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# The eroded Late Jurassic Kurbnesh carbonate platform in the Mirdita Ophiolite Zone of Albania and its bearing on the Jurassic orogeny of the Neotethys realm

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*Key words*: Late Jurassic, Early Cretaceous, carbonate platform, Mirdita Zone, Albania, Neotethys, Kimmeridian orogeny

ABSTRACT

Several Late Jurassic (Kimmeridgian?-Tithonian) to Early Cretaceous (Late Berriasian-Valanginian) shallow-water carbonate clasts of different facies are contained in mass-flow deposits in a pelagic sequence in the Kurbnesh area of central Albania. These clasts are used to reconstruct shallow-water carbonate platforms, which formed on top of the radiolaritic-ophiolitic wildflysch (ophiolitic mélange) of the Mirdita Zone. Stratigraphic interpretation of the platform carbonates was compiled on basis of calcareous algae, benthic foraminifera, and calpionellids. From biostratigraphic data and microfacies analysis, the Neocomian clasts can be directly correlated with autochthonous platform carbonates of the western part of the Munella carbonate platform, which at least reaches up to the Late Aptian. A Late Jurassic precursor platform (Kurbnesh carbonate platform; *nomen novum*) was completely eroded until the Valanginian and is only documented by the clasts described here. It was deposited on top of the Mirdita Ophiolite Zone nappe stack, which formed during the Middle to Late Jurassic Kimmeridian orogeny. Thrusting and imbrications as well as the formation of the syntectonic wildflysch (mélange) therefore occurred much earlier than previously assumed. Our results constrain the Kimmeridian orogeny, which was controlled by the closure of the Neotethys Ocean, and show excellent correlation with the Eastalpine-Dinaric-Hellenic orogenic system.

ZUSAMMENFASSUNG

Aus mikrofaziell unterschiedlichen Ober-Jura- (Kimmeridgium?/Tithonium) und Unter-Kreide-Flachwasserkalk-Klasten (Ober-Berriasium bis Valanginium), die in Form von Brekzienkörpern in pelagischen Sedimenten in der Gegend von Kurbnesh in Zentral-Albanien auftreten, werden jene Karbonatplattformen rekonstruiert, welche ursprünglich die Serie des radiolaritischen-ophiolithischen Wildflysches (Ophiolith-Mélange) in der Mirdita-Zone bedeckten. Die Stratigraphie basiert auf Kalkalgen, Benthosforaminiferen und Calpionellen. Stratigraphische und mikrofazielle Kriterien erlauben, die Neokom-Karbonatklasten mit den autochthonen Seichtwasser-Karbonaten des westlichen Abschnittes der Munella-Plattform, die mindestens bis in das obere Aptium reicht, in direkten Zusammenhang zu bringen. Eine heute vollständig erodierte Ober-Jura Karbonatplattform im Hangenden der Ophiolithdecken wird durch Komponentenanalyse rekonstruiert. Diese Ober-Jura-Karbonatplattform (Kurbnesh Karbonatplattform; *nomen novum*) war bis zum Valanginium vollständig erodiert und lässt sich nur durch die beschriebenen Klasten rekonstruieren. Sie wurde auf der Mirdita-Ophiolithzone abgelagert und versiegelte den Deckenstapel, der sich während der mittel- bis oberjurassischen Kimmeridischen Orogenese bildete. Deckenbau und Imbrikation sowie die Bildung des syntektonischen Wildflysches (der Mélange) fanden daher viel früher statt als bisher angenommen. Unsere Ergebnisse grenzen die Kimmeridische Orogenese, die von der Schließung des Neotethys-Ozeans gesteuert wurde, zeitlich ein, und zeigen sehr gute Korrelation mit dem Ostalpin-Dinarisch-Hellenischen orogenen System.

## Introduction and geological overview

The ophiolites of the Mirdita Zone as part of the so-called (Pindos-)Mirdita Ocean (e.g., Robertson 1994; Stampfli & Borel 2002; Dilek & Flower 2003) in the central part of Albania (Fig. 1) represent the remnants of Mesozoic oceanic lithosphere within the Dinaride-Hellenide segment of the Alpine orogenic system and form a north-south trending belt (e.g. Smith & Spray 1984; Channell & Kozur 1997). They consist of a variety of rocks attributed to the originally complete ophiolitic sequence through oceanic uppermost mantle and crust. However, recent studies on the ophiolites (e.g., Shallo 1994 with references; Robertson & Shallo 2000; Bortolotti et al. 1996, 2004; Shallo & Dilek 2003), which are partly based on older Albanian literature, discern two different rock associations, forming the Western and Eastern Ophiolite Belt (WOB and EOB) (see Nicolas et al. 1999 for comparison). Both are

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thought to 1) derive from the narrow (Pindos-)Mirdita Ocean between Apulia in the southwest and the Korabi-Pelagonian microcontinent to the northeast (e.g., Bortolotti et al. 1996; Dilek & Flower 2003, based on Robertson 1994) or 2) derive from the east of the Korabi-Pelagonian Unit (e.g., Kober 1914; Bortolotti et al. 2005; Gawlick et al. 2007. Formation of oceanic crust is mainly inferred to have started in Early Jurassic times (about 185 Ma; Shallo & Dilek 2003; for comparison: Dilek et al. 2005; Bortolotti et al. 2005), and intra-oceanic subduction in Late Jurassic time (~150 Ma; Shallo & Dilek 2003 with references) contemporaneous with the formation of flysch sediments (Robertson & Shallo 2000; Bortolotti et al. 2004). According to Peza & Marku (2002), Marku (2002) and others, the shallow-water carbonates of the Munella platform were formed not earlier than Barremian to Aptian time.

The ophiolite suites are associated with radiolarian cherts, mélanges, and flysch sequences. According to Gawlick et al. (2004, 2005a, 2007), the Perlat Formation (Bathonian to Oxfordian radiolaritic-ophiolitic wildflysch = ophiolitic mélange) was synchronously deposited with nappe thrusting and imbrication similar to the Rubik Mélange, but differs from the Rubik Mélange in age range and component composition (?Late Jurassic – Bortolotti et al. 2005 with references). In contrast, older studies (e.g., Meco & Aliaj 2000; Robertson & Shallo 2000; Shallo & Dilek 2003) considered it as a sedimentary sequence deposited in a rift-basin. The Perlat Formation occurs between the WOB and EOB and contains numerous different Triassic clasts and blocks (Gawlick et al. 2007) floating in a Middle to early Late Jurassic radiolarian chert and shale matrix. It differs in age and in the component spectrum also from the Simoni

