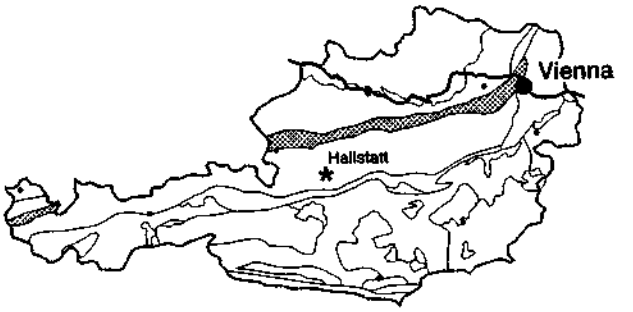
2.4. The Flysch Zone of the Eastern Alps

Wolfgang SCHNABEL



The zone along the northern front of the Northern Calcareous Alps, designated as 'Flysch Zone', is a comparatively narrow zone. Nevertheless two major Alpine palaeogeographic zones (Helveticum and Penninicum) are still preserved in it and are represented mainly by sequences from the Lower Cretaceous to the Paleogene. Older (Upper Triassic - early Lower Cretaceous) substrata are present in the Klippen Zones (Fig. 2.4.1., 2.4.2.).

The predominant unit is the East Alpine Flysch ("Rheno-Danubic" or "Rhenodanubian Flysch" after OBERHAUSER, 1968; RDF in the following). It is a supergroup of formations dominated by flysch facies from the Lower Cretaceous - middle Eocene, widely considered to be part of the Penninic realm. It extends from the west-east Alpine border to western Lower Austria more or less as one nappe (Main Flysch Nappe). Although admittedly sliced and tectonically disturbed, the entire sequence could well have had an average original thickness of about 2000 m (EGGER, 1987; BRAUNSTINGL, 1988).

In the easternmost section (Wienerwald), the Flysch Zone widens and has a more complex structure. It can be divided into three nappes with different facies, the Greifenstein Nappe to the north, the Laab Nappe to the south and the Kahlenberg Nappe to the southeast. A separate narrow imbricated zone, the 'Northern Zone', occurs at the northern edge of the Flysch Zone.

The second main unit within the narrow Flysch Zone is assigned to the Helvetic System *sensu lato.* On the surface it extends along strike from Switzerland through Vorarlberg and Bavaria and can be traced north of the Flysch Zone approximately to the area of Salzburg (South Helvetic Zone in Bavaria). It continues in Upper Austria, where it crops out in numerous elongated thrust slices ('strip windows') within the Flysch Zone. This northern Ultrahelvetic Zone consists chiefly of red and variegated marls and is late Lower Cretaceous to Eocene in age (upper slope). Tectonically it underlies the RDF.

East of the River Enns a new situation arises as the Rheno-Danubic Flysch has almost completely overthrust the Ultrahelveticum. In a complicated system of windows, half windows and double windows, which even include sequences of the oldest Molasse Basin (Inner Alpine Molasse - late Eocene to Oligocene), Helvetic units appear at the surface. The Cretaceous-Tertiary sequences here are termed "Buntmergelserie" (Variegated Marl Series) and present the southern Ultrahelvetic Zone. The increase in clay-content and agglutinated Foraminifera points toward deposition below the calcite compensation level on the continental slope. Contrary to the situation in the west, the pre-mid-Cretaceous substratum is present here (Gresten Klippen Zone, see below). During the Paleocene and Eocene, coarse chaotic sediments occur as a 'Wildflysch'-like facies, possibly derived from a marginal basement high. They may have accumulated as debris-flow or rock-fall deposits originating from escarpments or as the sedimentary fill of submarine canyons. Its most prominent exposure is the exotic granite of the Leopold-von-Buch memorial in western Upper Austria. This detrital assembly, and the klippen sequence itself, bear compositional similarities to the Bohemian Massif and its sedimentary cover (FAUPL,

