux mylonitic orthogneiss	LA ICP-MS	267±2	Veselá et al. 2011
Meta-rhyolite, Mörchenscharte	LA ICP-MS	293±1.9	Veselá et al. 2008
Tux Alps, rhyolitic to andesitic metavolcanic rocks, Porphyrmaterialschiefer	LA ICP-MS	284±2 /–3	Söllner (pers. comm.) in Veselá & Lammerer 2008
Rauher Kopf, meta-gabbro	LA ICP-MS	605±9.2	Veselá et al. 2008
Rauher Kopf, meta-gabbro	LA ICP-MS	534±9.4	Veselá et al. 2008
Mayrhofen rhyolitic and andesitic metavolcanics	multi-grain ID-TIMS	284±2/-3	Söllner et al. 1991
Meta-rhyolite, Venntal	LA ICP-MS	304±3	Veselá et al. 2011
Meta-andesite Schönach valley, inherited grains	LA ICP-MS	565±14	Veselá et al. 2011
Meta-andesite Schönach valley, inherited grains	LA ICP-MS	325.8±6.8	Veselá et al. 2011
Meta-andesite Schönach valley, older magmatic stage	LA ICP-MS	301.8±4.7	Veselá et al. 2011
Meta-andesite Schönach valley, younger magmatic stage	LA ICP-MS	279±4.8	Veselá et al. 2011
Central Tauern window			
Granatspitz metagranitoid	multi-grain ID-TIMS	333±28	von Quadt (unpubl.) in Finger et al. 1993
Granatspitz metagranitoid	multi-grain ID-TIMS	320–330	Cliff 1981
Granatspitz gneiss	SHRIMP	271±4	Eichhorn et al. 2000
Felbertauern augengneiss	SHRIMP	340±4	Eichhorn et al. 2000
Felbertauern augengneiss	SHRIMP	338.5±1.3	Kozlik et al. 2016b
Hochweissenfeld metagranite	multi-grain ID-TIMS	308±12	von Quadt (unpubl.) in Finger et al. 1993
Hochweißenfeld gneiss (in-situ anatectic granite)	SHRIMP	342±5	Eichhorn et al. 2000
Venediger tonalite gneiss	SHRIMP	296±4	Eichhorn et al. 2000
Falkenbachlappen rhyodacitic lava	SHRIMP	343±6	Eichhorn et al. 2000
Peitingalm gneiss (dacitic tuff)	SHRIMP	300±5	Eichhorn et al. 2000
Schönbachwald gneiss (rhyolitic tuff)	SHRIMP	279±7	Eichhorn et al. 2000
Heuschartenkopf gneiss (rhyolitic tuff)	SHRIMP	299±4	Eichhorn et al. 2000
Metagabbro clast in Habach phyllite	SHRIMP	506±9	Kebede et al. 2005
Hornblende-plagioclase gneiss, Basisamphibolit	SHRIMP	551±9	Eichhorn et al. 2001
Coarse-grained amphibolite, Basisamphibolit	multi-grain ID-TIMS	539±10	von Quadt 1992
Stubach Group: hornblende–plagioclase gneiss	SHRIMP	548±10	Loth et al. 1997
Stubach Group: amphibolite	SHRIMP	535±12	Loth et al. 1997
Stubach Group: amphibolite	SHRIMP	486±5	Loth et al. 1997

Table 1 (continued)

Name, unit	Method	Crystallization age ± error (Ma)	Reference
Migmatitic leucosome, Serie der Alten Gneise	SHRIMP	530–507	Eichhorn et al. 2001
Gneiss clast of meta-breccia, Basisschieferfolge	SHRIMP	530–507	Eichhorn et al. 2001
Muscovite gneiss, Sturmmannseck	SHRIMP	530–507	Eichhorn et al. 2001
Eclogitic amphibolite, Altkristallin (Serie der Alten Gneise)	multi-grain ID-TIMS and ICP-MS	488±12	von Quadt et al. 1997
Garnet amphibolite, Zwölferzug	multi-grain ID-TIMS	486±5	von Quadt 1985, 1992
Porphyroid gneiss, Sturmmannseck	SHRIMP	279±4	Eichhorn et al. 2001
Metabreccia	SHRIMP	593±22	Eichhorn et al. 1995
Fine-grained amphibolite, Eruptivgesteinsfolge	SHRIMP	547±27	Eichhorn et al. 1999
Older K2 gneiss, Eruptivgesteinsfolge	SHRIMP	547–529	Eichhorn et al. 1999
EOZ gneiss, Eruptivgesteinsfolge	SHRIMP	529±17	Eichhorn et al. 1999
Younger K2 gneiss, Eruptivgesteinsfolge	SHRIMP	519±14	Eichhorn et al. 1999
Hornblendite, Eruptivgesteinsfolge	Multi-grain ID-TIMS	496±2	von Quadt 1985, 1992
Coarse-grained amphibolite, Eruptivgesteinsfolge	SHRIMP	482±5	Eichhorn et al. 2001
Felbertal leucogranite	single grain ID-TIMS	336±16	Eichhorn et al. 1995
Felbertal metalamprophyre	titanite single grain ID-TIMS	283±7	Eichhorn et al. 1995
Basisamphibolit	single grain ID-TIMS	351±2	Kebede et al. 2005
Basisamphibolit	single grain ID-TIMS	349±1	Kebede et al. 2005
Basisamphibolit	single grain ID-TIMS	343±1	Kebede et al. 2005
Biotitporphyroblastenschiefer	single grain ID-TIMS	362±6	Kebede et al. 2005
Biotitporphyroblastenschiefer	LA ICP-MS	368±17	Kebede et al. 2005
Zwölferkogel granodiorite gneiss	SHRIMP	371±4	Eichhorn et al. 2000
Zwölferhorn paragneiss	SHRIMP	345±5	Kebede et al. 2005
Zwölferhorn paragneiss	SHRIMP	358±10	Kebede et al. 2005
Felbertal granitoid intrusion	SHRIMP	336±16	Eichhorn et al. 1995
Eastern Tauern window			
Malta tonalite	multi-grain ID-TIMS	314±7	Cliff 1981
Hochalm metagranodiorite	multi-grain ID-TIMS	313±10	Cliff 1981
Hochalm porphyritic metagranite	multi-grain ID-TIMS	256+58/−34	Cliff 1981
Alkaline gneiss		339±5	Kloetzli in Lerchbaumer et al. 2010

controversially; either as unconformable sedimentary (e.g., Höck 1993) or tectonic contact, i.e., as a major Alpine thrust fault (Höll & Eichhorn 2000).