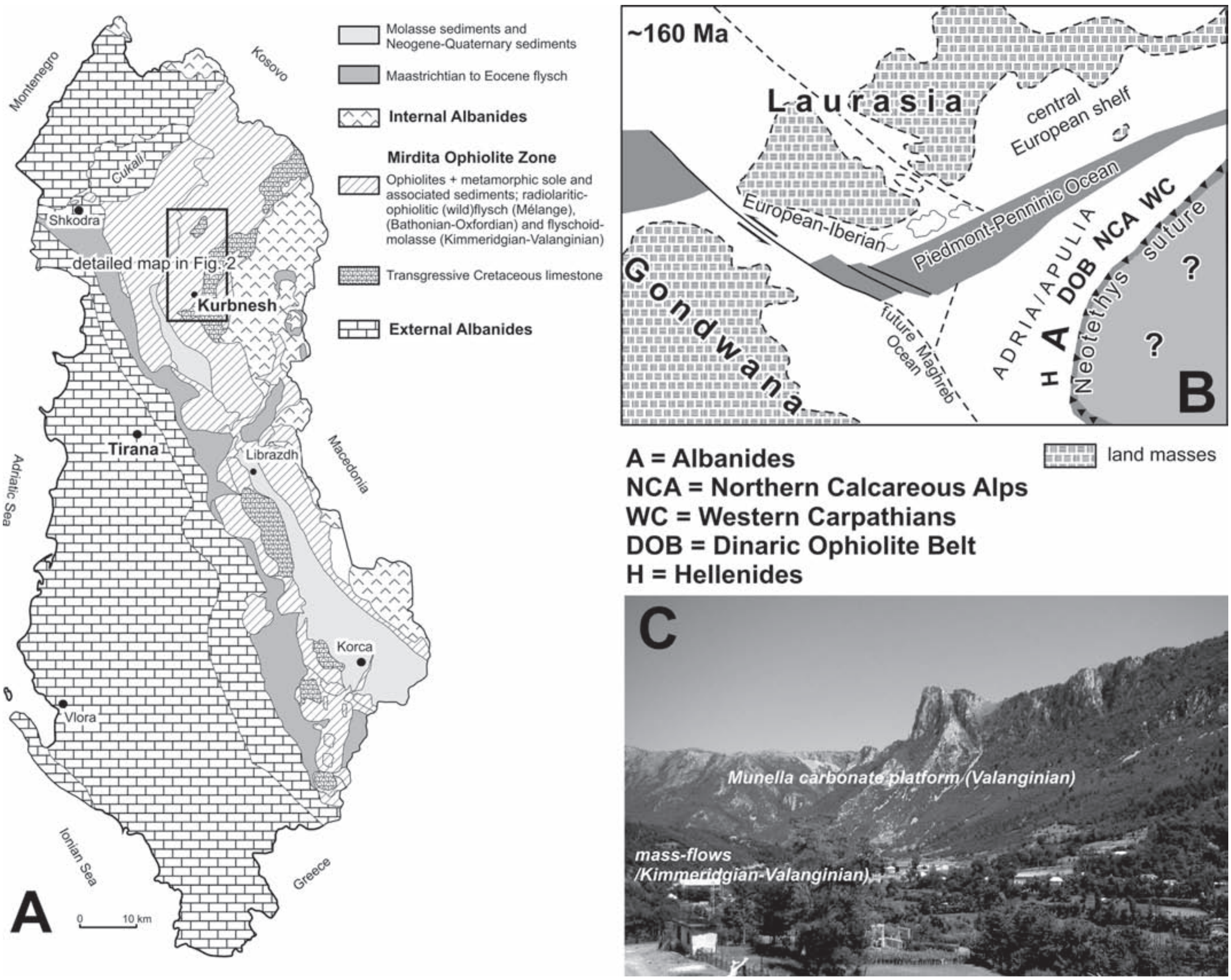


Fig. 1. A) Main tectonic units of Albania (after Xhomo et al. 2002) and geographic position of Kurbnesh. B) Palaeogeographic position of the Albanides (after Frisch 1980). C) View of Kurbnesh and the Mali i Shejtit Mountains with the mass-flows of the Kurbnesh and Firza Formations and the Munella carbonate platform.

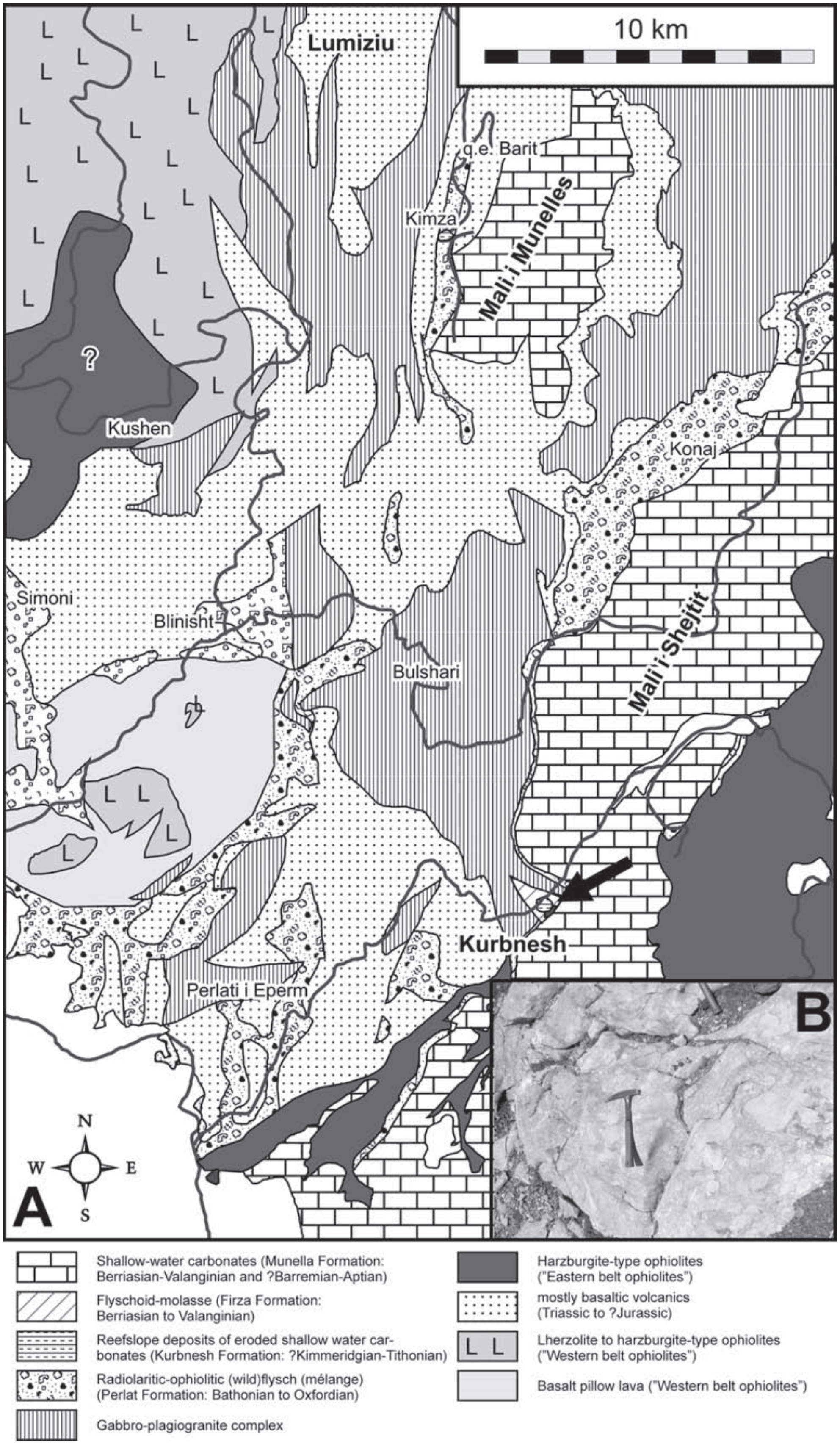


Fig. 2. A) Geological map of central Mirdita Zone with the Perlat-Kurbnesh area and the Mali i Sheijtit and Munella Mountains (Mali i Munelles). Arrow shows type locality of Late Jurassic Kurbnesh Formation. Map simplified on base of Harta Gjeologjike e Shqiperise 1:200.000 (Xhomo et al. 2002), including own results (Gawlick et al. 2007). B) Late Jurassic mass-flow sediments in Kurbnesh. Scale: hammer.