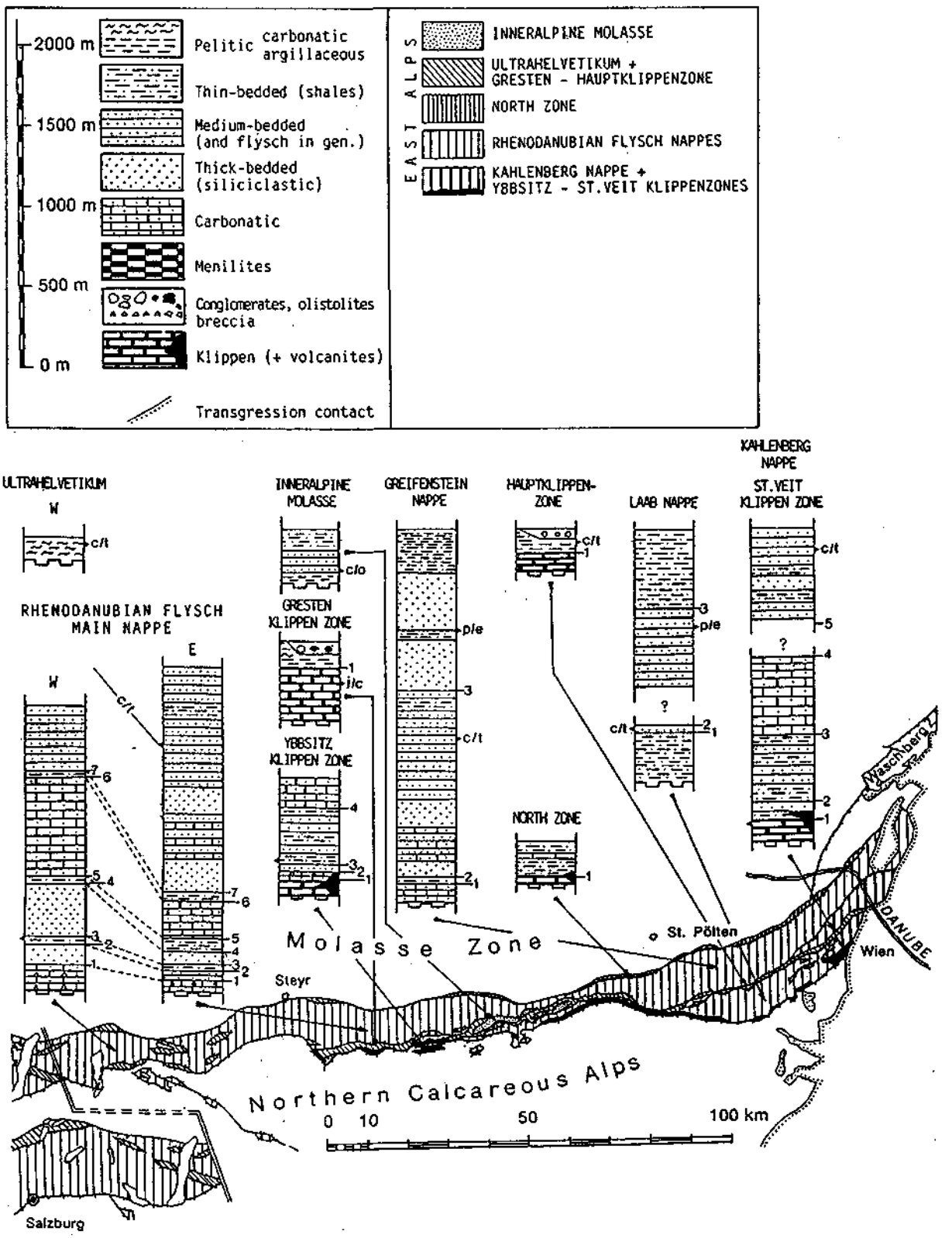
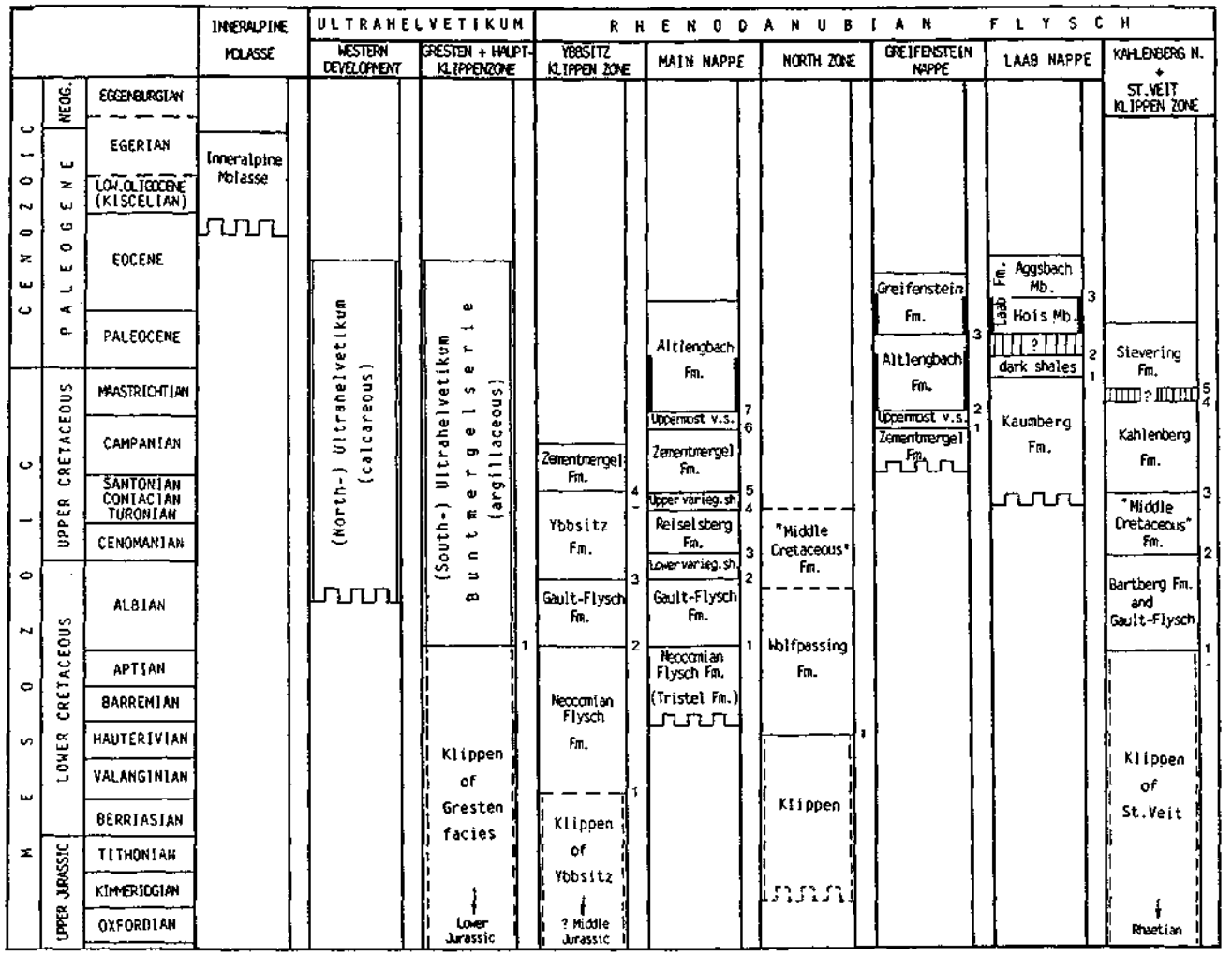


