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Lower Cretaceous sequences of the Manín Unit (Butkov Quarry, Strážovské vrchy Mts, Western Carpathians) – integrated biostratigraphy and sequence stratigraphy

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Abstract: The pelagic limestone sequence of Mt Butkov exposed by quarry of the Ladce Cement Works in middle Váh Valley is the best documented Lower Cretaceous sequence in Western Carpathians at all. Basal Berriasian gap represents a characteristic feature of the Manín Unit, it is connected with the paleogeographic setting of this unit in the basin. The Ladce Formation comprises Campylotoxus-, Verrucosum- and Peregrinus ammonite zones correlable with calpionellid Calpionellites Zone and with the lowermost part of the Tintinnopsella Zone. The Mráznica Formation is a product of a dysoxic episode spanning the ammonite Furcillata Zone – an equivalent of dinoflagellate Validum Zone. The Kališčo Formation has been deposited during ammonite Radiatus-, Loryi-, Nodosoplicatum-, Sayni-, and Ligatus zones. The lower part of the formation belongs to dinoflagellate Staurota and Stoveri zones, dinocysts are poorly represented higher up in the sequence. The Lúčkovská Formation is a terminal part of the Lower Cretaceous pelagic limestone sequence. Its lowermost part (? Balearis Zone) is poorly dated by ammonites, higher part of the sequence belongs to Hugii-, Nicklesi-, Pulchella-, Compressissima-, and Vanderheckii zones. The last mentioned zone is comparable with dinocyst Operculata Zone. The Podhorie and Manín formations represent products of „Urgonian" carbonate platform, which developed here since Aptian to the end of Early Albian. The Butkov Marl Formation is equivalent to nannoplankton Turriseiffelii Zone, compared with the duration of ammonite Inflatum and Dispar zones. Correlation of ammonites, aptychi, calpionellids, dinocysts and nannoplankton gives clue to precisioning of biostratigraphic division of Lower Cretaceous sequences in the Mediterranean area.

Key words: Lower Cretaceous, pelagic carbonates, sequence stratigraphy, ammonites, dinocysts, nannoplankton, biostratigraphy, Western Carpathians

1. Introduction

More than one half of century, the Manín Unit remains the source of controversies in the Carpathian geology. Extensive outcrops of its Lower Cretaceous sequence is exposed by the Butkov Quarry of the Ladce Cement Works in the middle Váh Valley. It has been studied by scientists of the Geological Institute of Slovak Academy of Science, the Comenius University in Bratislava and the Technical University in Ostrava from point of view of stratigraphy, paleontology, carbonate sedimentology and tectonics (Borza et al. 1987, Michalík & Vašíček 1987, Michalík et al., 1990, Vašíček et al., 1994, etc.). Since 1979 to 2004 more than twelve hundred ammonite specimens were collected. At present, this place represents the richest locality of Lower Cretaceous ammonites in the whole Western Carpathians with purely Mediterranean species from Early Valanginian Campylotoxus Zone to Late Barremian Vandenheckii Zone (Vašíček & Michalík 1986, Skupien et al. 2003). The ammonite associations resemble these from the Vocontian Trough in France. The Butkov section could serve as a key Valanginian – Barremian West Carpathian section correlable with these described from classical French and Spanish Mediterranean regions. However, active quarrying works remove documented sections each year.

The distribution of ammonites fits well with the orthostratigraphic scale proposed by Hoedemaeker et al. (2003). Vertical distribution of ammonites and aptychi in the sections studied was correlated with the distribution of calcareous microplankton (calpionellids, calcareous dinoflagellates and nannoplankton) as well as with the distribution of non-calcareous dinoflagellates.