Mafic to felsic metavolcanics of the Habach Complex formed in a continental arc setting (Steyrer 1984; Steyrer & Höck 1985; Vavra & Frisch 1989; von Quadt 1992; Höck 1993; Höck et al. 1993; Schuster et al. 2006; Pestal et al. 2009). According to Ordosch et al. (2019), the polymetamorphic Habach Complex consists of various pre-Variscan meta-igneous rocks, clastic metasediments and intercalations of sheared Variscan meta-granitoids (Höck 1993; Eichhorn et al. 2001). Excluding the sheared meta-granitoids, the Habach Complex can be subdivided, from bottom to top, into the Lower Magmatic Series, Upper Magmatic Series and the Habach Phyllite in between (Fig. 3b) (Höll 1975; von Gilg et al. 1988; Kraiger 1988; Höck 1993; Höll & Eichhorn 2000; Eichhorn et al. 2001; Pestal et al. 2009).

The Lower Magmatic Series is interpreted to represent a dismembered meta-ophiolite and consists of amphibolites, metagabbros, meta-ultramafic rocks (hornblendite, serpentinite) (von Quadt 1992) and minor metasediments of Cambrian to Ordovician age. Felsic orthogneisses intercalated within this sequence were derived from Early Cambrian I-type granitoids (Eichhorn et al. 1995). Moreover, it hosts the world-class Felbertal tungsten deposit (Höll & Eichhorn 2000; Raith et al. 2003; Kozlik et al. 2016a, b). The deposit consists of a metamorphosed stockwork of deformed quartz–scheelite veins, mineralized shear zones with strongly foliated quartz–scheelite ores and disseminated scheelite mineralization in the host rocks (Raith & Schmidt 2010; Raith et al. 2018).

The Upper Magmatic Series is considered as an island (?) arc sequence including various metamorphosed mafic (meta-andesite) to felsic (dacite and rhyolite) calc-alkaline volcanic rocks (Vavra & Frisch 1989; Frisch et al. 1993; Höck 1993; Höck et al. 1993) grading into the Habach Phyllite. This part also includes a stratiform Ni–Cu mineralization (Haidbach district) (Melcher et al. 2021). Reitz & Höll (1988) and Reitz et al. (1989) found late Neoproterozoic acritarchs and algae filaments in the Habach Phyllite. A wide range of mafic, intermediate and felsic rock types and extrusional features occur within the Habach Phyllite succession, including well-preserved lava, lapilli tuff and ash tuff, too. U–Pb dating of a meta-agglomerate from the Habach Phyllite gave a near-concordant age of 506±9 indicating a Cambrian age of deposition of this part of the section (Kebede et al. 2005). On the other hand, zircon ages of 362±6 Ma and 368±17 Ma from a biotite

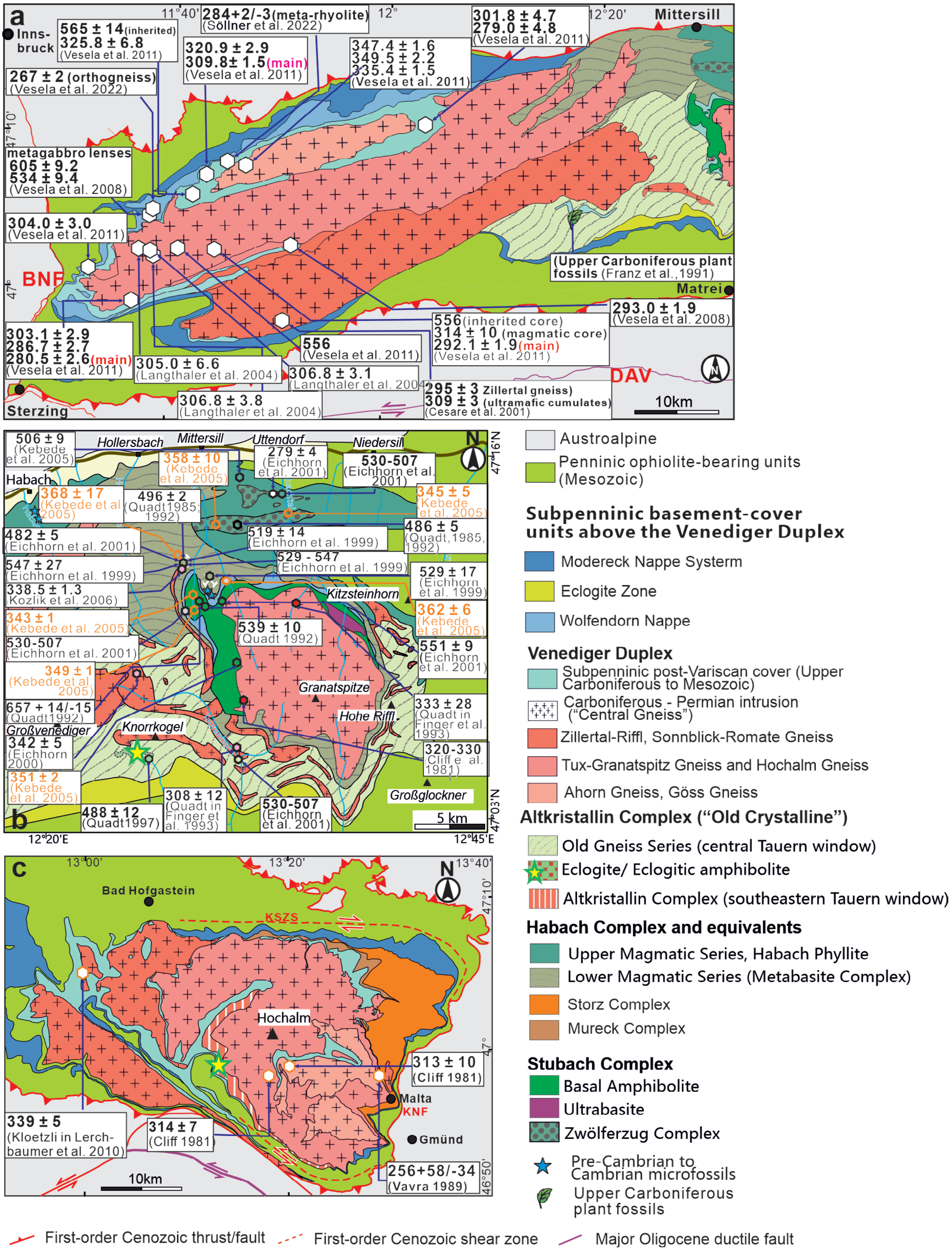

Fig. 3. Detailed geological maps of the basement units and U–Pb zircon geochronological ages (in Ma) in the Tauern basement. **(a)** Simplified geological map of the basement in the western Tauern window (after Veselá et al. 2011; Schmid et al. 2013). **(b)** Basement units in the central Tauern window (modified after Ordosch et al. 2019). **(c)** Basement units in the eastern Tauern window (after Schmid et al. 2013). For abbreviations, see captions of Figure 2. KSZS – Katschberg Shear Zone system.

porphyroblast schist are interpreted as detrital zircons indicating the maximum age of deposition during Late Devonian (Kebede et al. 2005; Pestal et al. 2009). A metagabbro clast in the Habach Phyllite succession yield a U–Pb zircon age of 506±9 Ma (Kebede et al. 2005).

