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The Permian and Triassic in the Albanian Alps

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ABSTRACT:

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The sedimentary succession of the Permian to Middle Triassic of the Albanian Alps is described, as part of the eastern Adria passive margin towards the Tethys. A carbonate ramp deepening towards NE in present day coordinates developed during the Middle Permian and was affected by block faulting with the deposition of carbonate breccia. The Early Triassic was characterized by intense terrigenous deposition with several cobble conglomerate units up to 80 m-thick, and by oolitic carbonate shoals. The fine clastic deposition ended gradually during the earliest Anisian and a wide calcarenitic ramp occupied the area, with small local carbonate mounds. Basinward, the red nodular limestone of the Han Bulog Formation was interbedded with calcarenitic material exported from the ramp. Drowning to more open conditions occurred towards the end of the Pelsonian. Subsequently, cherty limestone and tuffitic layers spread over the entire area. Towards the end of the Ladinian, with the end of the volcanic activity, red pelagic limestone was deposited locally for a short period. By the latest Ladinian most of the area returned to shallow-water conditions, with a peritidal carbonate platform. In the Theth area, in contrast, a basin with black organic-rich dolostone and limestone developed which seems to be unique in that part of the Adria passive margin. The occurrence of cobble conglomerate units in the Lower Triassic testifies to very active block faulting and high accommodation, not yet described for the area.

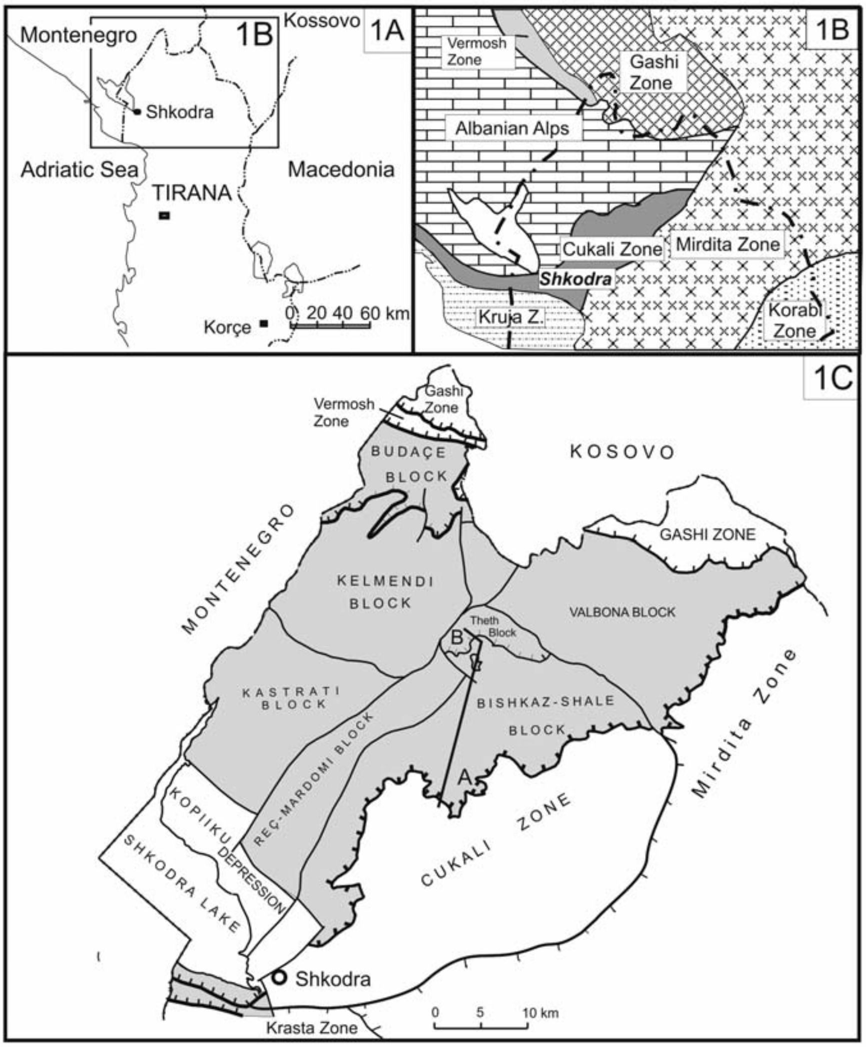
Key words: Permian; Triassic; Stratigraphy; Albanian Alps; Microfacies; Conodonts; Foraminifers.

INTRODUCTION AND PREVIOUS WORK

The aim of this paper is to describe the main features of the stratigraphy of the Permian to Middle Triassic succession in the Albanian Alps (the valleys of Kir and Shala) and to discuss their palaeogeographic evolution (Text-fig. 1). The Lower and Middle Triassic rocks will be described in detail, whereas understanding of the local Permian strata is still at a preliminary stage and only part of the succession will be described here.

The fieldwork was carried out over several years, from 1995 to 2002, by M. Gaetani and S. Meço. Further field checking took place in May 2012 and September 2014. Conodonts were studied by S. Meço (Triassic) and C. M. Henderson (Permian); foraminifers by R. Rettori and A. Tulone.

The Permian–Triassic rocks of the Albanian Alps were first analysed by Nopcsa (1905, 1929) and Arthaber (1908, 1909, 1911) within the framework of a general reconnaissance study of the stratigraphic succession of the area. Nopcsa (1929), in the summary of his previous works in his monumental book on the geology of Northern Albania, identified the basic stratigraphy and subdivided the structure into three main stacks (Schuppe). In the interval between the two world wars there were virtually no further investigations in this area. Only later, a number of short notes discussed some details of the succession, sometimes as internal document of the Geological Survey in Tirana (Meço 1968, 1988; Xhomo *et al.* 1982; Pirdeni 1981, 1987; Bignot *et al*. 1982; Shehu *et al*. 1983; Gjata *et al*. 1987; Theodhori 1988). The major contribution to the investigation of this area took place during the geological mapping of the country (ISPGJ-IGJN 1983, 1985, 1999) at the scale of 1:200.000, including the Albanian Alps. The mapping was later improved with the printing of sheets at the scale of 1:50.000 (Sherbimi Gjelogjik Shqiptar: Sheet 6 –Thethi 2003; Sheet 10 – Lekbibaj 2011). The conodonts of the Middle Triassic pelagic rocks were illustrated by Meço (1999, 2010), and the magnetostratigraphy of the Anisian of Nderlysaj was analyzed by Muttoni *et al*. (1998). Two major syntheses appeared recently. Meço and Aliaj (2000) divided the Albanian Alp Zone into two subzones: the Mahlsia e Mahde Subzone and the Valbona Subzone, illustrating the main features of the stratigraphic succession without introducing formal lithostratigraphic terminology. Subsequently, Xhomo *et al*. (2008) subdivided, with more detail, the Albanian Alps into several structural blocks (Text-fig. 1C). We adopt these subdivisions and deal here with the Bishkaz-Shale and Theth blocks. Microfacies analysis has never been undertaken; a preliminary note was published by Gaetani *et al*. (2014).



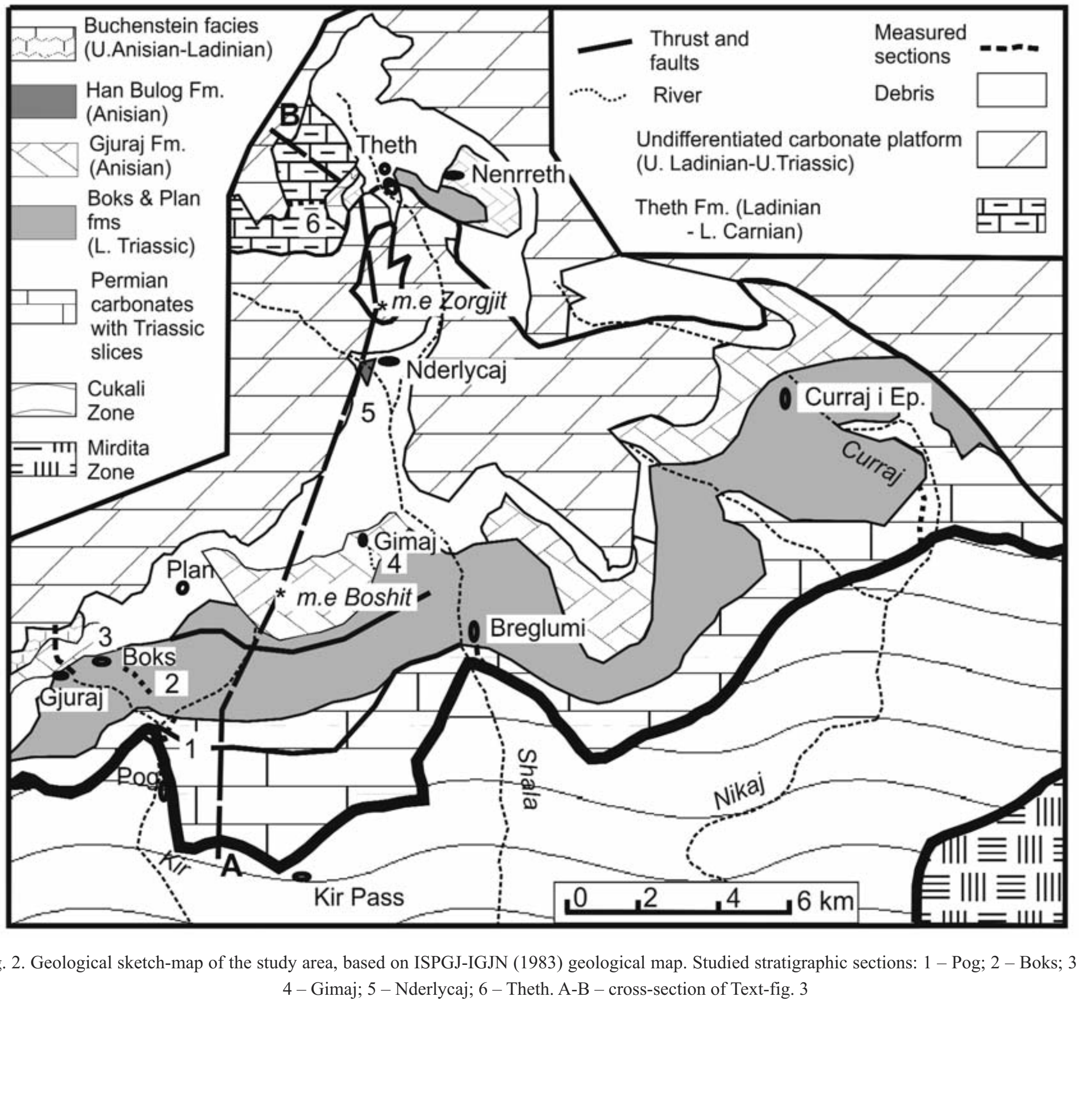
Text-fig. 1. Index map of the study area (1A and B), with structural map of the Albanian Alps (1C) [from Xhomo *et al*. (2008), simplified]

GEOLOGICAL SETTING

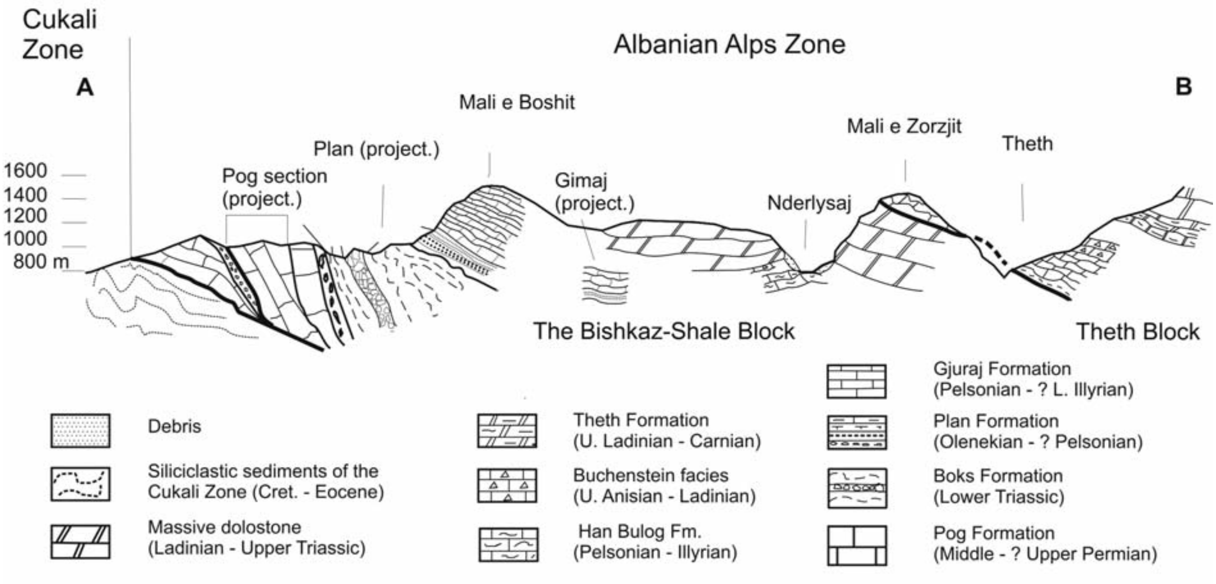
The Albanian Alps consists of several stacked thrust sheets with an internal stratigraphic succession spanning the Permian through to the Triassic and the Triassic through to the Cretaceous, verging to the south-east and thrust onto the Cukali Zone during the Paleogene (ISPGJ-IGJN 1983, 1999; Xhomo *et al.* 2008) (Text-fig. 1C). The Bishkaz-Shale Block (Xhomo *et al*. 2008) forms the lower thick stack, with a succession spanning the Middle Permian through to the Upper Triassic. Internal folds and thrusts complicate the stratigraphic succession. Tectonic repetitions enable the observation of a facies trend from south to north along the transect Gjuraj–Gimaj–Nderlysaj. We measured sections in the Kir, Shala and Curraj valleys, from Permian to Ladinian (Text-fig. 2). In that area, a very complex thrust-fault system brings the Albanian Alps to override the flyschoid Cretaceous–Eocene sediments capping the Cukali Zone.