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2. Biostratigraphy and sequence stratigraphy

2.1. Berriasian gap

The Butkov Lower Cretaceous sequence starts with the „Basal Breccia" with thickness of 1 to 5 meters. In fact, the breccia comprises clasts of Tithonian and Berriasian limestones only. Overlying limestone layers yielded Valanginian ammonite fauna. Thus, the Berriasian part of

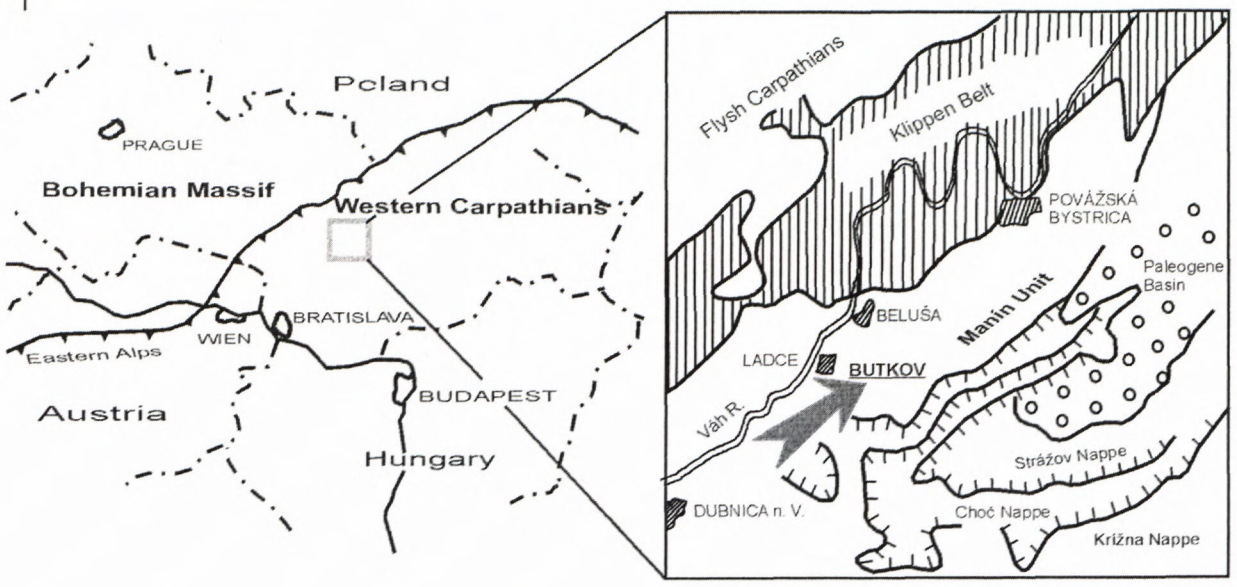

Figure l.: Setting of the Mt Butkov locality in the frame of Slovakia (left) and in the middle Váh Valley (right)

sequence is represented by a „hidden discordance" (Michalík & Vašíček 1987) and by sedimentary gap.

The regression at the Jurassic/Cretaceous boundary (Detraz & Mojon 1989) influenced sedimentation in the Mediterranean Tethys. Purbeck and sebkha facies characterised by calcrete horizons and by erosive gaps sedimented in the Boreal Realm (southern England, Paris Basin, nothern Germany), but also in Sub-Boreal and Sub-Mediterranean provinces (Basse-Provence, Sardegna and Spain, Jura Mountains, Hoedemaeker in Michalík, 2002). Frequent breccia beds are intercalated in the „maiolica" facies in southeastern France („Bréche de Chomerac" Jan du Chene et al. 1993) and in Italy. Despite of temporary middle Berriasian submersion, sea level rise continued at the end of the stage. Frequent gaps accompanied by allodapic layers with clasts of underlying rocks were described from the Berriasian – Valanginian boundary sequence along the border of the European continent and in the Vocontian Trough. Detraz & Mojon (l.c.) defined two „post-rift discordances" (at the beginning of both Late Berriasian and Early Valanginian), which should have been connected with mid Atlantic rifting, and with the Neo-Cimmerian movements. According to authors, mentioned above, this tectonic pulse merged with original eustatic signal (Vail et al., 1984), which represented the decisive element in Early Cretaceous evolution of sedimentary basins in closure of the Mediterranean Tethys.

