Mesozoic evolution of the Tatra Mountains (Carpathians)

by

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with 21 figures

Excursion guide

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1. Introduction

The Tatra Mts. belong to the Inner Western Carpathians which are linked in the west to the Eastern Alps (Fig. 1). The Tatra Mts., which provide Alpine-type relief, the highest in the Western Carpathians elevate up to ~ 2500 m above sea level and up to ~ 1500-1800 m above the surrounding Palaeogene basins.

The core of the Tatra Mts. is formed by Hercynian crystalline massif, which is covered by a thick pile of Mesozoic sedimentary rocks (BAC-MOSZASZWILI et al. 1979, NEMCOK et al. 1994). Generally, the massif is tilted towards the North.

The sedimentary cover of the Hercynian crystalline massif is locally undetached, but mostly it is built of several tectonic units of different dimensions, generally dipping towards the North. It is possible to recognise (see Fig. 2) the High-Tatric (Tatricum) units, Krizna (Sub-Tatric, Fatricum) and Choc (Hronicum) tectonic nappes which were transported from the South during post-Lower Turonian movements.

High-Tatric units build the highest, rocky part of the Tatra Mts. named – wierchy, while Krizna and Choc units build

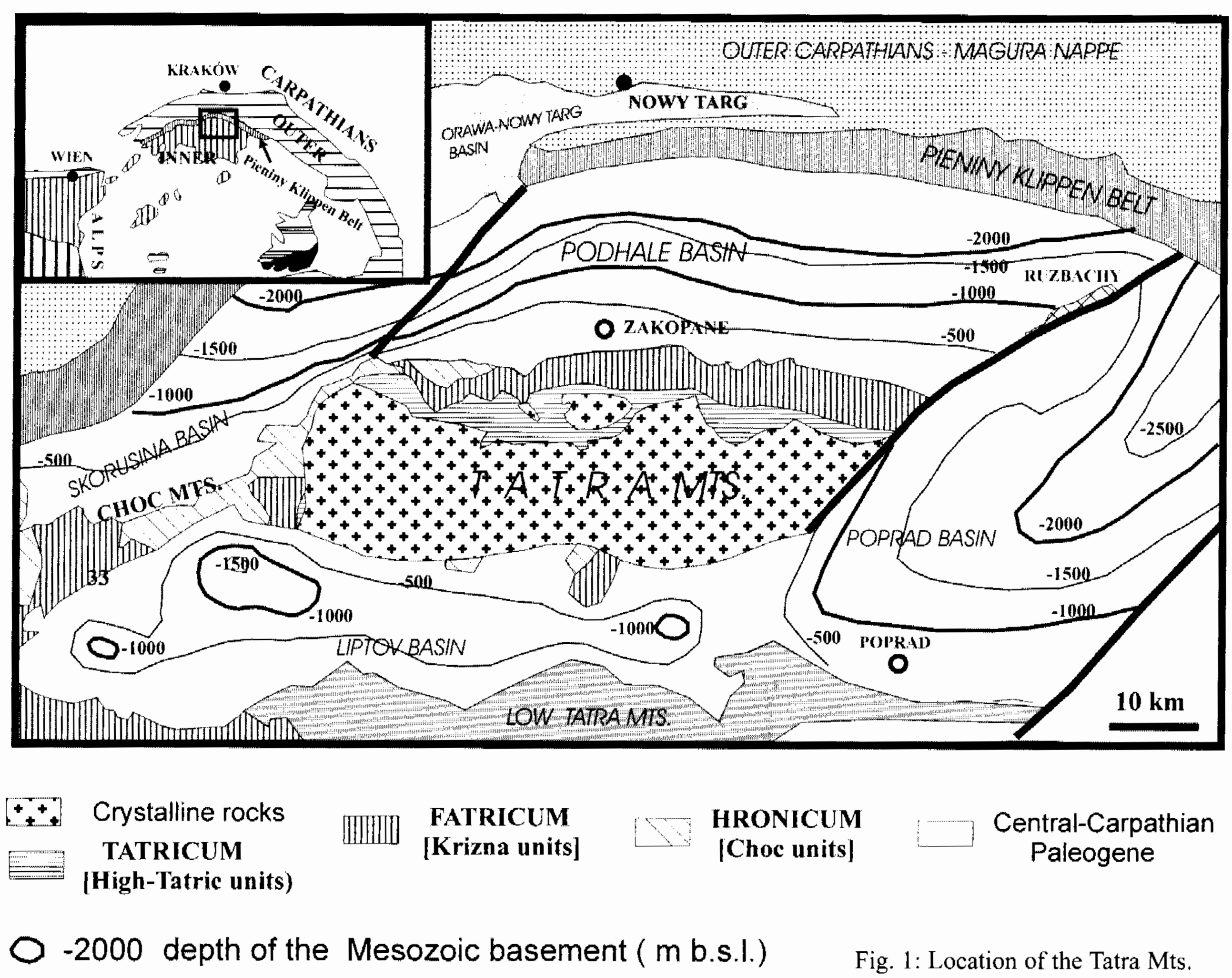


Fig. 1: Location of the Tatra Mts.

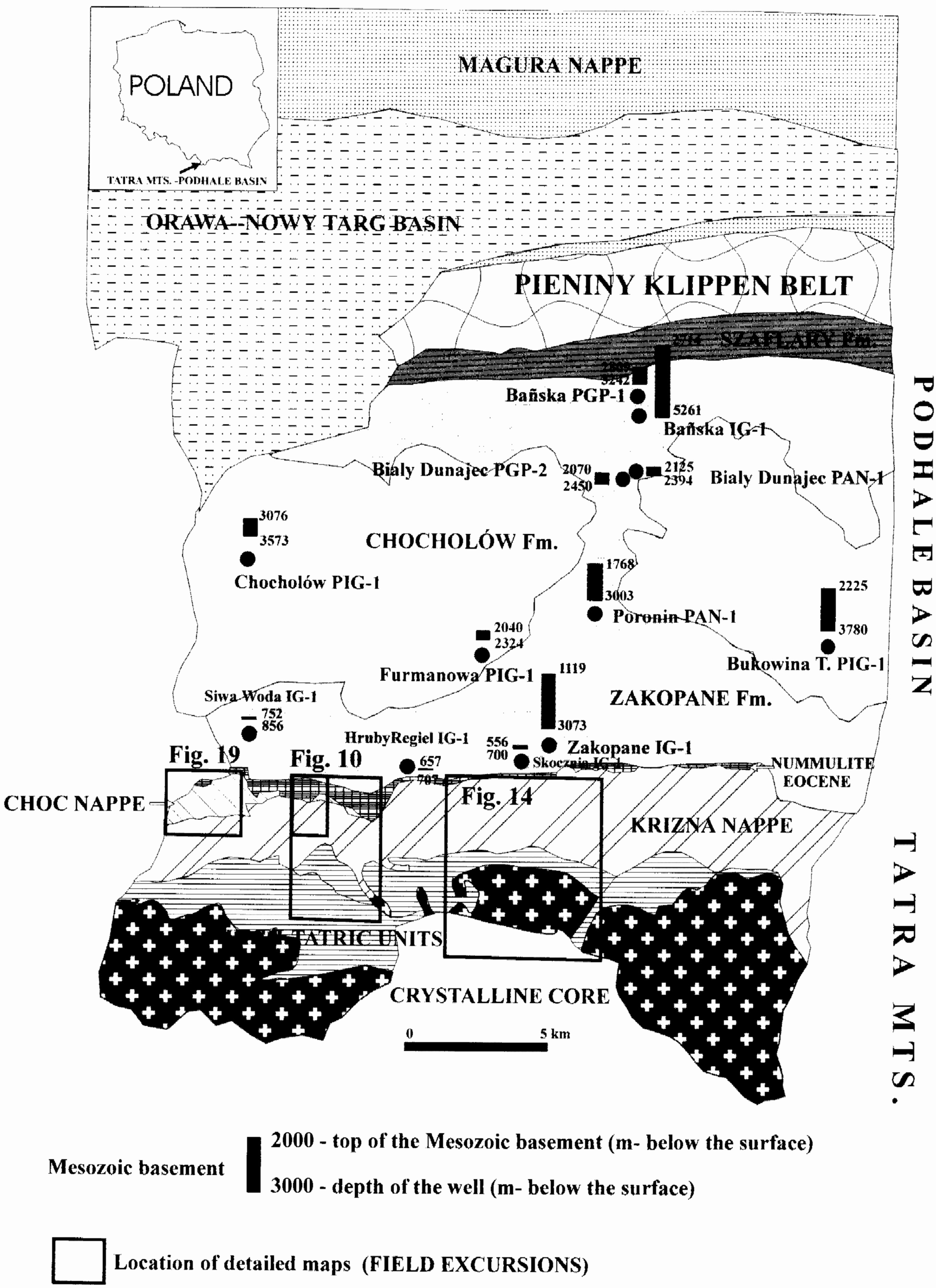


Fig. 2: Simplified geological map of the Tatra Mts.-Podhale region (with location of the detailed maps to the field excursions).

lower parts covered by forests hills, named regle (Fig. 3). Main features of the geological structure of the Tatra Mts. are well visible on a panorama from the Gubalowka Hill (Fig. 4).

Some of the tectonic units, that occur in the Tatra Mts. have been recognised also in the wells reaching the basement of the Palaeogene Podhale basin (Fig. 2). Below the Palaeogene post-overthrust sedimentary cover (middle Eocene-Oligocene-basal conglomerates, 'Nummulite Eocene' and Podhale Flysch, which attain up to 3000 m in thickness - see OLSZEWSKA & WIECZOREK 1998) the Mesozoic units stretch to the North up to the Pieniny Klippen Belt (Fig. 5).

The present structure of the Tatra Mts.-Podhale region is a result of:

- Mesozoic development of the northern margin of Apulia (Adria) (WIECZOREK 1995b, DUMONT, WIECZOREK & BOUILLIN 1996) and southern margin of the European platform
- post-Lower Turonian north directed overthrust of basement and sedimentary nappes at the beginning of the collision between Apulia (Adria) and European plates (PLASIENKA et al. 1997)
- Early-Middle Eocene extension leading to the development of Podhale Palaeogene Basin as a part of Central-Carpathian Paleogene Basin
- Early Miocene oblique collision of the Western Carpathian orogen with the North European platform (PLASIENKA et al. 1997) leading to:
  - shortening and emersion of the Podhale basin
  - Miocene and mainly post-Miocene elevation and exhumation of the Tatra Mts.

The analysis of the Mesozoic successions of Tatricum, Fatricum Hronicum enabled to distinguish: pre-rift, syn-rift, post-rift deposits related to evolution of two branches of the Western Tethys (see Fig. 6): Meliata-Hallstatt (Triassic-Jurassic) and Vahicum (Jurassic-Cretaceous) 'oceans' (MAHEL 1981, DERCOURT et al. 1990, KOZUR 1991, PLASIENKA 1995, PLASIENKA et al. 1997, WIECZOREK 1995b, 1996, DUMONT, WIECZOREK & BOUILLIN, 1996).

Some analogies of the Mesozoic successions of the Tatra Mts. to the Austrian Alps were described by many authors (e.g. UHLIG 1897, KOTANSKI 1965a, HAUSLER, PLASIENKA & POLAK 1993).

The general structure of the Tatra Mts. was studied by L. ZEUSCHNER (ZEJSZNER), R. MURCHISON - the authors of the first geological cross section from Tatra Mts. to the Pieniny Klippen Belt, (1849), by V. UHLIG – the author of geological monography and map of the Tatra Mts. (1897, 1899), M. LUGEON - the first geologist, who introduced the nappe theory to explain the structure of the Tatra Mts. (1903), F. RABOWSKI – the author of maps, numerous papers and monography of the High -Tatric zone (1959), E. PASSENDORFER - the father of geological researches in the Tatra Mts. after the second World War (1978), K. GUZIK – the author of detailed geological maps of the Tatra Mts. 1:10 000, Z. KOTANSKI - the author of numerous papers concerning the Tatra Mts. their structure, stratigraphy and sedimentology (e.g. 1961, 1965a, b, 1973a, b, 1996).

The bibliography of the geological studies in the Tatra Mts. led by Polish, Slovakian and foreign authors consist of some thousand papers.

The geology of the whole Tatra Mts. is presented on 'Geological map of the Tatra Mts.' 1:50.000 (NEMCOK et al. 1994, see also: MELLO & WIECZOREK 1993a, b, NEMCOK, WIECZOREK & ZELMAN 1993).

The geology of the Polish part of the Tatra Mts. is presented on the Geological Map of the Tatra Mts. 1: 30 000 (BAC-MOSZASZWILI et al. 1979).

The geology of the Mesozoic basement of the Podhale basin is studied on the basis of wells and seismic profiles (SOKOLOWSKI 1973, WIECZOREK & BARBACKI 1997, WIECZOREK & OLSZEWSKA 1999, WIECZOREK 1999).