In this study, we started with reference to the geological maps (ISPGJ-IGJN 1983, 1985, 1999). However, the tectonic setting of the lower part of the Bishkaz-Shale Block is more complicated than reported in these maps. Important duplex structures intersect the Permian rocks, which are subdivided by Triassic slices (Text-figs 2, 3). We therefore decided to describe only part of the Permian succession, as exposed along the Kir Valley, north of Pog, leaving the basal stack of the Albanian Alps, as exposed along the Shala and Curraj valleys, for a future study.

Along the Kir Valley near Pog, the slates of the Cukali Zone are overlain by breccias and conglomerates, more than 200 m thick. We have no data on the age of their matrix; some of the blocks and pebbles yielded Permian schwagerinids. This strip is inclined very steeply northwards, separating the carbonate succession, described herein, from another package of Permian carbonates, including shaly intercalations, cropping out southwards on the divide between the Kir and Shala valleys (see Text-fig. 1C). We did not study



Text-fig. 2. Geological sketch-map of the study area, based on ISPGJ-IGJN (1983) geological map. Studied stratigraphic sections: 1 – Pog; 2 – Boks; 3 – Gjuraj; 4 – Gimaj; 5 – Nderlycaj; 6 – Theth. A-B – cross-section of Text-fig. 3



Text-fig. 3. Geological cross-section across the study area; for location see Text-fig. 2

this southern Permian sheet. Moving northwards, the breccias and conglomerates show a major cataclastic horizon in the central part of the succession, followed upwards by the inception of calcareous slabs, suggesting the presence of a "flower structure".

The whole complex was successively disrupted and faulted during the Neogene because of the anticlockwise rotation linked to the Shkodre-Pes Line system (Dercourt 1967; Speranza *et al*. 1995; Mauritsch *et al*. 1995; Schmid *et al*. 2014).

The second major stacked slab is named the Valbona Block, with rocks spanning the Triassic through to the Cretaceous (Xhomo *et al.* 2008). A minor subdivision, previously considered to be located inside the Valbona Block, is now treated as independent block, the Theth Block, Triassic in age. Although partly covered by scree and tectonically disrupted, the Middle Triassic succession may be measured around the village of Theth.

The locations of measured sections and a geological cross-section through the study area are shown in Text-figs 2 and 3.

THE SUCCESSION

Pog formation (Middle Permian)

NAME: Proposed informally herein. Formal designation awaiting the search for a more complete and less disrupted section. The section cropping out along the road between the villages of Pog and Plan is described herein. Coordinates of the base of the section: N 42° 16' 33" 60: E 19° 41' 17" 00.

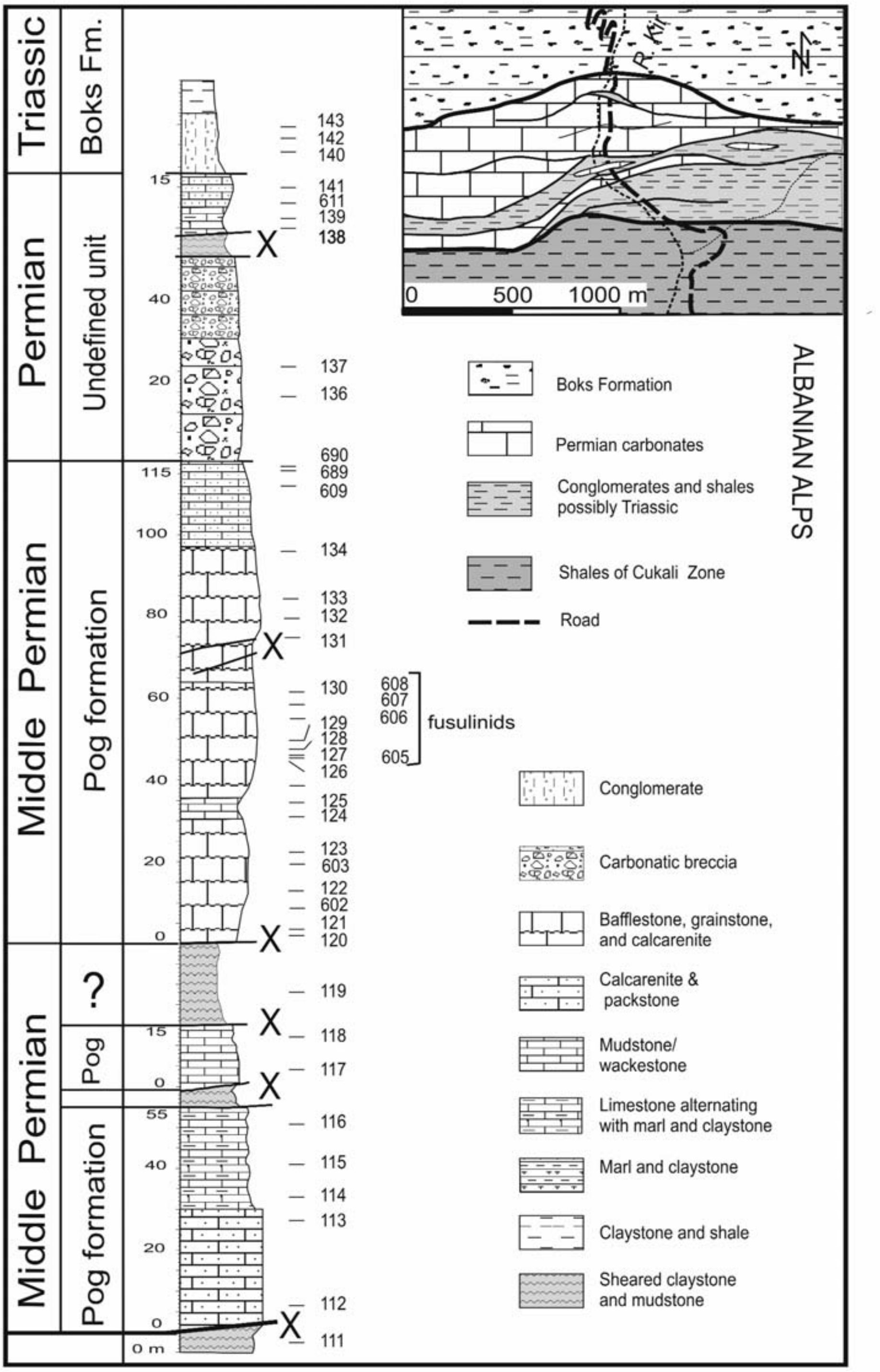
OCCURRENCE: It forms a disrupted strip along the sole of the Albanian Alps thrust sheets. All sections investigated so far show internal faulting. We did not study the area to the north of the Kir Pass, where there are scattered exposures of Permian rocks.

LITHOSTRATIGRAPHY: The succession of the Pog section, composed of carbonate lenses and bodies separated by faulted slices of grey-brown slates, is as follows (from bottom to top) (Text-fig. 4):

First carbonate unit: Bioclastic packstone, in some levels even a fine calcirudite, rich in crinoids, fusulinid fragments and *Tubiphytes*. They are overlain by limestone (mainly packstone) alternating with marls and claystone. The unit is about 55 m thick.

Second carbonate unit: The same facies as before, rich in fusulinid fragments, *Tubiphytes* and crinoids. The unit is about 15 m thick.

Third carbonate unit: It is the most complete and continuous of the three units. Massive light grey calcarenite without marly intercalations, rarely bafflestone. Bedding only faint or non-existent. At 30 m above the base, there is a thinner, 5 m-thick, bedded interval of grey mudstone/wackestone, which subdivides the calcarenitic succession (AA 124–AA125). The microfacies is dominated by bioclastic packstone, rich in *Tubiphytes*, phylloid algae, and crinoids. The matrix is usually fairly abundant, finely crystalline, with a calcareous cement. Fusulinids may be present, especially in the interval between 45 and 65 m above the base of this unit (AA604–AA608). The upper part, still massive (AA127–AA134), is characterised by increasing amounts of aggregated bioclasts and encrusting organisms (algal structures), in association with bivalves,



Text-fig. 4. Stratigraphic log of the Permian of Pog, measured along the road. To save space on the drawings the label AA (Albanian Alps) is omitted. Geological map of the area north of the village of Pog is inserted in upper-right corner. The road curves mentioned in the text where the first *Meandrospira pusilla* (Ho, 1959) have been obtained from the Boks Formation, are shown on the map gastropods, echinoids, corals, algae, peloids, *Tubiphytes,* and foraminifers. Conodonts have been etched out from the topmost 5 m (samples AA689–AA690). The unit is about 115 m thick in total.

Carbonate rudstone unit: The succession of clast-supported rudstone with angular clasts, 10 to 30 cm in size, with scarce matrix overlies the third carbonate unit with normal contact. Clasts are almost exclusively from the underlying carbonates, with a few dark cherts. The unit is about 70 m thick.

Fifth carbonate unit: The lowermost part is represented by well-bedded mudstone/packstone. Upward it is followed by massive light calcarenite, locally squeezed by faults. The unit is rich in fusulinid fragments and *Tubiphytes*. The unit is about 15 m thick.

The Carbonate rudstone unit and *fifth carbonate unit* are excluded from the Pog Formation, albeit according to the fossil content of the *fifth carbonate unit* they are still Permian in age.

A fault plane separates the described succession from conglomerates of the overlaying Boks Formation.

FOSSIL CONTENT AND AGE: Conodonts (Plate 1) were identified in three samples of the *third carbonate unit* (Text-fig. 4). Sample AA125 yielded *Mesogondolella omanensis* and *Jinogondolella* sp., which according to Kozur and Wardlaw (2010) and work in progress in Oman by C. M. Henderson, indicate the upper Roadian to Wordian. Samples AA689 and AA690 yielded a conodont assemblage of *Jinogondolella altudaensis*. This is very similar to the one illustrated by Wardlaw and Mei (1998) from the uppermost Altuda Formation of the Bird Mine section, West Texas, USA, just below a massive solution collapse breccia of the Tessey Formation, associated with a late Guadalupian lowstand. *Jinogondolella altudaensis* is of late (but not latest) Capitanian age.

The most common microfacies consists of a bioclastic medium-grained calcarenite (packstone to grainstone), usually devoid of siliciclastic material. Phylloid alga, *Tubiphytes* sp., including *T. carinthiacus,* and echinoids predominate. Accessory are bryozoans, brachiopod spines, small foraminifers, and other *incertae sedis* organisms. Algal coatings are usually significant. The cement is commonly sparry calcite.

The examined non-fusulinid foraminifers (*Palaeotextularia* sp., *Climacammina* sp., abundant *Hemigordiopsis renzi*, Neodiscidae, large miliolids, lagenids, globivalvulinids) are of low diversity and abundance. These are all long-ranging taxa of no biostratigraphic significance.

The fusulinid assemblage is fairly poor, with a few sparse specimens in the grainstone/packstone. The fusulinid-dominated microfacies has not been found. In samples AA605 and AA606, in which the fusulinids are better preserved, the following species and genera have been identified (by E. Ja. Leven, Moscow): *Verbeekina* sp., *Neoschwagerina* sp., *Parafusulina* ? sp., *Afghanella tumida* Skinner and Wilde, *Sumatrina* sp., Schwagerinidae gen. indet. (Plate 2). *Afghanella tumida* was first described from the upper Murgabian (i.e. Wordian in the International Scale) of Tunisia (Skinner and Wilde 1967).

A Guadalupian age is indicated by the foraminifer *Hemigordiopsis renzi* (Reichel).

Bignot *et al*. (1982) identified from the Pog section the genera *Neoschwagerina*, *Pseudofusulina*, *Verbeekina*, *Sumatrina*, and *Yabeina*.