Altkristallin (= Old Crystalline): paragneiss, micaschist, eclogite

The so-called Altkristallin Complex (= Old Crystalline) in the central and eastern Tauern basement is less well studied (Fig. 3b, c). Not much is known about the age of protoliths of metasedimentary rocks. It comprises paragneiss and micaschist which often contain migmatitic layers and aplites. In paragneiss samples, Siegesmund et al. (2023) found youngest zircon ages of 408 to 412 Ma, whereas the main detrital age populations include a dominant group at 490–420 Ma (Ordovician) and a subordinate one at 630–570 Ma (Ediacaran). The youngest arguable detrital age of 472–477 Ma shows a maximum Middle Ordovician age of sedimentation. Younger (Devonian) ages, 408–412 Ma, are explained as overgrowths by metamorphism. The $\varepsilon_{Hf(t)}$ values range between −28.0 and 9.0; the depleted mantle model ages are between 1.2 and 3.5 Ga with a peak at ca. 1.6 Ga. Lenses of fine-grained amphibolites also occur. Rare eclogites were found, too, for which von Quadt et al. (1997) reported an Early Devonian age (U–Pb zircon: 418±18 Ma; U–Pb zircon, laser ablation ICP-MS: 415±18 Ma; garnet-whole rock Sm–Nd age: 421±16 Ma) of eclogite metamorphism (von Quadt et al. 1997). Miller et al. (2007) described jadeite-gneisses which reached peak metamorphic conditions of 2.0–2.4 GPa and approximately 640 °C. These authors also found detrital/inherited ages of 466±2 Ma and 437±2 Ma. A further age population at 288±9 Ma may rather represent a significant metamorphic overprint. Highly discordant $^{206}Pb/^{238}U$ ages of zircon rims are in the range of 325–109 Ma indicating the pre-Alpine and/or Alpine, poorly defined age of the metamorphic overprint. Similar Early Paleozoic age populations as in the "Altkristallin" were found in a biotite-schist of the Storz Complex in the eastern Tauern window (see below).

Storz Complex

The Storz Complex is the polymetamorphic amphibolite-grade "Altkristallin" in the easternmost Tauern Window (Exner 1971, 1980) and is assigned there to the Mureck–Storz Nappe (Exner 1971; Schmid et al. 2013 and references therein). The Storz Complex includes orthogneisses, amphibolites, gabbroic amphibolites, hornblendites, anatectic plagioclase gneisses and rare metasedimentary rocks like garnet-micaschist and paragneiss (Exner 1971, 1980; Frisch et al. 1993; Schmid et al. 2013). Only multi-grain U–Pb zircon ages are available, and these are not fully conclusive. They include either Ediacaran or Late Cambrian age for metadacites (Vavra & Hansen 1991). According to Vavra & Frisch (1989) and Frisch et al. (1993), the Storz Complex is interpreted as an island arc complex. A metasedimentary biotite-schist of the eastern Tauern window includes age populations of 355 Ma, 371 Ma, 447 Ma, 497 Ma and 581 Ma, most of them considered as detrital zircons (Lerchbaumer et al. 2010).

In the Altkristallin of the southeastern Tauern window, which could be interpreted being part of the Storz Complex, Droop (1981) described a pre-Alpine eclogite within a major amphibolite body, which locally includes metagabbro, and found peak P–T conditions of 620 °C and >1.2 GPa.

Central Gneiss

Over the entire Tauern Window, several Variscan granite gneiss bodies are exposed in extensive domes called Central Gneiss domes (Fig. 2a, b). They all belong to the Subpenninic units of the Eastern Alps (Schmid et al. 2004, 2013). These domes include the Tux, Zillertal, and Venediger Central Gneiss cores in the western Tauern window, the Granatspitz Gneiss Core in the central Tauern Window, and the Göss, Hochalm and Sonnblick Gneiss cores in the eastern Tauern window (Figs. 2, 3). The dominant rock types are granite and granodiorite; tonalite and syenite also occur in the eastern Tauern window (Fig. 4) (Finger et al. 1993, 2007). Mafic rocks are very rare; associated ultramafic rocks, in part interpreted either as cumulates (Cesare et al. 2002) or dikes (Cornelius & Clar 1939), are described only from two places (Schätz & Neubauer et al. personal communication).

The Granatspitz Gneiss is a peraluminous S-type meta-granite forming a dome structure (Fig. 2) covering an area of ~100 km^2 (Kozlik et al. 2016b; Ordosch et al. 2019). The former intrusive contact with the overlying Basal Amphibolite unit is largely tectonically reworked (Frank 1969). Ages of 314±1 Ma (Kebede et al. 2005), 314±18 Ma (Kozlik et al. 2016a, b), and ages as young as 271±4 Ma (Eichhorn et al. 2000) have been reported for the Granatspitz Gneiss. In other Central Gneiss domes, ages range between 349 and 292 Ma (Table 1) showing the long-lasting granitic magmatism. Interestingly, multi-grain U–Pb zircon ages indicate even Triassic ages (Cliff 1981) and await improvement by more accurate methods. For subdivision of Central Gneiss protoliths and summarized Sr and Nd isotopic composition, we refer to Finger et al. (1993, 1997). The summarized Sr and Nd isotopic compositions indicate significant continental crust sources.