Fig. 2.4.1.: Tectonics and Facies of the Flysch Zone of the Eastern Alps (Eastern section; after ELIÁS, SCHNABEL & STRANIK,1990).



High sedimentation rate

Low sedimentation rate

Reduction of the lithological sequence

Transgression contact

Tectonic contact

M. Marls

Mb. Member

Fm. Formation

Fig. 2.4.2.: Stratigraphy of the Flysch Zone of the Eastern Alps (Eastern section; after ELIÁS, SCHNABEL & STRÁNIK, 1990).

1975a, 1978), but also display their own individual features (FAUPL & SCHNABEL, 1987, WIDDER, 1988).
Further east, in the area of the Wienerwald, this zone continues into the so-called "Hauptklippenzone" (Main Klippen Zone) in the same facies. Nevertheless, here it is no longer a window like the Gresten Klippen Zone, but a nappe separator, a suture separating two flysch nappes of different facies (the Greifenstein Nappe to the north from the Laab Nappe to the south). It is a long and distinct tectonic slice and not a window.

The Klippen Zones

The original base of the Rheno-Danubic Flysch (Penninic) and of the Buntmergelserie (Ultrahelvetic) is found in the Klippen Zones. These zones consist of Jurassic-Lower Cretaceous sequences in their cores. Their younger sedimentary cover consists of Buntmergelserie or Flysch.
Depending upon their tectonic positions, facies, ranges and types of cover, several different klippen zones can be identified, of which the Gresten Klippen Zone in the pre-Alpine area of western Lower Austria, the Hauptklippenzone (Main Klippen Zone) of the Wienerwald and the St. Veit Klippen Zone in the western outskirts of Vienna are the well known classic klippen zones. New investigations have shown that, to the west, the Ybbsitz Klippen Zone, a zone with deep-sea facies in the Jurassic and a cover of flysch, must be separated from the Gresten Klippen Zone with characteristic Lower Jurassic coal-bearing, shallow-water facies (Gresten facies) and a cover of Buntmergelserie.
In the Gresten Klippen Zone, two different facies can be distinguished: the Waidhofen Facies, with a distinct shallow-water Jurassic facies, and the Scheibbs Facies, with a deep-water facies (SCHNABEL, 1983). In this manner a continuous deepening along the southern European continental margin is evident (Fig. 2.4.3.).
Based mainly on their sedimentary cover (either Buntmergelserie or Flysch), the klippen zones can be assigned to the main tectonic systems as follows:
1) Helvetic (Buntmergelserie): Gresten Klippen Zone and Main Klippen Zone and
2) Penninic (Flysch): Ybbsitz Klippen Zone and St. Veit Klippen Zone.