In central Western Carpathian, Cretaceous basal breccia is typically developed in the Tatric Ridge (Reháková & Michalík, 1992) and its adjacent slope (Borza & Michalík 1987, Michalík et al. 1990b). However, its stratigrafic range is laterally variable. This fact could be explained by elevation of the Tatric Block during Late Cimmerian tectonic movements (Michalík 1990), combined with global sea-level fall during Early and Late Berriasian. At the end of the Berriasian (Be_{-7} sequence) sediments were eroded and the clastic material was deposited in channel fillings and submarine fans (the „Nozdrovice Breccia") on the Fatric Basin bottom, opened by pull-apart type tensional faults (Michalík & Reháková 1995, 1997). It is worth of mention, that in the Manín Unit all this part of sequence is missing, possibly due to erosion and transport into the Fatric Basin during deposition of Be_{-7} to Va_{-2} sequences.

2.2. The Ladce Formation

The basal unconformity on the base of the Ladce Formation comprises amalgamated Be-7 and Va-1 sequence boundaries (the „Late Cimmerian unconformity" of Haq et al., 1988). The Va-2 and Va-3 unconformities occur in the lowermost part of the formation, which is bare in ammonites. The Va-4 boundary is well developed, accompanied by redeposited sediments and by local gap (the „Oravice Event"). Short eccentricity cycles (á 100 ky) determine distribution of both clay component and the abundance of ammonites, which peak in transgressive system tracts. Supply of oxygen was insufficient during deposition, which probably coincided with the presence of warm deep water with increased salinity. The organic matter in planktonic „rain" was oxidized during passage through higher levels of water column.

The ammonite fauna of the Campylotoxus Zone confirms the start of thin bedded pale marly limestone deposition of the Ladce Formation during Early Valanginian. The basal Pertransiens Zone was not confirmed. *Vergoliceras salinarium* (Uhlig), *Kilianella retrocostata* Sayn, *Karakaschiceras inostranzewi* (Karakasch) occur together with the index *Busnardoites campylotoxus* (Uhlig). *Neocomites teschenensis* (Uhlig), *N. platycostatus* (Sayn), *N. beaumugnensis* (Sayn), *Olcostephanus guebhardi* Kilian occur somewhat higher up in the sequence. The sedimentation of the Ladce Formation was finished during Late Valanginian, which is documented by the occurrence of *Olcostephanus nicklesi* Wiedmann et Dieni, O. *tenuituberculatus* Bulot, *Himantoceras trinodosum* Thieuloy, *Rodighieroites belimelensis* Mandov (Peregrinus- to Furcillata zones). On the other hand, typical Mediterranean indexes like *Saynoceras verrucosum*, *Neocomites peregrinus*