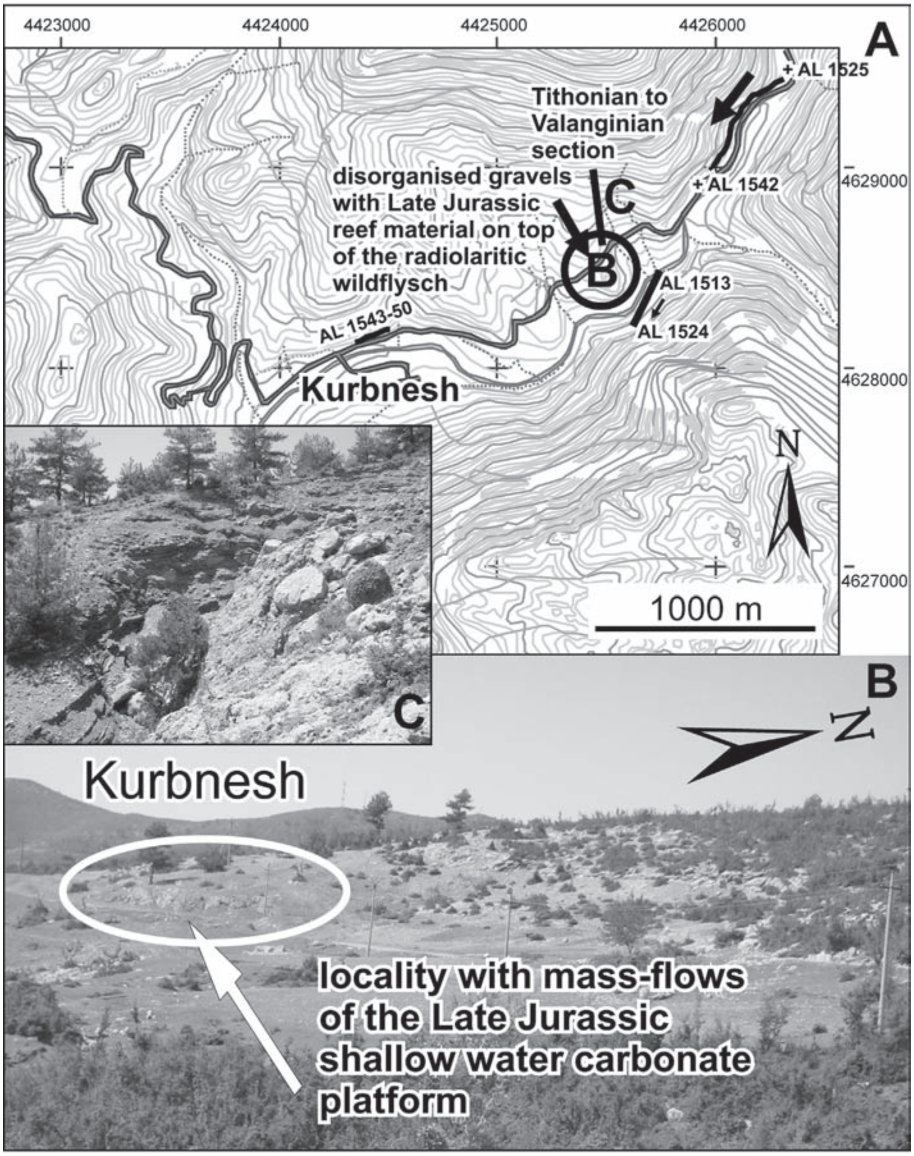


Fig. 3. A) Topographic map of Kurbnesh area and sample localities. B) Outcrop situation of the Kurbnesh Formation type loclity. C) Outcrop of Firza Formation with components of Kurbnesh carbonate platform.

Mélange (Middle Callovian to Early Oxfordian: Marcucci & Prela 1996; Bortolotti et al. 1996; Late Oxfordian/Early Kimmeridgian to latest Tithonian/Early Berrasian: Chiari et al. 2007) to the west (Bortolotti et al. 1996, 2004) and therefore represents another radiolaritic-ophiolitic wildflysch trench in front of an advancing ophiolite nappe.

The mélange is reported to be overlain by latest Tithonian to Early Cretaceous flysch deposits ("Firza-Flysch"; Gardin et al. 1996; Bortolotti et al. 1996) indicating the formation of a convergent tectonic regime (e.g., Shallo 1991; Meco & Aliaj 2000; Shallo & Robertson 2000). According to numerous authors thrusting therefore started during the Tithonian (Robertson & Shallo 2000; Hoxha 2001; Shallo & Dilek 2003; for comparison: Bortolotti et al. 1996, 2004). Gawlick et al. (2006, 2007), however, showed that the ophiolites were emplaced already in Bathonian to Oxfordian times and covered by Kimmeridgian(?) to Tithonian shallow-water limestones. They described, stratigraphically located between Perlat Formation and Firza Formation, another type of mass-flows of Kimmeridgian-Tithonian age: the Kurbnesh Formation (Gawlick et al. 2007), which contains components of different reefal limestones of Late Jurassic age in a hemipelagic matrix. The Late Jurassic shallow-water limestone clasts are of different facies and were detected near the village of Kurbnesh. They are also found in the overlying Firza Formation together with clasts of Neocomian shallow-water limestones (Gawlick et al. 2004, 2005a). The whole sequence represents a key section for the dating of the Perlat Formation (Fig. 1, 2, 3), which formed during nappe thrusting.

The present paper describes the mass-flow components in the Kurbnesh section together with new biostratigraphic and microfacies data. Our results allow to reconstruct a completely unknown Late Jurassic carbonate platform on top of the nappe stack of the Mirdita Zone. The results are important for the timing of the Kimmeridian orogenic movements and the reconstruction of the thrusting process in Middle to Late Jurassic time. They also close a gap of knowledge in the dynamics of the Neotethys realm between the Eastern Alps and the Dinarides on the one hand and the Hellenides on the other.

## Late Jurassic to Early Cretaceous resedimented and autochthonous shallow-water limestones

### *The Kurbnesh carbonate platform*

We interpret the ophiolitic mélange of the Perlat Formation to represent radiolaritic-ophiolitic wildflysch (Gawlick et al. 2007) corresponding to similar sequences known from the Northern Calcareous Alps (Hallstatt Mélange; Gawlick & Frisch 2003). In the surroundings of Kurbnesh the succession starts with a basal radiolaritic unit dated as Late Bajocian to Early Bathonian by means of radiolarian assemblages (Gawlick et al. 2005a, 2007; for comparison see Chiari et al. 2002). The overlying Perlat Formation is several hundred meters thick and contains up to kilometre-sized exotic blocks emplaced in radiolarites and partly siliceous shales, which yielded Late Bathonian to Oxfordian ages from radiolarian assemblages (Gawlick et al. 2007, Chiari et al. 2007). In the Kurbnesh section a large slide of serpentinite occurs on top of the Perlat Formation, followed in turn by 30–40 m thick mass-flow deposits called Kurbnesh Formation (Fig. 3, Fig. 4). The Kurbnesh Formation contains components of a completely eroded and so far unknown Late Jurassic shallow-water carbonate platform, for which the name “Kurbnesh carbonate platform” is introduced here.

Among these components, reefal boundstones with different microencruster associations (Fig. 5a), stromatoporoids (Fig. 5b), sponges, corals (Fig. 5c) and *Bacinella/Lithocodium* bindstones (Fig. 5d) are dominating. Common microencrusters include *Radiomura cautica* Senowbari-Daryan & Schäfer, *Koskinobullina socialis* Cherchi & Schroeder, “*Tubiphytes*” *morronensis* Crescenti, and foraminifera (Fig. 5a). Besides common remains of the dasycladale *Salpingoporella pygmaea* (Gümbel), a possible fragment of *Clypeina sulcata* (Alth) and the benthic foraminifer *Protopeneroplis striata* Weynschenk are identified as single bioclasts (Fig. 6).

The mass-flows of the Kurbnesh Formation are overlain by pelagic wackestones dated with calpionellids as Late Tithonian to Early Berriasian (Hoxha 2001; Marku 2002). Above these maiolica-type calpionellid limestones a more than one hundred meter thick succession of flysch-like deposits (mixed calcareous-siliciclastic turbidites, mass-flows = Firza Formation according to Bortolotti et al. 1996) follows, yielding Late Berriasian age (*oblonga* subzone, Fig. 7). These mass-flows eroded the underlying Late Tithonian to Early Berriasian *Calpionella*-

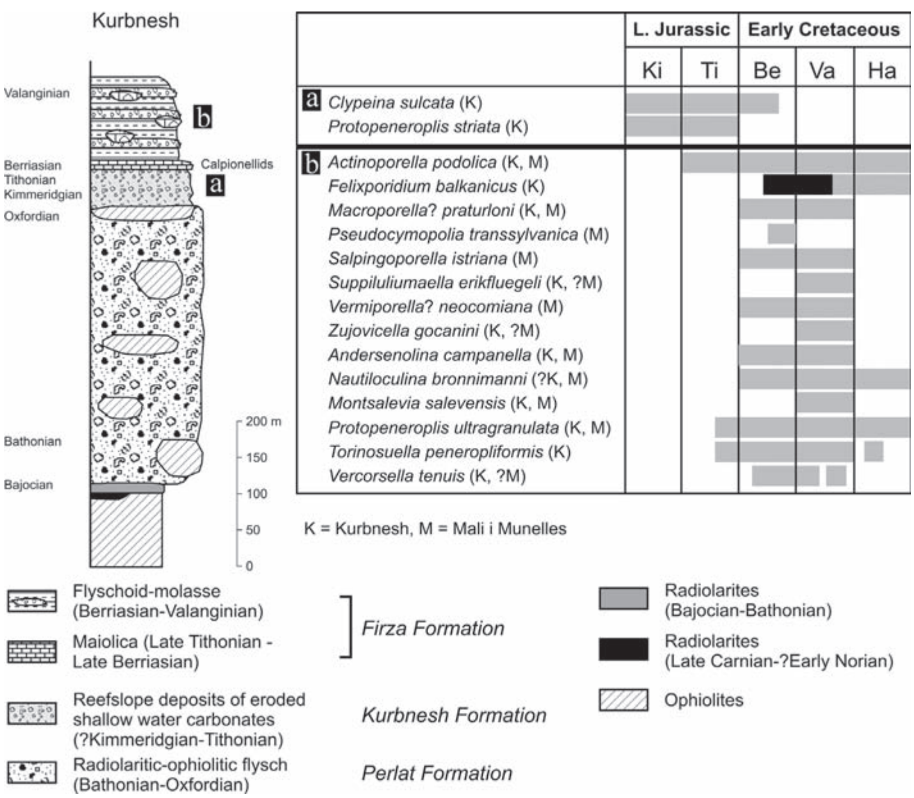


Fig. 4. Schematic succession of the Perlat, Kurbnesh and Firza Formations in the Kurbnesh area (after Gawlick et al. 2007), as well as stratigraphic ranges of the most important faunistic and floristic elements in components of the Kurbnesh Formation and the Neocomian parts of the Munella platform. Range charts adopted mainly from Bassoullet (1997), Bucur (1999), Granier & Deloffre (1993), Velić & Sokač (1983). Black bar show adapted stratigraphic range of *Felixporidium balkanicus* Dragastan according to the new results.

