MITT. ÖSTERR. MINER. GES. 163 (2017)

WALKING ON JURASSIC OCEAN FLOOR AT THE IDALPE (ENGADIN WINDOW) NEAR ISCHGL/TYROL

Karl Krainer[1] & Peter Tropper[2]

[1]Institute of Geology, University of Innsbruck, Innrain 52f, A-6020 Innsbruck

[2]Institute of Mineralogy and Petrography, University of Innsbruck, Innrain 52f, A-6020 Innsbruck

Introduction

In the Lower Engadine Window rocks of the Penninic Unit are exposed which originally were formed in the Piemont-Ligurian Ocean, the Iberian-Brianconnais microcontinent and the Valais Ocean. The Penninic rocks of the Lower Engadine Window are overlain by Austrolpine nappes: the Silvretta Metamorphic Complex (Silvretta-Seckau Nappe System sensu SCHMID et al. 2004) in the north, the Stubai-Ötztal Metamorphic Complex (Ötztal-Bundschuh Nappe System sensu SCHMID et al. 2004) in the southeast and east, and the Engadine Dolomites.

The Penninic rocks of the Lower Engadine Window are characterized by a complex tectonic structure and can be divided into three nappe systems (SCHMID et al., 2004; GRUBER et al., 2010; see also TOLLMANN, 1977; OBERHAUSER, 1980):

- a.) Lower Penninic Nappes including rocks of the former Valais Ocean (Cretaceous – Paleogene)
- b.) Middle Penninic Nappes composed of rocks of the Iberia-Brianconnais microcontinent, and
- c.) Upper Penninic Nappe, composed of rocks oft he former Piemont-Ligurian Ocean.

Lower Penninic Nappes include the Zone of Pfunds and Zone of Roz – Champatsch – Pezid. The dominant rocks are different types of calcareous mica schists and „Bündnerschiefer“. Locally fragments of the oceanic crust and upper mantle (ophiolites) are intecalated.

The **Middle Penninic Nappes** include the Fimber-Zone and Zone of Prutz – Ramosch. The Zone of Prutz–Ramosch is compsed of Triassic carbonate rocks, Quartzite of Ladis, Alpine Verrucano and Paleozoic phyllites in its lowerer part. The upper part is a melange-zone which includes the Fimber Zone and which is composed of a matrix of upper Cretaceous to Paleogene metasediments (Höhere Flyschschiefer) with olistoliths and/or tectonic slices of Alpine Verrucano, Quartzite of Ladis, Triassic carbonate rocks, Steinsberger Kalk, Neokomschiefer and Tristel-Formation. The Fimber Zone consists mainly of upper Cretaceous to Paleogene metasediments and abundant tectonic slices and olistoliths. The stratigraphic succession oft he Fimber Zone includes granitic and metamorphic basement rocks, overlain by Triassic dolomites and limestones including the Upper Triassic Keuper beds (sandstones, quartzites, limestones, shales, gypsum). Keuper beds are overlain by Steinsberg limestone containing ammonites, brachiopods, bivalves, and microfossils indicating Liassic age. Above follow Posidonia shales and Idalp sandstone, overlain by limestone breccias and limestone of Malmian age, whcih are similar to the Aptychus Limestones. The Lower Cretaceous includes calcareous schists with intercalated microbreccias (Neocomian Flysch) and fine-grained limestone breccias (Tristel beds), overlain by sandstones and breccias of Albian age and Couches Rouges of the Late Cretaceous. The youngest rocks are shales, sandstone and breccias which are termed „Bunte Bündnerschiefer“ and dated as Late Cretaceous to Eocene (BERTLE, 2002, BOUSQUET et al., Oberhauser). Locally small olistoliths or tectonic slices of ophiolites are exposed in the Fimber Zone (GRUBER et al., 2010). The Fimber Zone is interpreted to represent the continental margin of the Brianconnias microcontinent or the marginal part of the Piemont-Ligurian ocean (OBERHAUSER, 2007; BERTLE, 2002).

The **Upper Penninic Nappes** include the Bürkelkopf- and Flimspitz slices and represent rocks of the Jurassic-Cretaceous oceanic crust and upper mantle (ophiolites) and overlying deep-sea sediments. These ophiolites (Idalp Ophiolith) are the best preserved ophiolites of the Eastern Alps and are composed of ultrabasic rocks, metagabbros, metamorphic pillow basalts and overlying deep-sea sediments (HÖCK & KOLLER, 1987, 1989; HÖCK et al., 1986, 2004; KOLLER & HÖCK, 1987, 1990; KOLLER et al., 1996). All rocks of the Lower Engadine Window were metamorphically overprinted during the Alpine metamorphic event.

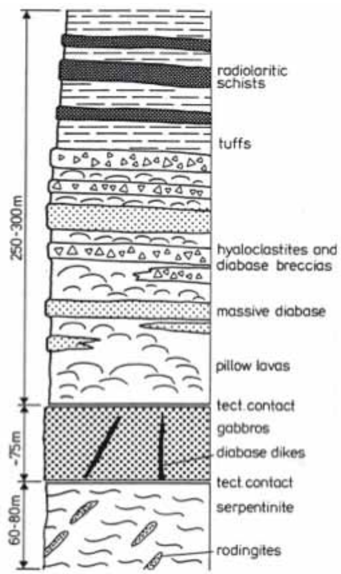

Figure 1: Interpretative litho-stratigraphy of the Idalp ophiolite (after HÖCK & KOLLER, 1987; HÖCK et al., 2004).