The Flysch Successions

Main Flysch Nappe and Greifenstein Nappe:

The principal stratigraphic and sedimentological features of the Main Flysch Nappe and the Greifenstein Nappe, which is the eastern continuation of the former in the area of the Wienerwald, are outlined in Fig. 2.4.4.
The entire sequence could have had an average thickness of about 2000 m (HESSE, 1982; PREY in OBERHAUSER, 1980, pp. 191-199). In Bavaria it embraces the late Lower Cretaceous to the Maastrichtian; towards the east the sequence becomes increasingly younger and extends into the early Eocene (nannoplankton-zone NP12) in the Greifenstein Nappe. Recently, a predominantly marly facies of nearly the same age (NP11) was established in Upper Austria (EGGER, 1989b).
There is a considerable lateral change in thickness insofar as lower formations (late Lower Cretaceous - Campanian) thin towards the east, whereas the higher ones beginning with the Maastrichtian, thicken in the same direction. This corresponds generally with current directions, which are predominantly longitudinal parallel to the axis of the elongated basin and switch to petrographically different sources (HESSE, 1965, 1982). These directions

are from west to east in the Lower Cretaceous (carbonate and quartz-arenite flysch), variable in the mid-Cretaceous and again from west to east in the Turonian-Campanian Zementmergel Formation (carbonate flysch). In the Maastrichtian-Paleocene (terrigenous flysch), current directions are from the east again (Bleicherhorn Formation in Bavaria and Altlengbach Formation, the predominant formation in the eastern Austrian sector), and heavy-mineral associations are garnet-dominated. In the easternmost section, the dominant directions indicate transport from west to east and northwest to southeast, beginning with nannoplankton zone NP3, and dominated by heavy-mineral associations with zircon/tourmaline/rutile. These results, including the data of coarse-grain analysis of the Greifenstein Formation, indicate a source area composed of acid crystalline and autochthonous Mesozoic rocks similar to the Bohemian Massif and the basis of the Molasse Zone (HÖSCH, 1985; RAMMEL, 1989).