Sample AA611 yielded the problematic organism *Vangia telleri* (Flügel), described previously from the Guadalupian of Karawanken, Slovenia, Sicily and Iran (Senowbari-Daryan and Rashidi 2011).

ENVIRONMENT: The studied succession of the Pog Formation represents a carbonate ramp, with local reworking by bottom currents accounting for the prevailing, apparently homogeneous, grainstone/packstone microfacies. A breccia body seals the carbonate ramp, suggesting the activation of a slope that enabled the accumulation of lithified packstone/grainstone from the previous ramp, but also dragging some older rocks including dark cherts.

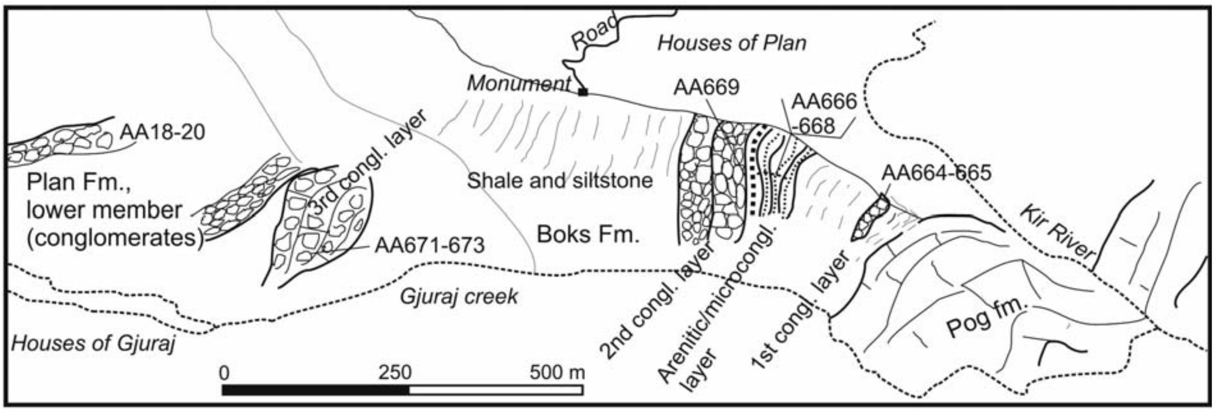
The *fifth carbonate unit* needs a better age definition to be better understood.

Boks Formation

NAME: Here proposed; it includes a part of what is termed T1 in the geological map of Albania (ISPGJ-IGJN 1983, 1999).

TYPE LOCALITY: The ridge between Gjuraj and Boks, along the Kir valley. The complete succession is not exposed in any section and thus cannot be measured; the base of the formation is affected by faults and its upper part is poorly exposed (Text-fig. 5).

OCCURRENCE: The formation forms a continuous belt in the two structural units considered herein. Due to soft rocks forming most of the formation, it is often poorly exposed and we presume internal fold and mi-



Text-fig. 5. The ridge where the conglomerates of the Boks and Plan formations are better exposed. Position of samples is indicated. The drawing is based on the oblique view from Google Earth

nor faults affect it in the Bishkaz-Shale Block. As the thickest soils are developed on the soft shales of the formation, most of the villages and houses are located on its area. In the Theth Block it forms the base of the structural unit and it is often laminated and sliced.

LITHOSTRATIGRAPHY: The base of the formation is nowhere well exposed. Its main part consists of a 300–500 m-thick succession of grey-brown shales rich in white mica, locally feebly metamorphosed to slates, splintery, and folded. Consequently, estimation of its thickness is only tentative. Within the shales, which form the bulk of the formation, at least three major conglomerate intervals are observed. The lowest one, about 100 m above the base, is 8–10 m thick, polymictic and clast-supported, and consists mostly of rounded calcareous pebbles, up to 50–100 cm in size (Pl. 3, Fig. 1). The contacts against the micaceous shales are sharp, emphasized by subsequent tectonics and giving a mega-boudinage appearance. The pebbles are mostly of two groups. The first group consists of grainstone/packstone rich in bioclasts with *Tubiphytes*, algal laminae, and fragments of fusulinids; it clearly originated from the underlying Permian rocks. The second group is composed of ooids suspended in a micritic matrix with less abundant lumps and coated grains; rarely with some fine quartz clasts. This lithology is not yet known in the underlying succession.

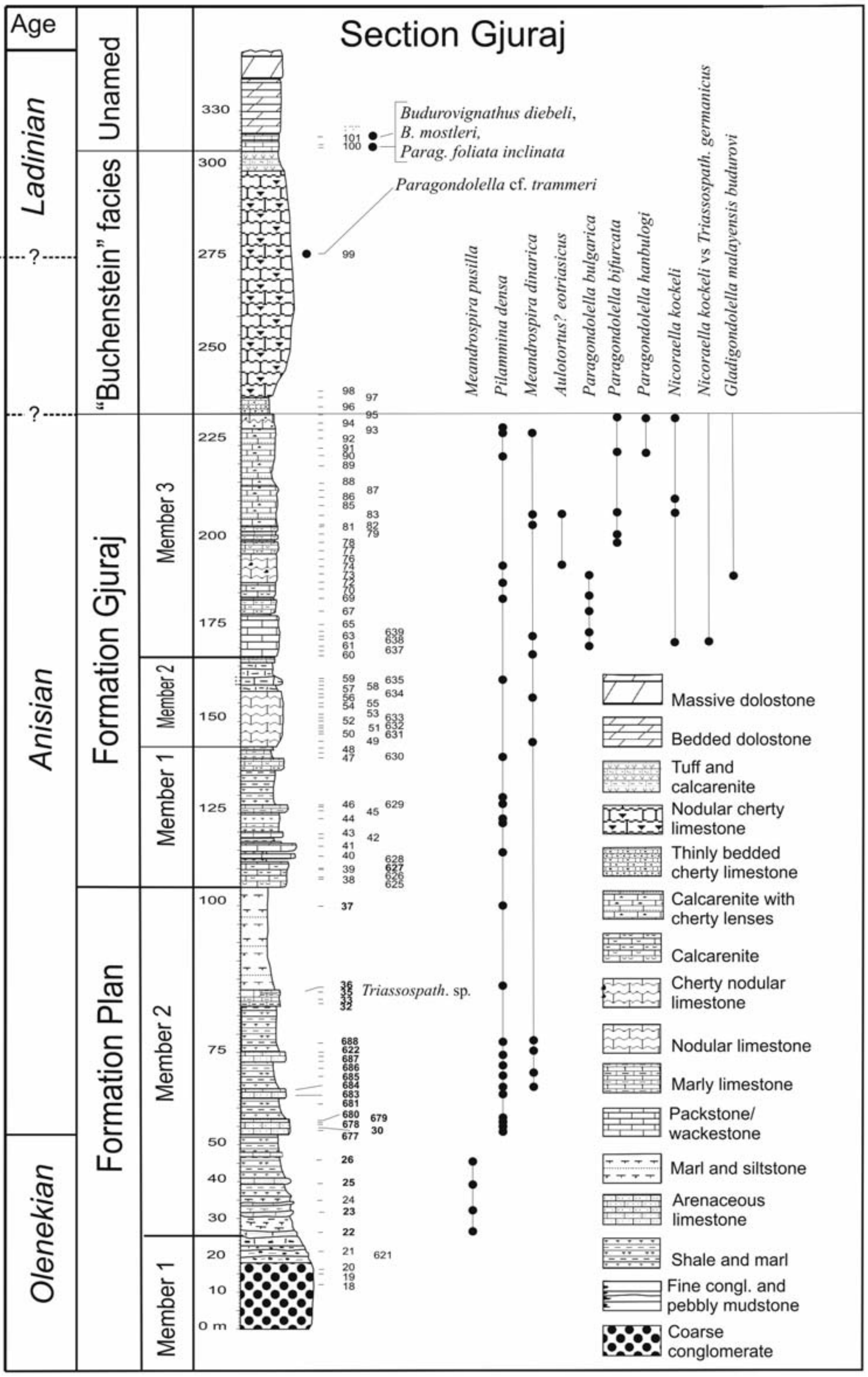
Some 100 m above the lowest conglomerate layer, there follows a 40 m-thick succession of coarse bedded arenites, and fine-grained conglomerates with gently erosional bases. Pebbles are fairly well-rounded, often of flattened shape (Pl. 3, Figs 3, 4). Oblique or undulating laminae suggest a possible shoreface setting. A few finer beds are composed of fine peloidal packstone in micritic matrix, containing ghost of *Meandrospira*. Some of them have 10–15% of fine quartz clasts. Another interesting microfacies consists of packstone/wackestone with small iso-oriented grains, possibly of organic origin, with a micritic matrix including small rounded calcitic spots.

The second conglomerate layer, at least 80 m-thick, forms a distinct ledge that is clearly visible in the landscape from Gjuraj towards the watershed of the Kir/Shala valleys. Its base shows thin-bedded arenites intermingled with pelites, overlaid by a polymictic cobble conglomerate with pebbles up to 1 m in size. The clast composition of this horizon is much more variable than that of the lower horizon, with more arenites, conglomeratic pebbles (derived from the underlying succession), and dolostones. The second conglomerate horizon, at least in its lower part, is somewhat bimodal. The smaller pebbles (up to 15–20 cm) are usually fairly rounded, whilst the larger are angular and irregular in shape. The second conglomeratic body seems to thin out across the Shala valley. It is overlain by a monotonous succession of poorly exposed grey splintery shales.

The third conglomerate horizon, tens of metres thick, crops out on the slope opposite the houses of Gjuraj (Text-fig. 5), and is composed of commonly poorly rounded clasts with sharp edges up, to 30 cm in size, within an abundant matrix. Clasts may be arenitic, mostly quartzarenite. The carbonate matrix consists of oolites and other coated grains. Laterally, this horizon passes into a 20-m-thick massive body of oolitic grainstone.

FOSSIL CONTENT AND AGE: We have a few data on the age of the formation. Along the first two curves of the road leading to Plan (Text-fig. 4, near the top of the geological sketch), we collected *Meandrospira pusilla* (Ho) from a marlstone below the first conglomerate horizon, which suggests an age between

Dienerian and Spathian, i.e. late Induan to Olenekian of the Early Triassic. An upper part of the overlying Plan Formation is still dated as Olenekian. Therefore, most of the unit is Olenekian in age. There are no convincing data for the lowermost part of the formation. Consequently, the location of the Permian-Triassic boundary is unknown. A search for pollen proved unsuccessful.



Text-fig. 6. The Gjuraj section, with the formations of Plan, Gjuraj, the Buchenstein facies and an unnamed unit are better exposed. The ranges of conodonts and of the most significant foraminifers are reported. To save space the label AA (Albanian Alps) is omitted

ENVIRONMENT: The whole area was a part of the continental margin, with high sedimentation rates. The abundant mud supply suggests a wide deltaic apron or a coastal flat. The interpretation of the conglomeratic horizons is problematic. They differ in clast shape and composition, and in the abundance and nature of the matrix. They suggest the onset of dramatic flooding on the flats. Perhaps the lowest horizon may be interpreted as the result of a single flooding. The second, because of its bimodal nature, and being preceded by an increasing input of fine conglomerates with rounded pebbles, could be the result of increased tectonic activity in the source area. The scarce evidence of fluvial transport, the bimodal nature of the clasts (rounded vs angular), and the scarce matrix might suggest the sudden removal of a cobble shore, along a scarp. The third horizon instead testifies to local oolitic shoals that could be laterally intermingled and contain sparse clastic inputs.

Plan Formation

NAME: Here proposed, after the village of Plan on the east side of the ridge where the type-section has been measured.

TYPE SECTION: To the north of the houses of Gjuraj, two twin gullies open. The section was measured along the gully to the east. Coordinates of the base of the section: N42°17'21"; E19°39'55" (Text-fig. 6).

OCCURRENCE: The formation is present in both the Bishak-Shale Block and the Theth Block, in the core of the thrust anticline near Nenrrethi (Text-fig. 2).

LITHOSTRATIGRAPHY:

Member 1: Member 1 consists of well-bedded conglomerate layers. The lower part of the member crops out sparsely in the woods, south-west of the measured section. It is about 50 m-thick, in banks 5-to 10 m-thick. The polymictic conglomerates are clast-supported, with well rounded clasts, 3 to 10 cm in size, dominated by arenitic pebbles. A few quartzitic pebbles are also observed. This member overlies the oolitic horizon intermingled with conglomerate that seals the Boks Formation. In the measured section (Text-fig. 6) the upper part of the member consists of thick beds of clast-supported polymictic conglomerate, with poorly rounded clasts up to 20 cm in size. The arenitic matrix is scanty and the clasts are mostly carbonates. A few imbricate structures were found. The roundness of the pebbles increases upwards.

Member 2: The member is 85 m thick in the Gjuraj section, and consists of marls and marly shales with intercalated fine calcirudite/calcarenite beds with ripple marks, and beds of pebbly mudstone. The calcarenites are packstone with some siliciclastic content, forming packages up to 3 m thick. Grey silty marls and occasional fine arenites characterize the topmost part of the member.