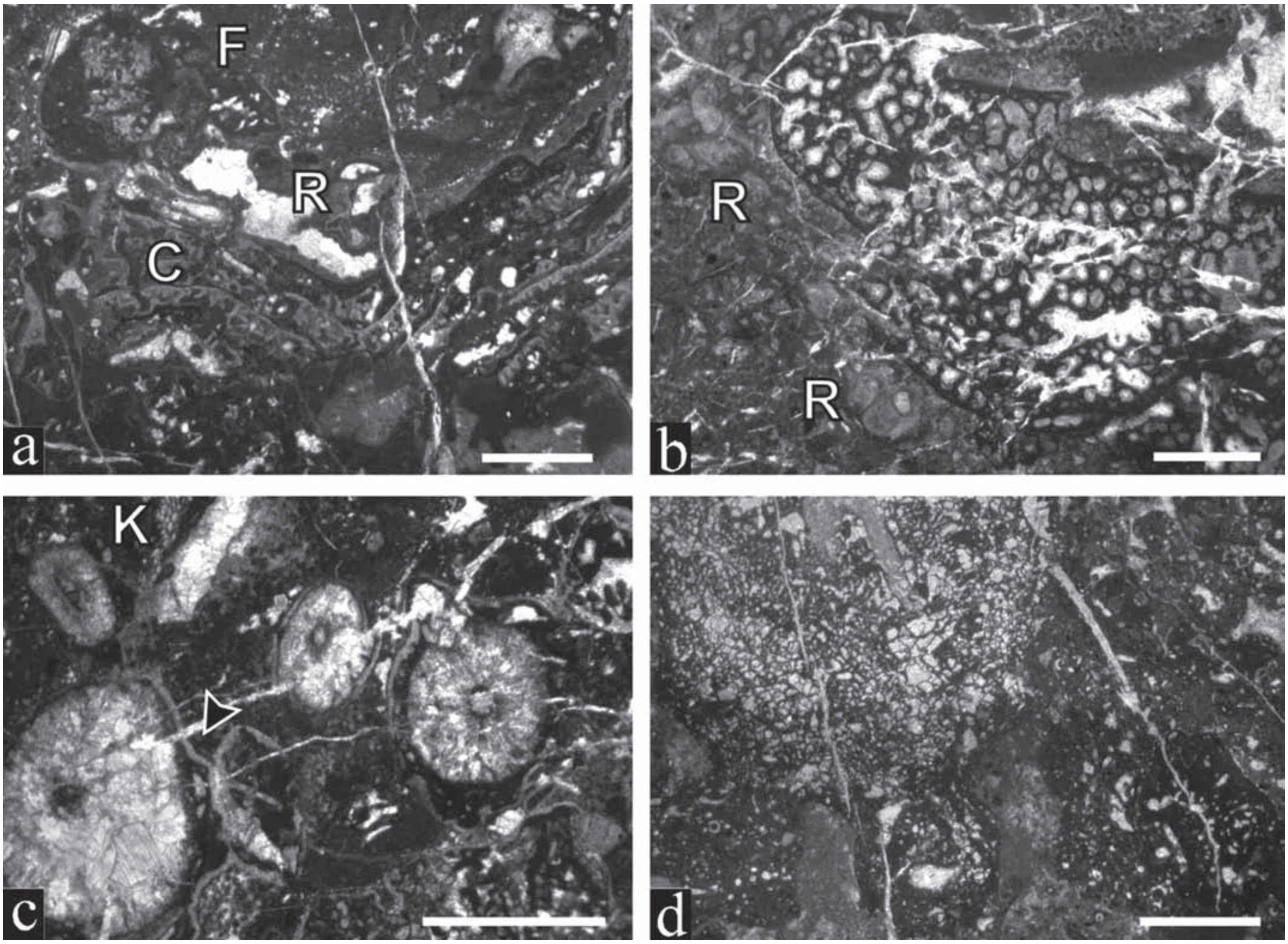


Fig. 5. Microfacies of Late Jurassic shallow-water limestone clasts from Kurbnesh and Firza Formations. a: Boundstone composed of microencrusters *Consinocodium japonicum* Endo (C) and *Radiomura cautica* Senowbari-Daryan & Schäfer (R), as well as foraminifera (F). Sample AL-66. b: Stromatoporoid *Tubuliella fluegeli* Turnšek encrusted by *Radiomura cautica* Senowbari-Daryan & Schäfer (R). Sample AL-69. c: Coral debris limestone with thin cement crusts (arrow). Note microencruster *Koskinobullina socialis* Cherchi & Schroeder (K). Sample AL-66. d: *Bacinella* bindstone. Sample AL-73. Scale bar for all figures = 2 mm.

limestones at the most places, therefore we summarize both as Firza Formation (Fig. 4).

The mass-flows contain a large number of reefal limestone clasts, which are, from their microfacies and microfossil content, similar to the mass-flows below the maiolica-type limestones, but of Late Berriasian(?) to Valanginian age. Especially the abundance of different taxa of dasycladales such as, for example, *Macroporella*? *praturloni* Dragastan (Fig. 8a), *Zujkovicella gocanini* (Radoičić) (Fig. 8b) or *Actinoporella podolica* (Alth) (Fig. 8d) and others is remarkable. Additionally, Valanginian reef limestones from the nearby Munella carbonate platform occur (Mali i Shejtit, Mali i Munelles – Fig. 2), Triassic carbonates and radiolarites, as well as volcanic, ultramafic, and gabbroic rocks occur as components in the mass-flows. In contrast to the Late Jurassic occurrences, single bioclasts (algae, foraminifera) are dominating. Imbrications in the type locality of the Munella platform show that tectonic shortening was again acitivated in the Early Cretaceous (Schlagintweit & Gawlick 2006).

*Munella carbonate platform*

The Early Cretaceous Munella platform (e.g., in the regions of Mali i Munelles, Mali i Shejtit – Fig. 2) represents the only autochthonous shallow-water carbonate platform in the area of the Mirdita Zone in central Albania covering large areas. It was dated by Peza & Marku (2002) and Peza & Zitt (2002) as Barremian to Aptian. According to our investigations at the western side of the Munella platform (Mali i Munelles), several imbricated slices of Berriasian-Valanginian shallow-water limestones occur above breccias with calpionellid limestone clasts of Late Berriasian age (*oblonga* subzone, Fig. 9). Here the cover of the

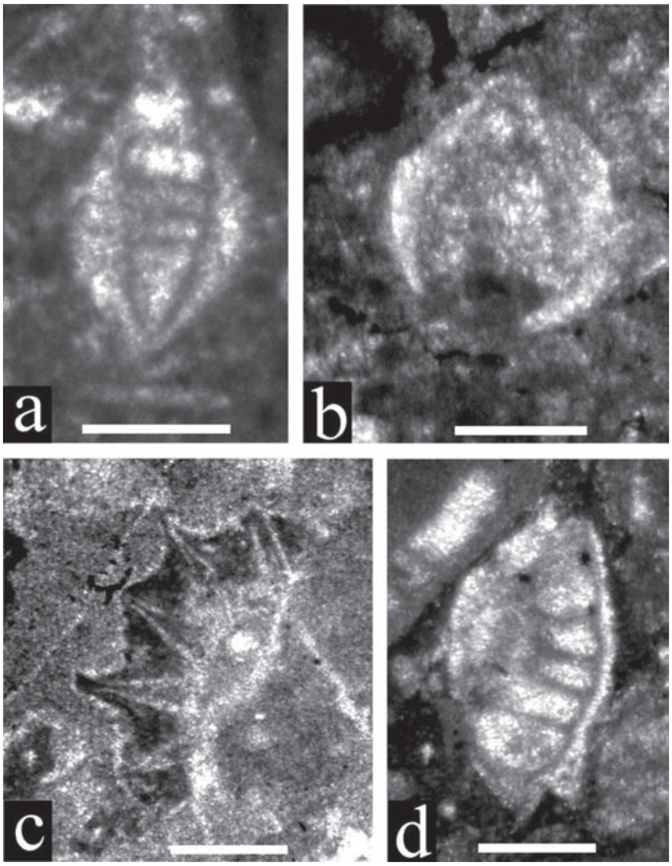


Fig. 6. Microfossils from Late Jurassic shallow-water limestone clasts. a, b, d: *Protopeneroplis striata* Weynschenk. Samples AL-49 and AL-52, scale bar = 0.2 mm. c: Possible fragment of *Clypeina sulcata* (Alth). Sample Al-52, scale bar = 0.5 mm.