Over the entire Tauern Window, five age groups of Central Gneisses could be distinguished: (1) A Late Devonian age in the Zwölferkogel granodiorite gneiss (371±4 Ma) (Eichhorn et al. 2000), (2) a dominant 350–325 Ma age group, which also includes in situ anatectic granites, (3) a subordinate age group of 314–305 Ma, which also includes rare ultramafic cumulates (Cesare et al. 2002), contemporaneous with rare metavolcanics, e.g., meta-rhyolite (Veselá et al. 2011), (5) a group at 295–292 Ma coinciding in age with some meta-tuff layers in cover sequences (Eichhorn et al. 2000; Veselá et al. 2011), and (6) a subordinate group at ca. 271 Ma, which is related to Permian felsic tuffs in the western and central Tauern window (Eichhorn et al. 2000; Veselá et al. 2011). In some areas like in

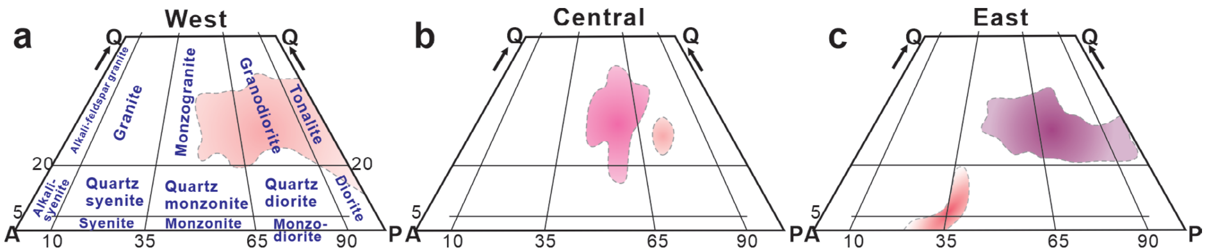

Fig. 4. Petrographic composition of Central Gneisses in western **(a)**, central **(b)**, and eastern Tauern window **(c)** in the Streckeisen diagrams; simplified after Finger et al. (1993). A – alkali-feldspar, P – plagioclase, Q – quartz. The dominant rock types are monzogranite and granodiorite of calc-alkaline series. Alkaline granitoids occur in the southeastern Tauern window and include syenite and quartz-monzonite.

the eastern Tauern window, a detailed succession of granitoid intrusions was postulated (Holub & Marschallinger 1989), which awaits confirmation and refinement by U–Pb zircon geochronology. The major-element composition of the Central Gneisses is well investigated and shows the calc-alkaline character of most intrusions (Marschallinger & Holub 1990; Finger et al. 1993, 1997; Frisch et al. 1993; Höck 1993; Cesare et al. 2002). A few alkaline bodies also occur, e.g., the Romate Gneiss (monzonite, syenite) in the eastern Tauern window (Fig. 4c). For the formation of ultramafic cumulates cogenetic with the Zillertal granodiorite, P–T conditions of ca. 2 kbar and 1000–1050 °C were postulated (Cesare et al. 2002).

The Hf isotope composition was only determined for one sample from a mylonitic orthogneiss with a U–Pb zircon age of 267±2 Ma associated with the Tux core (Veselá et al. 2022). The $\varepsilon_{Hf(t)}$ values range between −29.4 and 2.8. Their depleted mantle model ages range from 1.0 to 3.4 Ga with a dominance of Mesoproterozoic model ages.

Carboniferous and Permian cover units

Upper Carboniferous meta-conglomerates and overlying Permian to Upper Triassic, Jurassic and Cretaceous clastic cover strata are important for this overview as detrital zircon U–Pb studies were undertaken in some sections (Veselá et al. 2011, 2022), which could give information on the hinterland with its local and/or more distant sources. The local intramontane basins formed in grabens between Central Gneiss plutons in a horst-and-graben structure (e.g., Veselá & Lammerer 2008; Veselá et al. 2011) during latest Carboniferous/Permian times, as plant fossils testify (Franz et al. 1991; Pestal et al. 1999). Lithostratigraphic sections were compiled by Schmid et al. (2013). Carboniferous meta-conglomerates were deposited in local, closed basins now exposed between Central Gneiss domes and are affected by "the presence of hydrothermal tourmalinite veins documents a hydrothermal event after deposition" (Franz et al. 2021) in nearby Central Gneisses. Such hydrothermal events were dated ~260 Ma and ~210 Ma (Waitzinger & Finger 2018). Some clastic layers of Permian age above the western and central Tauern basement contain felsic volcanics (Eichhorn et al. 2000; Veselá & Lammerer 2008; Veselá et al. 2011, 2022). Lower Triassic quartzites occur elsewhere above the basement. Several intercalated rhyolitic and rhyodacitic tuffs and lavas yielded ages ranging from 304 to 271 Ma (latest Carboniferous to Middle Permian) (Eichhorn et al. 2000; Veselá et al. 2011). Fossil-bearing Middle Triassic dolomite, Upper Triassic gypsum-bearing clastics and Middle–Upper Jurassic marbles are comprised in the parautochthonous Subpenninic cover sequences. The Jurassic to Cretaceous clastic cover strata are assigned to the Kaserer Fm. in the western Tauern window and generally assigned to the Bündnerschiefer elsewhere. From these Permian to Cretaceous clastic layers detrital U–Pb zircon data were reported by Veselá et al. (2022). In these sequences, the youngest detrital grains range between 207±3 and 267±3 Ma, with a significant proportion of Triassic ages, of unclear origin. In addition, several age populations were found within the Permian to Jurassic sequences, a dominant one at 320–280 Ma (reflecting Central Gneisses), a subordinate one at ca. 460–440 Ma, a minor group at ca. 560–570 Ma, and a few Tonian (~900 Ma) ages. Interestingly, Triassic clastic sediments of the western Tauern window show similar Early Paleozoic to Ediacaran age populations (440–470 Ma, 580–630 Ma) (Veselá et al. 2022) as the biotite-paragneiss of the central Tauern window (Miller et al. 2007; Siegesmund et al. 2023) showing the long persistence of source regions or local recycling. The $\varepsilon_{Hf(t)}$ range between +7 and −27, showing the dominant recycled nature of zircons (Veselá et al. 2022).

Pre-Variscan and Variscan metamorphism

Pre-Alpine metamorphism of the Tauern basement was reviewed last time by Neubauer et al. (1999), and few further data were published since then. Local eclogites preserved within the Altkristallin basement of the southeastern (Droop 1981) and southern central Tauern window (Zimmermann & Franz 1989) predate Variscan migmatite-grade metamorphism which resulted in in situ-anatexis (at ca. 340 Ma). Eclogites of the southern central Tauern window were dated at 418±18 Ma, 415±18 Ma and 421±16 Ma (von Quadt et al. 1997). Droop (1981) and Zimmermann & Franz (1989) reported metamorphic conditions of 8 to 12 kbar (central TW) and >12 kbar (southeastern Tauern window) and 450–620 °C for these eclogites.

The highest-grade part of the Habach Complex reached Variscan metamorphic P–T conditions of ~0.8 GPa and

~650 °C constrained by a chemical monazite age of 363 ±11 Ma (Finger et al. 2016). These authors assume monazite growth in the presence of garnet because of the low Y content of monazite.