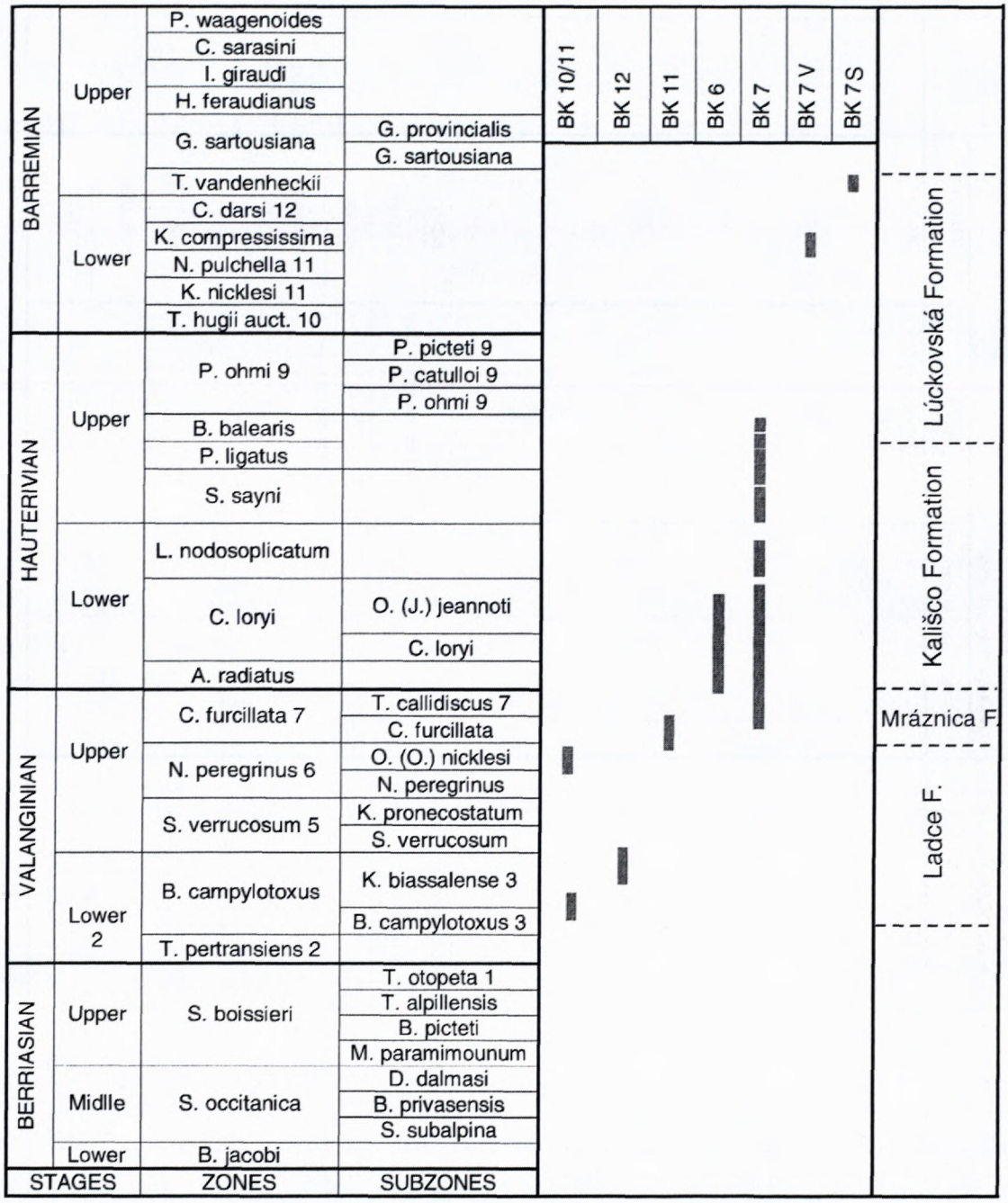

Figure 2.: Ammonite zonation of Lower Cretaceous with indication of documented zones in individual sections of the Butkov sequence

were not found in the Ladce Fm yet. The cephalopod distribution was correlated with the aptychi fauna collected in coeval strata. Twelve taxa of ribbed aptychi come from the Ladce Formation – for example *Lamellaptychus mortilleti mortilleti*, *L. aplanatus aplanatus*, *L. a. retroflexus*, *L. bermudensis*, *L. beyrichodidayi*, *L. symphysocostatus*; two taxa from this formation have been defined as new forms. Very interesting is the finding of *L. didayi* and *L. seranonis* at so low stratigraphical level – Campylotoxus Zone. Up to the present day was known that *L. didayi* and *L. seranonis* firstly appeared during Late Valanginian.

Marly limestones contain calpionellids and calcareous dinoflagellates of the Valanginian Calpionellites Standard Zone (Darderi- and Major Subzones). Calcareous nannofossil preservation is moderate to poor. *Nannoconus* spp. and *Watznaueria barnesae* constitute 40 – 90 % of rather low diverse assemblages. Calcareous nannofossils of the Ladce Formation allow to distinguish the Rucinolithus wissei NK-3A Subzone of the Calcicalathina oblongata NK-3 Zone. A very seldom, poorly preserved non-calcareous dinoflagellate association was ascertained in 34 - samples taken from the Ladce Fm for palynological (Spi) Zone with typical cosmopollitan forms like *Cometodiniumhabibii*, *Oligosphaeridium complex*, *Circulodinium Gonyaulacysta* and *Spiniferites*. The Verrucosum Zone on the 12th level of the Butkov quarry yielded no dinoflagellates at all.