Perlat Formation is formed by the Firza Formation followed by prograding platform carbonates of the Munella platform. Late Jurassic shallow-water carbonates are missing.

The Neocomian limestones comprise brecciated slope facies, platform margin deposits with corals and stromatoporoids (including taxa so far reported only from Late Jurassic strata, e.g., *Tubuliella fluegeli* Turnšek, *Tubuliella rotunda* Turnšek) interfingering with back-reef (e.g., *Bacinella* bindstones) and occasional lagoonal deposits of reduced thicknesses. Again, algal-debris-facies with abundant "coptocampylodons" occurs similar to the clasts in the Kurbnesh Formation. Within the lagoonal intercalations, the benthic foraminifera *Vercorsella tenuis* (Gusič & Velić) (Fig. 81) and *Montsalevia* gr. *salevensis* (Charollais et al.) (Fig. 8h) as typical Valanginian marker species occur.

The existence of Valanginian shallow-water limestones was unknown so far, since the flysch-type facies was attributed to both the Berriasian and the whole Valanginian by Peza & Marku (2002). These authors therefore assumed a Barremian to Aptian age of the *whole* Munella carbonate platform. In contrast, our results date the base for the Munella platform as Berriasian. The occurrence of *Recteodictyoconus giganteus* Schroeder and *Mesorbitolina texana* (Roemer) in mass-flows in other parts of the Mirdita Zone document that the shallow-water evolution of the platform lasted at least until the Late Aptian (Schlagintweit et al. 2006; Gawlick et al. 2007) (Fig. 10). There are also indications of emersion (microkarst), but the exact dating of the resulting sedimentary gap or "lost sequence" (Radoičić 1982) is still unknown ("Mirditian tectonic movements" or "Mirditian orogeny", e.g., Peza & Marku 2002).

### Stratigraphy and platform reconstruction

We obtained stratigraphic data from calcareous algae (mainly dasycladales) and benthic foraminifera. Interpretation is based on published stratigraphic range charts that were successively refined during the last decades (e.g., Granier & Deloffre 1993; Bassoullet 1997; Bucur 1999). The identification of *Protopeneroplis striata* in the mass-flows of the Kurbnesh Formation documents the existence of Late Jurassic shallow-water limestones, which have been completely eroded. The Munella carbonate platform in turn represents the Late Berriasian-Valanginian interval (Schlagintweit et al. 2006). Both, the Late Jurassic and the Berriasian-Valanginian shallow-water limestones were previously not recorded from the Mirdita Zone of Albania.

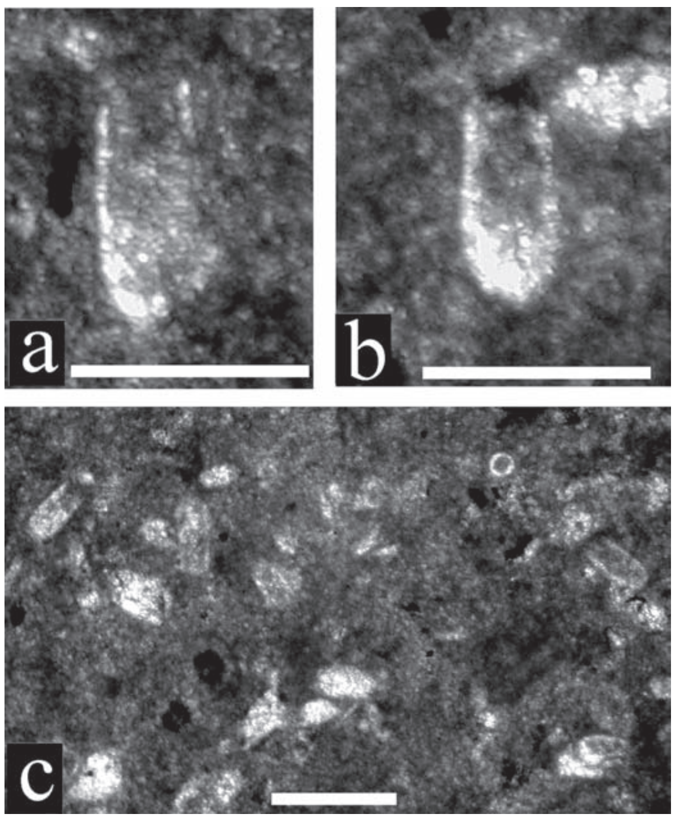


Fig. 7. *Calpionellopsis oblonga* (Cadisch) from the calpionellid limestones above the Kurbnesh Formation (see Fig. 4); sample AL 1543 in a, b = 0.1 mm, in c = 0.2 mm.