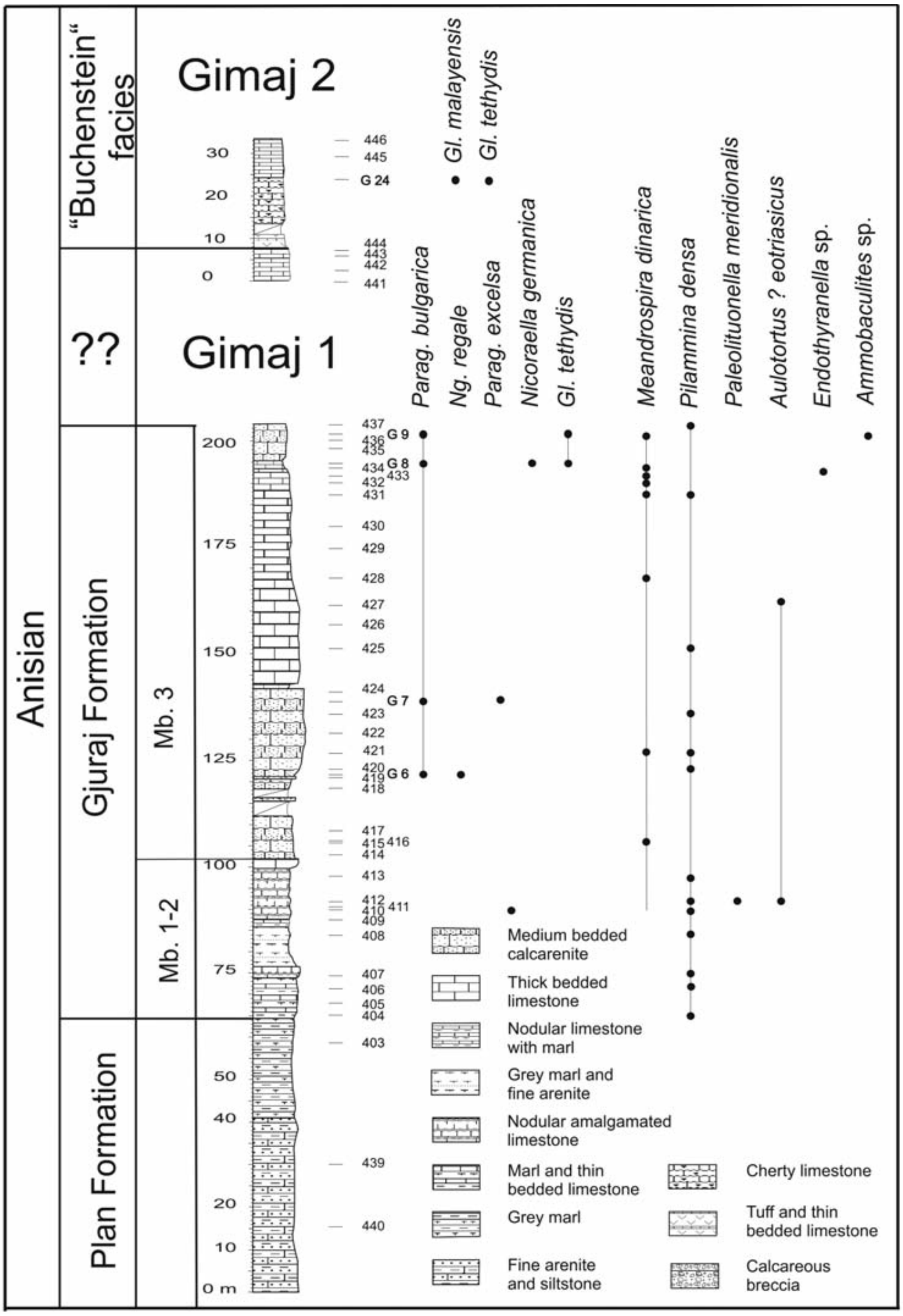
FOSSIL CONTENT AND AGE: The pebbles of the upper part of the conglomerate of Member 1 yielded well-preserved Permian microfacies with fusulinids and ooidal grainstone. Samples AA18, AA19, AA20 are mostly packstones with fusulinid fragments, echinoids, *Tubiphytes*, algal lumps, and abundant carbonate clasts.

The middle part of Member 2 yielded endobiontic bivalves (*Plagiostoma* sp.) and small gastropods (*Natiria* sp.). The conodont *Triassospathodus* sp. was collected at the top of the calcarenitic/marly interval (sample AA36). A carbonate clast of sample AA22 yielded *Lasiotrochus* cf. *L. tatoiensis* Reichel, showing the presence of reworked Palaeozoic (Permian) material in Early Triassic rocks. Bivalves and gastropods are scarce. Foraminifers are represented by *Meandrospira pusilla* (Ho) (FO in sample AA22), sometimes associated with agglutinated bilocular foraminifers (Ammodiscidae). *M. pusilla* ranges up to sample AA26, and its presence allows reference of this part of the succession to the Lower Triassic (Olenekian). An oligotypic assemblage of *M. pusilla* is present in the Tethyan domain during the Early Triassic (Rettori 1995). Generally, the abundance of *M. pusilla* decreases upwards, with concomitant appearance of the late Olenekian morphotype *M. cheni* (Ho). The latter taxon, however, has never been recorded in the studied material. Rare specimens of *M. pusilla* can also be found in Anisian shallow water limestones in association with typically Anisian taxa.

In the Gjuraj section, the Anisian taxon *Pilammina densa* appears in the first significant calcarenitic layer, some 28 m above the base of Member 2 (sample AA677, ca. 7 m above the LO of *M. pusilla*; see Text-fig. 6). *Meandrospira dinarica* appears 10 m higher, in sample AA684. This fact is unusual. In the Tethyan domain, *M. dinarica* is usually the first to appear in the early Anisian, and it ranges from the early Anisian to the Pelsonian (Premoli Silva 1971; Salaj *et al*. 1988; Mietto *et al.* 1991; Trifonova 1992; Rettori *et al.* 1994; Rettori 1995). *Pilammina densa* usually appears later, in the latest early Anisian and it is present up to the end of the

Pelsonian. During the Pelsonian, *P. densa* is usually abundant and shows an increase in test size (Gaetani 1969; Premoli Silva 1971; Rettori *et al*. 1994; Rettori 1995). In the Albanian material, however, in both the Gjuraj and Gimaj 1 sections, *P. densa* appears before the FO of *M. dinarica* and, throughout its range, is abundant and represented by large-sized morphotypes.

ENVIRONMENT: The conglomerate horizons are internally better organized, with better-rounded pebbles, of more homogeneous sizes in comparison with those of the underlying Boks Formation. They suggest a more mature distributary system. Size of pebbles, mixing of carbonate and arenite pebbles and pebbly mudstone all evidence repeated erosion. We prefer to keep the Boks Formation separate from Member 1 of the



Text-fig. 7. The composite section of Gimaj. Base of the log Gimaj 1: 940 m a.s.l.; N 42°18'57", E 19°45'07". Base of log Gimaj 2: 870 m a.s.l.; N42°19'07", E 19°45'16". To save space the label AA (Albanian Alps) is omitted. Sample G are conodont samples

Plan Formation because: (1) the basic lithology of the Boks Formation consists of micaceous shales, in which coarse conglomeratic bodies are embedded; (2) the pebbles and cobbles of the Boks Formation are mostly angular, poorly sorted and appear more linked to sudden floodings than to an organized distributary system. It is not certain, however, if the lower part of Member 1 was deposited already under marine influence or rather in a braided river environment. Instead, Member 2 was definitely deposited under marine conditions. The gradual increase in fine clastics and the interspersed calcarenites suggest the development of carbonate production in shoals within the marine muddy flat. Deposition of muddy sediments again dominated the uppermost part of Member 2.

Gjuraj Formation

NAME: This unit is named after Gjuraj, where the most complete exposure has been found.

TYPE SECTION: The succession was measured along the twin gully to the east, up to the top of the Gjuraj Formation. The upward succession ("Buchenstein" facies and unnamed unit in Text-fig. 7) was measured along the gully to the west. The coordinates of the base of the section are: N 42°17'22"; E 19°39'51".

OCCURRENCE: The formation provides a continuous belt of exposures along the Bishkaz-Shale Block (Text-figs 6, 7, partly 8), and more disrupted and scattered occurrences at the base of the Theth Block (Text-fig. 9).

LITHOSTRATIGRAPHY: The unit is basically calcareous. Three members may be distinguished (from bottom to top):

Member 1: The first metres still contain some arenites dispersed in the calcareous mass. They are overlain by alternating grey splintery marls and nodular grey limestone, in 10–30 cm thick beds. Fragments of bivalves and brachiopods are locally common. The thickness of the member is about 38 m at Gjuraj and 23 m at Gimaj.

Member 2: This is formed by a package of grey nodular limestone in 5–10 cm thick beds, capped by marls and marly limestone. This facies strongly resembles what is named in the Southern Alps as the Recoaro Limestone. Thickness ca. 24 m at Gjuraj and 15 m at Gimaj.

Member 3: This constitutes the bulk of the formation. The main lithology consists of calcarenite (rarely calcirudites and breccias) in medium to thick beds. The basic microfacies is grainstone, less frequently packstone or packstone/grainstone, with bioclasts and intraclasts, commonly coated by a micritic envelope. The cement is usually sparitic. Subordinate are beds of packstone/wackestone with finely recrystallized matrix and cement. Locally, as to the right of the gully where the type-section was measured, the bedding becomes massive, to form carbonate banks some 15–20 m in thickness. However, specific building organisms were not recognized. The thickness of this member ranges between 60 m at Gjuraj and 100 m at Gimaj.

FOSSIL CONTENT AND AGE:

Conodonts: Near the base of Member 3 of the Gjuraj section (Text-fig. 6, Plate 5) *Nicoraella kockeli* (Tatge), the transitional form *N. kockeli/ Triassospathodus germanicus* (Kozur), and *Paragondolella bulgarica* (Budurov and Stefanov) were found. These forms indicate the lower Pelsonian of the middle Anisian (Orchard *et al.* 2007). The sample from a little higher in the same section, yielded *Paragondolella bifurcata* (Budurov and Stefanov), *P. hanbulogi* (Sudar and Stefanov), *Gladigondolella malayensis budurovi* (Kovacs and Kozur) and *N. kockeli*.

Member 3 of the Gimaj 1 section yielded *Paragondolella excelsa* (Mosher), *P. hanbulogi* and *P. bulgarica* (Text-fig. 7).

The conodont associations found in Member 3 of the Gjuraj Formation are typical of the Pelsonian.

Brachiopods: Brachiopods may be locally common, especially in the Theth Block, and were found both along the deepest gully below the village of Theth (Text-fig. 2, section 6) and in the gully north of Nenrreth. *Punctospirella fragilis* (Schlotheim), *Mentzelia* sp., *Retzia* sp. and *Aulacothyris* sp., of Pelsonian age, were recognized.

Foraminifers (Plate 6): In the Gjuraj and Gimaj sections, the packstone/wackestone and calcarenitic beds contain abundant foraminifers. Both sections are dominated by *Pilammina densa* Pantic, associated with frequent *Meandrospira dinarica* Kochansky-Devide and Pantic. In samples AA72 and AA74 of Member 3 of the Gjuraj section, these two taxa are associated with *Pilamminella semiplana* (Kochansky-Devide and Pantic), and samples AA74 and AA83 yielded moreover *Aulotortus* ? *eotriasicus* Zaninetti, Rettori and Martini. The recorded taxa are present up to the level of samples AA92 at Gjuraj and AA437 at Gimaj, and enable reference of this part of the succession to the Pelsonian (Middle Triassic, Anisian) (Rettori 1995 and references cited therein). These age-significant foraminifers are associated with *Endotriadella* sp., duostominids, lagenids, algae, echinoderms, bivalves, algal aggregates and gastropods. Above samples AA92 at Gjuraj and AA437 at Gimaj, no biostratigraphically significant taxa were found. Starting with sample AA92 and higher of the Gjuraj section, the recorded foraminifers are represented exclusively by long-ranging, cosmopolitan multi-chambered agglutinated forms (Endotebidae and Endothyridae).

ENVIRONMENT: The lower part of the formation represents a gradual transition from a muddy flat to a carbonate ramp. Higher up, a carbonate ramp swept by current and waves predominates. The calcarenites were transported towards the open sea mostly grain by grain, rarely by dense bottom currents, as suggested by graded bedding in the lower part of the Nderlysaj section. The calcarenitic packages intermingle with deeper water carbonates in the Gimaj 1 and Nderlysaj sections in the Bishkaz-Shale Block.

Han Bulog Formation

NAME: This typical Rosso Ammonitico facies or Han Bulog facies was first named by Hauer (1888) from a locality in Bosnia and Herzegovina (see Sudar *et al*. 2013 for review).