2. An outline of the structure and Mesozoic stratigraphy of the Tatra Mts.

A thick pile of Mesozoic sedimentary rocks is built of several

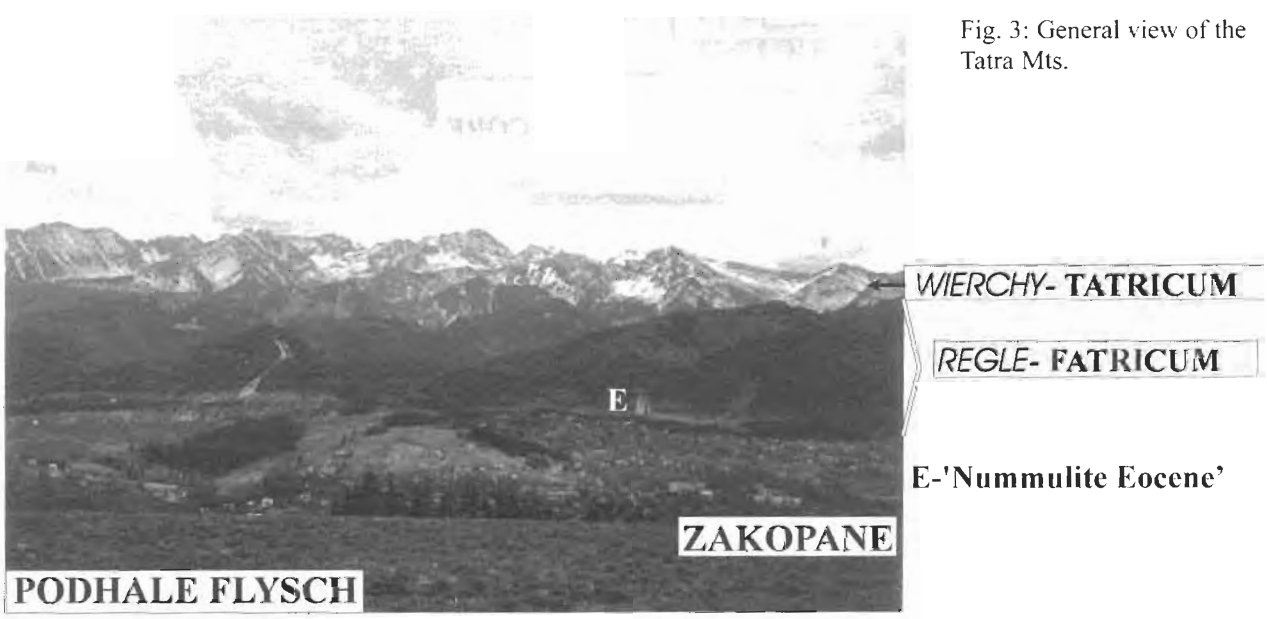


Fig. 3: General view of the Tatra Mts.

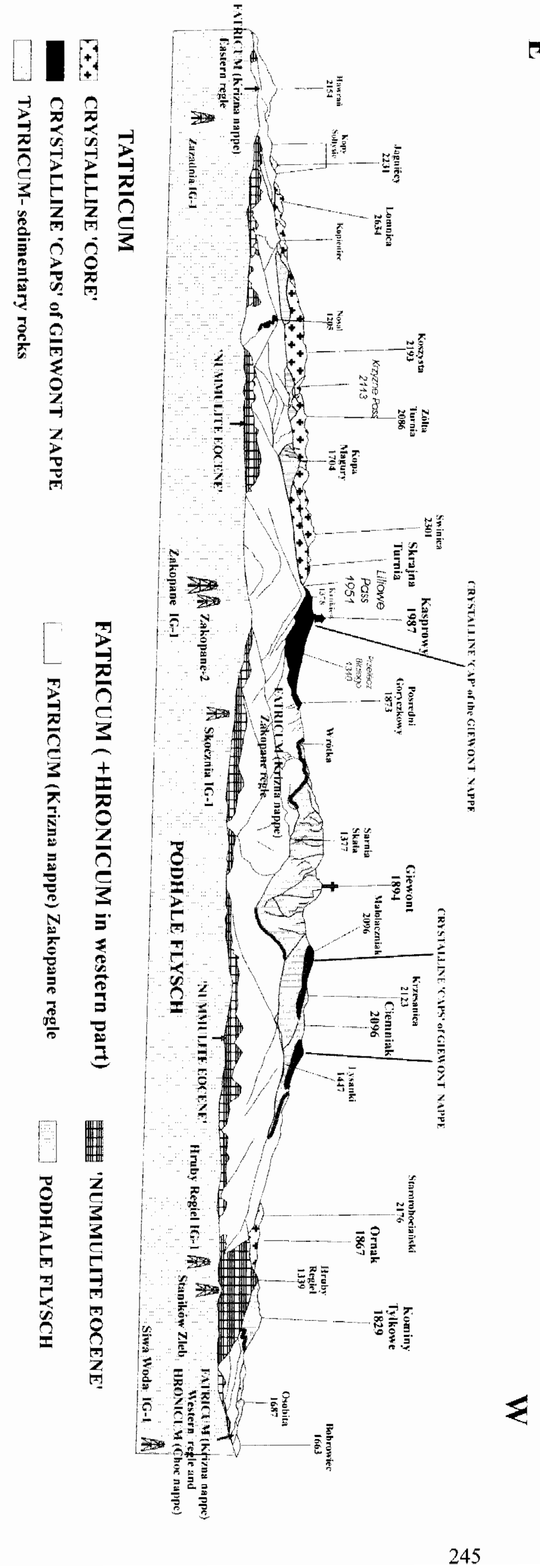


Fig. 4: Geological panorama of the Tatra Mts. from the Gubalowka Hill (after SOKOLOWSKI 1959, modified and completed).

tectonic units (nappes, scales) of different dimensions, generally dipping towards the North. Only locally the Tatricum sedimentary cover is undetached from the Hercynian crystalline massif. Among High-Tatric (Tatricum) units it is possible to distinguish Czerwone Wierchy unit, which is divided in two main elements - Zdziary and Organy (well visible at Koscieliska Valley) and a higher, basement-cover Giewont nappe, well developed in the central part of the Polish Tatra Mts. The crystalline rocks of the Giewont nappe, detached from the crystalline core, lie on sedimentary Mesozoic rocks of 'autochtonous' Tatricum, or on the Czerwone Wierchy unit forming so called crystalline 'caps' (Fig. 2).

The northern reach of Tatricum, below the Paleogene cover, has not been precisely recognised, but it is possible that it stretches up to the Pieniny Klippen Belt.

Tatricum succession is formed by ~ 2000 m thick complex of Triassic to Lower Turonian rocks (Fig. 7). Generally, it is characterised by continental clastic and shalow-marine carbonate complexes. Only Albian-Lower Turonian succession is characterised by deep-water sediments (LEFELD et al. 1985).

'Vermicular' limestones (Anisian), Carpathian Keuper, condensed red limestones with stromatolites (Bathonian), red nodular limestones (Kimmeridgian) and Urgonian limestones (Aptian) form easy to recognise horizons of thick Tatricum succession.

The presence of stratigraphic gaps is also a characteristic feature of this succession.

The Upper Scythian (Campilian) level of "Rauhwacken" formed the best level of detachment during overthrusting movements.

The Krizna nappe (Fatricum, sub-Tatric nappe) is formed by ~ 2000 m thick complex of Triassic to Aptian rocks (Fig. 8), which is divided into numerous tectonic units (partial nappes, scales - BAC-MOSZASZWILI 1998).

Usually the Campilian and Carpathian Keuper horizones formed detachment horizons. In the western part of the Tatra Mts. is recognise Bobrowiec unit (partial nappe) built of Middle Triassic-Lower Cretaceous rocks and divided on two scales.

On the Uplaz Mietusi numerous scales built mainly of Triassic rocks are recognised (see KOTANSKI 1965b). Some units, however, are built also from Jurassic-Lower Cretaceous rocks (e.g. Gladkie Uplazianskie unit).

The central part of the Fatricum zone (Zakopane regle) bet-ween the Mietusia Valley and Sucha Woda Valley is built of numerous scales comprising Middle-Upper Triassic, and sporadically, also Lower Triassic and Lowermost Jurassic rocks (see Fig. 14 and GUZIK & KOTANSKI 1963).

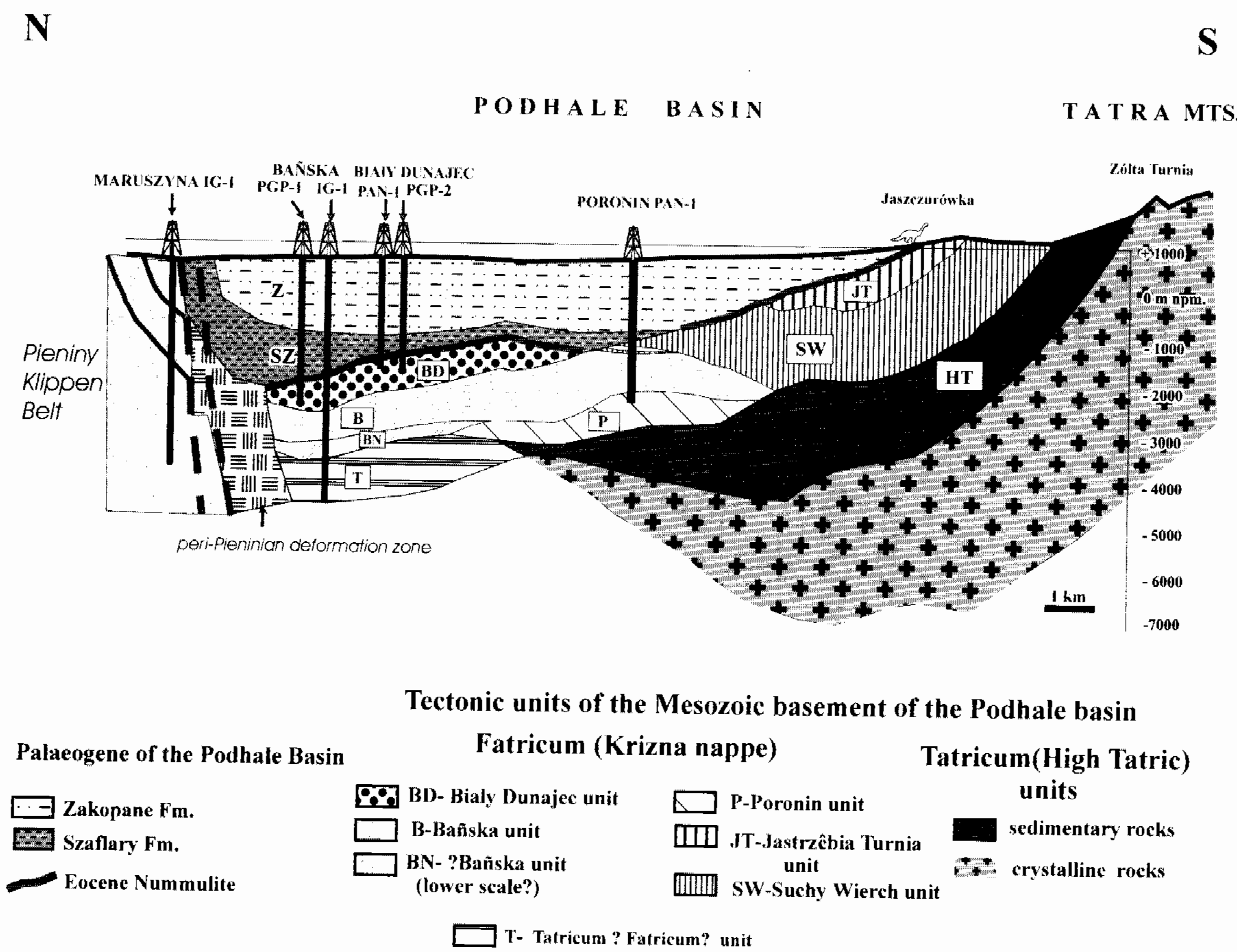


Fig. 5: Simplified geological cross-section from the Tatra Mts. to the Pieniny Klippen Belt (after WIECZOREK & BARBACKI 1997, modified and completed).

The Eastern part of the Fatricum zone is built of some units with well-developed Jurassic-Lower Cretaceous succession (Kopy Solysie and Havran units) (LEFELD et al. 1985).
The Mesozoic rocks belonging to the Krizna nappe were recognised also in the wells which are situated in the Podhale, north of the Tatra Mts. (WIECZOREK & OLSZEWSKA 1998).

Characteristic features of the Fatricum succession is the presence of:

- mainly dolomitic complexes of Anisian and Ladinian
- Carpathian Keuper
- organodetritic Rhaetian limestones
- marly-to-siliclastic rocks of Lowermost Jurassic
- Fleckenmergel complex (Lotharingian, locally to Bajocian)
- radiolarites and red nodular marly limestones (Middle-to-Upper Jurassic)
- maiolica (biancone) (Tithonian-Berriasian)
- grey marls with intercalations of siliclastic turbidites and of Muran (allodapic) limestones (Valanginian-?Aptian).

Generally deep-water basinal sediments prevail in Jurassic-Lower Cretaceous part of this succession.
Hronicum succession (Choc nappe) is formed by ~ 1000-?1500 m thick, mainly carbonate complex of the Middle Triassic to Lower Jurassic rocks (Fig. 9).
It differ evidently from the Tatricum and Fatricum successions by the lack of Carpathian Keuper and the presence of characteristic Wetterstein dolomites in the Triassic profile, as well as, by the lack of Fleckenmergel complex and the presence of thick complex of poorly bedded organodetritic and peloid limestones of Sinemurian-Pliensbachian age.
Siliciclastic sediments of Lowermost Jurassic, belonging probably to the Hronicum succession, occur only sporadically (Lejowa Valley).
The Choc nappe occurs only in the northern parts of the Chocholowska, the Lejowa and the Koscieliska valleys (Fig. 9).
In the Chocholowska Valley, Furkaska-Koryciska tectonic unit built of Ramsau dolomite, Reifling-Partnach beds and thick Wetterstein dolomite complex is recognised. It covers the lower-Siwa Woda Unit which is composed of younger rocks - Haupdolomite complex covered by some meters thick Rhaetian limestones.
Some scales composed of Lower Jurassic carbonate rocks are recognised around the Koscieliska Valley. The Mesozoic rocks belonging to the Choc nappe were recognised also in the shallow wells situated on the foot of the western part of the Tatra Mts.