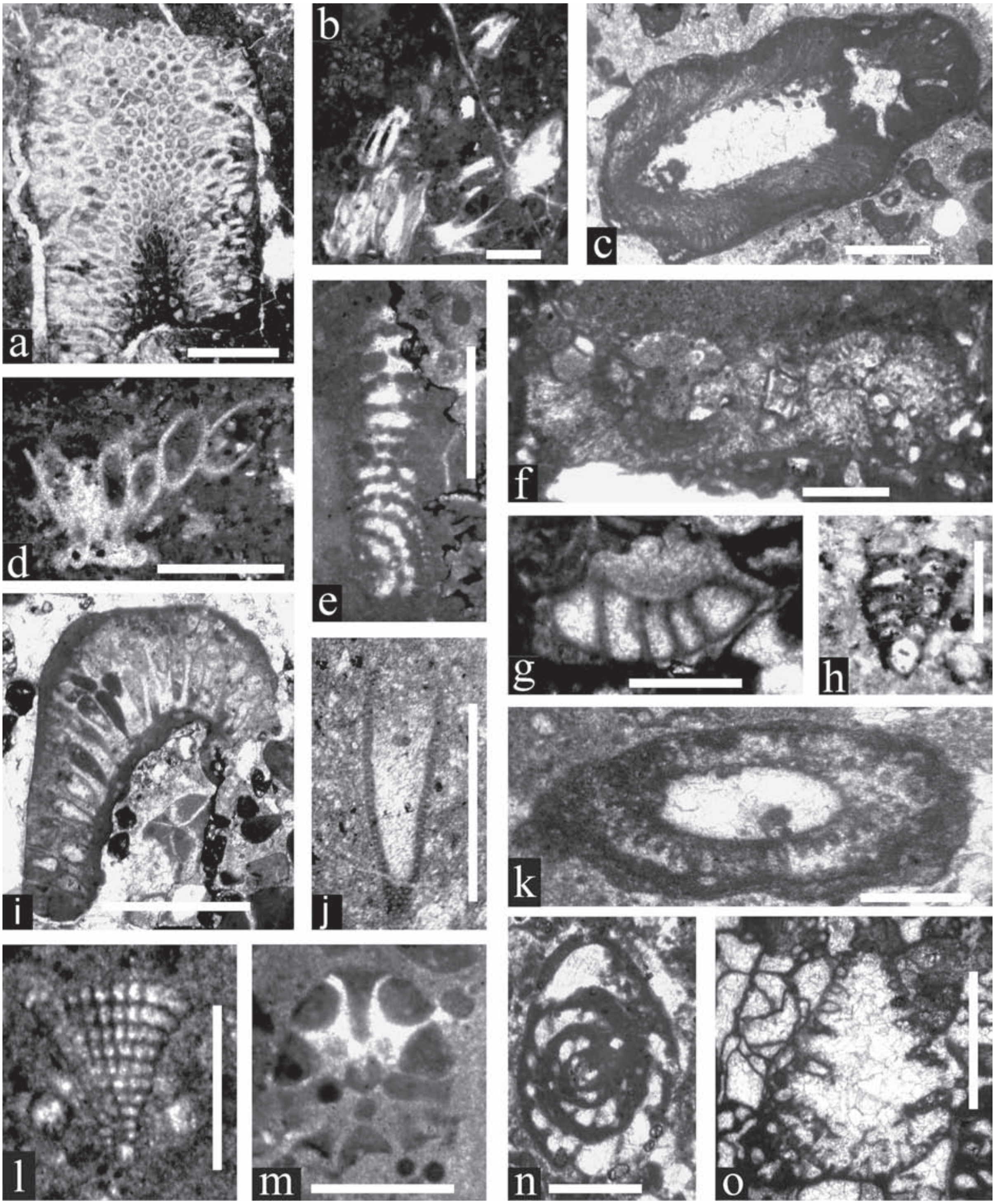


Fig. 8. Microfossils from Neocomian shallow-water limestones. a: Dasycladale *Macroporella*? *praturloni* Dragastan. Sample AL-1489. b: Dasycladale *Zujkovicella gocanini* (Radoičić). Sample AL-1481. c: *Pseudocymopolia transsylvanica* Dragastan. Sample AL-1022. d: Dasycladale *Actinoporella podolica* (Alth). Sample AL-1489. e: Foraminifer *Torinosuella peneropliformis* (Yabe & Toyama). Sample AL-1490. f: Protohalimedacean alga *Felixporidium balkanicus* Dragastan. Sample A-3709. g: Foraminifer *Protopeneroplis ultragranulata* (Gorbatchik). Sample A-3709. h: Foraminifer *Montsalevia* gr. *salevensis* (Charollais, Brönnimann & Zaninetti). Sample A-3707. i: Dasycladale *Suppiluliumaella erikfluegeli* Dragastan. Sample Al-842. j: Dasycladale *Vermiporella*? *neocomiana* Conrad. Sample A-3707. k: Dasycladale *Salpingoporella istriana* (Gusič). Sample A-3705. l: Foraminifer *Vercorsella tenuis* (Gusič & Velić). Sample AL-1512. m: Dasycladale *Cylindroporella sudgeni* Elliott. Sample AL-848. n: Foraminifer *Nautiloculina broennimanni* Peybernes. Sample A-3694-2, o: Foraminifer *Andersenolina campanella* (Arnaud-Vanneau, Boisseau & Darsac). Sample AL-95. Scale bars: a, i, o = 1 mm; b–f, j, k, m, n = 0.5 mm; g, l = 0.3 mm; h = 0.2 mm. Localitiy of Kurbnesh Formation: a, b, d–g, l, o. Neocomian carbonates of Munella platform (western slope, east of Kimza; see Fig. 2): c, h–k, m, n.

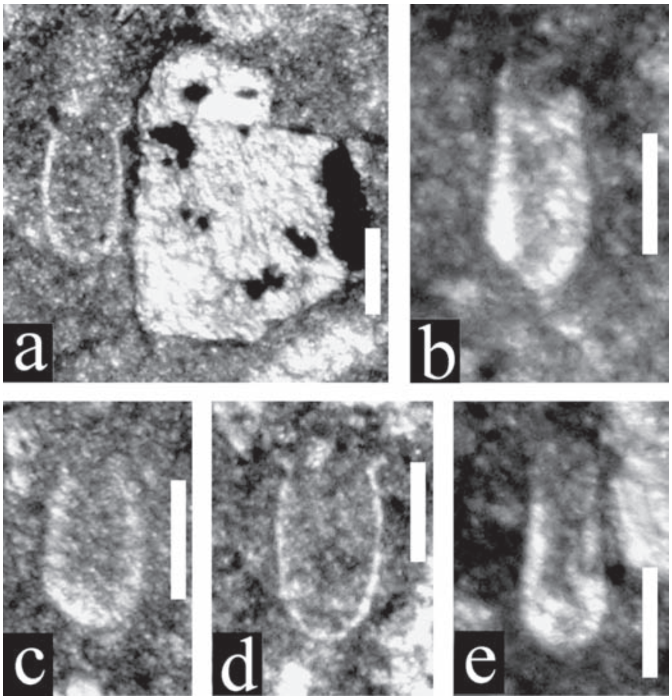

Fig. 9. Calpionellids from the Firza Formation below the Munella platform east of Kimza (see Fig. 2). a: *Tintinopsella carpathica* (Murgeanu & Filipescu) with clast of volcanic rock. Sample A-3682. b: *Calpionellopsis oblonga* (Cadisch). Sample AL-901. c: *Calpionella elliptica* Cadisch. Sample A-3682. d: *Tintinopsella carpathica* (Murgeanu & Filipescu). Sample A-3682. e: *Calpionellopsis oblonga* (Cadisch). Sample AL-901. Scale bars: 0.1 mm.

A reconstruction of the Late Jurassic Kurbnesh carbonate platform is shown in Fig. 11. The clasts are slope to platform margin deposits with coral-stromatoporoid reefs containing the encrusting foraminifer *Subbdelloidina*? *luterbacheri* Riegraf (Schlagintweit & Gawlick 2006), *Bacinella* bindstones (?back reef or reef flat), and *Coptocampylodon* algal-debris facies (Schlagintweit & Gawlick 2007). The existence of a back-reef lagoon is not directly evidenced in the clast spectrum. The relative rapid transition from flyschoid series to brecciated slope limestones and reefal platform margin deposits in the western part of the Early Cretaceous Munella carbonate platform can be explained by a steep by-pass slope.

**Regional comparisons and correlations**

Bathonian to Oxfordian ophiolite nappe thrusting in Albania has been proven by the analysis of the radiolaritic-ophiolitic wildflysch (mélange) and the dating of radiolarians (Chiari et al. 2002, Gawlick et al. 2007; Fig. 11). The existence of a carbonate platform (the Kurbnesh platform) above the nappe stack in the Kimmeridgian-Tithonian is proven by the dating of platform carbonate material contained as clasts in mass-flows of the Kurbnesh Formation. The actual controversial discussions about the tectonic interpretation of the ophiolites show that a large number of stratigraphic data from all the sediments which are in contact with the ophiolites is still needed. The paleogeographic position of the Kurbnesh carbonate platform and its reef margins is still unknown, but first comparisons with other regions in the Dinaride-Hellenide and East-Alpine realms can be drawn for a better understanding of the paleogeography.

*Slovenia and Croatia*

The most abundant stromatoporoids in our Albanian material, *Tubuliella fluegeli* Turnšek (Fig. 5b), *T.* cf. *rotunda* Turnšek and *Astrostylopsis* cf. *grabenensis* Germovshek, were also described from a Late Jurassic reef belt in Slovenia, the continuation of which has been suggested to be in Albania (Milan 1969; Turnšek 1966; Turnšek et al. 1981). These taxa are typical for the frontal reef part at the platform margin (Turnšek et al. 1981: "actinostromariid Zone"), which explains their occurrence in deposits like the slope deposits and mass-flows of the Kurbnesh Formation.

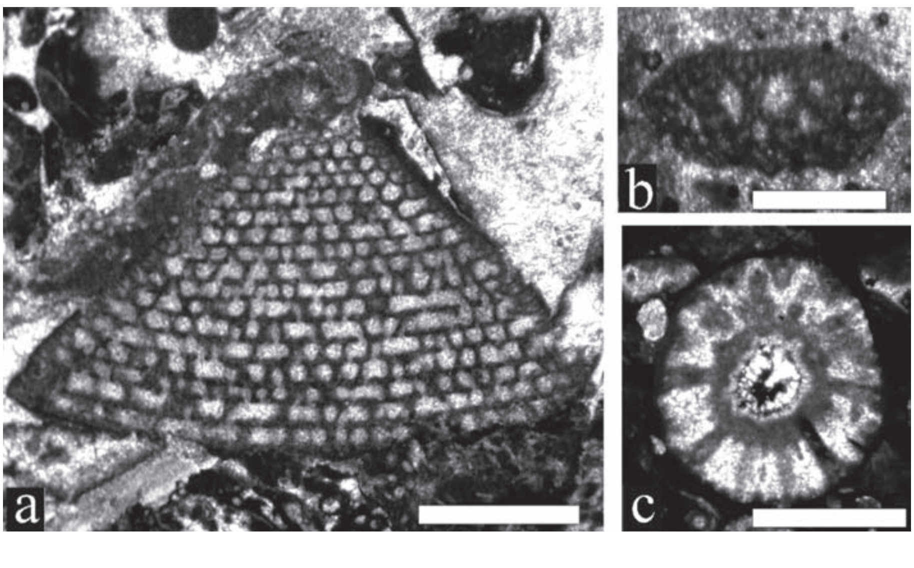

Fig. 10. Microfossils from Aptian shallow-water limestone clasts, locality Mali i Sheijtit (see Fig. 2), Munella platform. a: *Recteodictyoconus giganteus* Schroeder. Sample A-3746-1, scale bar = 1 mm. b: *Mesorbitolina texana* (Roemer). Sample Al-976, scale bar = 0.3 mm. c: *Acroporella radoicicae* (Praturlon). Sample A-3476-1, scale bar = 0.5 mm.