The **Idalp ophiolite** displays the uppermost unit of the Lower Engadin Window. The ophiolite body itself is subdivided into two independent units called Flimsspitze nappe (southern part) and Bürkelkopf nappe (northern part, DAURER, 1980). They are separated by a tectonic slice, consisting of diaphtoritic micaschists, gneisses, and amphibolites, known as the “Flimjoch wedge”, which originated from the neighouring Austroalpine Silvretta unit. The reconstructed stratigraphic columnar section of the Idalp ophiolite can be seen in Figure 1. The ophiolite sequence starts with serpentinites, which contain small inclusions of rodingites (former metasomatized metagabbros). The serpentinites are separated by a tectonic contact from the overlying gabbros, which are intruded by diabase dikes. The volcanic section has a tectonic contact at its base, and starts with pillow lavas intercalated with several layers of massive diabase, and with some hyaloclastites that increase in abundance towards the upper levels. At the stratigraphic top, tuffs with

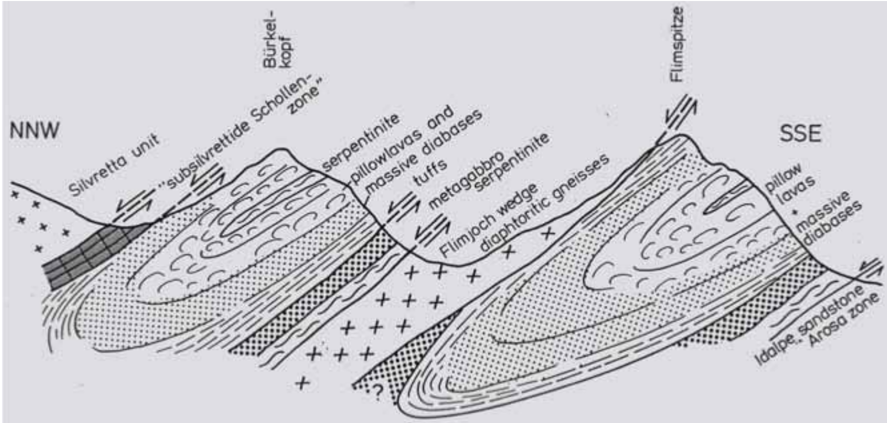

Figure 2: Geologic cross-section of the Silvretta Austroalpine and Idalp ophiolite units, between Flimspitze and Bürkelkopf, showing the two tectonic units of Flimspitze and Bürkelkopf nappes (after HÖCK & KOLLER, 1987; HÖCK et al., 2004).

radiolarian schists are deposited. The whole volcanic pile (including the sediments) has an approximate thickness of 250 to 300 meters.

The two tectonic subunits of the ophiolite complex consist of a serpentinite-gabbro association with a maximum thickness of 150 meters at its base and on top a large recumbent fold overturned towards the north, consisting of a small serpentinite + metagabbro body in the core, surrounded by massive lava-flows and pillows. The hyaloclastites, tuffs and radiolarites form the outermost part of the fold as shown in Figure 2.

According to HÖCK et al. (2004) and SCHUSTER et al. (2004) the metamorphic evolution of the ophiolites is twofold; an older HT oceanic metamorphic event can be separated from a younger HP imprint. Evidence for the former comes from the replacement of gabbroic clinopyroxenes by amphiboles (pargasite, magnesianhornblende to actinolite), which formed at relatively high temperatures. This, together with some metasomatic changes of the bulk geochemistry (mainly Na enrichment), and some local strong oxidation, argues for this hydrothermal event. The cores of these amphiboles in the altered gabbros, still contain high Cl contents of up to 4000 ppm. In the hyaloclastites and pillow breccias, the hydrothermal influx locally causes ~E-W striking epidote-rich veins, and high oxidation with an intense red color.

The Alpine metamorphic grade of the Idalp ophiolite sequence is at the transition between greenschist and blueschist facies with P-T conditions of ~300°C and 0.7-0.9 GPa (KOLLER, 1985; HÖCK et al., 2004). The mineral assemblages are defined by pumpellyite + chlorite + albite + epidote + actinolite + muscovite + titanite + hematite. Pumpellyite of the metagabbro is Mg-rich and pumpellyite compositions therefore plot into the blueschist-facies field in the Al-Fe-Mg ternary diagram after BARRIGA & FYFE (1983). Exact P-T conditions are hard to establish by using the mineral assemblages described above. Investigations of the Bündnerschiefer and associated metabasites of the Lower Engadin Window by BOUSQUET et al. (1998, 2002) reveal a clear HP-LT history with P-T estimates ranging between 1.1-1.3 GPa for a temperature around 350-375°C based on the occurrence of carpholite. Indication of the LT-HP metamorphic assemblages in the metabasites are rare. However, crossite and lawsonite occur in metabasites (LEIMSER & PURTSCHELLER, 1980), and Mg-pumpellyite in association with chlorite, albite, and phengite occurs in metapelites. The P-T conditions calculated by BOUSQUET et al. (1998) for the upper units of the Lower Engadin Window are ca. 0.6 GPa and 300°C. To provide additional P-T data pseudosection calculations were undertaken in the system KNCFMTiASH using the program THERIAK-DOMINO (DE CAPITANI & PETRAKAKIS, 2010) with an updated version of the internally consistent data set of HOLLAND & POWELL (1998, data set tcdb55). The pseudosection using the metagabbro bulk rock composition I48 from HÖCK & KOLLER (1987) yielded a maximal stability limit for assemblages containing pumpellyite without lawsonite and albite of 0.65 GPa at ca. 300°C, which correlates well with previous estimates (Fig. 3). If albite + pumpellyite coexist the maximal pressure is 0.5 GPa at 300°C. These calculations are only of semiquantitative nature since they also assume a rather complex mineral assemblage contining omphacite (Omph) + muscovite (Ms) + paragonite (Pg) + pumpellyite (Pump) + epidote (Ep) + titanite (Sph) ± albite, which has not been completely verified yet.