OCCURRENCE: The facies is rare in the Albanian Alps. It is exposed in the section of Nderlysaj (see Muttoni *et al*. 1998). It probably continues northwards, because large blocks are observed on the slope along the road from Theth to Nderlysaj. A few metres-thick succession of this facies is also present in the Gimaj 1 section.

LITHOSTRATIGRAPHY: The formation consists primarily of pinkish to greyish nodular limestone, in dm-thick beds, often amalgamated to form thicker packages. Usually these are mudstone or wackestone, but contamination with calcarenites is possible, hence the packestone/grainstone facies may be intercalated with the nodular limestone.

The 5-m-thick basal part of the Nderlysaj section is composed mainly of pink nodular limestone of the Han Bulog Formation. It is overlain by a ca. 20-m-thick calcarenite succession of the Gjuraj Formation (Text-fig. 8). In the lower part of the Gjuraj Formation, the calcarenites form finely graded beds but become thicker in its upper part. Calcarenites almost disappear in the upper part of the Han Bulog Formation, where they form at most very thin intercalations within the pinkish nodular limestone. Elsewhere, like in the Gimaj 2 section, only 4 m of the Han Bulog Formation caps the calcarenites.

FOSSIL CONTENT AND AGE: a detailed conodont and foraminiferal range chart of the Nderlysaj section was already published by Muttoni *et al*. (1998). It is reported herein with some modification in taxonomic identifications.

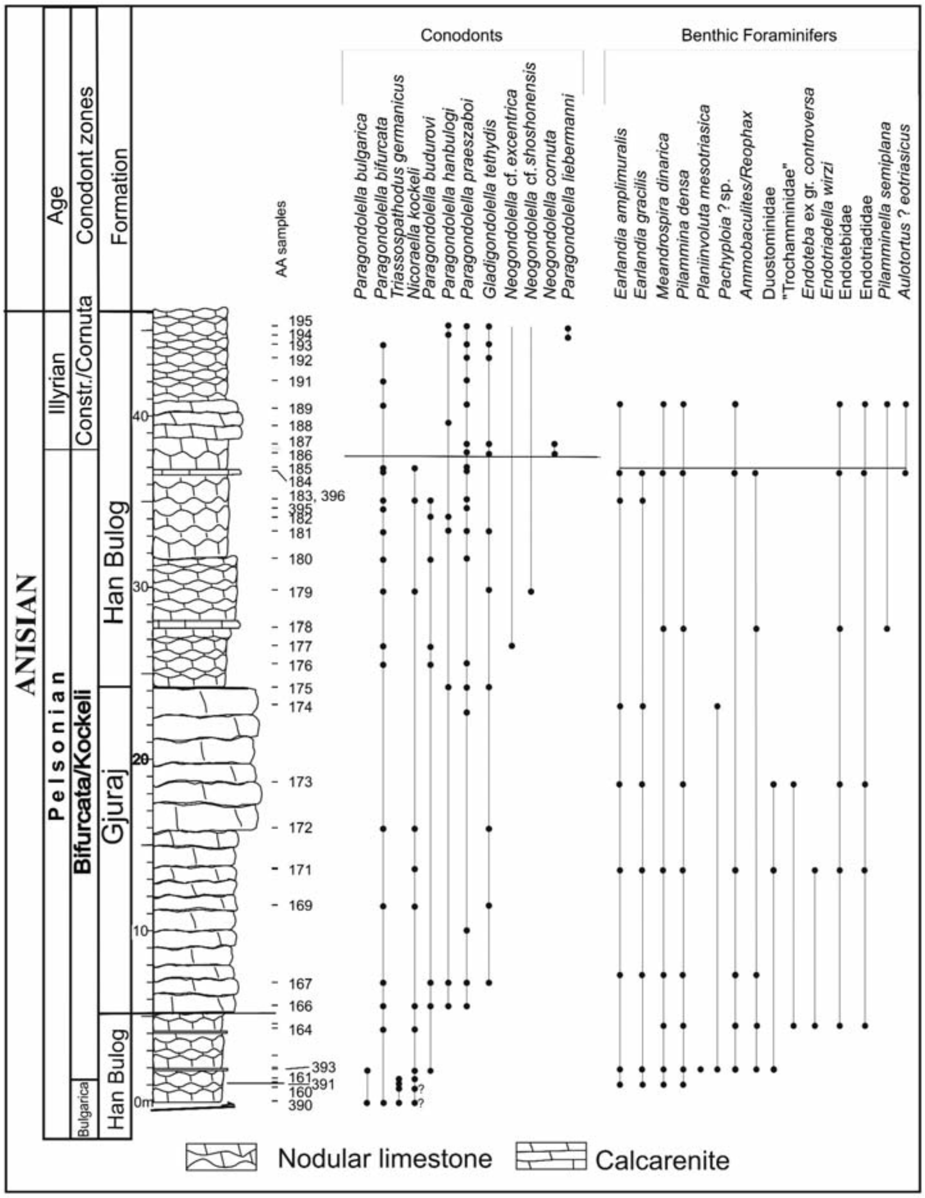
The lowermost 1.6 m of the Nderlysaj section (samples AA160-AA161 and AA390-AA393; Text-fig. 8) yielded the conodonts *Triassospathodus germanicus* (Kozur), *Paragondolella bulgarica* (Budurov and Stefanov), and forms referred questionably to *Nicoraella kockeli* (Tagte). Interbedded calcarenites yielded *Earlandia amplimuralis* Pantic*, Earlandia gracilis* (Pantic), *Mendrospira dinarica* and *Pilammina densa*. The listed taxa indicate a late Bithynian or Pelsonian age. Muttoni *et al*. (1998) tentatively referred this package to the late Bithynian. However, *Nicoraella kockeli*, which they reported questionably from this interval, suggests a Pelsonian age.

The overlying part, between the 5th and 38th metre level of the succession, was referred to the Bifurcata/Kockeli conodont Zone of Pelsonian age (middle Anisian), and only the higher, topmost 8 m of the succession, were referred to the Constricta/Cornuta conodont Zone of Illyrian (late Anisian) age. Ammonoids are only rarely present and are highly deformed.

The interval between 24 and 36 m is the richest in conodonts and yielded (amongst others): *Paragondolella bifurcata* (Budurov and Stefanov), *Paragondolella budurovi* (Kovacs and Kozur) and *Nicoraella kockeli* (Tatge), indicative of a Pelsonian age. Associated are *Paragondolella preszaboi* (Kovács, Papšova and Perri), and *Gladigondolella tethydis* (Huckriede), which range up to the topmost part of the succession.

The interval between 38 and 46 m contains an assemblage of *Paragondolella bifurcata, Neogondolella cornuta* (Budurov and Stefanov) and *Neogondolella constricta* (Mosher and Clark), suggesting an Illyrian age. The same age is confirmed by *Paragondolella liebermani* (Kovacs) and *Paragondolella pseudobifurcata* (Kovacs) found at the top of the section (samples AA194-AA195). The position of the Anisian/Ladinian boundary is in agreement with Brack *et al*. (2005).

ENVIRONMENT: The Han Bulog Formation represents a deeper, distal part of the basin, where the micritic mud was deposited in a quieter environment beneath the wave base. However, the carbonate ramp



Text-fig. 8. The section of Nderlysaj [from Muttoni *et al*. 1998, simplified]. The Pelsonian /Illyrian boundary is slightly different according to conodonts and foraminifers. To save space the label AA (Albanian Alps) is omitted

with its calcarenitic sediments was not far distant, as testified by packstone/grainstone intercalations and especially by the graded m-thick intercalations of the calcarenites from the Gjuraj Formation.

"Buchenstein" facies

NAME AND OCCURRENCE: This cherty facies, found throughout the Adria margin, is poorly exposed in the Albanian Alps. However, two sections were measured, at Gjuraj, on the Bishkaz-Shale Block, and in the Theth gully, on the Theth Block. In the Dinarides, these rocks are often merged in the "Porphyrite-Chert formation" (Pamic 1974; Pamic *et al.* 1998). In Montenegro, a similar succession was named "Cherty limestone and radiolarite" (Gawlick *et al*. 2012).

LITHOSTRATIGRAPHY: There are significant differences in the development of facies between the Gjuraj and Theth sections. The succession is as follows (from bottom):

1) Thin-bedded limestone, with gradual increase in the chert content in thin strips and lenses, while the calcarenitic content disappears. Tuffitic veneers, reddish or grey, form intercalations in the wackestone to mudstone nodular beds. This lowermost part is only 4.5 m thick at Gjuraj and 13 m thick in Theth.
2) Well-bedded nodular limestone (10-20 cm thick beds) with abundant cherts in thin lenses or black nodules, commonly with a dark green coating, possibly tuffitic in origin. This level is 8 m thick at Theth and 67 m thick at Gjuraj.
3) In this level, there is a significant increase in tuffitic intercalations. At Theth, the first tuffitic bed is about 50 cm-thick (below sample AA335) and is overlain by grey limestone, in amalgamated nodules up to 15 cm in size, although usually smaller. In turn, it is overlain by a succession of tuffs intercalated in thin grey limestone, often deeply recrystallized. Their thickness is 45 m at Theth, and only 5.5 m at Gjuraj, where the formation ends at this level.
4) The upper part of the unit was recognized only at Theth and is characterized by a more diffuse calcareous content, with black chert nodules and lenses. The tuffitic intercalations tend to decrease upwards, to almost fully disappear in the last 5 m. Thickness about 40 m.

The microfacies is a monotonous wackestone/mudstone with calcitized ghosts of radiolarians.

FOSSIL CONTENT AND AGE: A few conodonts have been found in the lower and upper parts of the unit. The lowermost 4 m of the Theth section (Text-fig. 9) yielded *Nicoraella kockeli* and *P. bifurcata*, indicative of the Pelsonian. The latter taxon, accompanied by *Paragondolella hanbulogi*, was found 14 m higher. *P. hanbulogi* suggests the Pelsonian, but it ranges up to the basal Illyrian. Another 70 m higher, sample AA339 yielded *Paragondolella liebermanni*, which still indicates the Illyrian. Another 20 m higher, sample AA340 yielded *Gladigondolella tethydis*, and sample AA342, near the top of the unit, yielded *Budurovignathus*? *diebeli*. The latter species suggests the late Ladinian (Longobardian). Consequently, the "Buchenstein" facies is interpreted herein as spanning a part of the Anisian and the Ladinian.

The cherts appeared already around the Pelsonian/Illyrian boundary, whereas the first tuffitic layer occurs higher than the level with *P. bifurcata* and *P. hanbulogi.* The volcanism could have started already in the latest Pelsonian or later, in the Illyrian.

The Han Bulog and "Buchenstein" facies interfinger laterally. This is indicated by conodonts from the Nderlysaj section, which suggest that the base of the Illyrian is in the Han Bulog facies. In the Theth section, the lowermost "Buchenstein" facies still contains conodonts indicating the Pelsonian. No tuffitic levels were found at Nderlysaj. However, the tuffs may have been swept to deeper parts of the basin by bottom currents. Sparse outcrops of cherty limestone are observed in woods above the Nderlysaj section. Also in the Gimaj and Gjuraj sections, tuffs are rare and cherty limestones predominate.

ENVIRONMENT: The "Buchenstein" facies testifies to the existence of basin(s), below wave base, as indicated by thin mudstone and wackestone beds with filaments and radiolarians. Volcanic activity is reflected by the tuffitic intercalations, but no lavas have been found. The wide occurrence of chert is linked to the great bloom of radiolarians that occurred in the late Anisian and in the Ladinian (De Wever *et al*. 2001; O'Dogherty *et al*. 2010). This bloom was also linked to an increase in volcanic activity and/or to a reduction in carbonate productivity (Gawlick *et al.* 2012). It is interesting to note that the volcanic activity started earlier in the Hellenides (Bithynian: Angiolini *et al*. 1992), by the latest Pelsonian or basal Illyrian in the Albanides, in the Illyrian in the external Dinarides (Gawlick *et al*. 2012), to eventually first occur in the late Illyrian in the Southern Alps (Brack and Rieber 1993).