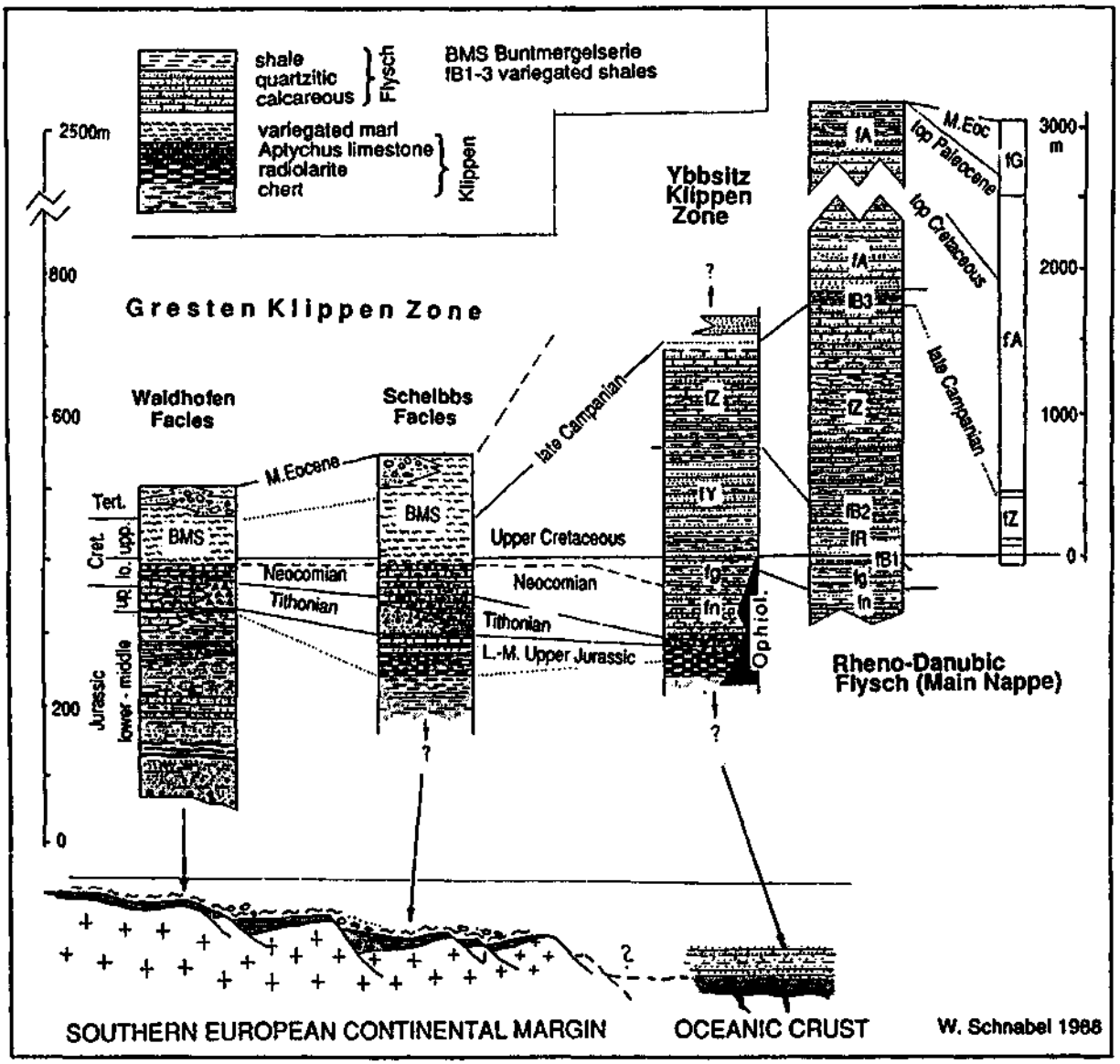


Fig. 2.4.3.: Paleogeographic position of the Klippen Zones along the Southern European Continental Margin (Helvetic domain) into the oceanic basin of the Penninic realm (after SCHNABEL, 1992).

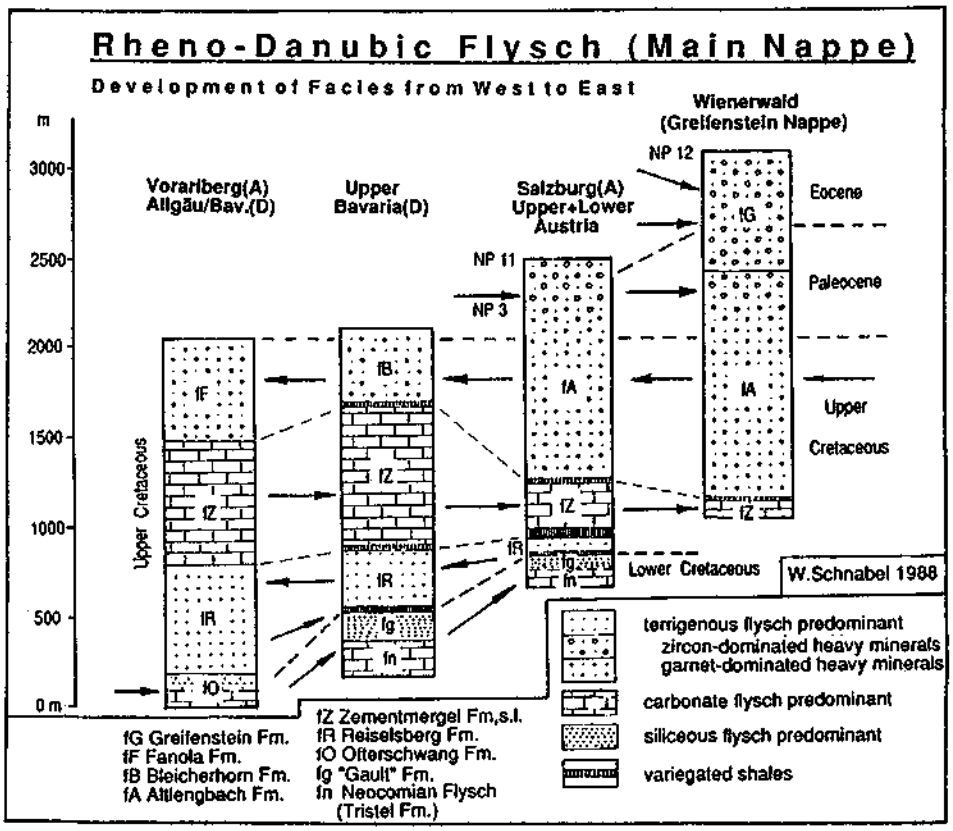


Fig. 2.4.4.: Rheno-Danubic Flysch; Main Nappe. Essential features of facies development from west to east. It should be mentioned, that particularly in the western part (left) the facies also changes from north to south. Arrows indicate predominant paleocurrent directions (after SCHNABEL, 1992).