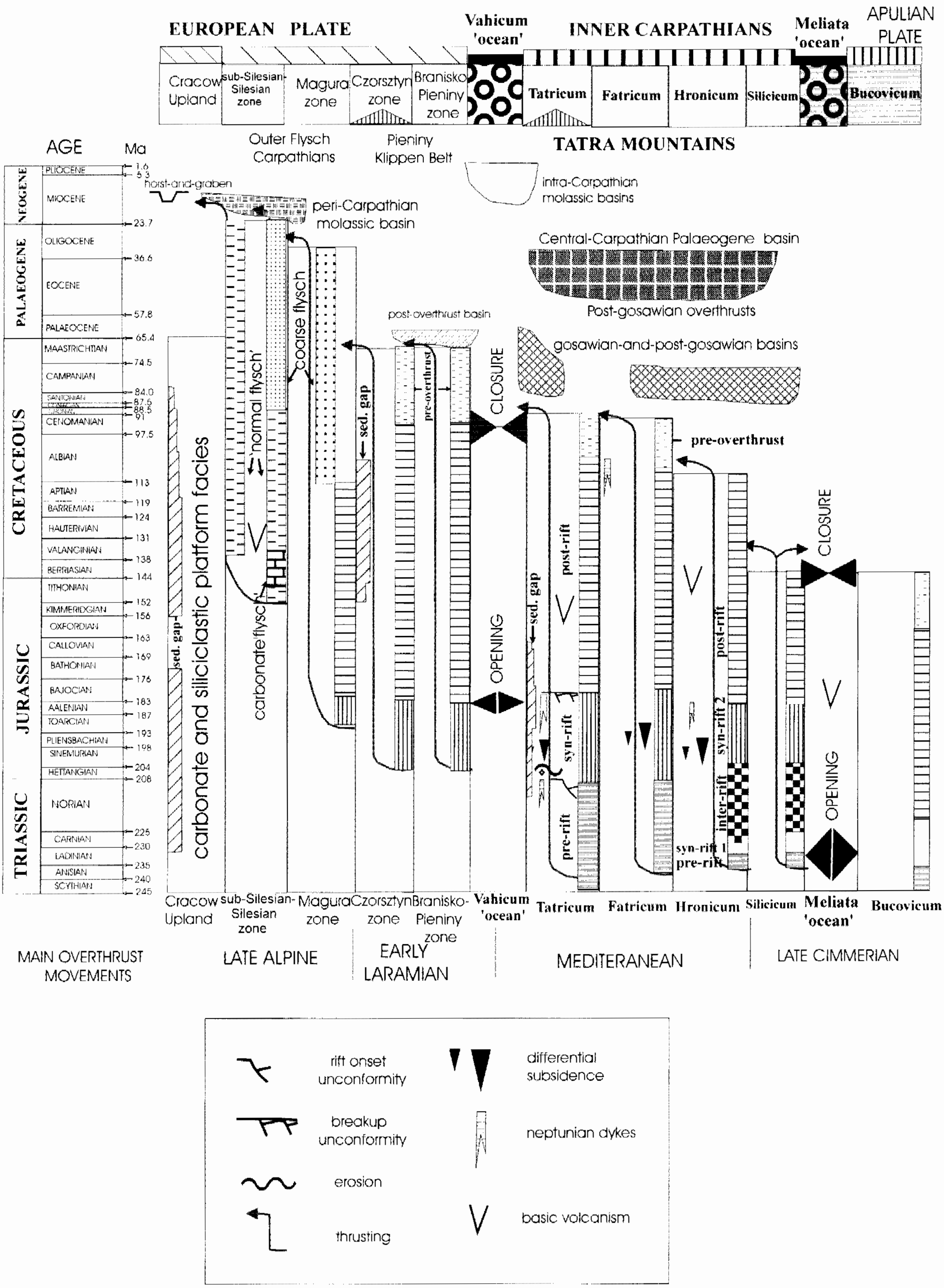
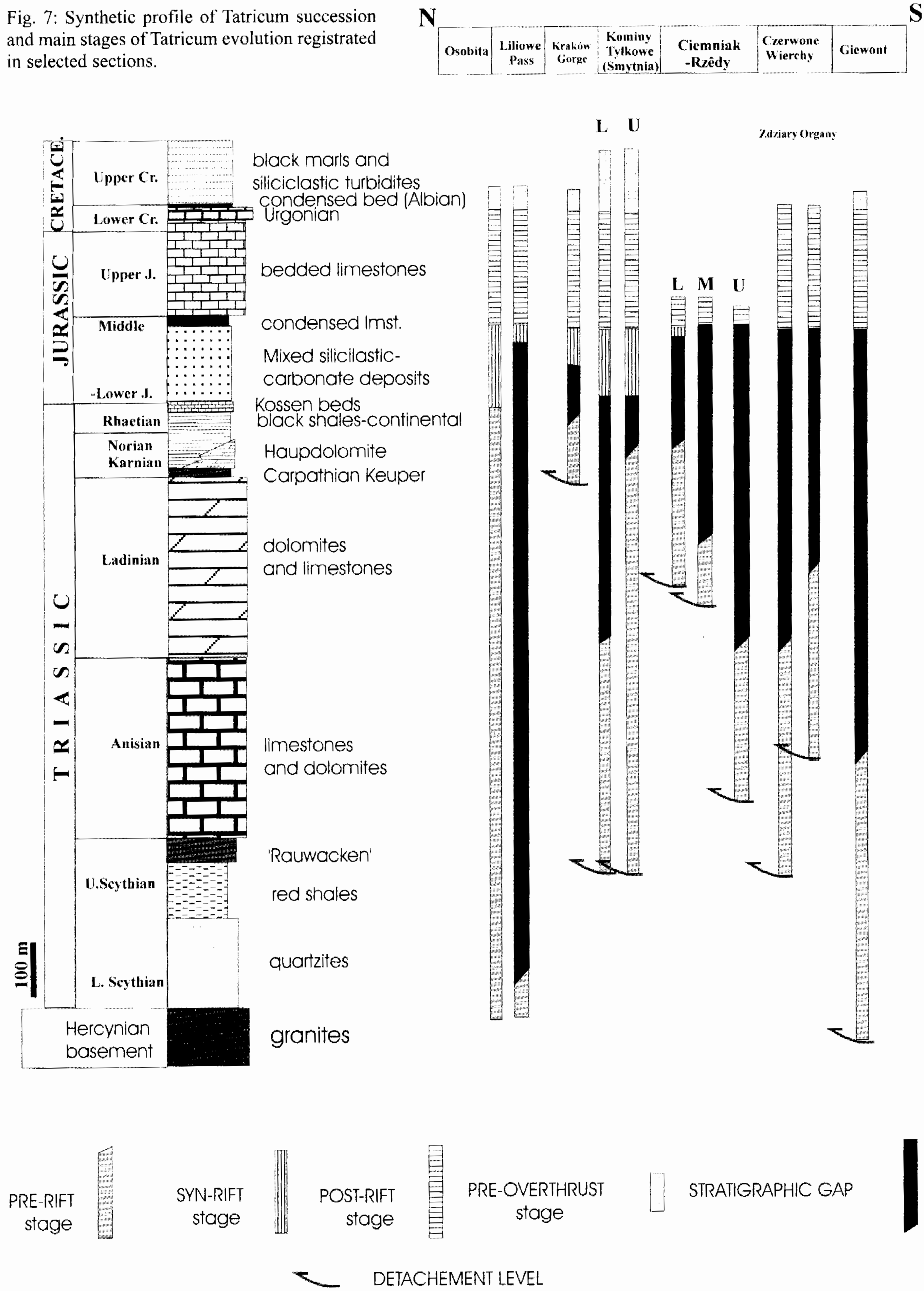


Fig. 6: Main events of the Carpathians evolution

Fig. 7: Synthetic profile of Tatricum succession and main stages of Tatricum evolution registrated in selected sections.



3. Mesozoic stages of the Tatra Mts. evolution

Each nappe system recognised in the Tatra Mts. represents a different segment of continental margin in Mesozoic paleogeography (Fig. 6).
In Triassic-Jurassic times Tatricum-Fatricum-Hronicum paleogeographic domains, which belonged to the distal margin of European plate, were bordered to the south by the oceanic Meliata-Hallstatt domain (Kozur 1991, Haas et al. 1995). From Middle Jurassic these domains were separated from the European margin by a new Tethyan branch called Vahicum (Mahel 1981, Plašienka 1995) situated between Tatricum domain and the Pieniny Klippen Belt domains.
The analysis of Mesozoic successions of the Tatra Mts. enabled to distinguish some principal stages of their evolution.

Triassic stage (Pre-rift stage in Tatricum-Fatricum domain, pre-rift, syn-rift, inter-rift stages in Hronicum domain)

In Tatricum-Fatricum domains, the deposition of relatively thin (about 100-150 m) series of siliciclastic (coarse-grained in the lower part, fine-grained in the upper part) continental deposits of Lower Scythian age was followed by development of an extensive carbonate platform reaching almost 1000 m in thickness, and persisting from Campilian to Late Ladinian. Demise of this platform was due to siliciclastic input as evidenced by Carpathian Keuper and Norian-Rhatian truly continental Tomanowa Fm.
In Hronicum domain (Furkaska-Koryciska unit in the Tatra Mts.), which belonged to a very distal part of European margin, the Early Anisian growth of carbonate platform was interrupted by a basinal sedimentation episode (Middle-Late Anisian). Development of intracratonic basin is documented by the presence of Reifling limestones, intercalations of marls (Partnach Beds) and slumpes. This event was probably related to the opening of Meliata domain.
The Ladinian Wetterstein carbonate platform prograding over basinal sediments documents the return to shallow-water sedimentation.

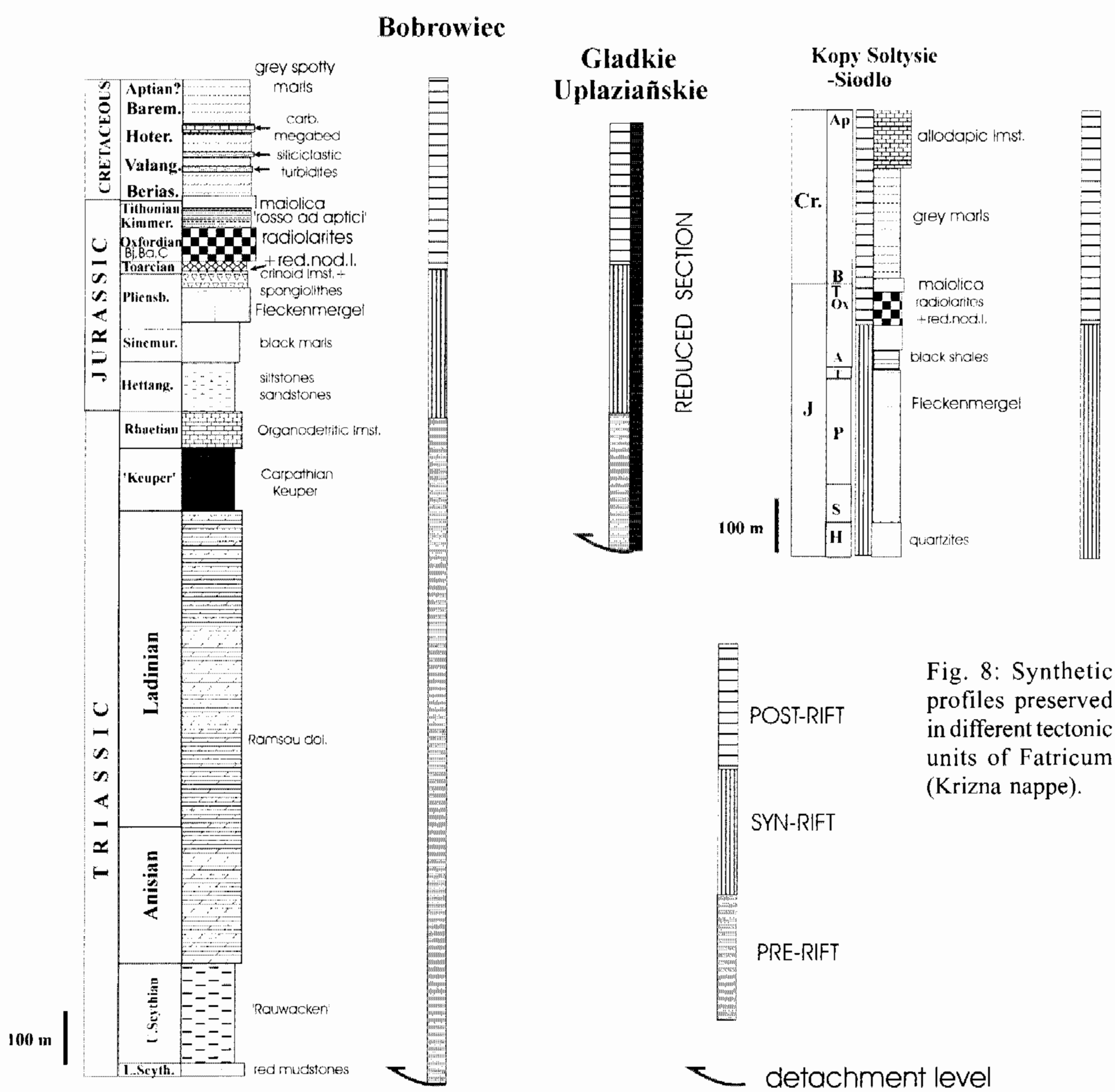


Fig. 8: Synthetic profiles preserved in different tectonic units of Fatricum (Krizna nappe).

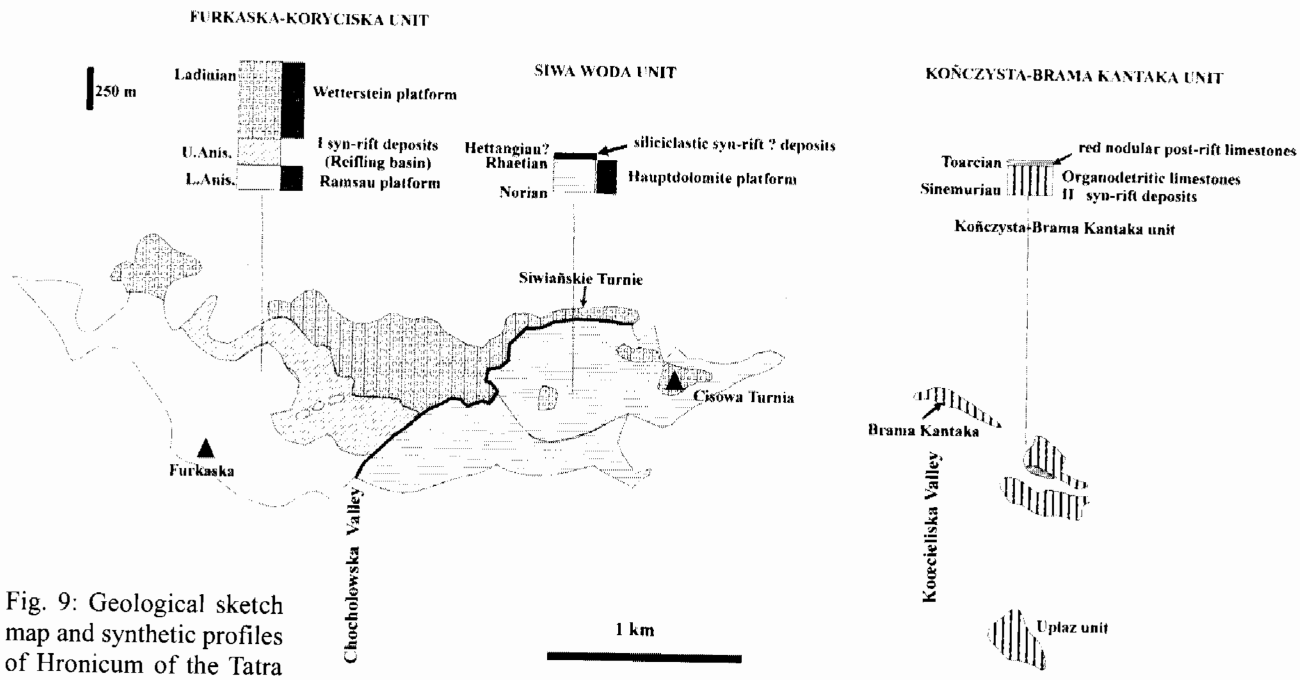


Fig. 9: Geological sketch map and synthetic profiles of Hronicum of the Tatra Mts.