"Unnamed unit"

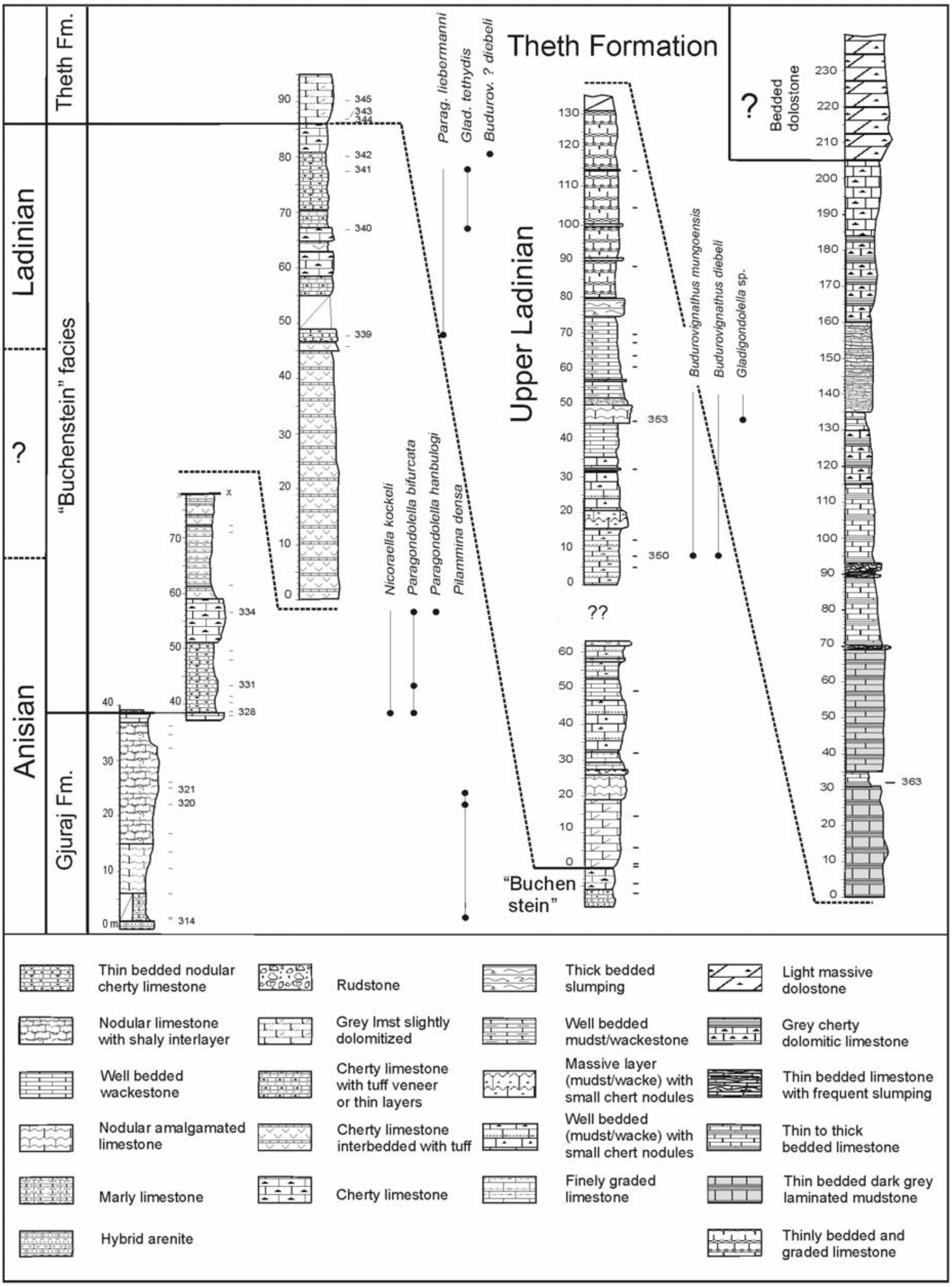
Above the "Buchenstein" facies in the Gjuraj section, there is a 3.7 m-thick nodular limestone with filaments (Text-fig. 6). The limestone forms 20–40 cm-thick amalgamated and vaguely nodular beds. It contains pelagic bivalves and ammonoid nuclei.

This "unnamed unit" is overlain by light coloured dolostone, well-bedded in the lower 10 m, then unevenly bedded. Missoni *et al*. (2012) described a similar kind of succession in the Dinarides.

The following conodonts were found in samples from the Gjuraj section: *Budurovignathus mostleri* (Kozur), *B. mungoensis* (Diebel), *B. diebeli* (Kozur and Mostler), *Paragondolella inclinata* (Kovacs) and *Paragondolella foliata* (Budurov) (Plate 4). This assemblage indicates a late Longobardian (Ladinian) age.

Theth Formation

NAME: Modified version of the 'Black limestones of Theth' of Meço and Aliaj (2000) and Xhomo *et al.* (2008).



Text-fig. 9. The composite sections measured around the village of Theth. The Gjuraj, "Buchenstein", and lower part of the Theth formations were measured in the deep gully to the south of the village, from 970 m to 1170 m a.s.l. After a grassy flat, starting at about 1250 m a.s.l, along the gully above and to the north of the road, the remaining part of the Theth Fm. was measured. To save space the label AA (Albanian Alps) is omitted

TYPE SECTION*:* The Theth composite section, composed of three parts, was measured along the gullies above the village (Text-fig. 9).

OCCURRENCE: The formation is developed only in the Theth Unit, interfingering with the thick-bedded dolostone capping the Middle Triassic succession. The thickness of the formation is c. 350–400 m.

LITHOSTRATIGRAPHY:

Part 1, 63-m-thick, was measured in the gully to the south of the village of Theth, directly overlying the "Buchenstein" facies. It is characterized by well-bedded dark grey mudstone/wackestone, slightly dolomitized, with a gradual disappearance of chert nodules. The mudstone can be finely laminated and interbedded with marls or clays. Individual graded calcarenitic or even fine calciruditic beds, with fragments of a carbonate platform, also occur. Slumps a few metres thick have also been observed.

Part 2 of the succession, starting at 1250 m a.s.l. in a gully north of the road, is characterized by a gradual reappearance of small black chert nodules, in a feebly nodular mudstone/wackestone succession. This part continues with major packages of dark grey mudstone/wackestone, with individual faintly graded beds in c-e sequences (Pl. 3, Fig. 6). Sporadic calciruditic, calcarenitic and slumped beds form individual layers up to 2 m thick. The clasts are up to 4.5 cm in size, and may be monogenic, with semi-consolidated fragments of mudstone/wackestone or angular fragments of white carbonates. Total thickness is ca. 130 m.

Part 3 (135 m thick) is characterized initially by faintly graded dark mudstone/wackestone, with a laminated top. Slumped beds, up to 5 m thick, occur ca. 90 m above the base of this part. The interval between 135 and 160 m is characterized by numerous slumps, forming packages several m-thick. The chert is diffuse and fine marly layers and interlayers are reduced.

The succession continues upwards with dark grey laminated mudstones with thin slumped beds, in which the laminae may be partly silicified.

The boundary with the overlying unit is gradual, with an increasing content of grey dolostone, commonly deformed by slumps or with dolostone breccia in thick beds, forming amalgamated packages.

FOSSIL CONTENT AND AGE: The fossil content of the formation is poor. From part 2 comes (Text-fig. 9): *Budurovignathus diebeli*, *Budurovignathus mungoensis* and *Gladigondolella* sp. These taxa suggest a late Ladinian–earliest Carnian age (Orchard 2010). Search for palynomorphs in the dark grey mudstone proved unsuccessful because of the high maturity of the organic matter.

We infer that the base of the Theth Formation may be of late Ladinian age, because of the presence of *Budurovignathus*? *diebeli* 6 m below the top of the "Buchenstein" facies. At about one quarter the distance above the base of the Theth Formation, we still have indications of a late Ladinian– earliest Carnian age. Due to the high sedimentation rate, it seems possible that at least part of the Theth Formation is of Carnian age.

ENVIRONMENT: The succession of the Theth Formation represents a highly subsiding intraplatform basin. It was fed primarily by the nearby platform, either in the form of micrite transported by feeble bottom currents or flocculated from suspension. The occurrence of frequent slumped beds, more common in part 3 of the succession, indicates slope instability. The bottom part of the basin was dysoxic to anoxic, since the laminated beds are commonly not disrupted by bioturbations.

DISCUSSION

There are several points in the interpretation of the succession that need to be discussed.

The Permian part. Permian rocks in the Kir valley are severely disrupted. This hampers an analysis of the base of the succession, which is always thrust onto the Cukali units. The shallow water carbonates of the Pog Formation rest on a layer up to 200 m-thick made of angular carbonate blocks up to few m-thick, embedded in a shaley matrix. Some of the blocks yielded fusulinids. Search for pollen in the shales proved unsuccessful, with only inertinite fragments detected. This layer is heavily disrupted with internal cataclastic horizons and separates the Permian rocks of Pog from the Permian rocks cropping out to the north of the Kir Pass (Text-fig. 2).

Of the three carbonate units here referred to the Pog Formation, the most significant is the third. About 115 m thick, a continuous carbonate succession is available, with its age suggested by fusulinids and conodonts; *Mesogondolella omanensis* at about 1/3 of its thickness and *Jinogondolella altudaensis* at the top suggest its Wordian age. The same age is also suggested by fusulinids.

The origin of the breccia is intriguing. At outcrop scale, the breccia only gently erodes the Pog Formation, possibly due to a landslide, accumulating the Pog material on the slope. The absence of deeper erosion channels and of karstic features within the top of the Pog Formation suggests that the landslide event occurred early after the deposition of the top of the Pog carbonates. What triggered the landslide? We may speculate that it might have been caused by a tectonic event or that it was possibly also linked to the end-Guadalupian global lowstand (Shen and Shi 2009; Shen *et al.* 2013).

We have no reliable data for the top of the Permian. Moreover, the strong difference in mechanical behaviour between hard carbonates and soft shales results in a tectonically disturbed contact at the base of the Boks Formation. There is a lack of information concerning the Upper Permian and the base of the Triassic succession.

The Lower Triassic succession represents one of the main issues of this paper. Initially, the sedimentation took place on a marine muddy bottom below wave base, with intermittent delivery of boulder and cobble bodies (Boks Formation). The latter are not internally organised in sequences, and resulted from short-lived streams in a somewhat rugged topography, possibly activated by earthquakes. In between the two main conglomerate bodies, fine conglomerates and coarse arenites are present. They were deposited under marine conditions, evidenced by the Olenekian foraminiferal taxon *Meandrospira pusilla*. Oolitic shoals were formed in local settings protected by clastic inputs. They are very similar to the oolitic facies described by Ciarapica and Passeri (2000), Passeri and Ciarapica (2010) in the Lagonegro area (Cappelluzzo calcarenites) in Italy.

The clastic deposition gradually evolved into a more mature distributary systems, with polymictic conglomerates and better-rounded pebbles, arenitic matrix and thin carbonate interbeds (Plan Formation). The distributary system of the terrigenous material was still in braided rivers or under shore-face conditions; a turbidity current system was not established. In addition, it needs to be emphasized that the conglomeratic deposition ended within the late Olenekian. The marine ingression moved far away from the clastic sources and a typical carbonate ramp developed in the Anisian (Gjuraj Formation). Occasionally, carbonate mounds grew inside the carbonate ramp and the calcarenitic debris flowed towards the basin that was opening to the north-east (present day coordinates), where the pelagic reddish nodular limestones of the Han Bulog Formation are intercalated in the resedimented calcarenitic layers. The age of the Han Bulog basin drowning is in the Pelsonian (middle Anisian) at Nderlysaj, but in the rest of the Albanian Alps, most of the middle Anisian was still in the calcarenitic facies.

The general final drowning occurred in the late Anisian as testified by the pelagic mudstone /wackestone of the "Buchenstein" facies, in which a significant tuffitic and pyroclastic input is recorded. No lavas have been observed. The occurrence of tuffs and pyroclastics suggest a more acidic composition than the basaltic composition of the time-equivalent Mirdita Zone lavas (Gawlick *et al*. 2008). Additionally the bloom of Radiolaria allowed the formation of strips and nodules of cherts. The drowning is interpreted as linked to extensional movements occurring along the Adria margin. The pelagic interval lasted most of the Ladinian. Towards the end of the Ladinian the fading of the extensional movements along the margin, coupled with the high carbonate productivity allowed a return to shallow water conditions. The Theth organic rich carbonates testify to an intraplatform basin, bordered by active slopes, as indicated by the frequency of slumped beds and brecciated intervals.

CORRELATIONS

Palaeogeographically, the described succession belongs to the eastern passive margin of the Adria promontory (Bortolotti *et al.* 2005). The correlations with the Dinarides and Hellenides, with other zones of the Albanides, as well as with the Southern Alps, are discussed.

Permian: In the Dinarid area various terminologies have been proposed, i.e. Karst Zone (Auboin *et al.* 1970), Dalmatian-Herzegovinan Zone (MD Dimitrijevic 1997, Adriatic Dinaridic Carbonate Platform (Pamic *et al.* 1998), and Adriatic Carbonate Platform basement (Vlahovic *et al.* 2005). Additionally, in Montenegro, there is the Budva Zone, overthrust by the Adriatic Carbonate Platform. In the Budva Zone, the succession was thought to start with the Lower Triassic (Dimitrijevic 1967); however, Krystyn *et al.* (2014) also reported deep water sediments of Late Permian age.