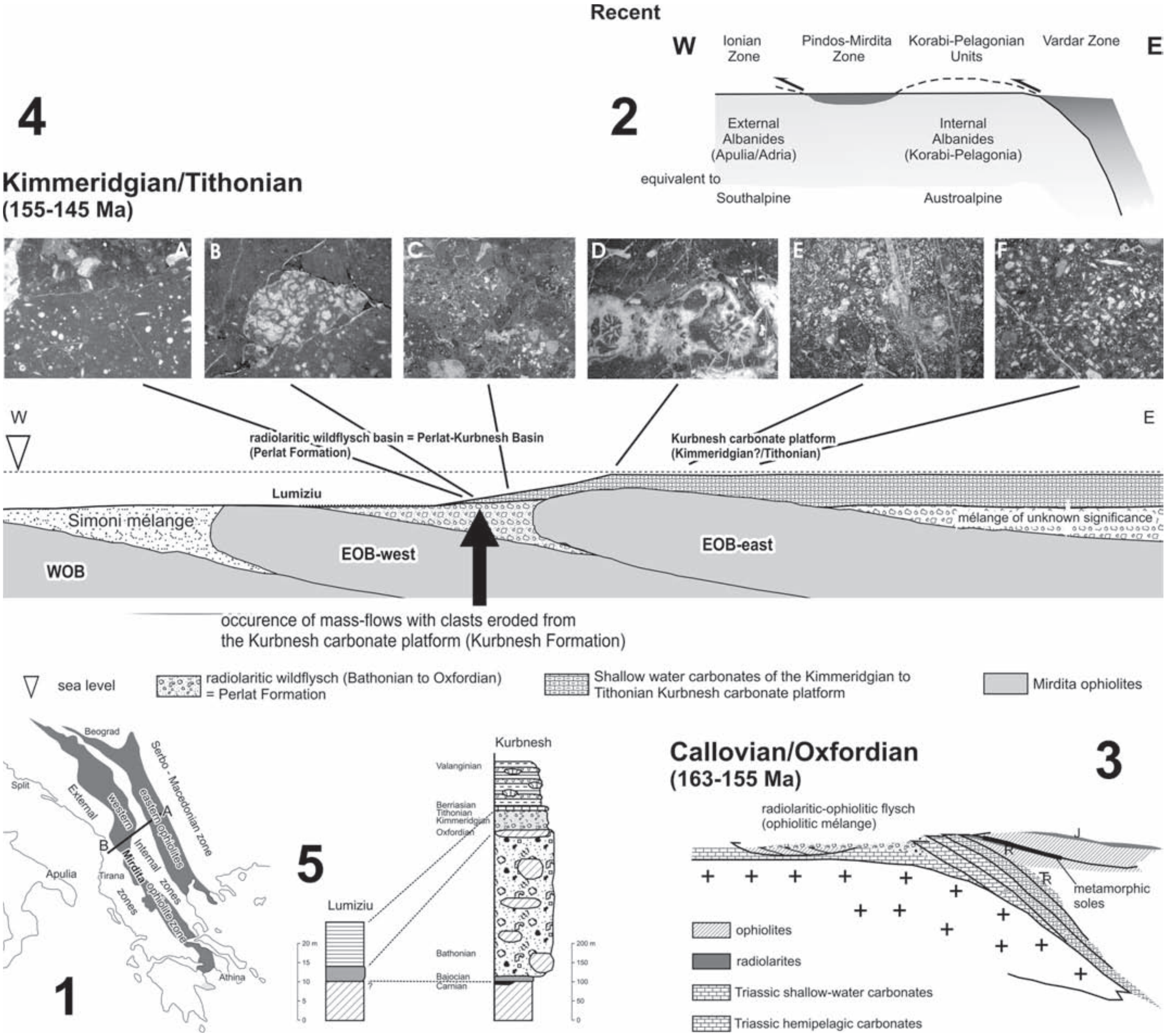


Fig. 11. 1) Regional geological setting showing the external zones, the western ophiolite zone (= central Dinaride, Mirdita, Hellenic ophiolite zones; does not mean WOB of Mirdita ophiolites), the internal zones (Korabi-Pelagonian Microcontinent = Pelagonian Zone, Korabi Zone, Drina-Ivanjica element) and the eastern ophiolites (Inner Dinaric ophiolite zone and Vardar zone; does not mean EOB of Mirdita ophiolites). Line A-B: sketch profile shown in 2. 2) Sketch profile (actual situation), with Pindos-Mirdita Ophiolite Zone forming a nappe on top of the Albanides (sensu Kober 1914). 3) Callovian/Oxfordian obduction and upper part of Perlat Formation receiving resediments from the overthrusted and imbricated, partly metamorphosed Korabi-Pelagonian Units (after Gawlick et al. 2007). 4) Late Jurassic Kurbnesh platform as reconstructed from components in the mass-flows of the Kurbnesh Formation, and nappe pile of the Mirdita ophiolites. Thin-section graphs: A) Radiolaria-spicula wackestone (below) and Late Jurassic shallow-water litho- and bioclasts (above). B) Clast of *Bacinella irregularis* Radoičić within stylobreccia. C) Diagenetic packstone (stylobreccia) with slope clasts. D) Reefal limestone with corals. E) *Bacinella* bindstone clasts. F) Algal-debris facies with *Coptocampylodon* sp. We assume a relatively steep slope to the west. WOB and EOB: Western and Eastern Ophiolite Belt of Mirdita Zone, respectively, in the sense of Robertson & Shallo (2000). Perlat Formation was deposited within EOB. 5) Comparison of the Lumiziu (Lumi i Zu – Chiari et al. 2007) section and the Kurbnesh section.

Both taxa are – according to our knowledge – only known from their type locality in Slovenia (Turnšek 1966) and the northern Velebit/Velika Kapela region in Croatia (Milan 1969). In contrast, resedimented ellipsactinids, which also flourished along the platform margins and are characteristic constituents of the Slovenian-Croatian reefs, are missing in the Kurbnesh Formation. There are different age classifications of the reefs: Turnšek et al. (1981) assume an Oxfordian to Early Kimmeridgian age for the reefal limestone in Slovenia, whereas in Croatia a Tithonian age is indicated (e.g., Matičec et al. 1997).

The described autochthonous Late Jurassic stromatoporoid-coral reef limestones of Slovenia-Croatia are similar with respect to their facies as, and can be directly compared with, the allochthonous Albanian occurrences. The reefal limestones are part of the Triassic to Cretaceous Adriatic-Dinaridic carbonate platform of the External Dinarides and did not form on top of ophiolitic series like in Albania. This shows that both shallow-water carbonate platform areas can be palaeogeographically connected since Kimmeridgian times.

### *Montenegro and Serbia*

Few outcrops of Late Jurassic reefal limestones with stromatoporoids and corals are described from Montenegro (e.g., Radoičić 1966), but until now they have not been studied in the same detail as in Slovenia and Croatia. Some details on stromatoporoid taxa from Montenegro were described by Turnšek (1968: p. 372), who stated that they belong to genera widely spread in Slovenia.

In biostratigraphy and facies the Neocomian Munella carbonate platform in Albania is similar to shallow-water components in mass-flows in the Mirdita Zone of Serbia and Montenegro (Metohija Unit in the Orahovac region), where autochthonous Neocomian shallow-water limestones are unknown. The components contain similar algal associations as the Munella platform carbonates (e.g., Radoičić 2005). In Serbia-Montenegro the Neocomian transgression is interpreted to have flooded only parts of the uplifted ophiolite complexes, their main part would have not become covered by sediments before Late Cretaceous times (e.g., Radoičić 1993). In this area, two Cretaceous units are established: the Metohija Unit in the east and the Kukes Unit, exposed over a larger area in the Albanian territory (Pejović & Radoičić 1973, Radoičić 1993, 2005). The Metohija unit comprises platform carbonates of the Tithonian-Valanginian age, which are similar to the situation in Albania (Kurbnesh/Munella platforms). In the Kukes Unit, the carbonate platform evolution probably started in the Hauterivian. However, more data on stratigraphy, facies and the overall sedimentary evolution are needed in both regions to correlate the Mirdita Zone of Serbia and Albania.