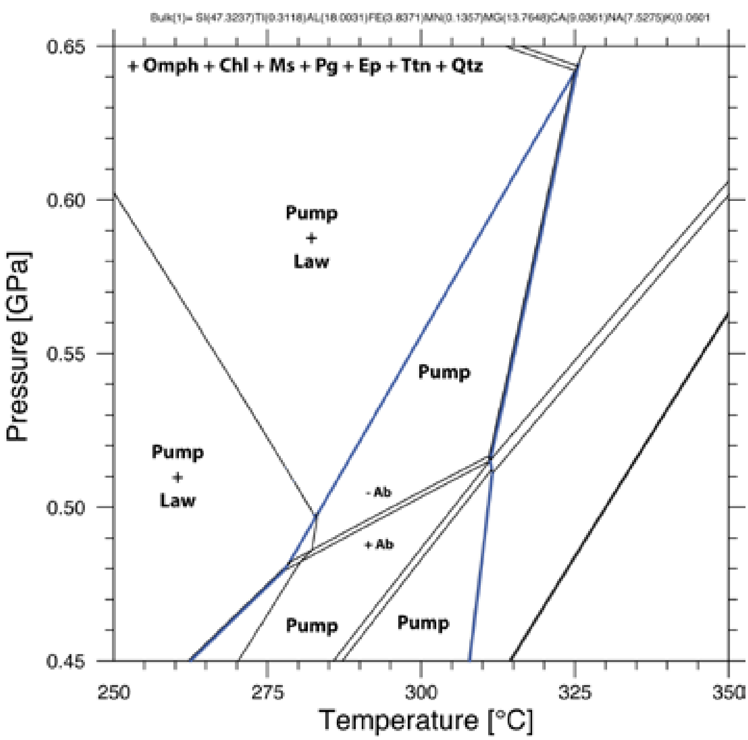

Figure 3: Pseudosection of metagabbro sample ID48 from HÖCK & KOLLER (1987). The blue line marks the stability field of pumpellyite without lawsonite. –Ab indicates that albite is unstable, +Ab: albite is stable.

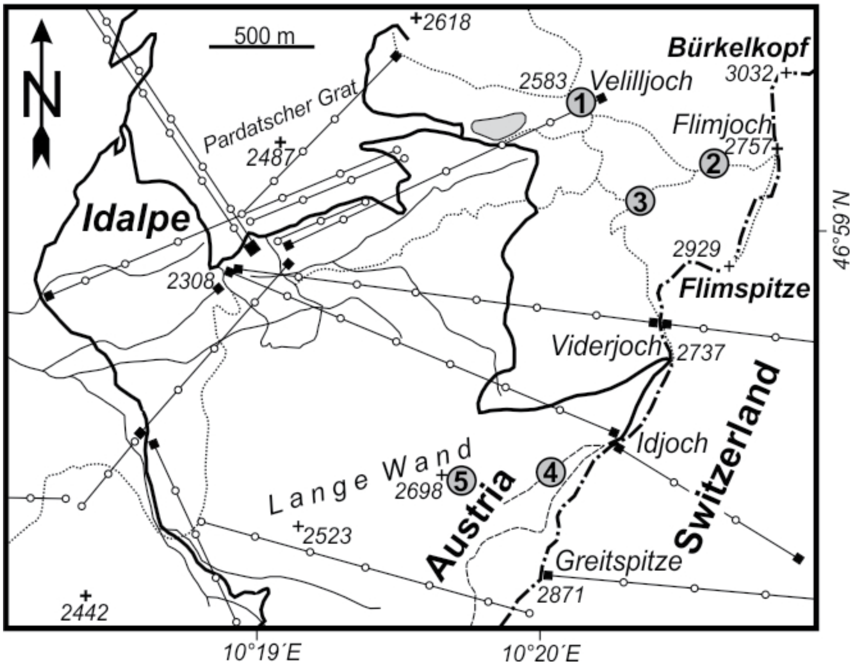

Figure 4: Map of Idalpe showing the excursion route and stops 1 – 5.