Laab Nappe (Fig. 2.4.5.):

In the Laab Nappe a flysch with variegated shales dominates the Upper Cretaceous from the Turonian onward (Kaumberg Formation). Current directions from northwest to southeast suggest an internal basement high within the flysch domain in late Cretaceous time. Traces of chrome spinel in the heavy mineral spectra point toward ultramafic rocks (FAUPL, 1975). Following a gap, the Laab Formation continues with thick-bedded terrigenous flysch in the late Paleocene (Hois Member) and clayey flysch in the Eocene (Agsbach Member). Current directions indicate transport from northwest to southeast in the Hois Member and from east to west in the Agsbach Member (RINGHOFER, 1976).
A normal sedimentary transition between the Kaumberg Formation and the Laab Formation has not been proven. Considering the different tectonic style and the stratigraphic gap, a tectonic contact (overthrust, as argued by FUCHS, 1985) remains a possibility, although an assignment of the Kaumberg Formation to the Helvetic realm (Buntmergelserie) is not feasible.

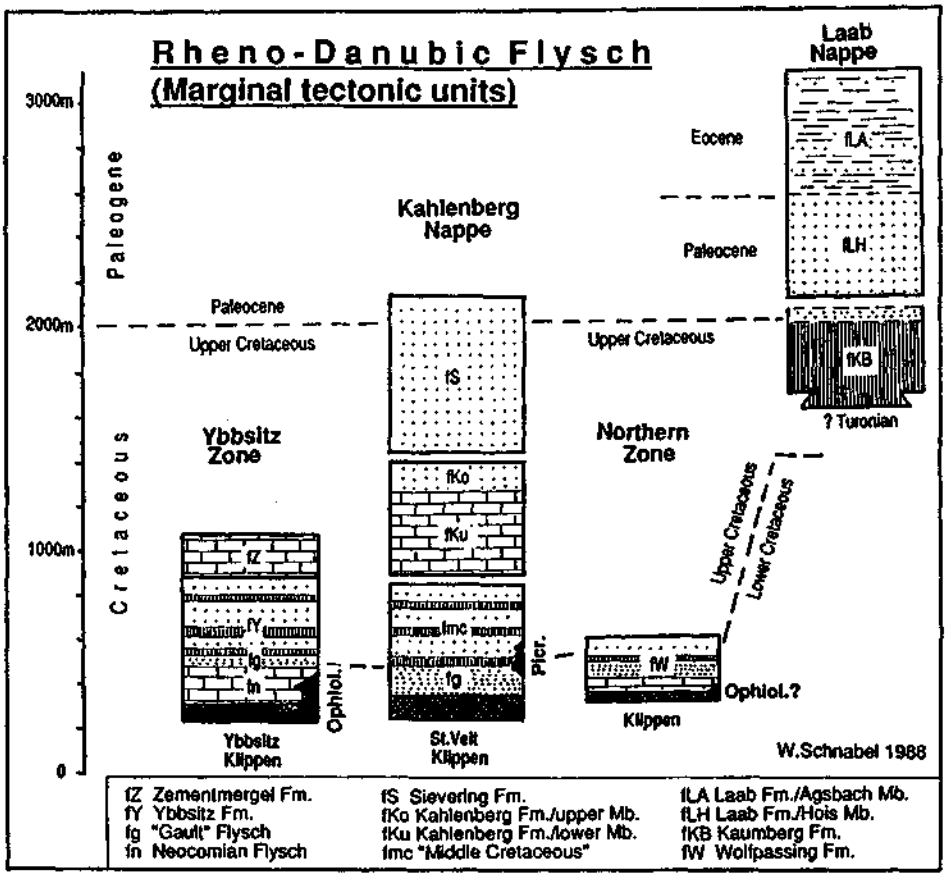


Fig. 2.4.5.: Rheno-Danubic Flysch; Marginal tectonic units. For legend see Fig. 2.4.4. (slightly modified after SCHNABEL, 1992).

Kahlenberg Nappe (Fig. 2.4.5.):

The Kahlenberg Nappe includes the Klippen Zone of St. Veit, which presumably represents the Upper Triassic to early Lower Cretaceous substratum of the flysch formations (TOLLMANN, 1963, p. 134; PREY, 1975). The flysch cover comprises sequences from the Aptian/Albian up to the Paleocene. The Kahlenberg Nappe is extensively dismembered tectonically owing to progressive, possibly gravitational sliding to the north over the other flysch nappes (PREY, 1971, 1979). In essence, the older parts (klippen and basal flysch) are accumulated in the south, the younger parts in the north. Only the mid-Cretaceous variegated shale formation is present everywhere as a tectonic lubricant and is thus the common link, which provides a good reason to consider all these dismembered slices as of common origin.
Apart from its klippen substratum (St. Veit Klippen Zone), the flysch sequence itself begins with Aptian/Albian/Cenomanian-Coniacian variegated shales and intercalations of sandstone. Owing to the scarcity of marker fossils and the consequent difficulties in precise dating, this time span is often referred to as 'Mid-Cretaceous.' The occurrence of sporadic picritic volcanic rocks of the same age is worth noting. The Kahlenberg Formation (Santonian-Maastrichtian) is a carbonate flysch with transition to terrigenous flysch in the