Early –Middle Jurassic syn-rift stage

The abrupt changes in facies of the Jurassic formations across Tatricum-Fatricum-Hronicum domains are interpreted as related to rifting processes which preceded the opening of Vahicum domain.

In Tatricum domain an Early Jurassic erosional surface, which in the Smytnia Valley truncate (from West to East) the Norian dolomites, Carpathian Keuper, Ladinian and also Upper Anisian rocks, is interpreted as rift-onset unconformity (DUMONT, WIECZOREK & BOUILLIN 1996).

During Early-Middle Jurassic time, the Tatricum domain underwent a period of tectonically controlled subsidence combined with local uplift. It is manifested by:

- prominent thickness variations (0-500 m) of the mixed siliciclastic-carbonate deposits
- stratigraphic gaps, which span different periods
- local deposition of lithologically variable sediments, with differences in clastic input
- the periodical supply of crinoids and spiculits as well as bored Triassic pebbles

Some parts of the Tatricum zone (sedimentary area of Giewont and Czerwone Wierchy unit) probably remained emerged till Bajocian-Bathonian times. The erosion reached down the Lower Anisian. This situation is typical for rift shoulders during the syn-rift stage of the passive-margin evolution.

The effects of the rifting processes of Early Jurassic age can be detected also in Fatricum domain of generally basinal development in Jurassic-Cretaceous.

The early Jurassic (Hettangian) influx of terrigenous sediments probably reflects the beginning of syn-rift sedimentation. The overlying Fleckenmergel facies, widespread in Western Carpathians and Eastern Alps, is regarded as rift-related (EBERLI 1987). The spotty marls complex in the eastern part of the Tatra Mts. is about 400 m thick and Late Sinemurian-Early Bajocian in age (LEFELD et al. 1985). The periodical supply of crinoids and spiculits is documented by the intercalations of encrinites and spongiolites.

Chondrites-Zoophycos-Planolites trace fossil assemblages (WIECZOREK 1995a) witness the early phase of the deepening of Fatricum basin.

In the western part of the Tatra Mts. this complex dated as Sinemurian-Early Pliensbachian is reduced to some tens of meters. It is followed by spongiolites, encrinites (locally manganiferous) and by red nodular limestones.

These lateral and vertical changes could be related to block tilting during Domerian-Toarcian times.

In Hronicum domain, the stratigraphic record is very incompletete, but Early Jurassic rift-related pattern of deposition is suggested by the presence of highly variable sediments: crinoid limestones, organogenic limestones, peloid limestones and spongiolites.

The biomicritic red nodular limestones which cover these sediments and fill the neptunian dykes (UCHMAN 1988) could be interpreted as a mark of post-rift stage, that began in this domain probably earlier than in Tatricum-Fatricum one.

Middle Jurassic-Early Cretaceous post-rift stage

An important change in Mesozoic evolution of Tatricum and Fatricum domain tooke place in the Middle Jurassic. In Tatricum domain the Bajocian-to-Callovian beds can be regarded as early post-rift sediments as indicated by:

- the presence of condensed horizons and local angular unconformites observed at their base (breakup unconformity)
- their widespread distribution in relation to syn-rift deposits
- their deep-water characteristics

In Tatricum domain, the onset of subsidence is testified by

the succession of crinoid (Bajocian-Bathonian) to biomicritic (Bathonian to Callovian) condensed sediments covering the substratum with local angular unconformity. Neptunian dykes accompanied the drowning of Tatricum domain, which become a submarine plateau during Late Jurassic. This event could be related to the epening of Vahicum domain - a possible prolongation of Ligurian ocean.
A local Tithonian-Berriasian volcanic activity in Tatricum domain (Osobita, Bobrowiecka Valley) seems to be a response to a new rifting event recorded in the Outer Carpathians (Silesian Basin). The shallowing of Tatricum domain in Early Cretaceous led to the development of a new shallow-water carbonate platform (Urgonian platform).
In Fatricum domain, the onset of prolonged subsidence marked by Late Bathonian - Kimmeridgian radiolaritic sedimentation (Polak, Ondrejcikova & Wieczorek 1998) locally separated by red nodular marly limestones (?Callovian) and followed by 'rosso ad aptici' facies (Lower Tithonian), maiolica facies (Upper Tithonian-Berriasian), spotty marls (Lower Cretaceous) witnesses the deepening of Fatricum domain, where the sedimentation was controlled mainly by oceanographic factors (Wieczorek 1988, 1996).
The input of siliciclastic and bioclastic material recorded by ?Barremian -?Aptian turbidites followed by the appearance of Aptian olistholites (Lefeld 1974) evidences the beginning of compression preceding the nappe emplacement.

Albian-Turonian pre-overthrust stage

This interval is recorded only in Tatricum succession and it is characterised by the presence of:

- Albian condensed sediments (glauconitic limestones with phosphatic stromatolites), which cover the Urgonian limestones and fill neptunian dykes
- Cenomanian black marls
- Lower Turonian grey marls with intercalations of silicilastic turbidites (Krajewski 1984, Olszewska & Wieczorek 1995).

The collapse of the Urgonian platform and the deepening of the Tatricum domain preceded post- Early Turonian overthrusting movements related to the early phase of collision with European plate and the beginning of Vahicum domain subduction (Plasienka et al. 1997).

4. Field excursions

4.1. Field excursion: Koscieliska Valley. Main theme: Mesozoic of Tatricum (High-Tatric)

along with some outcrops of Fatricum (Krizna nappe) and Hronicum (Choc nappe) (Fig. 10)

Koscieliska Valley is a unique valley in the Tatra Mts., where without climbing, during 1 hour's walk, it is possible to cross 3 main tectono-paleographical zones of the Inner Carpathians – Hronicum, Fatricum and Tatricum (Fig. 11). Moreover, just at the entrance to the valley, Eocene nummulite limestones crop out. Together with underlying conglomerates they lie discordantly on the empiled Mesozoic units.

Stop 1 - Brama Kantaka

Choc nappe (Hronicum) – the highest nappe in the Koscieliska Valley

White and red crinoid limestones of the Lower Jurassic (Sinemurian-Pliensbachian) built the crags on both side of the valley (Grabowski 1967). Other Choc crags are visible above, on the eastern slope of the Koscieliska Valley. They are built by laterally variable carbonate deposits (white and red crinoid limestones, organodetritic limestones, peloid limestones, spongiolites), which could be interpreted as a syn-rift deposits (Fig. 9). They cover the Lower Cretaceous deposits of the Krizna nappe (Bobrowiec unit) cropping out in the scarps and gullies along Koscieliska Valley.

During the walk along the valley we cross poorly exposed Kri•na nappe, which overthrust the Czerwone Wierchy (Tatricum) unit. The contact of these units can be seen at the gully, not far from the next narrowing of the valley called Brama Kraszewskiego.

Stop 2 - Brama Kraszewskiego

Jurassic of the Czerwone Wierchy (Tatricum) unit

Bajocian white crinoid limestones, which lie directly on Anisian limestones with a large stratigraphic gap, are covered by pinkish and grey pelagic limestones of Callovian-Oxfordian age and by red nodular limestones of Kimmeridgian age.
Bathonian condensed red limestones, which are regarded as the first post-rift sediments, crop out on the Koscieliska slope, but they are not present in the Brama Kraszewskiego profile.
Along Koscieliska valley in the distance of some hundreds meters, we cross thick layered, grey limestones. Diplopora-fauna and macrofossils show the Anisian age of this profile (Kotanski 1961). Some layers represent so called vermicular limestones.
Campilian (Upper Scythian) marly shales are the oldest Triassic sediments preserved only locally at the base of this unit. They form a detachement level of the Czerwone Wierchy unit which thrust over parautochthonous Cretaceous deposits.

Stop 3 - Pisana Alp

In panorama to the north-east and to the north-west the trust plane of the Czerwone Wierchy unit is well visible (Triassic carbonate rocks lie upon Cretaceous marls).
On the eastern side we can see two elements of Czerwone Wierchy units, dissected by sub-vertical fault: Organy element and Zdziary element (Fig. 12).
Pisana alp is built by Cenomanian-Lower Turonian marls with intercalations of siliciclastic turbidites. Small outcrops are visible just along the valley, but a much better profile is

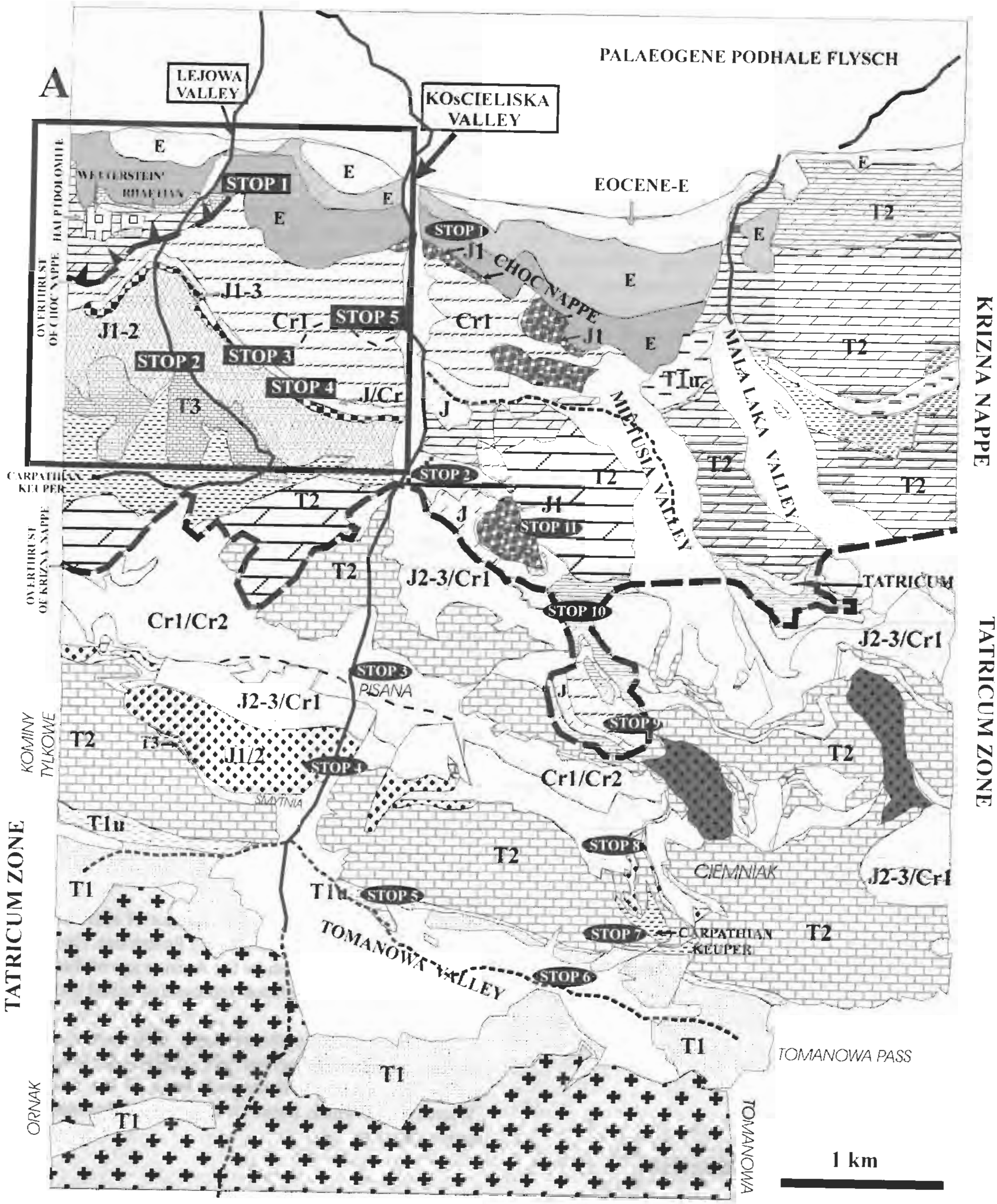


Fig. 10: Geological excursions to the Koscieliska Valley and (A) to the Lejowa Valley (geological map based on BAC-MOSZASZWILI et al. 1979, NEMCOK et al. 1994, modified).

visible in the Zelezniak gully. At the base of this deep-water sequence a some centimeters thick condensed layer of Albian age is visible (KRAJEWSKI 1984). Grey-green glauconitic limestones contain phosphoclasts and stromatolitic structures and are rich in macrofossils (ammonites- Mortoniceras, Desmoceras, Douvilleiceras) and microfossils (hedbergellids).

Urgonian reef-slope limestones, which underlie these deep-water deposits, built white crags above the Pisana alp.