### *Greece*

Late Jurassic shallow-water limestones occur in Greece, both as carbonate platform sequences and as components. In the Pelagonian Zone, Scherreiks (2000) reported Late Jurassic ophiolite emplacement and a mélange with components and debris of Late Jurassic shallow-water limestones in a radiolaritic matrix. In a schematic paleogeographic model, a low-angled shelf was assumed, where clasts of *Cladocoropsis mirabilis* Felix, a typical inhabitant of low-energy lagoonal settings (Flügel 1974), were transported towards the basin. The Late Jurassic clasts of the Kurbnesh Formation, however, indicate that they derive from a rimmed platform type. Late Jurassic, autochthonous *Cladocoropsis* wackestone, for instance, was described by Carras (1995) from the Parnassos Zone.

Another Late Jurassic series of mass-flows with Tithonian carbonate clasts was described by Dragastan & Richter (1999) from the Beotic Zone SW of Corinth, NE-Peleponnesus. The authors suggested an isolated carbonate platform of the Parnassos-Kiona Zone as source area. The abundant occurrence of oolites and *Rivularia*-type cyanophycean algae, however, differs markedly from our material, in which we found no evidence for high-energy outer platform shoals exists.

From the Methana peninsula, tectonically part of the Subpelagonian Zone, Dragastan & Richter (2003) reported allochthonous algae-rich Late Jurassic limestone clasts in an “accretional prism” with ophiolites and various mass-flows. These deposits are of Late Berriasian to Hauterivian age and, thus, younger than the Kurbnesh Formation. Micropaleontologically, however, they are identical to the carbonatic clasts of the Berriasian-Valanginian flyschoid deposits (Firza Formation) in Albania.

### *Austria (Northern Calcareous Alps)*

The scenario in the Albanian Mirdita Zone not only conforms with the adjacent areas of the Dinaride-Hellenide system, but even better resembles the evolution of the radiolaritic carbonate-clastic wildflysch basins (Hallstatt Mélange – Frisch & Gawlick 2003) in the Northern Calcareous Alps (Gawlick & Frisch 2003). These basins were topped by the Kimmeridgian to Early Berriasian Plassen Carbonate Platform, which shows good correspondence to the eroded Late Jurassic Kurbnesh carbonate platform in the Albanides. The Plassen Carbonate Platform was deposited above structures and a relief caused by Callovian to Oxfordian thrust tectonics and was deposited in a persistingly mobile tectonic environment (Gawlick & Schlagintweit 2006). The tectono-sedimentary scenario of the Late Jurassic platform carbonate clasts in the Kurbnesh Formation in Albania correlates with that of the erosional products of the Plassen Carbonate Platform, contained in the Barmstein Limestone in the Northern Calcareous Alps (Gawlick et al. 2005). The Barmstein Limestone represents mass-flows with shallow-water bioclasts and reefal limestone components. The Kurbnesh platform in Albania formed in a very similar way with its onset of shallow-water carbonate production on top of the Middle to Late Jurassic nappe stack formed during the Kimmeridian orogeny.

## Discussion

Gawlick et al. (2007) showed that the ophiolite nappes of the Mirdita Zone were already emplaced on top of the Pelagonian units in the late Middle Jurassic, as documented by the supply of Hallstatt- and Dachstein-type limestone clasts into the upper part of the Perlat Formation (Callovian to Oxfordian). Formation of oceanic crust in the Neotethys Ocean, where the Mirdita ophiolites derive from, started in the Middle Triassic (Late Anisian: Gawlick et al. 2006, 2007; for comparison: Robertson & Shallo 2000 with references, Bortolotti et al. 2004), its destruction probably initiated in the late Early Jurassic (Gawlick et al. 2007). We interpret the whole succession containing components of very different size in radiolaritic to shaly matrix (Perlat Formation) as a sedimentary mélange and synorogenic radiolaritic flysch sequence formed simultaneously to Bajocian/Bathonian inner-oceanic thrusting and Callovian/Oxfordian ophiolite obduction and nappe stacking upon the Pelagonian Zone to the west of the Neotethys Ocean. The Perlat Formation, thought to have formed between the WOB and EOB, in fact was deposited in front of an advancing nappe within the EOB, whereas the Simoni Mélange further to the west have formed in a position between WOB and EOB (Fig. 11). Both formations differ in age and component content (Bortolotti et al. 1996; Gawlick et al. 2007).

After obduction, nappe stacking, and syntectonic formation of the sedimentary mélange (Perlat Formation), Late Oxfordian radiolarites and the Kimmeridgian?-Tithonian Kurbnesh carbonate platform were deposited, which could be reconstructed by component analysis in mass-flow deposits of the Kurbnesh Formation (Fig. 11).

The around 30–40 m thick Kurbnesh Formation overlies the Perlat Formation and corresponds in time with the upper part of the Lumiziu (Lumi i Zi; Fig. 2) section (Chiari et al. 2007). There, 12 m thick green siltstones, tuffites and green radiolarian cherts probably represent the distal part of the Perlat-Kurnesh basin.

The detection of the Kimmeridgian?-Tithonian Kurbnesh carbonate platform means that the first thrusting process in the underlying ophiolite nappes had already terminated at that time, and not in Barremian time as proposed by several authors (e.g., Bortolotti et al. 2004 with references; Peza & Marku 2002). Our data give a clear upper time constraint for early nappe thrusting and syntectonic sedimentation. This has far-reaching consequences on the interpretation of the Kimmeridian orogeny in the Neotethys realm.

Our results are in agreement with the situation known from other regions in the Alpine-Dinaride-Hellenide mountain belt (e.g., Bortolotti et al. 2003). The detection of the eroded Late Jurassic Kurbnesh carbonate platform above the ophiolite nappes shows that the orogenic events must have occurred before sedimentation of the platform carbonates; they also predate the mass-flows of the Kurbnesh Formation, which contain the platform components (Fig. 11). We consider the underlying ophiolitic mélange of the Perlat Formation as synorogenic sediment. The Perlat Formation was deposited in the Middle to Late Jurassic period (Bajocian to Oxfordian) contemporaneous with nappe thrusting. The depositional area was a trench in front of the advancing nappes.

This situation completely conforms to that in the Northern Calcareous Alps, where a radiolaritic flysch with components of all sizes, up to nappe size, formed contemporaneously with nappe advancement (Gawlick et al. 1999). There the according tectonic features and radiolaritic flysch sediments are overlain by the Kimmeridgian to Berriasian shallow-water Plassen Carbonate Platform forming during a convergent tectonic regime.

**Conclusions**

1. The detection of Late Jurassic shallow-water carbonate clasts in mass-flows (Kurbnesh Formation) covering the radiolaritic-ophiolitic wildflysch or mélange (Perlat Formation) shows that first nappe stacking in the Albanian ophiolite belt ended much earlier then previously assumed. Nappe stacking during Kimmeridian (Middle to Late Jurassic) orogeny led to exposure and erosion, and finally to the sedimentation of the Kurbnesh carbonate platform, which covered the tectonic structures.
2. According to actual knowledge, the Kurbnesh carbonate platform was completely eroded soon after sedimentation and lithification of its rocks. It is only detectable in form of clasts and blocks in mass-flow deposits of the Kurbnesh and Firza Formations.
3. We dated the beginning of sedimentation in the younger and still preserved Munella carbonate platform (*sensu stricto*) as Late Berriasian to Valanginian, hence significantly earlier then previously reported (Barremian). On its western slope Valanginian limestones (mainly of platform margin facies) form several superimposed tectonic slices, which indicate a setting of ongoing tectonic shortening in Valanginian times.
4. The Kurbnesh carbonate platform represents the facial and stratigraphic counterpart of the Plassen carbonate platform of the Northern Calcareous Alps.

Triassic spreading of Mirdita ocean floor (Gawlick et al. 2007) and its Middle Jurassic destruction clearly imply that the Albanian ophiolites – as well as their continuations to the north and south – derive from the Neotethys (= Vardar-Meliata) Ocean east of the Pelagonian continental fragment and consequently were brought into their present position by far-distance transport during W-vergent thrusting in Middle to Late Jurassic times similar to the situation in the Dinarides (Schmid et al. 2008).

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