Variscan migmatization is closely related to the intrusion of precursor rocks of the present Central Gneiss. Locally, andalusite can be found (Grundmann 1989). The U–Pb zircon ages of 351–343 Ma for the Basal Amphibolite by Kebede et al. (2005) may record an early stage of high-grade migmatization. Scheelite in the Felbertal tungsten deposit recrystallized at 342–337 Ma during metamorphism and granite emplacement (Raith & Stein 2006). Metarodingite of the Stubach Complex contains mineral assemblages for which P–T conditions of ca. 420 °C and 2 kbar have been estimated (Koller & Richter 1984). In the southeastern regions Variscan garnet–staurolite–kyanite assemblages were reported by Droop (1981). As already mentioned, von Quadt (1992) reported U–Pb lower intercept zircon ages of 314+4/−3 Ma and 301±3 Ma for Variscan metamorphism in the central Tauern window. A local Permian thermal overprint has recently been confirmed by a U–Pb titanite age of 282±2 Ma (Eichhorn et al. 1995; for previous literature, see Frank et al. 1987). In summary, pre-Alpine metamorphism within the Tauern window appears to have been polyphase: (1) high-pressure metamorphism at the Silurian/Devonian boundary, (2) Variscan metamorphism, related to Variscan granite intrusions (ca. 330–300 Ma), and (3) Permian thermal overprint, probably localized along distinct shear zones.

Discussion

In the following, we discuss the nature, age, and geodynamic significance of the main Subpenninic basement complexes, and develop a three-stage tectonic model for the geodynamic evolution of the Subpenninic basement in the Tauern window. Finally, we discuss the potential location of the Tauern basement within the Variscan framework of Central Europe.

The Stubach Complex: an ophiolite

From magmatic members of the ophiolitic Stubach Complex, U–Pb zircon ages range between 551 and 507 Ma (late Ediacaran to Cambrian) (von Quadt 1985, 1992). It remains unclear which type of ophiolite it represents as modern studies are missing. The most likely explanation is a back-arc basin ophiolite (Vavra & Frisch 1989). It is structurally separated from the Habach and Storz complexes, representing an arc, by the biotite schists with its Late Devonian U–Pb zircon ages (e.g., Lerchbaumer et al. 2010).

Composition and age of the arc material

Nearly all metasedimentary and metavolcanic basement units including the Habach and Storz Complexes can be deduced from arc-related material. In the Lower Habach Complex, U–Pb zircon ages range from 582 to 547 Ma, in the Upper Habach Complex from 550 to 506 Ma (Ediacaran to ca. middle Cambrian). The Ediacaran age is largely in accordance with fossil data, although some fossils also argue for an older stage in the Ediacaran (Reitz & Höll 1988; Reitz et al. 1989). For the Storz Complex, the age is less clear. Vavra & Hansen (1991) argue, based on complex multi-grain zircon U–Pb data, for a Vendian (now Ediacaran) to Cambrian age for the Storz Complex. This age range is similar to both the Lower and Upper Habach Complexes in the Central Tauern window.

Altkristallin

At least, some major portions of the Altkristallin have to be separated from the Storz Complex, as the maximum sedimentation age is younger than the Habach Complex and magmatic protoliths are subordinate. Some portions of the Altkristallin in the south-central Tauern window must be younger than ~437 Ma (Silurian) (Miller et al. 2007) or even Early Devonian as Siegesmund et al. (2023) found a youngest detrital zircon ages of 408 to 412 Ma in biotite-paragneiss samples. The main age populations in this study include two populations, dominant at 490–420 Ma (Ordovician) and subordinate at 630–570 Ma (Ediacaran) (Siegesmund et al. 2023). The eclogites in the central southern Tauern window yield an age of high-pressure metamorphism in the earliest Devonian (~418 Ma; von Quadt et al. 1997) which is also supported, although poorly dated, by the HP metamorphism in the jadeite gneiss (Miller et al. 2007). In the overlying Eclogite Zone, some of the eclogites may represent originally Devonian eclogites overprinted by Alpine (Eocene to Oligocene) eclogite facies, as indicated by pre-Alpine garnet cores (Nagel et al. 2013). The eclogites in the southeastern Tauern window basement (Droop 1981) await geochronological dating. In summary, the Altkristallin shows a composition typical for an accretionary wedge with young detrital material (Siegesmund et al. 2023) and presence of eclogites (von Quadt et al. 1997). It could be correlated with the Cenerian accretionary orogeny (Zurbriggen 2015, 2017) previously known as the Caledonian event in Austroalpine basement units (Frisch et al. 1987).

Origin of Central Gneisses

The Central Gneisses show calc-alkaline characteristics with dominant granodiorite and granite, subordinate tonalite, and rare syenite and monzonite. Inherited zircons include Late Ediacaran ones (556 Ma) similar in age with zircons in the intruded basement complexes (Veselá et al. 2011). However, the Central Gneisses intruded into the Stubach, Habach and Storz complexes and can, therefore, not be the melting products of the arc complexes of the Tauern basement except for locations of in-situ anatexis (Eichhorn et al. 2000). We consider, therefore, that the Central Gneisses were derived from melting of an underplated crust during the Variscan orogeny. This contained Ediacaran crustal elements as the inherited zircons show. In late-stage Central Gneisses, melting may have been triggered by intrusion of overheated ultramafic magmas as suggested by few relics of ultramafic magmas in the Zillertal core (Cesare et al. 2002) and Granatspitz core (Schätz et al. personal communication).

The Central Gneisses are considered to have intruded during the main stage of the Variscan orogeny (340–320 Ma), preceding a phase of erosion and onset of deposition of the intramontane post-Variscan molasse-type clastics in the Late Carboniferous (Franz et al. 1991; Pestal et al. 1999; Veselá & Lammerer 2008; Veselá et al. 2011). Finger & Steyrer (1990) explained the formation of Central Gneiss protoliths as I-type arc magmatism related to the subduction of Paleotethys. However, the long duration of magmatism may indicate an early stage of subduction (Late Devonian granites) finally progressing into Variscan collision. Future detailed field-based geochemical and isotopic studies may resolve details of the Variscan subduction to collision to potential slab break-off processes as suggested for the earliest Permian Zillertal granodiorite and associated ultramafic cumulates (Cesare et al. 2002).

Geodynamic model of the Tauern basement

Based on the data discussed above, we develop a four-stage model for the geodynamic evolution of the Subpenninic basement in the Tauern window (Fig. 5). All data suggests that an arc system with the Habach and the correlative Storz complexes developed during late Ediacaran to Cambrian times (Fig. 5a). We suggest that the subducting ocean is the Prototethys Ocean (von Raumer et al. 2013; Neubauer et al. 2022).