On the Adriatic Carbonate Platform, the Permian rocks occur in Central Dalmatia, within the two major associations: the Evaporite Complex of the Central Dinarides (Tisljar 1992; Sremak 2005) and the succession of the Velebit Mountains (Sremak 2005; Alijnovic *et al.* 2008; Isozaki *et al.* 2011). In both areas, the major carbonate succession is of Wordian age, and continues up through the rest of the Guadalupian, turning to more restricted evaporitic facies in the Lopingian, as part of the epeiric carbonate platform bordering Gondwana (Vlahovic *et al.* 2005). The same trend occurs on the more distal part of the Adria margin in the Jadar Block (Filipovic *et al.* 2003; Sudar *et al.* 2007).

In the Hellenides, the most studied section is on the island of Hydra, which is referred to the Sub-Pelagonian Zone (Baud *et al.* 1990; Grant *et al.* 1991; Vachard *et al.* 1998; Jenny *et al.* 2004). A lower mostly carbonate package that spans the late Asselian–early Artinskian, is overlain by a terrigenous sequence of the Riga and Cap Bisti units, which in turn are overlain by a carbonate succession of Wordian age.

The Pog succession is the local evidence of the widespread Middle Permian carbonate platform that borders the Gondwana margin along the Adria promontory, from Greece to Dalmatia and Serbia.

Triassic: Of considerable interest is the correlation with successions in nearby southern Montenegro, with both the Budva Zone and the southern end of the Karst Zone/ Dinaric Carbonate Platform (Auboin *et al.* 1970; Dimitrijevic 1997; Radoicic and d'Argenio 1999; Gawlick *et al.* 2012). The outcrops are mostly in the mountains between the lake of Shkodre (Scutari) and the sea, where both the Cukali-Budva Zone and the Dinaric Carbonate Platform crop out (Radoicic and d'Argenio 1999).

In the Budva Zone, Krystyn *et al.* (2014) described a mostly terrigenous succession, in which both the Induan and Olenekian stages are recognized by ammonoids and/or conodonts.

The Triassic of the Dinaric Carbonate Platform was studied by Vinassa de Regny (1903), Martelli (1903, 1904, 1906), Bukowski (1927), Dimitrijevic (1967), and Dimitrijevic and Dimitrijevic (1969). The succession starts with the "Campilian" (= Olenekian?) (see Dimitrijevic 1997. p. 23). It is made of biomicrites, biosparites, largely dolomitized, what is rare in the Albanian Alps. The unit is overlain by the so-called "Anisian Flysch" (Dimitrijevic 1967). Three major conglomeratic depositional systems cross from the Dinaric Carbonate Platform to the Budva Zone, oriented NE to SW in present day coordinates. Our Boks and Plan formations might correlate with this terrigenous interval. According to our data, however, terrigenous sedimentation (especially the coarser terrigenous material) occurred in the Albanian Alps only during the Early Triassic, and not in the Anisian. In addition, deposition did not take place by bottom turbidity currents, as illustrated by Dimitrijevic (1967). It might be necessary to reconsider the Montenegro successions, because it looks strange that such geographically relatively closely spaced conglomerate bodies have such different ages. Moving to the Central Dinarides (Plavno), the Lower Triassic succession consists of carbonates (lower Griesbachian), overlain by red clastics (upper Griesbachian to Smithian), and mixed lime/mudstone /calcisiltites (Spathian-Anisian) (Herak *et al.* 1983; Aljinovic *et al.* 2014).

Episodes of terrigenous (breccia) deposition suggesting some tectonic activity are known from the Dinarides (Jelaska *et al*. 2003; Balini *et al.* 2006) and Southern Alps around the Olenekian/Anisian boundary or, more frequently, from the Anisian (Bosellini 1968; Broglio Loriga *et al.* 1982; Fois and Jadoul 1983; Farabegoli *et al*. 1985; De Zanche *et al.* 1993).

Concluding, the Early Triassic coarser clastic deposition seems to be restricted to the Albanian Alps and perhaps to Montenegro; the age of the "Anisian Flysch" needs to be reconsidered. The Montenegro succession of the Dinaric Carbonate Platform continues upwards into transgressive calcarenites and fairly rapidly into open sea deposition of the Han Bulog Formation, around the Pelsonian–Illyrian boundary (i.e. Bolievici; Martelli 1904, 1906; Fischer and Jacobshagen 1976; Gawlick *et al.* 2012). Locally, in the Albanian Alps (Nderlysaj) the drowning occurred earlier, at the beginning of the Pelsonian. In Montenegro, the trend from the carbonate platform to basin deposition is NE to SW (Gawlick *et al.* 2012), while in the Albanian Alps this trend is in the opposite direction. Similarly as in the Albanian Alps, where tuffitic layers interbedded with cherty limestone span most of the upper Anisian and Ladinian, in Montenegro the "chert-radiolarite formation" overlies the Han Bulog Formation. Volcanic activity and silica-rich waters characterized both areas. The recovery of the carbonate platform occurred both in the Albanian Alps and in the Dinaric Carbonate Platform at the turn of the Ladinian and the Carnian. In Montenegro however, the organic-rich facies of the restricted basin has not been described yet.

With the Hellenides, links are recognized with the Pelagonian areas, especially in Argolis, the island of Hydra (Jacobshagen 1986; Angiolini *et al.* 1992; Muttoni *et al.* 1997). The terrigenous prism in the basal Triassic (Ag. Nikolaos Formation) expanded on a marine flat on which a carbonate ramp had been established (Eros Limestone) since the late Olenekian. The drowning of the ramp occurred during the Pelsonian with the Han Bulog Formation (Fischer and Jacobshagen 1976). Peculiar to the area are the volcanics, outpouring already during the Pelsonian. Open sea deposition continued throughout the Ladinian and partly in the Carnian, when shallow water carbonate deposition was gradually re-established.

Eastwards, there is a passage across the Adria margin towards a deeper sea. The deformed margin of Adria crops out in Albania in three major tectonostratigraphic zones (beyond the Albanian Alps); from west to east, these are: the Cukali, Mirdita and Korabi zones. The presence of two ophiolitic belts led many authors to propose a two-ocean model (Shallo 1992; Robertson and Shallo 2000; Meço and Aliaj 2000). However, the single ocean model (Vardar Ocean) is progressively gaining more evidence and support (Collaku *et al.* 1992; Beccaluva *et al.* 1994; Bortolotti *et al.* 2005, 2006; Schmid *et al.* 2008; Gawlick *et al.* 2008; Schefer *et al.* 2010; Zelic *et al.* 2010; Borojevic Sostaric *et al.* 2014, among others). In this model, the Korabi Zone is still a part of the Adria margin and the Mirdita Zone overthrust the Korabi Zone during the Alpine convergence and collision (Schmid *et al.* 2008 among others).

The Cukali Zone succession starts with debris flows (a few tens of metres) with semiconsolidated blocks containing Pelsonian foraminifers (Theodhori 1988; Meço and Aliaj 2000). It is overlain by a late Anisian deeper-water succession continuing into an open sea environment throughout the Triassic (Gjata *et al.* 1987; Theodhori 1988; Marcucci *et al.* 1994; Chiari *et al.* 1995; Meço and Aliaj 2000). Middle Triassic volcanism is noted. Meço (2005, text-fig. 10) reported a section in which Norian platy limestone overlie tectonically thick limestone with Permian fusulinids. This may be evidence that the Cukali Zone represents shallow water conditions during the Permian. However, it may also represent a block fallen into the basin from the marginal part of the carbonate platform, when the Cukali Zone was already basinal in the Permian.

In the Caja Subzone of the Korabi Zone, the Devonian succession is unconformably covered by ca. 100 m of Permian/Triassic? conglomerate and sandstone, overlain in turn by up to 400 m thick arenaceous to pelitic successions with limestone intercalations, bearing Olenekian/early Anisian conodonts (Meço and Aliaj 2000). No younger Triassic rocks are known from that area (Meço and Aliaj 2000). Instead, in the Korabi Highland Subzone, a mostly terrigenous Lower Triassic is overlain by a mixed volcanic/carbonatic succession, with a platy and cherty open sea limestone, with Ladinian and Carnian conodonts (Meço 2010).

In the marginal part of the Mirdita Zone, within the blocks forming the sole of the nappe, fragments of Olenekian-Middle Triassic succession are recognized (Kçira, Qerreti, Rubiku, Miraka among others) (Shallo 1992; Kellici and de Wever 1994; Kodra *et al.* 1995; Muttoni *et al.* 1996; Chiari *et al*. 1994, 1996; Germani 1997; Gawlick *et al*. 2008). Pelagic deposition started in the Spathian (late Olenekian) (Muttoni *et al.* 1996; Germani 1997), and there was an outpouring of volcanics from the middle Anisian. Evidence of new oceanic crust starts from the late Anisian (Chiari *et al*. 1996; Gawlick *et al*. 2008).

In palinspastic view, the tectonostratigraphic units, from west to east, are as follows: Albanian Alps, Cukali, Korabi, and Mirdita zones.

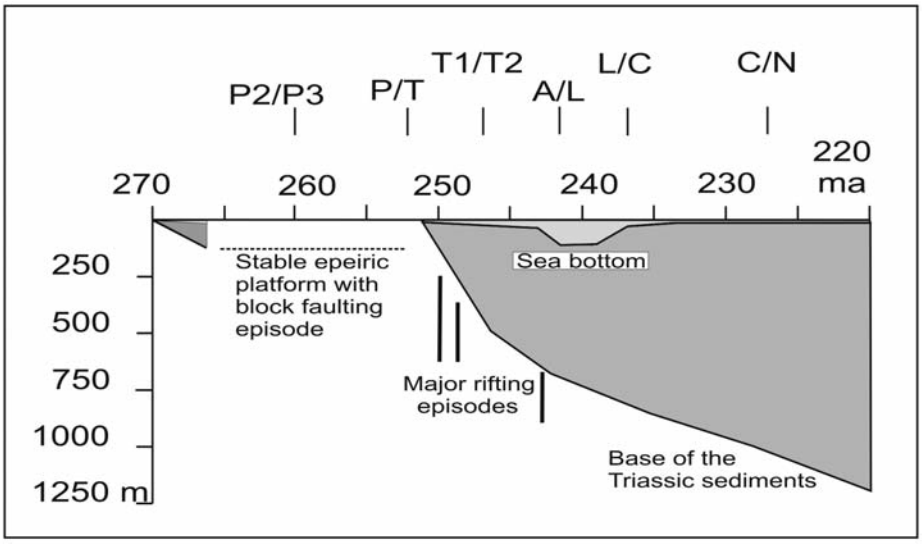
To summarize, a strong rifting phase occurred in the Albanian Alps during the Early Triassic. In the Korabi Zone, terrigenous sedimentation prevailed in the earliest Triassic, but without coarser conglomeratic bodies, whereas in the margin facing the future ocean, deeper water carbonate sediments occurred already during the Olenekian.

In the Anisian, drowning occurred in most of the Albanian Alps in the latest Pelsonian and locally earlier in the Pelsonian. In the latest Pelsonian, drowning also took place in the Cukali Zone. The drowning probably occurred earlier in the Korabi Zone and it was definitely deep in the marginal Mirdita Zone, where new oceanic crust started to accrete in the Illyrian/Fassanian.

The open sea conditions continued everywhere on the here considered part of the Adria margin throughout most of the Ladinian. Only the Albanian Alps returned to shallow-water environment in the latest Ladinian, while the Cukali, Korabi and marginal Mirdita zones remained in open sea conditions.

CONCLUSIONS

The sedimentary succession of the Permian to Middle Triassic of the Albanian Alps shares most of the regional trend of evolution of the Adria passive margin typical of the neighbouring regions. A carbonate ramp deepening towards the NE, in present co-ordinates, formed during the Middle Permian, and was affected by block faulting, with the deposition of carbonate breccia. The conodonts from the massive carbonates gave new insights in the local biostratigraphy. The Lower Triassic was characterized by intense terrigenous deposition with four main conglomerate levels, the main one being up to 80 m-thick. Clastic deposition ceased gradually by the Olenekian /Anisian boundary and a wide calcarenitic ramp occupied the area, with local small mounds. Basinward, red nodular limestones were interbedded with calcarenitic layers exported from the ramp. The general change to more open conditions occurred towards the end of the Pelsonian/beginning of the Illyrian. The cherty lime-



Text-fig. 10. Tentative subsidence curve for the Triassic of Albanian Alps. Thickness of sediments not decompacted. The most important subsidence occurred during the Early Triassic, when thick conglomerate bodies were deposited. Numeric ages according to Mundil *et al*. (2010) and Ogg *et al.* (2014)

stone spread everywhere, with more abundant tuffitic beds in the Theth sector. Towards the end of the Ladinian, with the end of volcanic activity, red pelagic limestone re-appeared for a short interval in the Bishkaz Zone of the Shale Block. At the Ladinian–Carnian boundary the area returned to shallow water conditions, with the development of a carbonate platform. In the Theth area, a restricted basin, with black organic-rich dolostone and limestone developed already in the late Ladinian, possibly extending into the early Carnian, which seems to be unique in that part of the Adria passive margin.