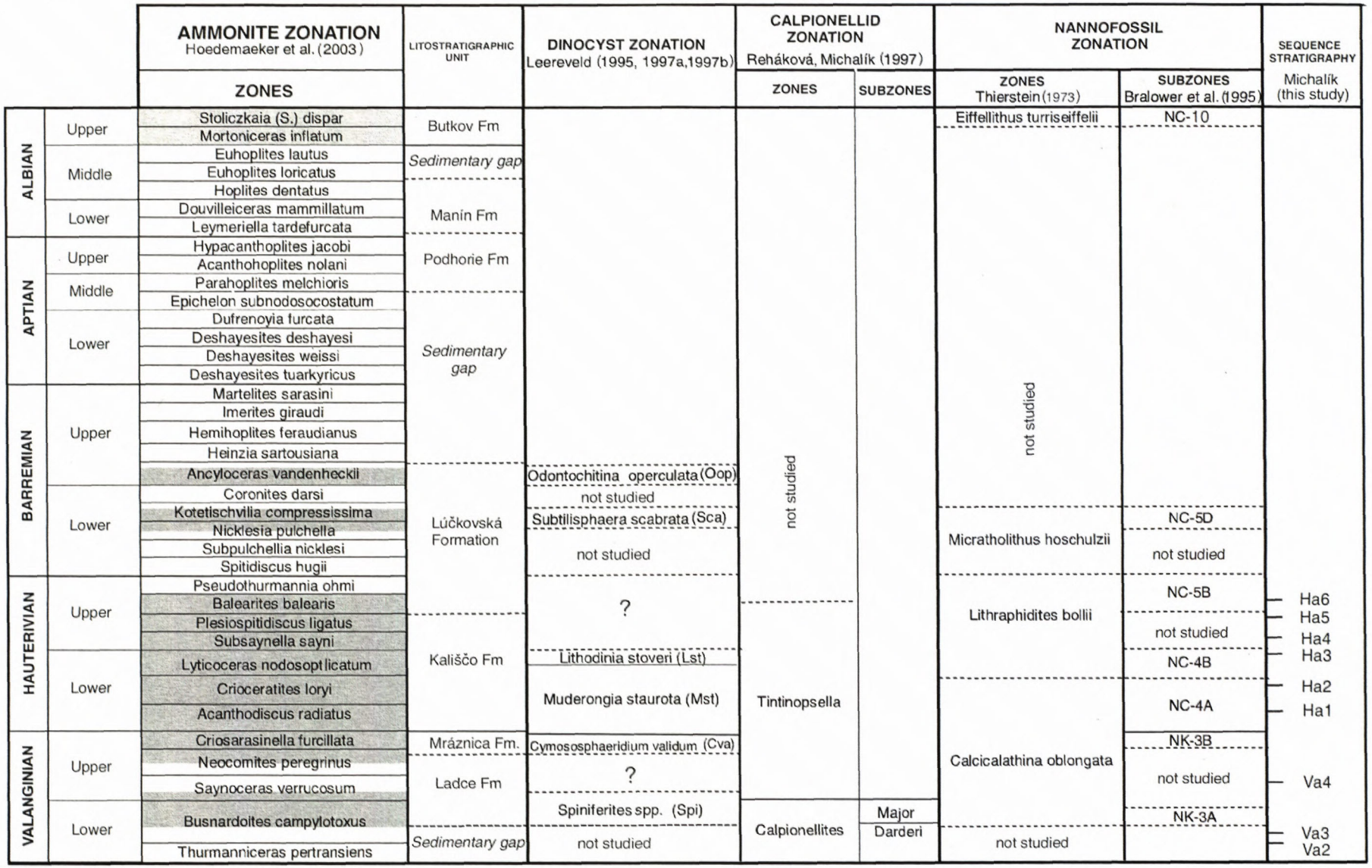

Figure 3.: Correlation of several parabiostratigraphic scales (based on ammonites, dinocysts, calpionellids and nannoplankton) and sequence stratigraphic elements of Lower Cretaceous resulting from the Butkov sequence study