During latest Silurian to earliest Devonian subduction of metasedimentary units like the Altkristallin protoliths, formation and subsequent exhumation of eclogites occurred. These are now exposed in the Altkristallin unit. Consequently, this metasedimentary Altkristallin unit could potentially represent a Silurian accretionary wedge (Fig. 5b) consistent with the dominant Ordovician–Silurian detrital zircons (Siegesmund et al. 2023). The late Ediacaran to Cambrian arc (Habach, Storz) was already extinct at this time (Silurian). This requires either another new ocean or, as an alternative explanation, the Habach and Storz arc complexes continue in age to Silurian, for which evidence is missing at the present stage of research. We tentatively assume the closure of a back-arc basin, potentially the one represented by the Stubach Complex (Fig. 5b). Another potential setting is continental collision and underplating of continental crust at the Silurian/Devonian boundary. In the next step, starting with the Late Devonian, thrust emplacement of the Stubach back-arc basin occurred as well as emplacement of the extinct late Ediacaran to Cambrian arc above the Late Devonian Basal Schists. Then underplating by another continental plate continued during continent collision (Fig. 5c). During this main stage of Central Gneiss intrusions, extensive Central Gneiss bodies were emplaced mainly during late Early Carboniferous and early Late Carboniferous in the 350–325 Ma-period, and few in the latest Carboniferous/earliest Permian (Table 1). The latter stage is associated with emplacement of ultramafic rocks too (Cesare et al. 2002) implying high heat flow as elsewhere in Alps (Marotta & Spalla 2007). The collision finally resulted in delamination of the lower plate mantle lithosphere and the rise of overheated mafic lithospheric melts, which triggered melting of the continental crust (Fig. 5d), in a stage of Central Gneiss intrusions, a model initially proposed by Cesare et al. (2002).

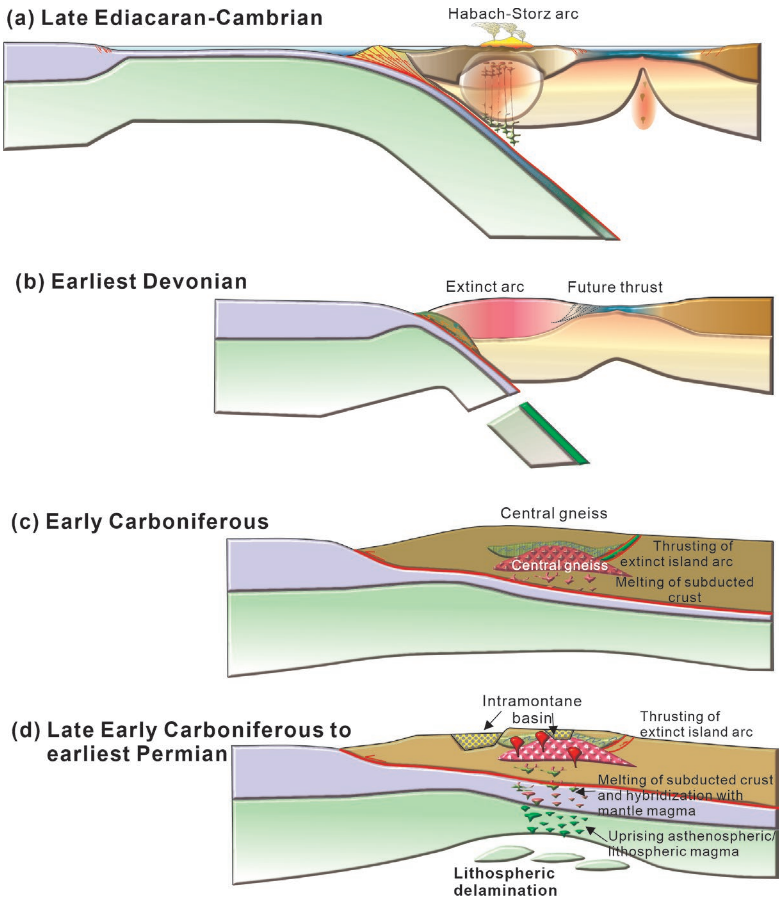

Fig. 5. Four-stage tectonic model for the geodynamic evolution of the Tauern basement. **(a)** Development of an arc system along margins of a major ocean (Prototethys). **(b)** Early Devonian subduction of metasedimentary units during subduction of oceanic lithosphere and formation and subsequent exhumation of eclogites. **(c)** Late Devonian continental underplating during final subduction and collision, which led to the intrusion of the Central Gneiss protoliths. **(d)** These processes were followed by latest Carboniferous to earliest Permian delamination of the lower plate mantle lithosphere and rise of overheated mafic lithospheric melts, which triggered melting of the doubled continental crust and magma hybridization.

Location of the Tauern basement within the European Variscides

To discuss these questions, we also use a compilation of basement ophiolites and oceanic ultramafic/mafic complexes (Fig. 6a) and dated basement eclogites (Fig. 6b) of the entire Alps and the extra-Alpine Variscides (Fig. 7). As already mentioned, the Subpenninic basement of the Tauern window is the extension of the Helvetic basement exposed in the External Massifs and of the Penninic basement exposed in the Western Alps. It is located between the Moldanubian zone of extra-Alpine Variscides and the combined Austroalpine/Southalpine unit (Fig. 7), and all authors agree on this location (e.g., von Raumer et al. 2013; Franke et al. 2021; Franke & Żelázniewicz 2023). Common features with the Moldanubian zone and the External Massifs are the voluminous Variscan, Early to Late Carboniferous granitoids, which are seemingly rare within the Austroalpine/Southalpine basement (but see below).

Models for the location of the Subpenninic basement units in the Tauern window are numerous and include the ones of Ratschbacher & Frisch (1993), von Raumer et al. (2013), Faure & Ferrière (2022), Finger & Riegler (2022), and Siegesmund et al. (2023). However, no model is considering the supposed partly juvenile character of the Tauern basement, which was originally postulated by Frisch et al. (1993) and for which Veselá et al. (2022) and Siegesmund et al. (2023) found some evidence through the mixed, relatively young juvenile