Aim of the excursion

The area around Idalpe south of Ischgl in the Samnaun Mountain Group (Tyrol) offers an excellent opportunity to study rocks of the Lower Engadine Window, particularly the remants of the oceanic crust and upper mantle („Idalpe Ophiolite“ of the Bürkelkopf-Flimspitz Unit) and sedimentary rocks, particularly Steinsberger Kalk (Lias) and Idalpsandsteinfolge (Dogger) of the Fimber Zone. The excursion will focus on the metagabbro, pillowbasalt and overlying deep-sea-sediments (radiolarite), exposed at Velliljoch and along the trail to Flimjoch and Viderjoch, on the Bündnerschiefer, exposed near Idjoch, the Steinsberger Kalk and Idalpsandstein, exposed at Lange Wand (Fig. 4).

Excursion route

The excursion route starts at Ischgl (1376 m), from where a cable car brings us to Idalpe (2308 m). From Idalpe the excursion route follows the road and trail towards the east to Velilljoch (2583 m) where Gabbro and deep-sea sediments (radiolarite) are well exposed (Stop 1). From Velilljoch the route follows the trail to Flimjoch (2757 m). Along the trail large blocks with well-preserved pillow basalts, derived from Bürkelkopf) are present (Stop 2). The route crosses a coarse-grained rock glacier on which also blocks of pillow basalt are visible, derived from Flimspitze (Stop 3). The route follows the trail to Viderjoch (2737 m) and Idjoch at the Austrian-Swiss border. Bündnerschiefer are well-exposed along a ski trail west of Idjoch (Stop 4). At Lange Wand (2698 m) the upper part of Steinsberger Kalk and overlying Idalpsandstein are well exposed (Stop 5).

Description of Stops

Stop 1 Metagabbro – Deep-sea sediments, Velilljoch

The gabbros occur greenish to grey in colour are coarse-grained and magmatic clinopyroxenes are still visible on the surface (Fig. 5a). The former plagioclase domains show white- to greenish colours while the clinopyroexen domains are darke brown to bronze coloured. The radiolarites are fine grained, strongly foliated and show mostly green and red colours (Fig. 5b). The pillow basalts occur yellow- to greenish whereby the rims of the pilows appear bleached (Fig. 5c). The inter-pillow spaces are dark green (Fig. 5d).

The metagabbros contain abundant relict magmatic clinopyroxene (Cpx) crystals in a very fine grained matrix consisting of albite (Ab) + muscovite (Ms) + epidote (Epi) as shown in a photomicrograph in Figure 6a and in a BSE image in Figure 6b. The BSE image shows the fine grained matrix of Ab + Ms, which contains abundant Epi-bearing veins (Fig. 6b, d). Magmatic clinopyroxene is replaced by pumpellyite (Pump) + amphibole (Amph) + chlorite (Chl) + magnetite (Mt) as shown in Figure 6c.

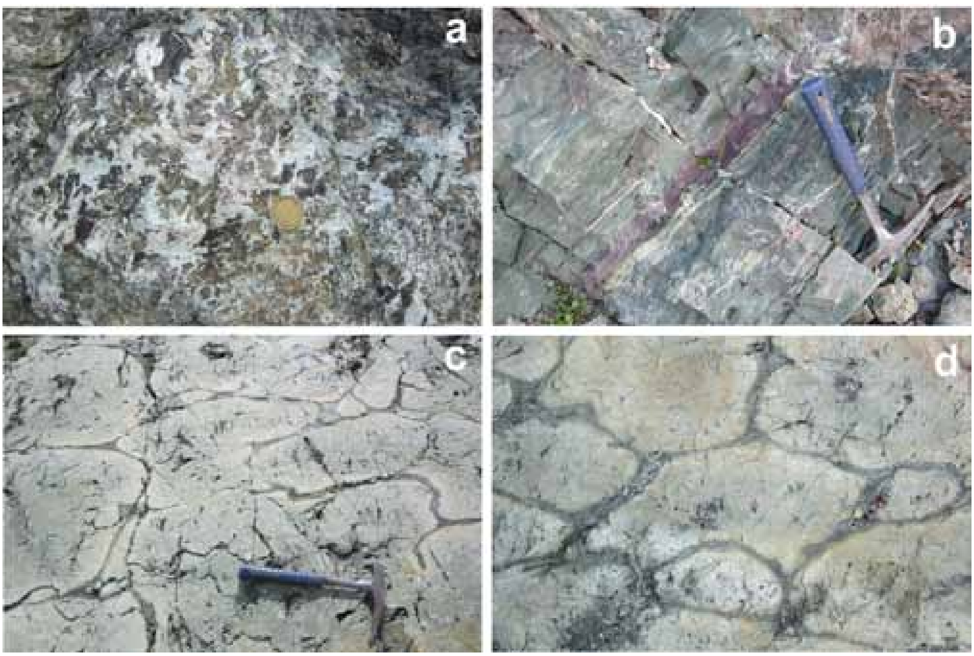

Figure 5: Field relations of a) metagabbro, b) radiolarite and c+d) pillow basalts.