Description of the route

We can observe along the valley the older Lower Cretaceous

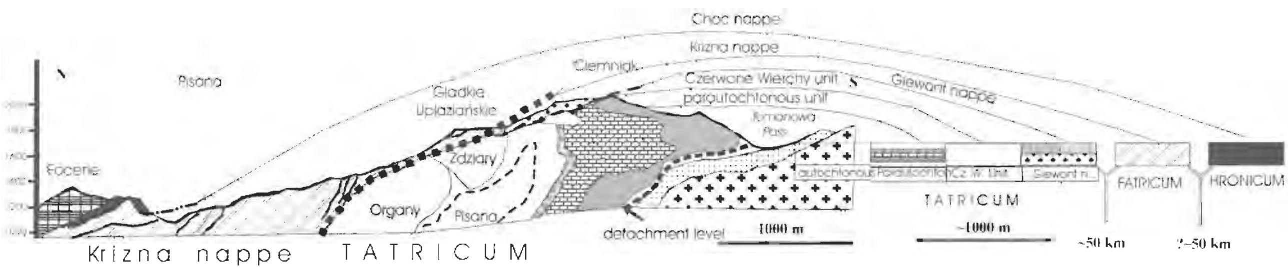


Fig. 11: Arrangement of tectonic units along the Koscieliska Valley (based on BAC-MOSZASZWILI et al. 1983, modified) and their approximate palinspastic position.

(layered shallow-water limestones) and Jurassic deposits. The high wall of Raptawica crag is built of the poorly layered Upper Jurassic white limestones, with intercalation of 2-3 m thick layer of red-nodular limestones (rosso ammonitico). At the foot of this wall a red band is visible. These Bathonian condensed red limestones with Fe-crust and locally with stromatolites mark the beginning of post-rift history of Tatricum domain. Below this layer there occurs ~ 400 m thick complex of mixed silicilastic-carbonate sediments, which contains small bored Triassic pebbles. The periodical supply of these pebbles indicates the eroded areas elevated due to uplift and differential subsidence. This complex laterally and vertically variable, with different stratigraphic gaps at its base could be interpreted as syn-rift deposits. Sandy-crinoid limestones dominate at the top. The sandstones, which occur in the middle part of the complex show cross-bedding. Spiriferina-bearing limestones, which enable the dating of the lower part of this complex as Sinemurian, could be easily found in the rubbble in the forest, at the foot of the lowest cliffs.

Stop 4 - Smytnia Valley

In the Smytnia Valley- western tributory of the Koscieliska Valley, we can observe (Fig. 13) an erosional surface truncating (from West to East) the Norian dolomites, Carpathian Keuper, Ladinian and also Upper Anisian rocks. Due to erosion, the thickness of Middle Triassic series gets from about 700 m on the Kominy Tylkowe crest to ~ 100 m in the Smytnianskie Turnie. This surface is interpreted as rift-onset unconformity.

The uneven, interpreted as a fossil cliff (RADWANSKI 1959), top of Norian dolomites is cut by a network of neptunian dykes filled by sandy Lower Jurassic. This is a witness of the extension at the beginning of the Jurassic.

Another network of neptunian dykes, filled by pinkish pelagic limestones of Bathonian age occurs at the base of this Lower-Midddle Jurassic complex. This is a witness of extensional movements at the beginning of post-rift stage.

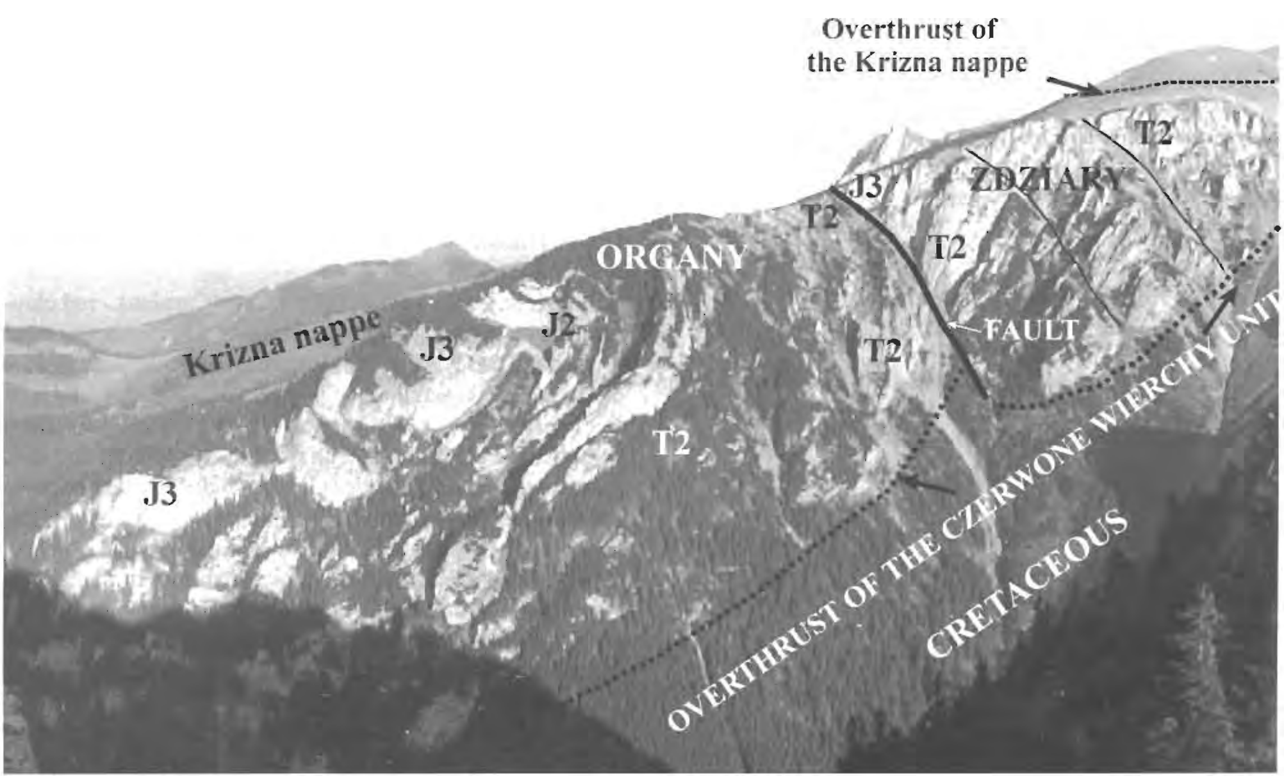


Fig. 12: General view on the overthrust of the Czerwone Wierchy unit (Tatricum) - eastern slope of the Koscieliska Valley.

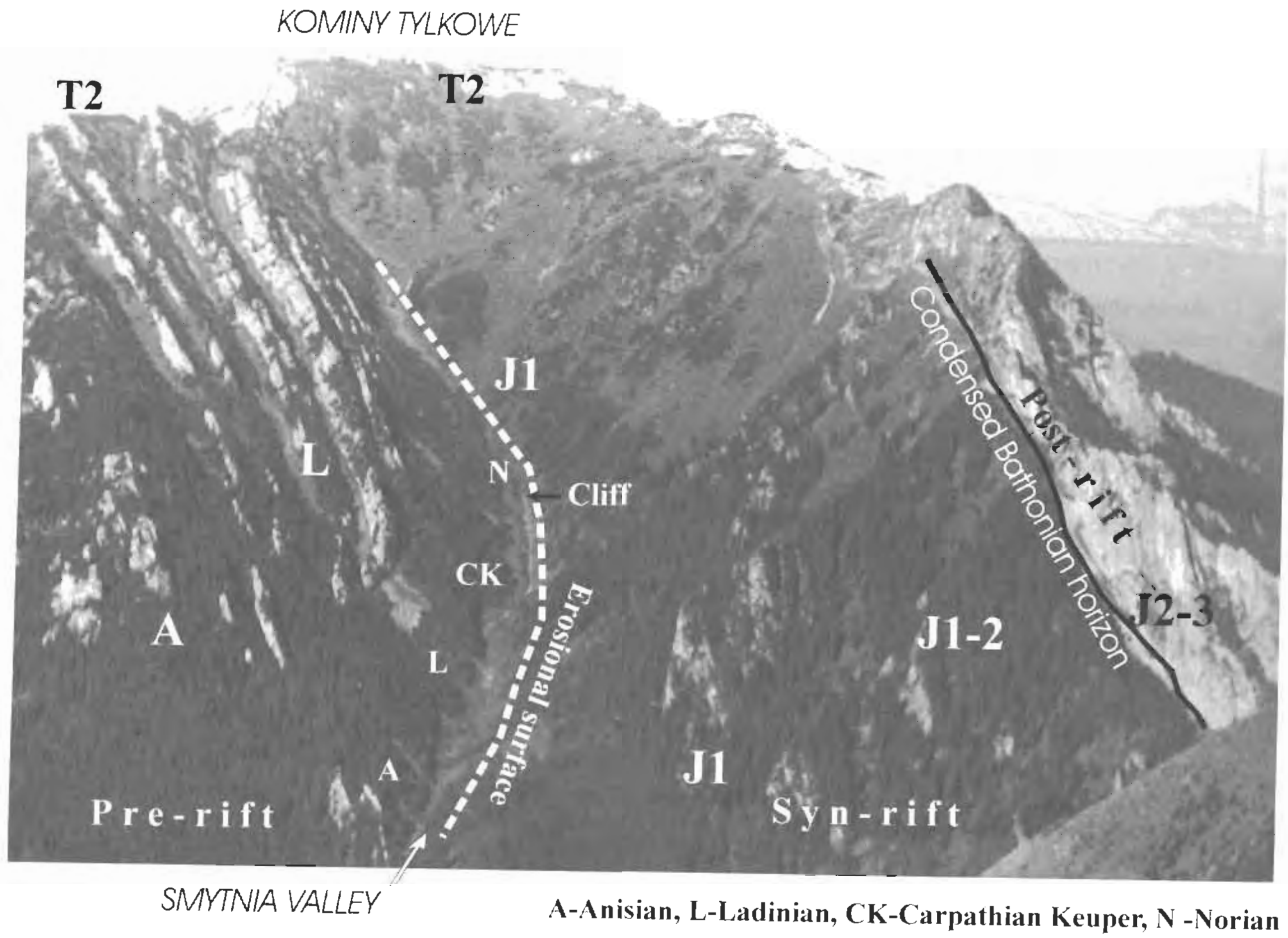


Fig. 13: Geological view on the Kominy Tylkowe massif (Smytnia Valley).

Stop. 5 - Tomanowa Valley
Triassic of Tatricum

In the Tomanowa Valley we observe Lower Triassic (Werfenian) pinkish quartzites, Campilian 'Rauhwacken', and Anisian carbonates detached from Lower Triassic sedimentary cover of Hercynian granitic massif.

Stop 6 - Tomanova Valley
Panorama of Tatricum

In a higher part of the Tomanowa Valley we observe, to the west, a panorama of Tatricum zone between the Ornak Massif and the Kominy Tylkowe Massif. Ornak is a crystalline massif, whose northern slope is covered by Lower Triassic quartzites. They occur also, as isolated 'island', in tectonic graben, on the Ornak ridge. Iwaniacka Pass (between Ornak and Kominy Tylkowe) is prepared in clayey sequence of Upper Scythian (red clays and Rhauwacken), which served as a detachment level during Alpine thrust movements. The best profile of the Triassic of Tatricum in the Tatra Mts.crops out on the slopes and on the ridge of the Kominy Tylkowe massif (PIOTROWSKI 1965).
To the east direction we observe a panorama of Tatricum zone between Tomanowa peak (Hercynian crystalline massif covered by Lower Triassic quartzites), Tomanowa Pass (Lower Triassic), Stoly (which form recumbed syncline of Middle Triassic carbonates much better seen from Liliowe Pass – Fig. 18) and Rzedy below Ciemniak (three scales composed of Triassic and Jurassic rocks with different stratigraphic gaps).

Stop 7 - Czerwone Zlebki
Upper Triassic of Tatricum

We observe Carpathian Keuper facies (Carnian) - red clay-stones with intercalations of sandstones. This is a continental to lagoonal facies typical for Tatricum and Fatricum domains of the Inner Carpathians. In this profile Carpathian Keuper is covered by Tomanowa Formation (Norian-Rhaetian) composed of black shales with sideritic concretions and with intercalation of sandstones. Black shales contain famous macroflora (E-quisetum, Schizoneura, Clathropteris, Pecopteris, Palyssia and others) described by RACIBORSKI (1890). On the Slova-kian side of this massif in Tomanawa Formation footprints of reptiles (Coelurosaurichnus tatricus MICHALIK, PLANDEROVA & SYKORA 1976) were found, which proved the terrestrial, locally swamp environment of their deposition.
Above we can see crags built by Triassic and Jurassic rocks, which form three overturned scales. Siliclastic rocks ('Lias-sic") occur only in the lowest scale, in the higher scales - Bajocian encrinites and Bathonian condensed bed with

stromatolites rest directly on Ladinian dolomites, locally with angular unconformity (Kotanski 1961). The neptunian dykes filled with Middle Jurassic material (pinkish encrinites or/and red biomicrites) occur frequently in the Triassic, or rarely in 'Liassic" host rocks.

Stop. 8 Panorama of Tatricum zone

A very characteristic point named Zab (tooth) is built by siliciclastic rocks (Tomanowa Fm. and 'Liassic") in inverted position.

In panorama we can see the upper part of Krakow gorge: layered Middle Triassic limestones covered by Carpathian Keuper, Tomanowa Fm. and "Liassic" siliclastic rocks. The condensed Middle Jurassic limestones with stromatolites excellently show inverted position of the complex. The opposite (northern) side of the Krakow gorge is built of Upper Jurassic-Lower Cretaceous limestones. The white organogenic and organodetritic limestones, which built Wysoka Turnia and the other crags above Krakow gorge belong to Urgonian (Masse & Uchman 1997).
Cenomanian-Lower Turonian marls, which form topographic depressions, will be seen below the overthrust of the Krizna nappe (Gladkie Uplazianskie scale).
Traversing a slope of the Ciemniak massif we cross the crystalline 'cap' of the Giewont nappe and Triassic limestones and dolomites (Chuda Turnia crag), probably detached from their basement.