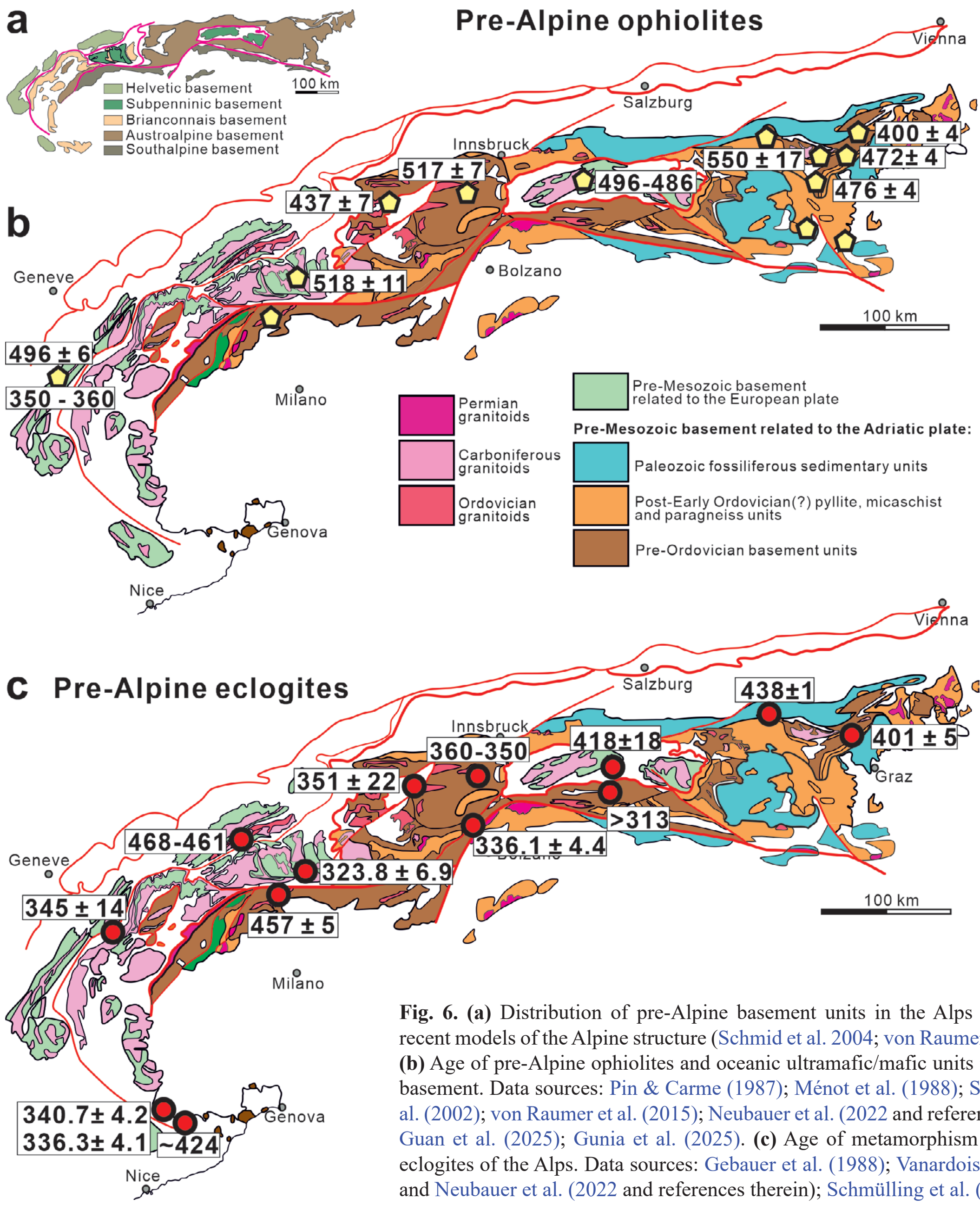

Fig. 6. (a) Distribution of pre-Alpine basement units in the Alps according to recent models of the Alpine structure (Schmid et al. 2004; von Raumer et al. 2013). **(b)** Age of pre-Alpine ophiolites and oceanic ultramafic/mafic units in the Alpine basement. Data sources: Pin & Carme (1987); Ménot et al. (1988); Schaltegger et al. (2002); von Raumer et al. (2015); Neubauer et al. (2022 and references therein); Guan et al. (2025); Gunia et al. (2025). **(c)** Age of metamorphism in basement eclogites of the Alps. Data sources: Gebauer et al. (1988); Vanardois et al. (2022) and Neubauer et al. (2022 and references therein); Schmülling et al. (2025).

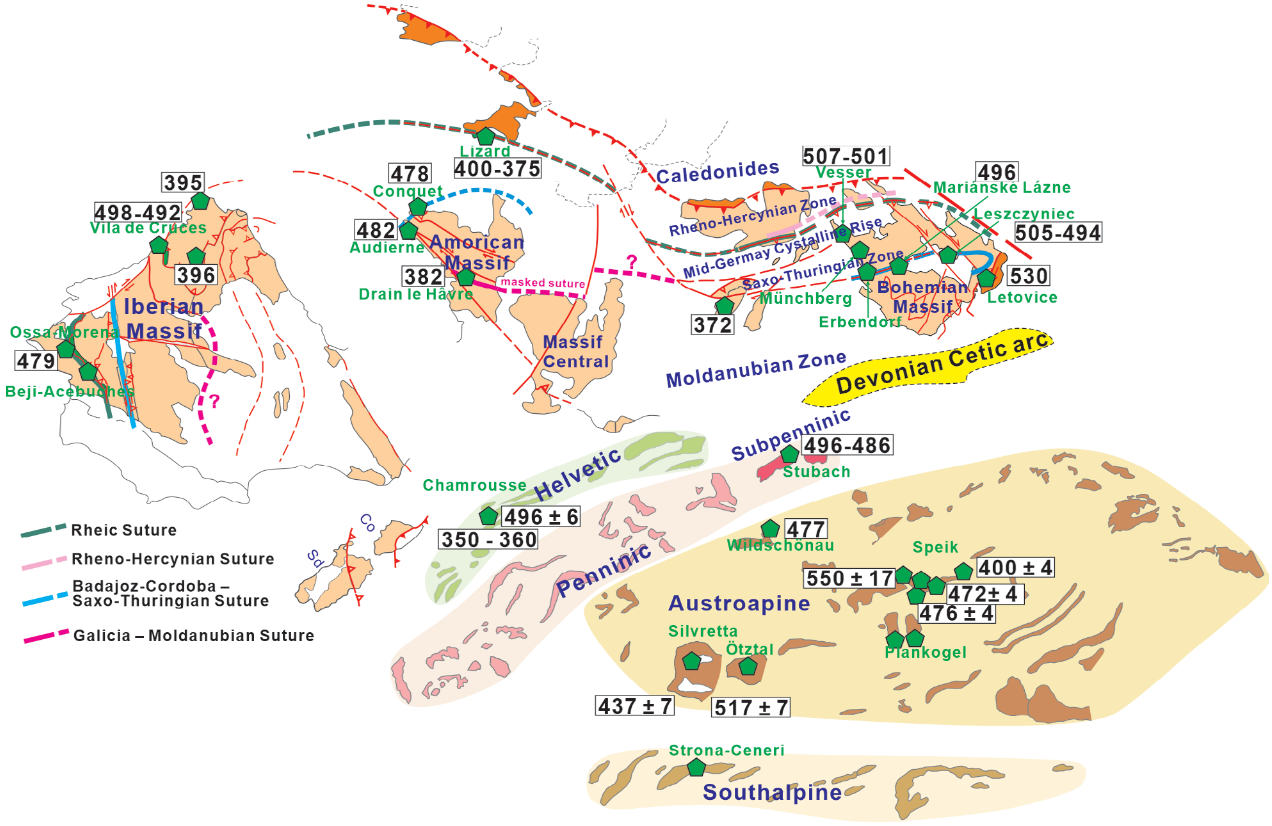

Fig. 7. Tentative location of the Subpenninic basement in the Tauern area within the Variscan Central European basement. Protolith ages of ophiolites are shown. Data of extra-Alpine Variscides are from Paquette et al. (2017) supplemented by recent findings reported in Gunia et al. (2025). Austroalpine data compiled from Neubauer et al. (2022) and Guan et al. (2025). Note the location of the Devonian Cetic arc between the Bohemian Massif in the north and the Subpenninic basement (location after Finger & Riegler 2022).