hanging wall. Its palaeocurrents reflect east-west transport. It contains garnet-dominated heavy-mineral suites (MÜLLER, 1987); on the other hand, the thick terrigenous turbidites of the Maastrichtian Sievering Formation contain acidic crystalline rock fragments and zircon-dominated heavy minerals, also coming from the east in the same direction (FAUPL et al., 1970).
Although there is evidence for a separate basin differing from the depositional conditions of the other flysch nappes, the sequence of the Kahlenberg Nappe is undoubtedly part of the Rheno-Danubic Flysch in its eastern sector and likely to be derived from the southern part of the original flysch trough. Tectonically it is the highest nappe, since outliers have been proven to overlie the Laab Nappe tectonically (PREY, 1983).

North(ern) Zone (Fig. 2.4.5.):

In the eastern sector, the Flysch Zone is bordered in the north by a zone which mainly consists of Lower Cretaceous flysch sediments (Wolfpassing Formation). It continues towards west, at least to the area of the town of Steyr, highly imbricated and intersliced with Helvetic Buntmergelserie (EGGER, 1989a). The 'Neocomian Flysch' in the Haunsberg area (Salzburg) could belong to the same zone. An olistostromatic horizon and isolated boulders at that locality provide valuable clues to the nature of the basement of the flysch. Here at its northernmost rim, these wildflysch-like sediments contain a rock assembly similar to that of the European plate at its southern margin (FRASL & FLÜGEL, 1987).
The presence of serpentinites near the village of Kilb has been noted. These are embedded in basal flysch sequences (Aptian/Albian-Cenomanian, [PREY, 1977]). The continuity of the Northern Zone along the northern edge of the Flysch Zone clearly shows its tectonic independence within the Flysch Zone. It is not part of the Main Flysch Nappe, contrary to previous interpretations (see also GRÜN et al., 1972).

References

BRAUNSTINGL, R., 1988: Die Flyschzone südwestlich von Steyr (Oberösterreich): Geologischer Bau und Überlegungen zum Ultrahelvetikum. - Jb. Geol. Bundesanst. **131**, 231-243, Wien.

EGGER, H., 1987: Die Geologie der Rhenodanubischen Flyschzone südöstlich von Steyr (Oberösterreich, Niederösterreich). - Anz. Österr. Akad. Wiss., Math.-Naturwiss. Klasse **126**, 59-66, Wien.

EGGER, H., 1989a: Über einige Beobachtungen in der Flyschzone südlich von St. Peter in der Au (Niederösterreich). - Anz. Österr. Akad. Wiss, Math.-Naturwiss. Klasse 126, 59-66, Wien.

EGGER, H., 1989b: Zur Geologie der Flyschzone im Bundesland Salzburg. - Jb. Geol. Bundesanst. **132**, 375-395, Wien.

ELIÁS, M., SCHNABEL, W. & STRÁNIK, Z., 1970: Comparison of the Flysch Zone of the Eastern Alps and the Western Carpathians based on recent observations. - In: Thirty years of geological cooperation between Austria and Czechoslovakia, 37-46 (Geological Survey Vienna - Geological Survey Prague).

FAUPL, P., GRÜN, W., LAUER, G., MAURER, R., PAPP, A., SCHNABEL, W. & STURM, M., 1970: Zur Typisierung der Sieveringer Schichten im Flysch des Wienerwaldes. - Jb. Geol. Bundesanst. **113**, 73-158, Wien.

FAUPL, P., 1975: Schwermineralien und Strömungsrichtungen in den Kaumberger Schichten (Oberkreide) des Wienerwald-Flysches, Niederösterreich (Heavy minerals and paleocurrents from the Kaumberg beds (Upper Cretaceous) of the Flysch-Zone of the Vienna Woods, Lower Austria). N. Jb. Geol. Paläont, Mh., 1975, 528-540, Stuttgart.

FAUPL, P. & SCHNABEL, W., 1987: Ein Breccienvorkommen bei Scheibbs (Niederösterreich). Zur Kenntnis paläogener Grobklastika aus der Buntmergelserie. - Jb. Geol. Bundesanst. **130**, 153-161, Wien.

FRASL, G. & FLÜGEL, E., 1987: Clasts from the Haunsberg Wildflysch (N of Salzburg) - Implications on the Northern Border Zone of the Rhenodanubian Flysch Trough. - Geodynamics of the Eastern Alps (eds. Flügel, H.W. & Faupl, P.), 70-84 (Franz Deutike), Wien.