Stop 9 - Gladkie Uplazianskie
Jurassic of Fatricum (Krizna nappe)

Small tectonic scale is built of Triassic-Lower Cretaceous rocks belonging to Fatricum (Krizna) nappe system. The Triassic sequence, which is only partly preserved, formed a detachment horizon. The thinned profile of Jurassic and Lower Cretaceous rocks is composed of: Lower Jurassic sandstones, Lotharingian spotty limestones and marls (Fleckenmergel facies)
Domerian spongiolites, Toarcian crinoid limestones and red limestones with Fe-concretions, Bajocian? - Kimmeridgian radiolarites with numerous radiolarian fauna (Polak, Ondrejicikova & Wieczorek 1998), red nodular limestones, grey, locally pinkish marls, Maiolica (Biancone) white limestones, grey marls without intercalations of siliciclastic turbidites or allodapic limestones. It contrasts (Fig. 8) evidently in thickness and also in lithology with other Fatricum profiles (Bobrowiec unit, Kopy Soltysie unit).
Generally the Gladkie Uplazianskie profile from Bathonian to Early Cretaceous is a deep-water sequence of a starved basin.

Description of the route

We traverse Gladkie Uplazianskie slope observing a profile which is covered with Middle Triassic dolomites of a higher Krizna scale (Gladkie scale) Going down along the slope we cross another Krizna scales built mainly by Triassic dolomites (rarely by Carpathian Keuper).

Stop 10 - Piec

From a crag called Piec, built of Middle Triassic dolomites (Krizna nappe, Piec scale), we can see an instructive panorama of Czerwone Wierchy (High Tatric) zone in surrounding of the Mietusia Valley. The overthrust of Krizna nappe is well visible, however one of High-Tatric scales (Niedzwiedz scale built of Upper Jurassic-Lower Cretaceous white limestones) is situated in unusual position, between two Krizna units.
In the further plane we can see Giewont nappe overthrust by other Krizna scales.

Stop 11 - Uplaz Alp
Jurassic of Hronicum (Choc nappe)

Near the shelter we can see Lower Jurassic spongiolites of Krizna nappe. Different in lithology blocks cover the alp. These are crinoid limestones, full of brachipods, resembling Hierlatz facies. In some blocks fragments of neptunian dykes (yellowish or pinkich pelagic limestones) can be seen. These blocks belong to an isolated scale of the Choc nappe.
Other scales of the Choc nappe occur above Mietusia Valley (white crags) and are built of variable limestone facies of Lower Jurassic age, different from coeval facies of Krizna nappe.
Going down to the Koscieliska Valley we cross Lower Cretaceous and Jurassic rocks of Krizna scales.

4.2. Field excursion: Liliowe Pass
In memory of an excursion of IX International Geological Congress, Wien, 1903 (Fig. 14)

From Kuznice situated in the Krizna nappe zone (Fig. 14) we go by a cable car to Kasprowy Wierch (1987 m a.s.l.).

From a cable car, on the right, we can see the overthrust of the Krizna nappe (Suchy Wierch unit) on the Giewont nappe (High Tatric, Tatricum). We change the cable car at Myslenickie Turnie station situated on Mesozoic cliff built of Giewont nappe rocks (Middle Triassic).
On the right we observe (Fig. 15) the Giewont nappe - its crystalline basement and Mesozoic sedimentary cover (Triassic – Scythian-Lower Anisian and Middle-Upper Jurassic) well visible on the southern side of the Giewont massif.

On the left we can see (Fig. 16) Zawrat Kasprowy (Giewont nappe) - Upper Jurassic white cliff with Bajocian-Bathonian condensed sequence at its foot. They cover directly Anisian limestones and dolomites.
Kasprowy Wierch is built of Hercynian crystalline rocks that form a crystalline 'island' lying upon Mesozoic sedimentary rocks of autochtonous Tatricum (Fig. 17).

Fig. 14: Geological excursion to the Liliowe Pass (geological map based on BAC-MOSZASZWILI et al. 1979, NEMCOK et al. 1994, modified).

Fig. 15: General view on the southern side of the Giewont massif (Giewont nappe, Tatricum).

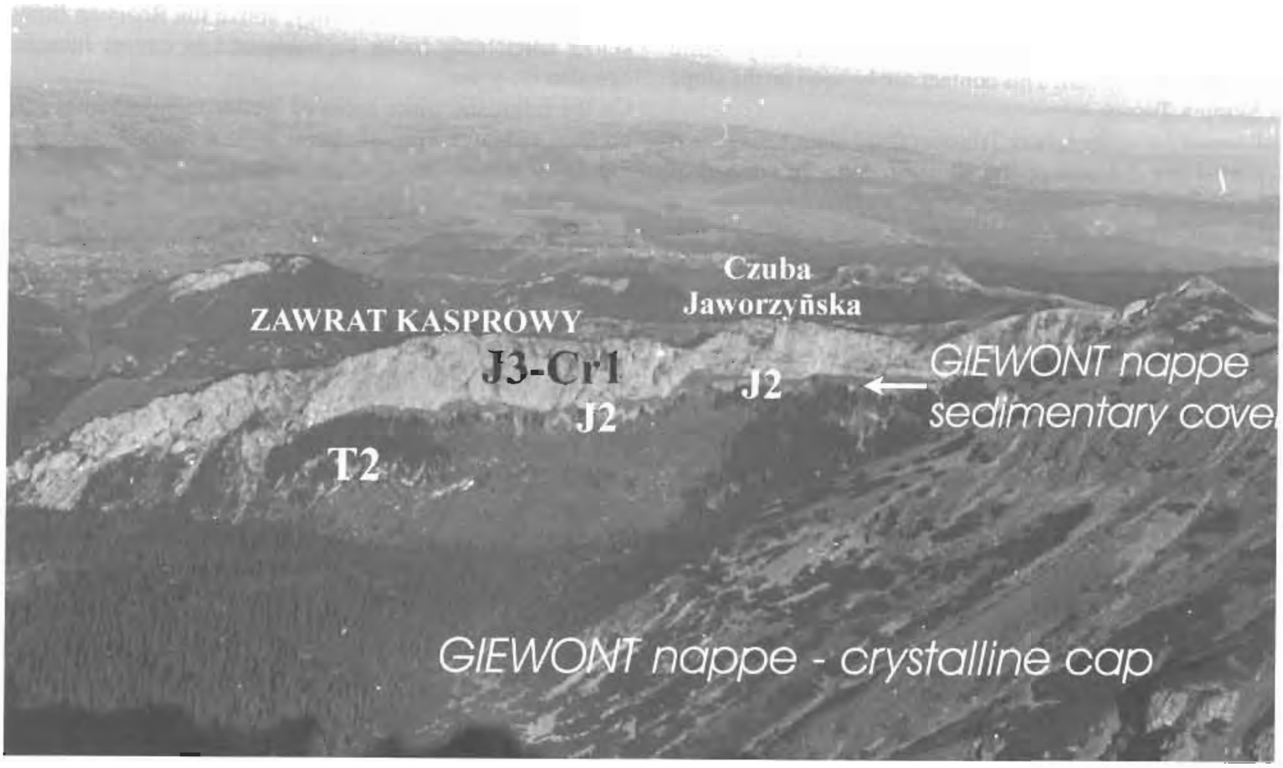


Fig. 16: View on Zawrat Kasprowy – sedimentary cover of the Giewont nappe (Tatricum).

To see better this situation we go to the Liliowe Pass, famous in the history of geology. Here, during IX International Geological Congress (Wien, 1903) a discussion between Victor Uhlig – the author of Geological Map of the Tatra Mts. and Maurice Lugeon- who had never been in the Tatra Mts. before, took place. After this heated discussion the nappe conception of the Tatra Mts. structure was accepted. On the Liliowe Pass we can notice that the crystalline rocks of the Giewont nappe are underlain by a thin Mesozoic series (Liliowe succession - Fig. 7) which is not detached from 'autochtonous' crystalline core of the Tatra Mts. Only one small sheet of the Middle Triassic limestones lying just at the base of the Giewont nappe was detached during overthrust movements.

The pass is formed in Cenomanian-Lower Turonian marls that cover the Urgonian rocks. The profile of Mesozoic of

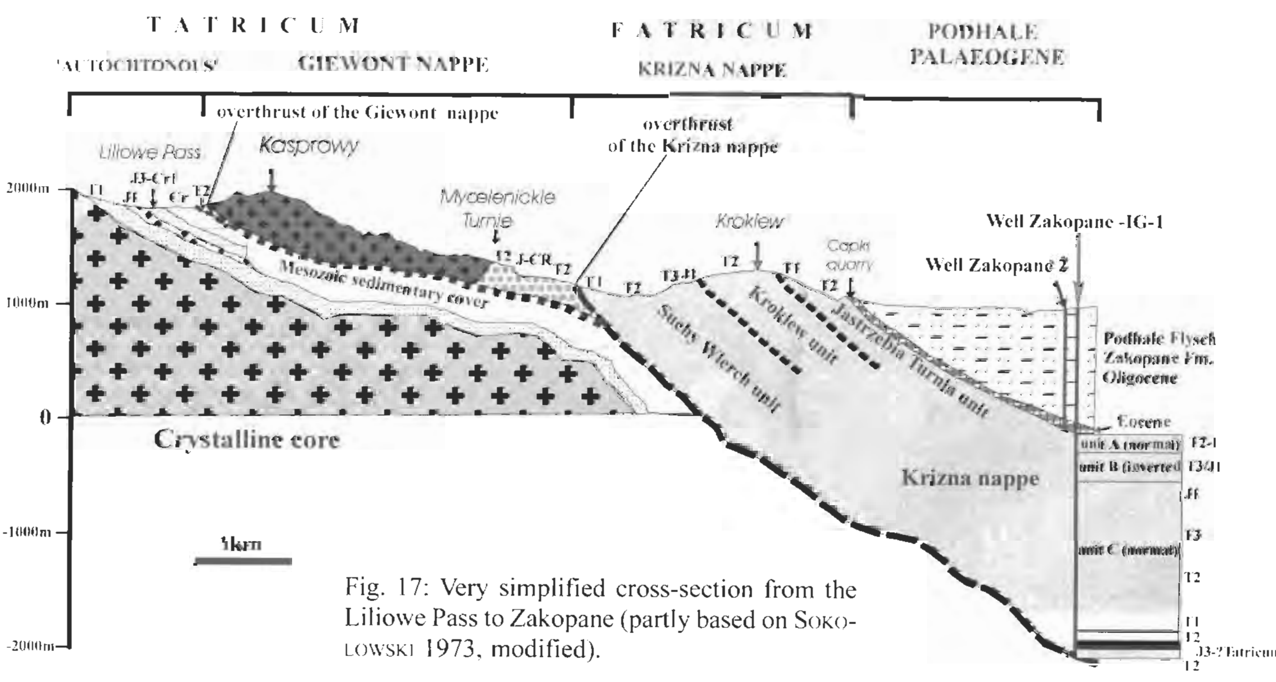


Fig. 17: Very simplified cross-section from the Liliowe Pass to Zakopane (partly based on Sokolowski 1973, modified).

this Tatricum series is incomplete due to the absence of some horizones, which probably were removed during Jurassic syn-rift erosion. The Lower Jurassic rocks lie directly on Lower Triassic quartzites, which cover the crystaline 'autochtonous' massif. This contact can be seen on the slope of Skrajna Turnia.

Better profiles of the Lower Triassic (flood plain-to-lagoonal deposits) are exposed on the slope of Zolta Turnia and of Koszysta, well seen from the Kasprowy Wierch.

From Liliowe Pass we can observe the back (southern) side of Czerwone Wierchy massif with Stoly recumbed syncline (Fig. 18). This kind of folds closed from the south and open to the north, is a characteristic feature of the structure of Tatra Mts., which proves a tectonic transport from the South.

4.3. Excursion: Lejowa Valley. Main theme: Jurassic and Lower Cretaceous of Fatricum (Krizna nappe, Bobrowiec unit)

along with some Triassic outcrops of Fatricum (Krizna nappe) and Hronicum (Choc nappe) (Fig. 10 (A))

In the Lejowa Valley it is possible to observe generally deep-water profile of Jurassic of Fatricum (Krizna nappe, Bobrowiec unit).

At the entrance to the valley one can see Eocene nummulite limestones, which along with underlying conglomerates lie discordantly on the Rhaetian limestones of Hronicum (Siwa Woda unit).

Stop 1 - Rhaetian of Hronicum

(Siwa Woda unit)

Below the Eocene complex the Rhaetian organodetritic limestones (Norovica Fm.) yielding rich fauna of brachiopods (*Rhaetina gregaria*), corals and forams (*Triassina hantkeni*) - (GAZDZICKI 1974, MICHALIK & GAZDZICKI 1981) crop out. They cover grey, yellowish weathered, layered dolomites - Hauptolomite complex.

On the same slope of the valley, above the Rhaetian limestones siliciclastic rocks, probably of Lowermost Jurassic age also crop out..

On the ridge, the white rocks of Wetterstein dolomites can be seen (Cisowa Turnia). They form a tectonic cap of a higher Hronicum unit (Furkaska-Koryciska unit), which is much better exposed in the Chocholowska Valley (Fig. 9, Fig. 19).

Description of the route

Waking along the valley we cross the contact between Hauptdolomite of Hronicum and Lower Cretaceous grey marls of Bobrowiec unit (Krizna nappe, Fatricum).

On the slopes we can see Jurassic radiolarites. At the bottom of the valley, spotty marls of Fleckenmergel facies (Lotharingian) crop out. Further, we can see black marls without burrows (Lower Sinemurian) - a witness of anoxic condition at the beginning of Fatricum basin deepening.

Stop 2 - Huty Lejowe Alp

Upper Triassic-Lower Jurassic of Fatricum

In the scarps, and at the bottom of the valley grey marls of the Kopieniec Fm. (in older literature known as Gresten beds) crop out. They contain some intercalation of sandstones (better visible in outcrops 1 km further). In a lower part of the profile there also occur intercalations of black organogenic limestones. The bottom of the Kopienic Fm. is diachronous (GAZDZICKI & IWANOW 1976), however it generally corresponds to the beginning of Hettangian. The influx of siliclastic material followed by anoxic basin sediments is a turning point in the evolution of Fatricum domain, which could be regarded as the beginning of syn-rift sedimentation. In a tributory of the Lejowa valley Rhaetian profile com-

Fig. 18: Geological view on the Ticha Valley from the Liliowe Pass.

posed of black organogenic limestone with brachiopods and megalodonts (Gazdzicki 1974) can be seen.