Stops 2 and 3 Pillow-Basalt

The pillow basalts also contain relict magmatic clinopyroxene crystals in a very fine grained matrix consisting of pumpellyite (Pump) + albite (Ab) + amphibole (Amph) + titanite (Ttn) as shown in Figures 7a, b. The fine grained matrix can only be discerned using BSE images, which reveal the assemblage Pump + Ab +

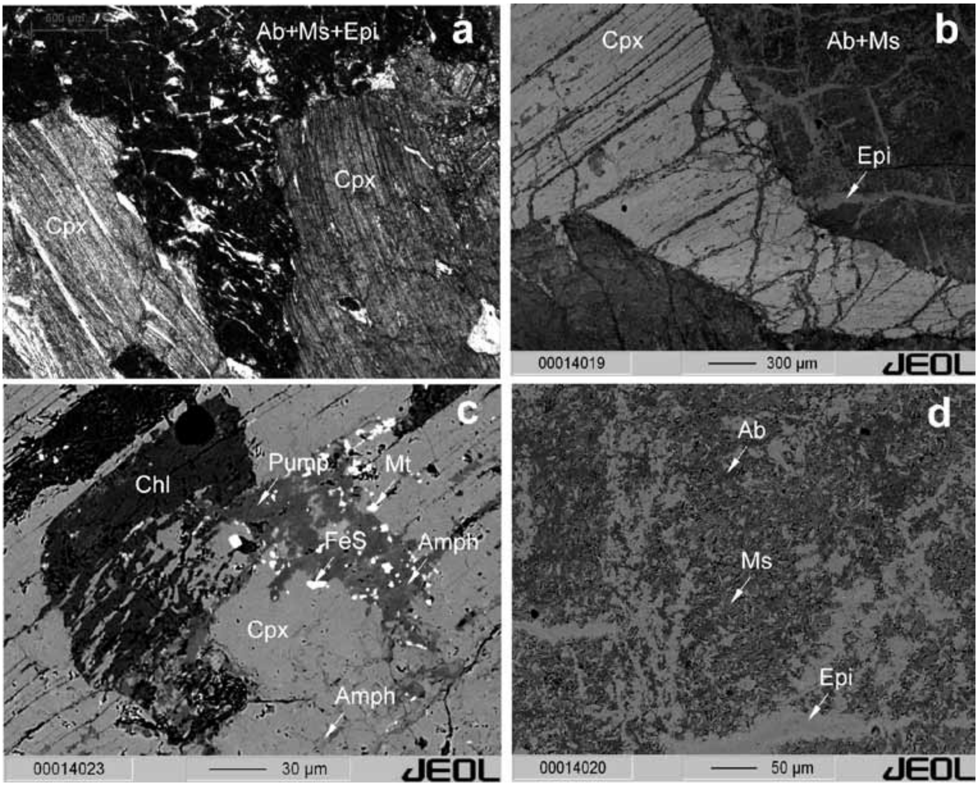

Figure 6: Photomicrographs and Backscatter electron (BSE) images showing the petrography of the metagabbros. a) photomicrograph of relict magmatic clinopyroxene (Cpx) crystals in a very fine grained matrix consisting of albite (Ab) + muscovite (Ms) + epidote (Epi). b) BSE image showing relict Cpx in the fine grained matrix of Ab + Ms, which contains abundant Epi-bearing veins. c) BSE image of the replacement of magmatic Cpx by pumpellyite (Pump) + amphibole (Amph) + chlorite (Chl) + magnetite (Mt). D) BSE close-up image of the matrix consisting of Ab + Ms + Epi-veins.

Amph + Ttn (Fig. 7b, c). c) BSE close-up image image of the fine grained matrix of Pump + Ab + Amph + Ttn. Calcite (Cc) + Ab + Epi-bearing veins often crosscut the matrix (Fig. 7d).

Stop 4 Bündnerschiefer (Flysch sediments), near Idjoch

Along the ski run west of Idjoch flysch sediments are well exposed, composed of alternating marly sediments, phyllitic rocks and sandstones which display graded bedding. The rocks are intensively folded (Fig. 8). Sandstones contain planctic foraminifers (including *Globigerina* ex gr. *cretacea*) indicating Cretaceous age (BERTLE, 2002). According to BERTLE (2002) the heavy mineral assemblage which is composed of apatite, tourmaline, rutile, zircon, chromspinel and brookit, is similar to that of the Palombini-Formation of the Arosa Zone and indicates that the sediments are derived from ophiolites of the south Penninic Zone (Piemont-Ligurian ocean).