2.3. The Mráznica Formation

The Mráznica Formation (the Peregrinus and Furcillata zones) has been insufficiently studied in detail due to poorer exposures and worse eustatic record. Therefore, the exact position of missing sequence boundaries (Va-5, 6 and two unnamed ones) is unknown. The formation sedimented under poorly stratified water column. The oxygen was transported by vertical currents and enabled life of infaunal organisms (bioturbation). However, the bottom was too soft and not enough consolidated for colonisation by benthic fauna. Moreover, local anoxia was caused by input of unoxidated organic matter. Temporal terrigeneous input indicates raised humidity. Condensation of the uppermost part of the sequence (Callidiscus Subzone) is probable, but not confirmed yet.

The boundary between the Ladce Fm and overlying it Mráznica Fm is not sharp. Abundant ammonite remnants (several hundreds of specimens) of the Furcillata Zone date Late Valanginian age of the Mráznica Fm: *Criosarasinella furcillata* Thieuloy, *C. mandovi* Thieuloy, *C. coniferus* Busnardo, *Teschenites subflucticulus* Reboulet. Higher part of the sequence yielded *Crioceratites heterocostatus* Mandov, *Teschenites subpachydicranus* Reboulet, *Olcostephanus densicostatus* (Wegner), *Oosterella cultratoides* (Uhlig). All the ammonite shells found are dominated by sculptured forms.

Marly limestone sequence contain very rare microfossils of the Tintinnopsella Zone, rare remaniellids indicate erosion of older deposits. Calcareous nannofossils belong to the Late Valanginian Tubodiscus verenae Subzone (NK–3). The nannofossils assemblages are composed of both cosmopolitan representatives (*Watznaueria barnesae, Cyclagelosphaera margerelii, Rhagodiscus asper, Zeugrhabdotus embergeri, Cretarhabdus* spp., *Micrantholithus* spp.) together with Tethyan taxa (*Conusphaera mexicana, Cyclagelosphaera deflandrei, Cruciellipsis cuvillieri* and *Nannoconus* spp.). Rare Upper Valanginian and Lower Hauterivian Boreal taxa has been noticed (*Micrantholithus speetonensis, Crucibiscutum salebrosum, Nannoconus pseudoseptentrionalis*). Rich and diverse association of Upper Valanginian non-calcareous dinoflagellates belongs to the *Cymososphaeridium validum* (Cva) Zone determined by Leereveld (1997a, b). *Cymososphaeridium validum, Dingodinium cerviculum, Oligosphaeridium asterigerum* and *Bourkidinium elegans* occurred for the first time here. The composition of dinoflagellate assemblages reflects original marine environment of several hundred meter depths (littoral to brackish types predominate, e.g. *Circulodinium, Muderongia*).

2.4. The Kališčo Formation

The formation starts with calciturbidite layer. Five Hauterivian sequence boundaries (Ha-1-5) have been recognized in the Kališčo Fm and one (Ha-6) in the basal part of the Lúčkovská Formation. Due to poorer exposures we do not know the exact position of the Ha-7 sequence boundary.

Thick-bedded limestones of the lowstand tracts (thickness of 1-3 m) contain brachiopod shells and crinoid calyces. Rich ammonite and nannofossils associations characterise transgressive system tracts. The radiolarians reached the maximum of abundance during maximum flooding intervals. Calcareous lamellaptychi are represented by thick-valved types dominated by *L. didayi* and *L. seranonis*. Highstand system tracts are build of thin bedded limestones with marly intercalations.