Stop 3 - Gully in Posrednia Kopka
Jurassic of Fatricum

In the gully we can see grey spotty limestones with numerous traces of Zoophycos, Chondrites, Planolites (Wieczorek 1995a). Black shales intercalations are devoid of traces.
Macrofossils are represented by belemnites, ammonites (Echioceras), rarely by nautilids .
Their age is determinated as Lotharingian. The thickness of this complex (~ 100 m) is about 5 times thinner than in the Kopy Solysie profile (Eastern Tatra Mts.).
In the upper part intercalation of spongiolites could be seen. Spongiolites are covered by crinoid limestones and red limestones with Fe-concretions (rarely with stromatolitic structures) and macrofauna: ammonites, belemnites,and nautlilids. Their Toarcian age is proved by the presence of ammonites of the zone Hildoceras bifrons (Lefeld et al. 1985).
These beds are better exposed on the ridge between Lejowa and Chocholowska valley where Fe-concretion were exploited in the XIX century. We can see another outcrops of this profile along our route on the Swinska Turnia.
This complex, variable in thickness and in lithology, is interpreted as syn-rift sequence.
A more monotonous post-rift seqence of radiolarites and red nodular limestones (Bathonian-Kimmeridgian) we can observe in the small cliff. Lying above, about 20 m thick profile of grey marls with intercalations of reddish marls with aptychids can be interpreted as rosso ad aptici facies (Kimmeridgian/Tithonian). It is followed by a thick layered white limestone of Maiolica facies (Tithonian/Berriassian), and by grey marls with intercalations of silicilastic turbidites (Valanginian).

Stop 4 - Swinska Turnia
Lower Jurassic of Fatricum

On the Swinska Turnia crag we observe a profile of spongiolites with intercalations of crinoid limestones, covered by true crinoid limestones and red nodular limestones with Fe-concretions (some traces of ancient exploitation).
Descending from the ridge to the Koscieliska Valley we observe Carpathian Keuper below the Kominarski Przyslop Pass. On the cliffs, which are visible on the left, the Jurassic radiolarites and red nodular lime-stones crop out.

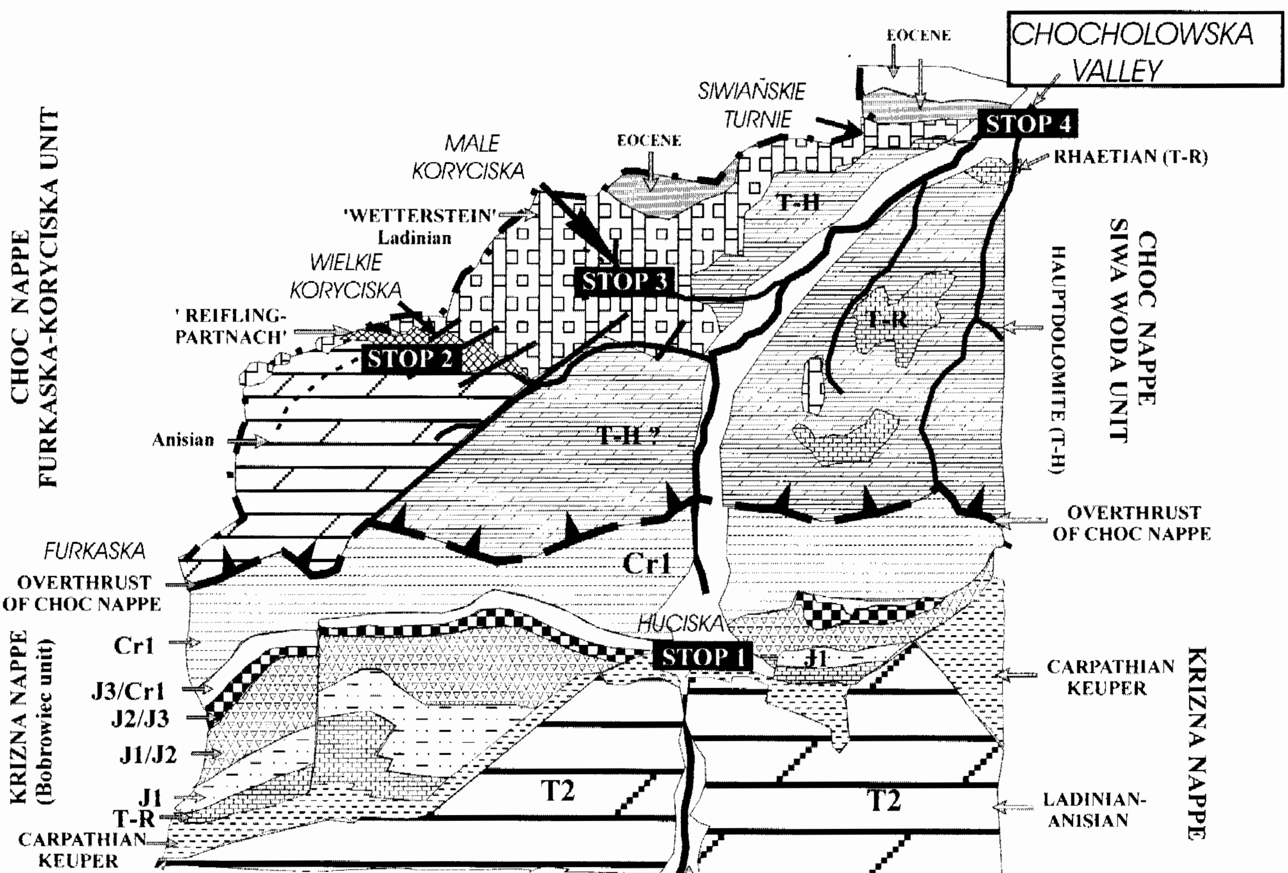


Fig. 19: Geological excursion to the Chocholowska Valley (geological map based on Bac-Moszaszwili et al. 1979, Nemcok et al. 1994, modified).

Stop 5 - Wsciekly Zleb
Lower Cretaceous of Fatricum

At Koscieliska Valley we turn left to a gully (Wsciekly Zleb), where we can observe Lower Cretaceous (Valanginian-?Aptian) marls (spotty marls), with intercalations of siliciclastic tutrbidites and megabeds of alladapic limestones (Muran limestones) composed of shallow-water material (redeposited from shallow carbonate platform).

4.4. Excursion: Chocholowska Valley

Main theme: Triassic of Choc nappe (Hronicum) (Fig.19)

It is the longest Valley in the Western Polish Tatra Mts. It cuts the Eocene at the entrance, and further, the Choc nappe (Triassic), the Krizna nappe (Bobrowiec unit) and the High Tatric (Tatricum) zone.

Stop 1 - Huciska Alp
Mesozoic of Fatricum

We can see a panorama around the Huciska alp. This alp is prepared in clayey Carpathian Keuper, which served as a detachment horizon between two scales of the Bobrowiec unit (Krizna nappe). The lower one is built by Middle Triassic rocks. They form characteristic white crags visible in panorama. We can see some outcrops some tens of meters south of Huciska Alp. The upper scale is built of Jurassic-Lower Cretaceous rocks. The exposures of Maiolica – white, layered limestones, inclined to the north, and of the Lower Cretaceous marls are seen on both sides of the Huciska alp. The older part of the Bobrowiec unit (Kopieniec Fm,. Fleckenmergel, crinoid limestones, radiolarites) profile crops out in the Dluga Valley and on the Wierch Banie hill, where Toarcian Fe-concretions were exploited in the 19-th century (KRAJEWSKI & MYSZKA 1958).
The hills, visible to the north, are built of Triassic rocks of the Furkaska-Koryciska unit (IWANOW & WIECZOREK 1989), the highest unit in the Tatra Mts. belonging to the Choc nappe, which we will observe in two small tributary valley of Chocholowska Valley. KOTANSKI (1973a) considers it as the Strazow nappe (Silicicum).

Stop 2 - Wielkie Koryciska Valley
Middle Triassic of Hronicum (Reifling and Partnach beds)

We cross the Wetterstein dolomites, which form a large crag at the entrance to the valley. They belong to Furkaska – Koryciska unit, which is in tectonic contact with the lowest-Siwa Woda unit, built in this region by layered dolomites (Hauptdolomite complex - Norian?).
Further in the valley we can see Reifling limestones – grey-brown nodular limestones containing ammonites (Arcestes, Dinarites), pelecypods (Daonella), foraminifers and conodonts, which date this level as Upper Anisian (KOTANSKI 1973a, b, ZAWIDZKA 1972)
In the Reifling complex there occur two, some meters thick

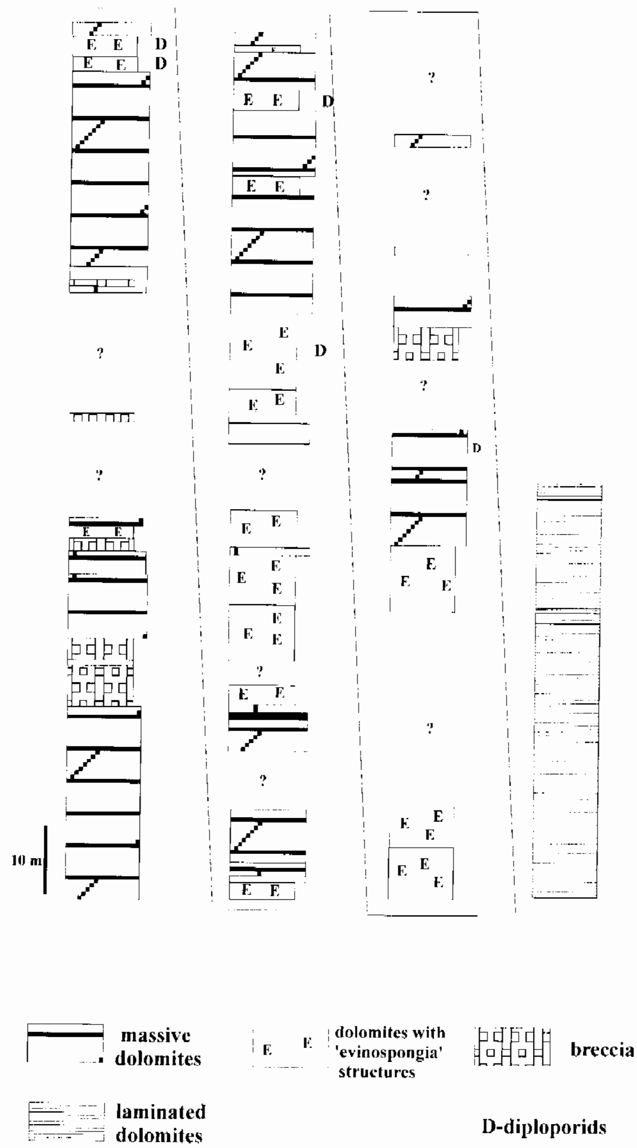


Fig. 20: Profile of Wetterstein dolomites in the Male Koryciska Valley.

intercalations of grey marls called Partnach beds (with analogy to the Northern Calcareous Alps). At this level KOTANSKI (see 1996) found fragments of labyrinthodont described as *Tatrasuchus kulczyckii* gen et sp, n. by MARYANSKA & SHISKIN (1996).
In a gully we will see a slump with limestone blocks containing corals. The Reifling-Partnach complex could be interpreted as deposits of intraplatform small basin (see also MASARYK, LINTNEROVA & MICHALIK 1993). This complex pass is covered by shallow-water Wetterstein dolomites. The contact is sedimentary.
To see better the profile of Wetterstein dolomites we go to Male Koryciska Valley.

Stop 3 - Male Koryciska Valley
Wetterstein dolomites

At the entrance to Male Koryciska valley we can see

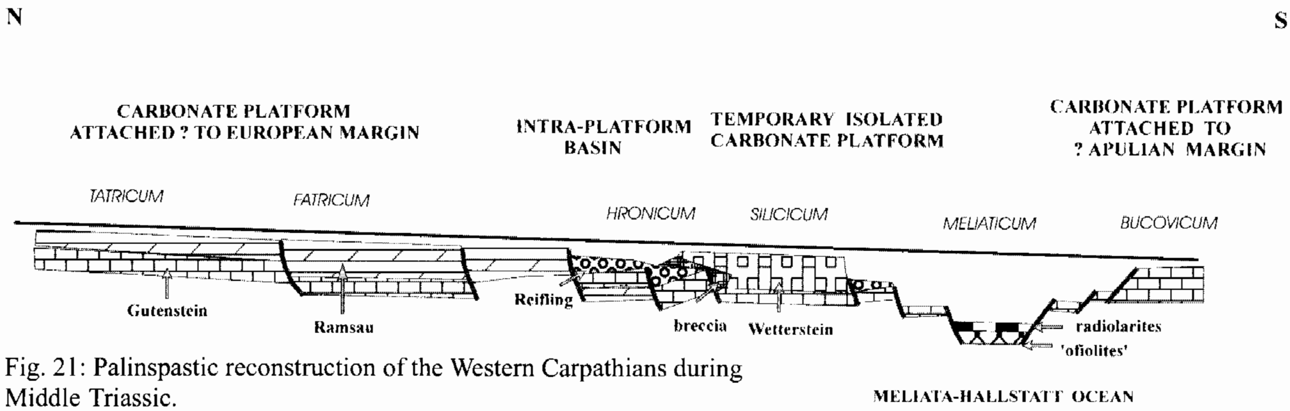


Fig. 21: Palinspastic reconstruction of the Western Carpathians during Middle Triassic.

Hauptdolomite complex - layered dark-grey dolomites with intercalations of black shalles (Siwa Woda unit).

Further we can see the Wetterstein dolomites (Furkaska-Koryciska scale), which lie above the Hauptolomite complex in tectonic contact.

In the valley we observe about 200 m thick complex of Wetterstein dolomites (Fig. 20) composed of massive dolomites, brecciated dolomites, layers with 'evinospongia' structures, layers with large diploporids (Teutloporella) and algues, and laminated dolomites. The Wetterstein complex dated as Ladinian (Kotanski 1973a) is interpreted as platform deposits belonging to passive margins of Meliata ocean (Fig. 21 and Fig. 6).

Similar deposits, much better exposed, are well known from the Northern Calcareous Alps (Brandner & Resch 1981, Henrich 1983).