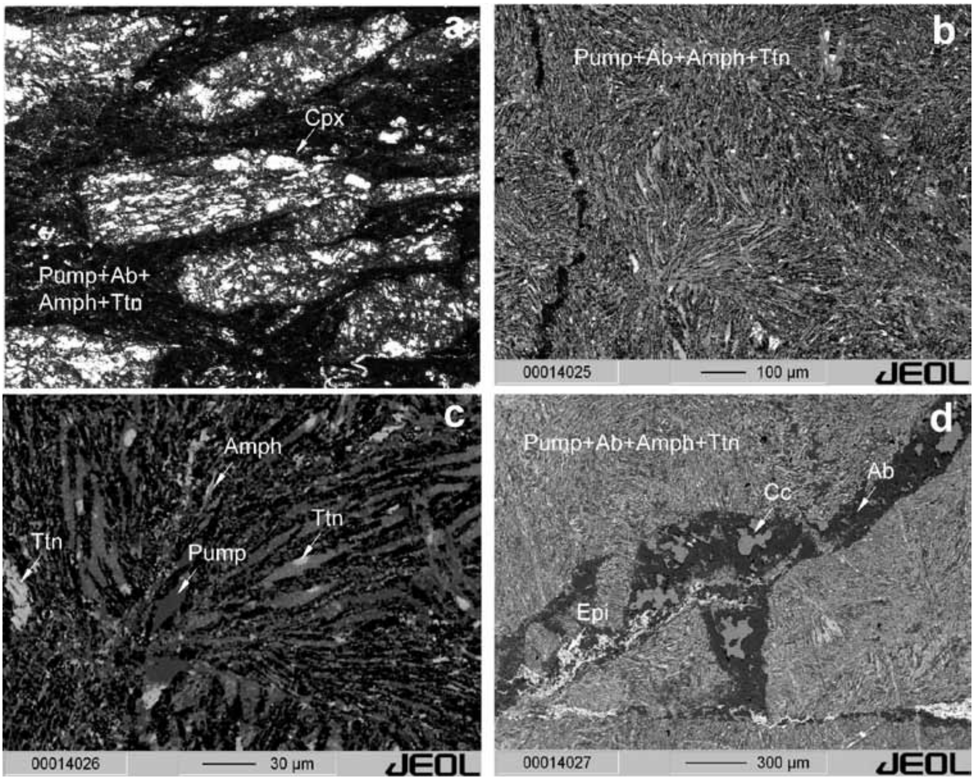

Figure 7: Photomicrographs and Backscatter electron (BSE) images showing the petrography of the pillow basalts. a) photomicrograph of relict magmatic clinopyroxene (Cpx) crystals in a very fine grained matrix consisting of pumpellyite (Pump) + albite (Ab) + amphibole (Amph) + titanite (Ttn). b) BSE image showing the fine grained matrix of Pump + Ab + Amph + Ttn. c) BSE close-up image image of the fine grained matrix of Pump + Ab + Amph + Ttn. Pump frequently contains Ttn inclusions. d) BSE image of the matrix crosscut by calcite (Cc) + Ab + Epi-bearing veins.

Figure 8: Folded Bündnerschiefer (flysch sediments) near Idjoch composed of phyllitic rocks and intercalated brownish sandstone beds.

Stop 5 Steinsberger Kalk and Idalpsandstein at Lange Wand

Steinsberger Kalk: The term „Steinsberger Kalk" was already used in the literature in 1866 and described as a reddish limestone containing ammonoids and brachiopods, compared with the Adnet and Hierlatz limestone (THEOBALD, 1866). The name is derived from Steinsberg near Ardez in the Lower Engadine (type locality) where the Seinsberg Limestone (Steinsberger Kalk, Steinsberger Lias) overlies Triassic dolomites and is described as light-gray, partly reddish, locally cherty, coarese-grained limestone („Spatkalk") containing belemnites, terebratulid brachiopods, Arcestes cf. bucklandi and Gryphaea cf. obliqua (CADISCH, 1932). The Steinsberger Lias at the type locality also contains polymict breccias (CADISCH, 1932). According to CADISCH (1932) these rocks are part of the Falknis-Sulzfluh Nappe (Lower Austroalpine). The Steinsberger Kalk has never been studied sedimentologically, a type secction so far was not described and defined. In the Fimber Valley south of Ischgl (Fimber Zone) the Steinsberger Kalk according to OBERHAUSER (1980) is approximately 80 m thick and composed of

- Dark gray, brownisch weathered limestone which is overprinted by low-grade metamorphism (calcareous marble) and contains belemnites and ammonoids,
- Overlain by whitish, limestone (marble) containing abundant echinoderm fragments.

Locally, the Steinsberger Kalk is overlain by dark, metamorphically overprinted schists containing harpoceratids and bivalves („Posidonienschiefer"; OBERHAUSER, 1980). From a well-exposed section through the Steinsberger Kalk at Malfragkopf THUM (1970) described fossils indicating a lower Jurassic (Liassic) age.

The Steinsberger Kalk forms the prominent cliff of the Lange Wand. The upper part of the Steinsberger Kalk is composed of light-gray, indistinctly bedded, coarse limestone containing abundant crinoidal debris. At Lange Wand the Steinsberger Kalk in its upper part is mostly recrystallized due to metamorphic overprinting, but locally the sedimentary character is well preserved. In the upper part of the succession at Lange Wand one limestone type is crinoidal packstone to rudstone

Figure 9: Thin section photograph of Steinsberger Kalk at the Lange Wand. The limestone is a crinoidal packstone to rudstone composed of abundant crinoid fragments and subordinately of brachiopod shells, bivalves and bryozoans. Plane light, width of photograph is 6.3 mm.

composed of abundant crinoid fragments, subordinately of shells including bivalves and punctate brachiopods, ostracods, bryozoans and foraminifers (Fig. 9). The limestone also contains micritic intraclasts and few small quartz grains. The depositional environment of the Steinsberger Kalk is not well established. WAIBEL & FRISCH (1989) interpret the Liassic sediments as neritic deposits, whereas deposits from the Middle Liassic on are interpreted as turbidites with associated debris flows, contourites and pelagic limestones which formed in environments ranging from a mid-fanto an abyssal plain (WAIBEL & FRISCH, 1989).