FUCHS, W., 1985: Großtektonische Neuorientierung in den Ostalpen und Westkarpaten unter Einbeziehung plattentektonischer Gesichtspunkte. - Jb. Geol. Bundesanst. **127**, 571-631, Wien.

GRÜN, W., KITTLER, G., LAUER, G., PAPP, A. & SCHNABEL, W., 1972: Studien in der Unterkreide des Wienerwaldes. - Jb. Geol. Bundesanst. **115**, 103-186, Wien.

HESSE, R., 1965: Herkunft und Transport der Sedimente im bayerischen Flyschtrog. - Zeitschr. Dt. Geol. Ges. 116, 403-426, Hannover.

HESSE, R., 1982: Cretaceous-Paleogene Flysch Zone of the East Alps and Carpathians: identification and plate-tectonic significance of "dormant" and "active" deep-sea trenches in the Alpine-Carpathian Arc. -- Trench-forearc geology (ed. Legget, J.K.)., 471-494 (Geological Society, London, Spec. Publ. **10**), London.

HÖSCH, K., 1985: Zur lithofaziellen Entwicklung der Greifensteiner Schichten in der Flyschzone des Wienerwaldes. - Unpublished PhD thesis, University of Vienna, 250p., Wien.

MÜLLER, M., 1987: Zur Lithofazies und Stratigraphie der Kahlenberger Schichten der Flyschzone des Wienerwaldes. - Unpublished PhD thesis, University of Vienna, 195p, Wien.

OBERHAUSER, R., 1968: Beiträge zur Kenntnis der Tektonik und Paläogeographie während der Oberkreide und dem Paläogen im Ostalpenraum. - Jb. Geol. Bundesanst. **111**, 1 - 88, Wien.

OBERHAUSER, R. (ed.) 1980: Der geologische Aufbau Österreichs, 699p. (Geologische Bundesanstalt Wien, Springer) Vienna and New York).

PREY, S., 1971: Mehrmalige Schweregleitungen als Denkmöglichkeit zur Auflösung der Strukturen im Bereich der Hauptklippenzone des Wienerwaldes. - Anz. Österr. Akad. Wiss., Math.-Naturwiss. Klasse 1971, 188-192, Wien.

PREY, S., 1975: Neue Forschungsergebnisse über Bau und Stellung der Klippenzone des Lainzer Tiergartens in Wien (Österreich). - Verh. Geol. Bundesanst., 1975, 1-25, Wien.

PREY, S., 1977: Der Serpentin von Kilb in der Flysch-Mittelkreide am Nordrand der Flyschzone (Niederösterreich). - Verh. Geol. Bundesanst., 1977, 271-277, Wien.

PREY, S., 1979: Der Bau der Hauptklippenzone und der Kahlenberger Decke im Raume Purkersdorf-Wienerwaldsee (Wienerwald). - Verh. Geol. Bundesanst., 1979, 205-228, Wien.

PREY, S., 1983: Die Deckschollen der Kahlenberger Decke von Hochrotherd und Wolfsgraben im Wienerwald. - Verh. Geol. Bundesanst., 1982, 243-250, Wien.

RAMMEL, M., 1989: Zur Kenntnis der Flyschzone im Untergrund des Wiener Beckens. Die Glaukonitsandsteinserie. - Unpublished PhD thesis, University of Vienna, 149p, Wien.

RINGHOFER, W., 1976: Sedimentologische und stratigraphische Untersuchungen im Hinblick auf Transport und Ablagerungsbedingungen in den alttertiären Anteilen der Laaber Teildecke (Hois- und Agsbachschichten). Unpublished PhD thesis, University of Vienna, 106p., Wien.

SCHNABEL, W., 1983: Bericht 1982 über geologische Aufnahmen in der Grestener Klippenzone (Westliche Niederösterreichische Voralpen) mit großregionalen Faziesvergleichen auf den Blättern 54 Melk, 71 Ybbsitz und 72 Mariazell. - Jb. Geol. Bundesanst. **126**, 301-302, Wien.

SCHNABEL, G.W., 1992: New data on the Flysch Zone of the Eastern Alps in the Austrian sector and new aspects concerning the transition to the Flysch Zone of the Carpathians. - Cretaceous Research 13, 405-419 (Academic Press Ltd.), Oxford.

TOLLMANN, A., 1963: Ostalpen-Synthese. - 256p. (Franz Deutike). Wien.

WIDDER, R.W., 1988: Zur Stratigraphie, Fazies und Tektonik der Grestener Klippenzone zwischen Maria Neustift und Pechgraben/O.Ö. - Mitt. Ges. Geol. Bergbaustud. Österr. **34/35**, 79-133, Wien.