Stop 4 - Siwianskie Turnie

Rhaetian of Hronicum

At the foot of Siwianskie Turnie, which are built of Wetterstein dolomites a section of Rhaetian rocks (Norowica Fm.) - dark-grey, layered, organodetritic limestones with brachiopods, corals, forams and the youngest conodonts (Misikella) crop out (Gazdzicki 1978). They lie above the Hauptdolomite complex (exposures mainly on the other side of Chocholowska valley) and belong to the Siwa Woda unit. The prolongation of this unit to the east is well-known in the Lejowa Valley. This unit is also recognised in the Siwa Woda situated some km to the north of the Chocholowska Valley.

References

Bac-Moszaszwili, M. (1998): Geology of the Subtatric units, Western Tatra Mts., Poland. - Studia Geol. Polonica, **111**: 113-136, Warszawa.

Bac-Moszaszwili, M., Burchart, J., Glazek, J., Iwanow, A., Jaroszewski, W., Kotanski Z., Lefeld J., Mastella, L., Ozimkowski, W., Roniewicz, P., Skupinski, A. & Westwalewicz-Mogilska, E. (1979): Geological map of the Polish Tatra Mountains 1:30.000, Wyd. Geol., Warszawa.

Brandner, R. & Resch, W. (1981): Reef development in the Middle Triassic (Ladinian and Cordevolian) of the Northern Limestone Alps near Innsbruck, Austria. - SEPM Special Publications, **30**: 203-231, Tulsa.

Dercourt, J., Ricou, L.E., Adamia, S., Csaszar, G., Funk, H., Lefeld, J., Rakus, M., Sandulescu, M., Tollmann, A. & Tchoumachenko, P. (1990): Anisian to Oligocene paleogeography of the European Margin of Tethys (Geneva to Baku). - Mem. Soc. Geol. France, nouv. ser., **154 (III)**: 159-190, Paris.

Dumont, T., Wieczorek, J. & Bouillin, J.-P. (1996): Inverted Mesozoic rift structures in the Polish Western Carpathians (High-Tatric units). Comparison with similar features in the Western Alps. - Eclogae Geol. Helv., **89**: 181-202, Basel.

Eberli, G.P. (1984): The evolution of the southern continental margin of the Jurassic Tethys Ocean as recorded in the Allgau Formation of the Austroalpine Nappes of Graubinden (Switzerland). - Eclogae. Geol. Helv., **81**: 175-214, Basel.

Gazdzicki, A. (1974): Rhaetian microfacies, stratigraphy and facial development in the Tatra Mts. - Acta Geol. Polonica, **24**: 17-96, Warszawa.

Gazdzicki, A. (1978): Conodonts of the Genus *Misikella* Kozur and Mock, 1974 from the Rhaetian of the Tatra Mts. (West Carpathians). - Bull. Acad. Pol. Sc. Ser. Sc. Terre, **26**: 341-350, Warszawa.

Gazdzicki, A. & Iwanow, A. (1976): The diachronism of the Rhaetian and "Gresten" Beds in the Tatra Mts. (West Carpathians). - Bull. Acad. Pol. Sci. Terre, **24**: 117-122, Warszawa.

Grabowski, P. (1967): Budowa geologiczna choczanskich lusek Uplazu, Konczystej i Bramy Kantaka na wschód od Doliny Koscieliskiej. - Acta Geol. Polonica, **17**: 670-696, Warszawa.

Guzik, K. & Kotanski, Z. (1963): Tektonika regli zakopianskich. - Acta Geologica Polonica, **13**: 387-412, Warszawa.

Haas, J., Kovacs, S., Krystyn, L. & Lein, R. (1995): Significance of Late Permian-Triasic facies zones in terrane reconstructions in the Alpine-North Pannonian domain. - Tectonophysics, **242**: 19-40, Amsterdam.

Hausler, H., Plasienka, D. & Polak, M. (1993): Comparison of Mesozoic successions of the Central Eastern Alps and the Central Western Carpathians. - Jb. Geol. B.-A., **136**: 715-739, Wien.

Henrich, R. (1983): Der Wettersteinkalk am Nordwestrand des tirolischen Bogens in den Nördlichen Kalkalpen: der jüngste Vorstoß einer Flachwasserplattform am Beginn der Obertrias. - Geologica et Palaeontologica, **17**: 137-177, Marburg/Lahn.

Iwanow, A. & Wieczorek, J. (1987): Problem najwyzszych jednostek tektonicznych w Tatrach. - Przeglad Geol., **10**: 525-528, Warszawa.

Kotanski, Z. (1961): Tektogeneza i rekonstrukcja paleogeografii pasma wierchowego w Tatrach. - Acta Geologica Polonica, **11**: 187-476, Warszawa.

Kotanski, Z. (1965a): Analogie litologiczne triasu tatrzanskiego z triasem wschodnioalpejskim. - Ann. Soc. Geol. Pol., **35**: 143-162, Krakow.

Kotanski, Z. (1965b): Budowa geologiczna pasma reglowego miedzy Dolina Malej Laki i Dolina Koscieliska. - Acta Geol. Polonica, **15**: 257-330, Warszawa.

KOTANSKI, Z. (1973a): Upper and middle subtatric nappes in the Tatra Mts. - Bull. Acad. Pol. Sci., ser. sci. geol., geogr., **21**: 25-83, Warszawa.

KOTANSKI, Z. (1973b): Ammonites, nautiloids and daonelles from the Upper Subtatric Triassic in the Tatra Mts. - Ann. Soc. Geol. Pol., **43**: 439-451, Krakow.

KOTANSKI, Z. (1996): History of discovery and age of labyrinthodont remains in the Tatra Mts, Poland. - Prace Muzeum Ziemi, **3**: 47-52, Warszawa.

KOZUR, H. (1991): The evolution of the Meliata - Hallstatt ocean and its significance for the early evolution of the Eastern Alps and Western Carpathians. - Palaeogeogr., Palaeoclimat., Palaeoecol., **87**: 109-135, Amsterdam.

KRAJEWSKI, K. (1984): Early diagenetic phosphate cements in the Albian condensed glauconitic limestone of the Tatra Mountains, Western Carpathians. - Sedimentology, **31**: 443-470, Amsterdam.

KRAJEWSKI, R. & MYSZKA, J. (1958): Wapienie manganowe w Tatrach miedzy Dolina Chocholowska Lejowa. - Biul. IG, **149**: 209-257, Warszawa.

LEFELD, J. (1974): Middle - Upper Jurassic and Lower Cretaceous biostratigraphy and sedimentology of the Sub-Tatric succession in the Tatra Mts. Acta Geol. Polonica, **24**: 277-363, Warszawa.

LEFELD, J. (Ed.) GAZDZICKI, A., IWANOW, A., KRAJEWSKI, K. & WÓJCIK, K. (1985): Jurassic and Cretaceous lithostratigraphic units of the Tatra Mountains. - Studia Geol. Polonica, **84**: 1-93, Warszawa.

LUGEON, M. (1903): Les nappes de recouvrement de la tatra et l'origin des Carparthes. - Bull. Lab. Geol. Univ. Lausanne.

MAHEL, M. (1981): Island character of Klippen Belt: Vahicum continuation of Southern Penninicum in West Carpathians. - Geol. Zb., Geol. Carpath., **32**: 293-305, Bratislava.

MARYANSKA, T. & SHISKIN, M. (1996): New cyclotosaurid (Amphibia: Temnospondyli) from the Middle Triassic of Poland and some problems of interrelationships of capitosauroids. - Prace Muzeum Ziemi, **43**: 53-83, Warszawa.

MASARYK, P., LINTNEROVA, O. & MICHALIK, J. (1993): Sedimentology, lithofacies and diagenesis of the sediments of the Reifling interaplatform basins in the Central Western Carpathians. - Geol. Carpath., **44**: 233-249, Bratislava.

MASSE, J.-P. & UCHMAN, A. (1997): New biostratigraphic data on the Early Cretaceous platform carbonates of the Tatra Mountains, Western Carpathians, Poland. - Cretaceous Research, **18**: 713-729, Amsterdam.

MELLO, J. & WIECZOREK J. (1993a): Kriznansky prikrov (veporikum). - (In: Vysvetliky ku geologickej mape Tatier, 1:50.000), 36-49, Bratislava.

MELLO, J. & WIECZOREK, J. (1993b): Chocsky prikrov (hronikum). - (In: Vysvetliky ku geologickej mape Tatier, 1:50.000), 50-57, Bratislava.

MICHALIK, J. & GAZDZICKI, A. (1983): Stratigraphic and environmental correlations in the Fatra- and Norovica Formation (Upper Triassic, Western Carpathians). - Osterr. Akad. Wissenschaft., Schrift. Erdwiss. Kom., **5**: 267-276, Wien.

MICHALIK, J., PLANDEROVA, E. & SYKORA, M. (1976): To the stratigraphic and paleogeographic position of the Tomanova - Formation in the Uppermost Triassic of the West Carpathians. - Geol. Zb., Geol. Carpathica, 27: 299-318, Bratislava.

MURCHISON, R. (1849): On the geological structure of the Alps, Apennines and Carpathians.- Quart. J. Geol. Soc., **5**: 157-313, London.

NEMCOK, J. WIECZOREK, J. & ZELMAN, J. (1993): Tatrikum. - (In: Vysvetlivky ku geologickej mape Tatier, 1:50.000), 25-35, Bratislava.

NEMCOK, J., BEZAK, V., BIELY, A., GOREK, A., GROSS, P., HALOUZKA, R., JANAK, M., KAHAN, S., KOTANSKI, Z., LEFELD, J., MELLO, J., REICHWALDER, P., RACZKOWSLI, W., RONIEWICZ, P., RYKA, W., WIECZOREK, J. & ZELMAN J. (1994): Geological map of the Tatra Mountains. - (In: NEMCOK, J. (Ed.): Regionalne geologicke mapy Slovenska, 1:50.000), Geol. Ustav. D. Stura, Bratislava.

OLSZEWSKA, B. & WIECZOREK, J. (1995): Preliminary report on foraminifers from the youngest (Middle-Upper Cretaceous) deposits of the Tatra Mts. (Western Carpathians). - Annual Assembly IGCP 362, **1995**: 61-62, Maastricht.

OLSZEWSKA, B. & WIECZOREK, J. (1998): The Paleogene of the Podhale Basin (Polish Inner Carpathians) - micropaleontological perspective. - Prz. geol., **46**: 721-728, Warszawa.

PASSENDORFER, E. (1978): Rozwój pogladow na budowe geologiczna Tatr w okresie powojennym. - Prace Muzeum Ziemi, **28**: 3-33, Warszawa.

PIOTROWSKI, J. (1965): Trias srodkowy masywu Kominów Tylkowych i jego tektonika. - Acta Geol. Polonica, **15**: 255-292, Warszawa.

PLASIENKA, D. (1995): Passive and active margin history of the northern Tatricum (Western Carpathians, Slovakia). - Geol. Rundsch., **84**: 748-760, Stuttgart.

PLASIENKA, D., GRECULA, P., PUTIS, M., KOVAC, & HOVORKA, D. (1997): Evolution and structure of the Western Carpathians: an overview. in: Geological evolution of the Western Carpathians - (In: GRECULA, P., HOVORKA, D. & PUTIS, M. (Eds.): Mineralia Slovaca-Monograph), 1-24, Bratislava.

POLAK, M., ONDREJICIKOVA, A. & WIECZOREK, J. (1998): Lithobiostratigraphy of the Zdiar Formation of the Krizna nappe (Tatry Mts.). - Slovak Geol. Mag., **4**: 35-52, Bratislava.

RABOWSKI, F. (1959): Serie wierchowe w Tatrach Zachodnich. - Prace Inst. Geol., **27**: 5-178, Warszawa.

RACIBORSKI, M. (1890): Flora retycka w Tatrach. - Rozpr. Akad. Um., **21**: 292-326, Warszawa.

RADWANSKI, A. (1959): Struktury litoralne w liasie w Dolince Smytniej. - Acta Geol. Polonica, **9**: 231-280, Warszawa.

SOKOLOWSKI, S. (1959). Outlines of geology of the Tatra Mountins. - Biul. IG, **149**: 71-98, Warzawa.

SOKOLOWSKI, S. (1973): Geologia paleogenu i mezozoicznego podloza poludniowego skrzydla niecki podhalanskiej w profilu glebokiego wiercenia w Zakopanem. - Biul. IG, **265**: 5-74, Warszawa.

UCHMANN, A. (1988): Red limestones - the youngest lithological unit of the Choc nappe, Tatra Mts. - Ann. Soc. Geol. Polon., **58**: 277-286, Krakow.

UHLIG, V. (1897): Geologie des Tatragebirges. - Anz. Akad. Wiss. math.-nat. Kl., Bd. **64**: 643-684, Wien.

UHLIG, V. (1899): Geologische Karte des Tatragebirges. - Anz. Akad, Wiss, math.nat.Kl., Bd. **68**, Wien.

WIECZOREK, J. (1988): Maiolica. A unique facies of the Western Tethys. - Ann. Soc. Geol. Pol., **68**: 255-276, Krakow.

WIECZOREK, J. (1995a): Trace fossils from Fleckenmergel facies (Jurassic) of the Tatra Mts. - Geobios, M.S. **18**: 425-431, Lyon.

WIECZOREK, J. (1995b): Mesozoic evolution of the Tatra Mts. (Western Carpathians). - Geol. Soc. Greece, sp. Publ., **4**: 139-142, Athens.

WIECZOREK, J. (1996): Jurassic of the Tatra Mts. - Carpathian sector of the Western Tethys. - (In: RICCARDI, A.C. (Ed.): Advances in Jurassic Research), GeoResearch Forum, vol. **1-2**: 397-404, Transtec Pub. Switzerland.

WIECZOREK, J. (1999): Geological framework of the Tatra Mountains-Podhale geothermal system (Carpathians). - Bulletin d'Hydrogeologie, **17**: 261-269, Neuchatel.

WIECZOREK, J. & BARBACKI, A. (1997): Geological cross-section of the Podhale basin and its substratum based on the seismic and borehole data; implications for geothermics. - Prz. Geol., **7**: 715-720, Warszawa.

WIECZOREK, J. & OLSZEWSKA, B. (1999): Mesozoic basement of the Podhale basin (Western Carpathians, Poland). - Geologica Car-pathica, **50**: 84-86, Bratislava.

ZAWIDZKA, K. (1972): Stratigraphic position of the Furkaska limestones (Choc nappe, the Tatra Mts). - Acta Geol. Polonica, **22**: 459-466, Warszawa.