Idalpsandstein: For the sandstone-dominated succession, which is dated as middle Jurassic (Dogger) by ammonites and belemnites, OBERHAUSER (1980) introduced the term Idalpsandstein. The Idalpsandstein overlies the Steinsberger Kalk and Posidonienschiefer, is approximately 40 m thick and interpreted as flysch deposits (OBERHAUSER, 1980). From a locality WNW of Höllenspitz OBERHAUSER (1984) described the Idalpsandstein as a succession composed of mudstone-siltstone with intercalated massive sandstone and sandstone beds displaying graded bedding and load casts which is at least 150 m thick. Fine grained sediments contain trace fossils (*Zoophycos, Chondrites*) and rarely Belemnites. At the Lange Wand the Idalpsandstein is a few tens of m thick and composed of mudstone-siltstone with intercalated fine- to coarse-grained sandstone beds.

Idalpsandstein under the microscope is moderately to porly sorted, the detrital grains are angular to subangular (Fig. 10). The sandstone is composed of mono- and polycrystalline quartz, detrital feldspar grains (plagioclase and potassium feldspars) which are commonly altered to various degrees (partly forming pseudomatrix). Subordinate are granitic rock fragments of quartz and feldspar, metamorphic rock fragments composed of mica (muscovite, chlorite, biotite) and quartz, and detrital mica (mostly muscovite). Accessory grains are zircon, tourmaline, apatite and opaque minerals. Rarely fossil fragments (echinoderms) are present. The sandstone contains high amounts of matrix which partly was formed diagenetically („pseudomatrix“) by the alteration of detrital feldspar grains to phyllosilicates. Locally coarse-grained calcite cement occurs which randomly replaces detrtial feldspar and quartz grains. Few sandstones are cemented by coarse bocky clacite.

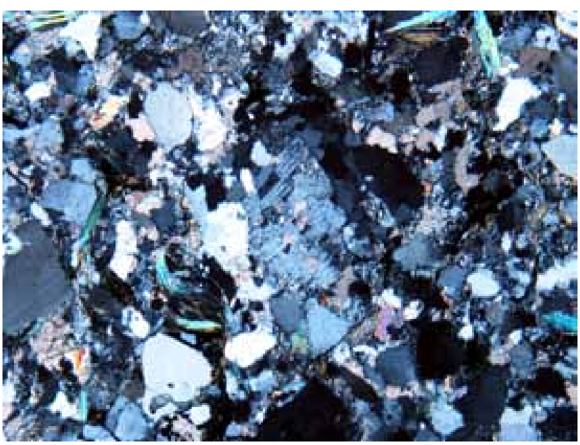

Figure 10: Coarse-grained sandstone composed of mono- and polycrystalline quartz, detrtial feldspar grains, detrital mica mostly muscovite), rock fragments composed of large feldspars and quartz (granitic) and few metamorphic rock fragments. The sandstone contains coarse, blocky carbonate cement. Polarized light, width of photograph is 3.2 mm. Idalpsandstein at Lange Wand.

References

BARRIGA, F. & FYFE, W.S. (1983): Development of rodingite in basaltic rocks in serpentinites, east Liguria, Italy. - Contrib. Mineral. Petrol., 84, 146-151.

BERTLE, R.J. (2002): Kreide und Paläogen in der Fimber-Zone (Unterengadiner Fenster, Schweiz-Österreich): neue Mikrofossilfunde und deren paläogeographische Bedeutung. – Eclogae Geol. Helv., 95, 153-167.

BOUSQUET, R., BERTLE, R., GOFFÉ, B, KOLLER, F. & OBERHAUSER, R. (2004): Day 4: HP/LT metamorphism within the North Penninic Ocean (Lower Engadine Window, Austria – Switzerlan). - In: GOSSO, G., ENGI, M., KOLLER, F., LARDEAUX, J.M., OBERHÄNSLI, R. & SPALLA, M.I. (2004): Thermo-mechanical evolution of the Alpine Belt, from the Engadine Window to the Matterhorn, 32nd IGC Florence, Field Trip Guide Book B29, 22-27.

BOUSQUET, R., GOFFÉ, B., VIDAL, O., OBERHÄNSLI, R. & PATRIAT, M. (2002): The tectono-metamorphic history of the Valaisan domain from the Western to the Central Alps: new constraints on the evolution of the Alps. - Geol. Soc Amer. Bull., 114, 207-225.

BOUSQUET, R., OBERHÄNSLI, R., GOFFE, B., JOLIVET, L. & VIDAL, O. (1998): High-pressure - low-temperature metamorphism and deformation in the Bündnerschisfer of the Engadin window: implications for the regional evolution of the Central Alps. - J. Metam. Geol., 16, 657-674.

CADISCH, J. (1932): Die Schichtreihe on Ardez (Steinsberg) im Unterengadiner Fenster. - Eclogae Geol. Helv., 25, 17-22.

DAURER, A., (1980): Short notes on the Idalp ophiolites (Engadin Window, Tyrol, Austria). - Ofioliti, 5, 101-106.