Ammonites *Teschenites flucticulus* Thieuloy, *Eleniceras tchechitevi* Breskovski, *Jeanthieuloyites nodosus* (Mandov), *Olcostephanus hispanicus* (Mallada) prove for earliest Hauterivian age (the Radiatus Zone, although zonal index was never found) of the Kališčo Formation base. More frequent criceraticone forms like *Crioceratites nolani* (Kilian) and *C. loryi* Thieuloy (zonal index) together with sole *Olcostephanus (Jeannoticeras) jeannoti* (d´Orbigny) occur higher up in the sequence. The Nodosoplicatum Zone was not documented (like nowhere in Western Carpathians) yet. The Sayni Zone was proved by findings of *Subsaynella sayni* (Paquier) co-occurring with *Ptychoceras meyrati* Ooster in pelagic chert limestone sequence of the Kališčo Fm. Plesiospitidiscus ligatus (d´Orbigny) accompanied by P. meyrati and Abrytusites thieuloyi Vašíček & Michalík dates Late Hauterivian Ligatus Zone (Fig.3). *Tintinnopsella carpathica* occurs sporadically in the Kališčo Fm. Calcareous nannofossils denote the NC-4A and NC-4B Subzones correlated with the onset of the Nodosoplicatum Ammonite Zone. Low content of nannoconids and the abundance of *Micrantolithus hoschulzii* is a characteristic feature of Early Hauterivian nannofossil associations. Association of non-calcareous dinoflagellates belongs to the *Muderongia staurota* (Mst) Zone, the span of which is correlated with the ammonite Radiatus and lowermost Nodosoplicatum zones. This assumption is estimated also by the first appearance of *Achomosphaera verdieri, Histiocysta outananensis, Florentinia* sp., *Coronifera oceanica* and by the presence of coeval nannofossils. *Lithodinia stoveri* (Lst) dinozone was identified in the uppermost Lower Hauterivian ammonite Nodosoplicatum Zone.

The lithology of upper part of the Kališčo Fm did not supported dinoflagellate preservation. It is worth of mention that the brackish species (*Muderongia*) of non-calcareous dinoflagellates dominated just during the lowstand conditions of global sea-level. On the other hand, neritic (*Oligosphaeridium, Spiniferites*) and oceanic (*Pterodinium*) dinoflagellate species prevailed during the transgressive and high stand intervals in the time of higher nannoplankton and microplankton diversity.

2.5. The Lúčkovská Formation

The sequence stratigraphic pattern of the Barremian part of the Lúčkovská Formation and of the „Urgonian" complex (Podhorie- and Manín formations) was not studied due to lack of undisturbed, fresh and properly oriented exposures (this part of the sequence is not quarried in the last time).

Although we were not successfull in searching for the *Pseudothurmannia balearis,* the index of the Late Hauterivian Balearis Zone, the ammonites found in the basal

Figure 4.: Panoramic view on north-western slope of Mt Butkov with the Ladce Cement Works quarry.

part of well bedded grey micritic limestones of the Lúčkovská Fm use to be associated with it: frequent Barremites, Crioceratites ex gr. majoricensis Nolan, ?Discoidella vermeuleni Cecca, Faraoni et Martini. Neither Late Hauterivian Ohmi Zone nor several next Barremian ammonite indexes (Hugii, Nicklesi, lower part of Pulchella and Darsi Zones) were found. However, presence of the Compressissima Zone is supported by abundant barremitids, but also Nicklesia pulchella (d´Orbigny), Moutoniticeras nodosum (d´Orbigny), Dissimilites dissimilis (d´Orbigny), Patruliusiceras lateumbilicatum Avram, Parasaynoceras tzankiovi Avram, Metahoplites cf. nicklesi (Karakasch), Holcodiscus cf. gastaldii Kilian, Paraspiticeras sp. The ammonite finding of Toxancyloceras vandenheckii (Astier) coming from scree in the highest part of the Lúčkovská Fm sequence supports the presence of the basal Late Barremian Vandenheckii Zone.

The Upper Hauterivian aptychi association is characteristic of angulocostate lamellaptychi only (*L. angulocostatus angulocostatus*, *L. a. angulicostatus*). These valves represent stratigraphically youngest specimens within lamellaptychi associations studied.

Sporadic *Tintinnopsella carpathica* occurs in the lowermost part of the formation. The calcareous nannofossil assemblage belongs to the Litraphidites bollii Zone, NC-5B Subzone. If compared with Kališčo Fm, nannoconid abundance increased. The block from the eastern part of the 7th etage (BK-7/V) belongs to the Early Barremian Micratholithus hoschulzii Zone, NC-5D Subzone.