Hf isotopic characteristics mixed with old continent-derived isotope signatures. Frisch et al. (1993) explained the combination of ophiolite, island arc units and Variscan granitoids (Central Gneiss) by comparison with Archean greenstone belt terranes. The assessment of the potential juvenile character should be a core goal of future research as particularly island arc complexes are rare in the European Variscides. Late Ediacaran to Cambrian island arc successions occur in Austroalpine and Penninic units of the Alps (Maino et al. 2019; Neubauer et al. 2022 and references therein) and uppermost units in the Bohemian massif, i.e. the Ediacaran–Cambrian Barrandian unit in the Prague syncline (Žák et al. 2025). This does not exclude that more arc successions will the detected in the future within the Variscides.

To discuss these questions, we also use a compilation of basement ophiolites and oceanic ultramafic/mafic complexes in Alps (Fig. 6a) and dated basement eclogites of the entire Alps (Fig. 6b) and extra-Alpine Variscides (Fig. 7). The ophiolites known in the Austroalpine and Helvetic realms cover a similar age range as the Stubach Complex (Fig. 7) and cannot, after our opinion, be easily correlated with the extra-Alpine Rheic and Saxo-Thuringian sutures of distinct ages, which continue across the entire European Variscides. E.g., correlation with the Rheic suture would imply strike-slip duplication. On the other hand, new reports from the Alpine–Carpathian–Balkan area suggest that a Late Silurian to Carboniferous ophiolitic succession exits (Figs. 6a, 7), which could be tentatively correlated with the postulated Balkan–Carpathian Ocean in southeastern Europe (Putiš et al. 2009; Plissart et al. 2017; Neubauer et al. 2022 and references therein), which closed during the Variscan plate collision. How these ophiolites in the Alpine basement relate to the extra-Alpine Variscides (e.g., Regorda et al. 2020; Murphy et al. 2025; Schulmann et al. 2025) is an open question and matter of ongoing debate. Together with the arc successions and microcontinental fragments within the extra-Alpine Variscides (e.g., Finger & Riegler 2025), this implies to take into account further elements, e.g., continental promontories such as the Iberian arc and Paleo-Adria.

The earliest Devonian age of eclogite metamorphism in the Tauern Altkristallin is in line with the younger metamorphic amphibolite facies age of ca. 400 Ma from the Speik complex (Guan et al. 2025), which follows an eclogite age of ca. 438 Ma (Schmülling et al. 2025) Similar ages of eclogite metamorphism occur in the southernmost External Massifs (e.g., 424 Ma; Vanardois et al. 2022). Older ages were determined in the Swiss External Massifs and in the Southalpine unit, which are between 470 and 457 Ma (Gebauer et al. 1988;

Franz & Romer 2007). These eclogites may represent the same Silurian to earliest Devonian subduction zone.

Arc complexes in the Austroalpine unit of Eastern Alps were originally postulated by Frisch et al. (1987) both west and east of the Tauern window corresponding to what is now known as Silvretta–Gleinalpe Complex. They were dated in the Gleinalpe at 490 Ma (Guan et al. 2025), at ca. 470 Ma in Ötztal/Texel Complex (Klug et al. 2025) although older, Cambrian, sectors are also known (e.g., Neubauer et al. 2020; Huang et al. 2021).

The position of the Subpenninic basement of the Tauern window depends on the location of the Variscan Central Gneisses with respect to its potential correlation with the Helvetic and Penninic granite gneisses in the Western Alps, which were recently studied in detail (e.g., Ruiz et al. 2022; Fréville et al. 2024). The other potential correlation is with the Modanubian zone stretching from the southern Bohemian massif to the French Massif Central (Fig. 7) (Moyen et al. 2025). The Devonian Cetic ridge (or Cetic arc) separates the Moldanubian zone from the Subpenninic basement (Fig. 7) (Finger & Riegler 2022). However, the Cetic arc is potentially overrated in its distribution. On the other hand, more reports indicate that Variscan granitoids similar to the Central Gneiss protoliths occur in some Lower Austroalpine units, which were paleographically closest to the Subpenninic basement prior to the opening of the Piemontais–Ligurian ocean. These Variscan granitoids include those of the Err–Bernina basement (von Quadt et al. 1994), granitoids that intruded into the Schladming and Seckau Complex (Schermaier et al. 1997; Mandl et al. 2018, 2022; Huang et al. personal communication). Consequently, we tentatively argue for underplating by the Austroalpine unit during continent collision. Furthermore, similar Variscan granitoids of Carboniferous age occur in Western Carpathians, in the eastern extension of the Austroalpine units (for details, see Broska et al. 2013, 2022; Kohút & Larionov 2021).

The age populations of detrital zircons in the Altkristallin and the few reports of inherited zircons in Central Gneisses of the Subpenninic basement are similar as such reported in the Austroalpine units (Chang et al. 2021; Siegesmund et al. 2021, 2023).

Conclusions

Based on published data, the main conclusions of this review of the polymetamorphic basement in the Tauern window are:

- The Subpenninic basement in the Tauern window includes Ediacaran to Cambrian arc complexes variably metamorphosed during Variscan times.
- Eclogite formation indicates latest Silurian/earliest Devonian subduction.
- A four-stage model explains the tectonic evolution of the Subpenninc basement in the Tauern window: (i) formation of Ediacaran to Cambrian arc complexes and a back-arc ophiolite at the margin of the Prototethys Ocean, (ii) latest Silurian/earliest Devonian subduction of the Altkristallin, a tentative accretionary wedge, and (iii) formation of voluminous Variscan granites (now the Central Gneisses) due to underplating by continental crust and continent collision, and subsequent Early Carboniferous to earliest Permian slab delamination resulting in the final intrusion of Central Gneisses.
- Although abundant Variscan granites argue for correlation with Penninic and Helvetic basement units of the Central and Western Alps and the Moldanubian zone of extra-Alpine Variscides, inherited and detrital ages argue for a Variscan underplating of the Austroalpine mega-unit.

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