DE CAPITANI, C. & PETRAKAKIS, K. (2010): The computation of equilibrium assemblage diagrams with Theriak/Domino software. - Am. Mineral., 95, 1006-1016.

GRUBER, A., PESTAL, G., NOWOTNY, A. & SCHUSTER, R. (2010): Erläuterungen zu Blatt 144 Landeck. - Geol. B.-A., Wien, 1-200.

HÖCK, V. & KOLLER, F. (1989): Magmatic evolution of the Mesozoic ophiolites in Austria. - Chem. Geol., 77, 209-227.

HÖCK, V. & KOLLER, F. (1987): The Idalp ophiolite (Lower Engadine window, Eastern Alps), its petrology and geochemistry. – Ofioliti, 12, 179-192.

HÖCK, V., KOLLER, F., OBERHAUSER, R. & UCIK, F. (1986). Exkursion E 1-4. Das Unterengadiner Fenster und sein Rahmen im Bereich Fimbertal-Samnaun verbunden mit einer Gesamtübersicht über den östlichen Fensterteil. - Exkursionsführer zur Wandertagung 1986 der Österreichischen Geologischen Gesellschaft in Dornbirn, 107-122.

HÖCK, V, KOLLER, F., BERTLE, R. & BOUSQUET, R. (2004): Fimber unit and the Idalp ophiolite (South Pennic unit, Lower Engadine Window; Austria-Switzerland). - In: GOSSO, G., ENGI, M., KOLLER, F., LARDEAUX, J.M., OBERHÄNSLI, R. & SPALLA, M.I. (Eds): Thermo-Mechanical Evolution of the

Alpine Belt, from the Engadin Window to the Matterhorn, Field trip guide book B29, 32nd International Geological Congress, 253-263.19-21.

HOLLAND, T. J. B. & POWELL, R. (1998): An internally-consistent thermodynamic data set for phases of petrological interest. - J. Metam. Geol., 8, 89-124.

KOLLER, F. (1985): Petrologie und Geochemie des Penninikums am Alpenostrand. - Jb. Geol. B.-A., Wien, 128, 83-150.

KOLLER, F. & HÖCK, V. (1987): Die mesozoischen Ophiolithe der Ostalpen. - Mitt. Österr. Min. Ges., 132, 61-77.

KOLLER, F. & HÖCK, V. (1990): Mesozoic ophiolites in the Eastern Alps. - In MALPAS, J., MOORES, E.M., PANAYIOTOU, A. & XENOPHONTOS, C. (Eds.), Ophiolites – Oceanic Crustal Analogues, Nicosia, 253-263.

KOLLER, F., DINGELDEY, CH., & HÖCK, V. (1996): Exkursion F: Hochdruck-Metamorphose im Recknerkomplex/Tarntaler Berge (Unterostalpin) und Idalm-Ophiolith/Unterengadiner Fenster. - Mitt. Österr. Min. Ges., 141, 305-330.

LEIMSER, W. & PURTSCHELLER, F. (1980): Beiträge zur Metamorphose von Metavulkaniten im Pennin des Engadiner Fensters. - Mitt. Österr. Geol. Ges., 71/72, 129-137.

OBERHAUSER, R. (1980). Das Unterengadiner Fenster. - In: OBERHAUSER, R. (Ed.), Der Geologische Aufbau Österreichs, Springer Verlag, Wien, 291-297.

OBERHAUSER, R. (1984): Bericht 1983 über geologische Aufnahmen im Unterengadiner Fenster auf Blatt 170 Galtür. - Jahrb. Geol. B.-A., 127/2, 250-251.

OBERHAUSER, R. (2007): Profilschnitt vom Bodensee ins Unterengadin. - Beilage in: OBERHAUSER, R., BERTLE, H. & BERTLE, R. (2007): Geologische Karte von Vorarlberg 1:100.000. Geol. B.-A., Wien..

SCHMID, S.M., FÜGENSCHUH, B., KISSLING, E. & SCHUSTER, R. (2004): Tectonic map and overall architecture of the Alpine orogen. - Eclogae Geol. Helv., 97/1, 93-117.

SCHUSTER, R., KOLLER, F., HÖCK, V., HOINKES, G. & BOUSQUET, R. (2004): Explanatory notes tot he map: metamorphic structure oft he Alps metamorphic evolution of the Alps. - Mitt. Öster. Mineral. Ges., 149, 63-87

THEOBALD, G. (1866): Die suedoestlichen Gebirge von Graubuenden und dem angrenzenden Veltlin (Vol. 3). J. Dalp.

THUM, I. (1970): Neuere Daten zur Geologie des Unterengadiner Fensters (unter besonderer Berücksichtigung der Schwermineralanalysen). - Mitt. Öster. Geol. Ges., Wien, 62 (1969), 55-77.

TOLLMANN, A. (1977): Geologie von Österreich, Band I, Die Zentralalpen. - Verlag Franz Deuticke, Wien, 766p.

WAIBEL, A.F. & FRISCH, W. (1989): The Lower Engadine Window. Sediment deposition and accretion in relation to the plate-tectonic evolution of the Eastern Alps. – Tectonophysics, 162, 229-241.

received: 05.07.2017
accepted: 11.07.2017