Rich palynomorphs were observed in the Lúčkovská Fm, although none specific dinozone could have been determinable in the lower part of sequence. Early Barremian *Subtilisphaera scabrata* (Sca) dinozone (with the first occurrence of *Cerbia tabulata*) and Late Barremian *Odontochitina operculata* (Oop) dinozone (with the first occurrence of *Prolixosphaeridium parvispinum*) were identified in the upermost part of the formation. Dinoflagelate cysts of littoral environment (*Cerbia, Tenua*) dominate over neritic types.

2.6. The Podhorie and Manín formations

Dark bituminous organodetrital cherty limestones of the Podhorie Fm contain bad preserved, corroded dinoflagellates, such as *Cerbia tabulata, Cleistosphaeridium clavulum, Oligosphaeridium dividuum*, which allow to suppose Late Barremian or younger age of the formation. Upwards, they pass into carbonate platform limestones of the Manín Formation (Michalík and Soták, 1990). These shallow water carbonate deposits have not been studied in detail, yet.

2.7. The Butkov Formation

Dark brown gray shales of the Butkov Formation rest with gap on the corroded condensed surface of the Manín Formation. They contain glauconite grains, plant debris and planktonic foraminifers (Boorová and Salaj, 1992). Dinoflagelate cysts of open neritic (*Achomosphaera, Litosphaeridium*) and pelagial associations (*Pterodinium*) dominate over acritarchs (*Wallodinium, Veryhachium*), bisaccate pollen grains and microforaminifers. The first occurrence of *Litosphaeridium siphoniphorum* coincides with Late Albian ammonite Inflatum Zone, the appearence of *Protoellipsodinium conulum* together with *Endoceratium dettmaniae* and *Ovoidinum verrucosum* coincides with the youngest Albian ammonite Dispar Zone. *Atopodinium perforatum, Dinopterigium cladoides, Pervosphaeridium pseudhystrichodinium, P. truncatum, Xiphophoridium alatum*, and other Albian forms are abundant in dinoflagellate associations. Very rare findings of *Eiffelithus*

turriseiffelii allow to suppose late Early Albian age of the formation or assign the base of the Eiffelithus turriseiffelii Zone (CC9) sensu Perch-Nielsen (1985).

3. Conclusions:

1. The pelagic limestone sequence of Mt Butkov exposed by the Ladce Cement Works quarry is the best documented representative Lower Cretaceous sequence in Western Carpathians at all.
2. Basal Berriasian gap represents a characteristic feature of the Manín Unit, it is connected with the paleogeographic setting of this unit in the basin.
3. The Ladce Formation comprises Campylotoxus-, Verrucosum- and Peregrinus ammonite zones correlable with calpionellid Calpionellites Zone and with lowermost part of the Tintinnopsella Zone.
4. The Mráznica Formation is a product of dysoxic episode spanning the ammonite Furcillata Zone – an equivalent of dinoflagellate Validum Zone.
5. The Kališčo Formation has been deposited during ammonite Radiatus-, Loryi-, Nodosoplicatum-, Sayni-, and Ligatus zones. The lower part of the formation belongs to dinoflagellate Staurota and Stoveri zones, dinocysts are poorly represented higher up in the sequence.
6. The Lúčkovská Formation was the last part of the Lower Cretaceous pelagic limestone sequence. Its lowermost part (? Balearis Zone) is poorly dated, higher part of the sequence belongs to Hugii-, Nicklesi-, Pulchella-, Compressissima-, and Vanderheckii zones. The last zone is comparable with dinocyst Operculata Zone.
7. The Podhorie and Manín formations represents products of „Urgonian" carbonate platform, which developed since Aptian to the end of Early Albian.
8. The Butkov Marl Formation is equivalent to nannoplankton Turriseiffelii Zone, compared with the duration of ammonite Inflatum and Dispar zones.
9. Correlation of ammonites, aptychi, calpionellids, dinocysts and nannoplankton gives clue to precisioning of biostratigraphic division of Lower Cretaceous sequences.

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