Consequently, an extensional phase is recognized in the Albanian Alps during the Early and Middle Triassic (Text-fig. 10). The major rifting took place during the Early Triassic, when block faulting led to the emersion of rift shoulders. It is uncertain whether or not the block faulting was accompanied by transcurrent movements. The coarse conglomerate bodies may be interpreted as a result of these movements. In the Anisian, the marine ingression with carbonate sedimentation took over. At the end of the Pelsonian, the shallow platform drowned to deeper water conditions, returning to shallow waters towards the end of the Ladinian. The deeper water interval lasted about 10 MY (Mundil *et al.* 2010; Ogg *et al*. 2014).

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THE LIST OF COMPLETE PALAEONTOLOGICAL NAMES USED IN THE TEXT

Foraminiferida

Afghanella tumida Skinner and Wilde, 1967
Aulotortus? *eotriasicus* Zaninetti, Rettori and Martini, 1994
Climacammina sp.
Earlandia amplimuralis Pantic, 1972
Earlandia gracilis (Pantic, 1972)
Endoteba sp.
Endotebanella sp.
Endotriadella sp.
Hemigordiopsis renzi Reichel, 1945
Lasiotrochus cf. *L. tatoiensis* Reichel, 1946
Meandrospira cheni (Ho, 1959)
Meandrospira dinarica Kochansky-Devidé and Pantic, 1965
Meandrospira pusilla (Ho, 1959)
Neoschwagerina sp.
Palaeolituonella meridionalis (Luperto, 1965).
Palaeotextularia sp.
Parafusulina ? sp.
Pilammina densa Pantic, 1965
Pilamminella semiplana (Kochansky-Devidé and Pantic, 1965)
Sumatrina sp.
Verbeekina sp.

Microproblematica

Tubiphytes carinthiacus (Flügel, 1966)
Vangia telleri (Flügel, 1984)

Conodontophorida

Budurovignathus diebeli (Kozur and Mostler, 1971)
Budurovignathus mostleri (Kozur, 1972)
Budurovignathus mungoensis (Diebel, 1956)
Gladigondolella malayensis Nogami, 1968
Gladigondolella tethydis Huckriede, 1958
Jinogondolella altudaensis (Kozur, 1992)
Jinogondolella sp.
Mesogondolella omanensis Kozur and Wardlaw, 2010
Neogondolella constricta (Mosher and Clark, 1965)
Neogondolella cornuta (Budurov and Stefanov, 1972)
Nicoraella kockeli (Tagte, 1956)
Paragondolella bifurcata (Budurov and Stefanov, 1972)
Paragondolella bulgarica (Budurov and Stefanov, 1975)
Paragondolella cf. *trammeri* Kozur, 1971
Paragondolella excelsa (Mosher, 1968)
Paragondolella foliata (Budurov, 1975)
Paragondolella hanbulogi (Sudar and Stefanov, 1979)
Paragondolella inclinata (Kovacs, 1983)
Paragondolella liebermani (Kovacs and Krystyn, 1994)
Paragondolella preszaboi (Kovács, Papšova and Perri, 1996)
Paragondolella pseudobifurcata (Kovacs, 1994)
Triassospathodus germanicus (Kozur, 1972)
Triassospathodus sp.

Brachiopoda

Punctospirella fragilis (Schlotheim, 1814)
Mentzelia sp.
Retzia sp.
Aulacothyris sp.

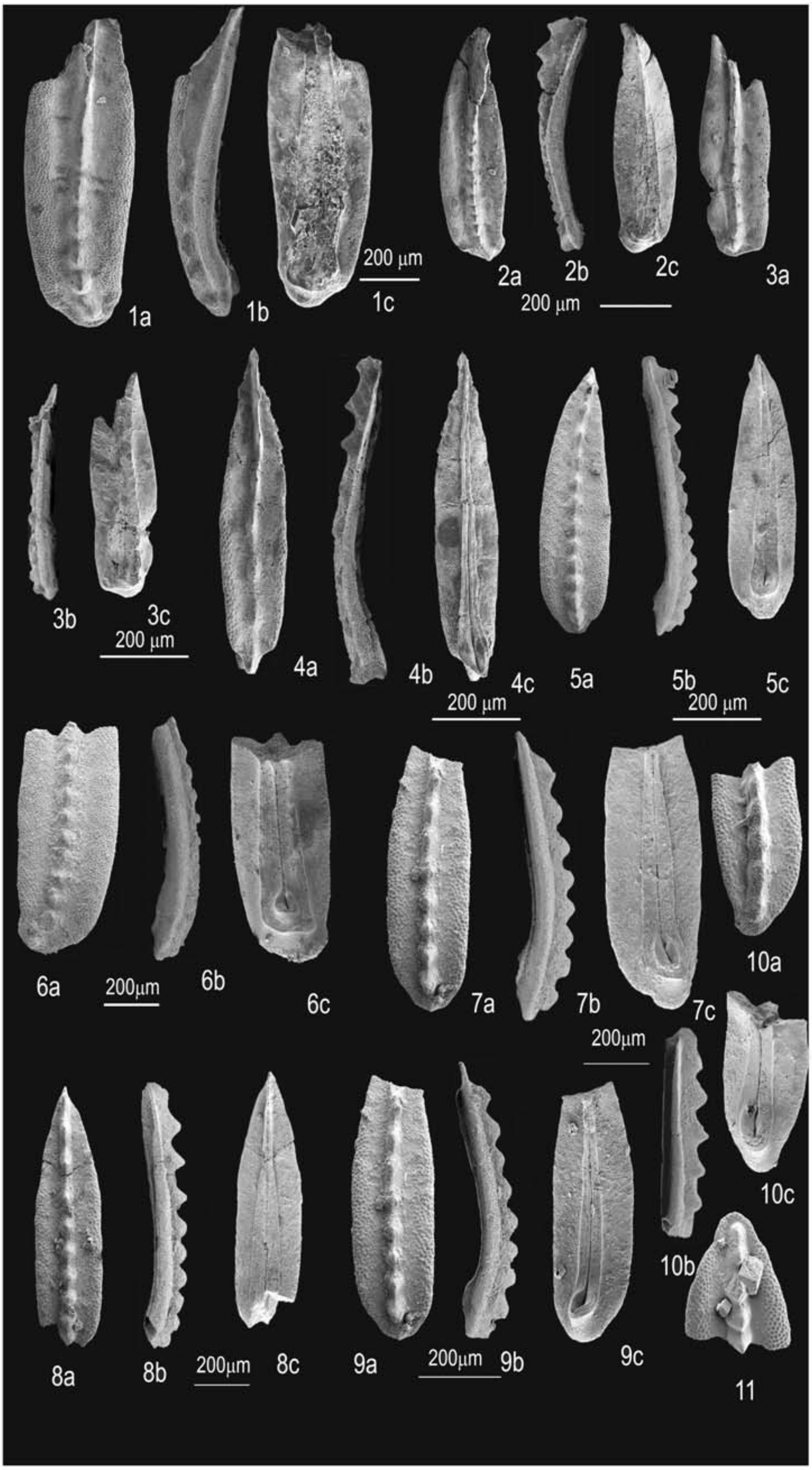
Mollusca

Plagiostoma sp.
Natiria sp.

PLATE 1

Conodonts from the Permian. Magnification according to the scale bar

1-3 – *Mesogondolella omanensis* Kozur and Wardlaw, 2010; Pog section, sample AA125.
4 – *Jinogondolella* sp.; Pog section, sample AA125.
5-6 – *Jinogondolella altudaensis* (Kozur, 1992); Pog section, sample AA 689.
7-10 – *Jinogondolella altudaensis* (Kozur, 1992); Pog section, sample AA 690.
11 – *Jinogondolella altudaensis* (Kozur, 1992), upper view of a fragment with the typical serration. Pog section, sample AA 690. a – upper, b – lateral and c – lower views, respectively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5a
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5c
200 μm
6a
200μm
6b
6c
7a
7b
7c
200μm
10a
10b
10c
8a
8b
200μm
8c
9a
200μm
9b
9c
11

PLATE 2

Foraminifers and microfacies from the Permian of the Pog section

1, 3 – *Hemogordiopsis renzi* Reichel, 1945; sample AA605, thin section 1-3 ; sample AA500, a pebble inside a breccia collected at the top of Permian carbonates in the Curray area (Text-fig. 2); sample AA605, thin section 6-2.
4 – *Verbeekina* sp.; sample AA606, thin section 3-1.
5, 6 – *Neoschwagerina* sp.; sample AA605, thin section 3-1; sample AA605, thin section 7-3.
7 – *Parafusulina* ? sp.; sample AA606, thin section 4-1.
8, 12 – *Afghanella tumida* Skinner et Wilde, 1967; sample AA606, thin section 1-1; sample AA606, thin section 1-4.
9 – *Sumatrina* sp.; sample AA606, thin section 1-2.
10, 11 – *Afghanella* sp.; samples AA606, thin section 1-3; AA 606, thin section 2-1.
13 – *Tubiphytes carinthiacus* (Flügel, 1966); sample AA121.
14 – *Vangia telleri* (Flügel, 1984); sample AA611.
15 – Biocalcarenite with crinoids, *Tubiphytes* and fusulinids; sample AA120.

Scale bar 200 μm

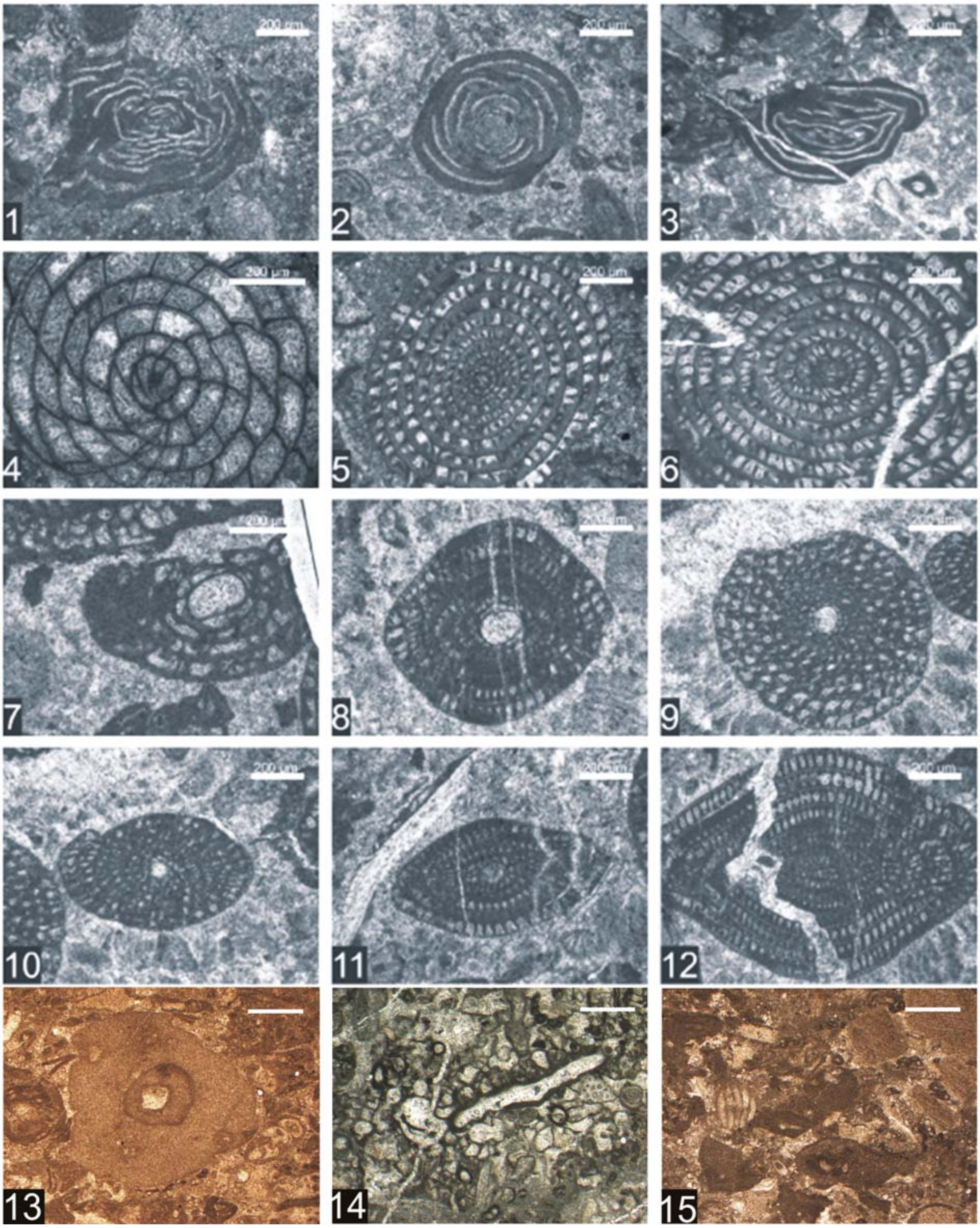
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PLATE 3

Field pictures

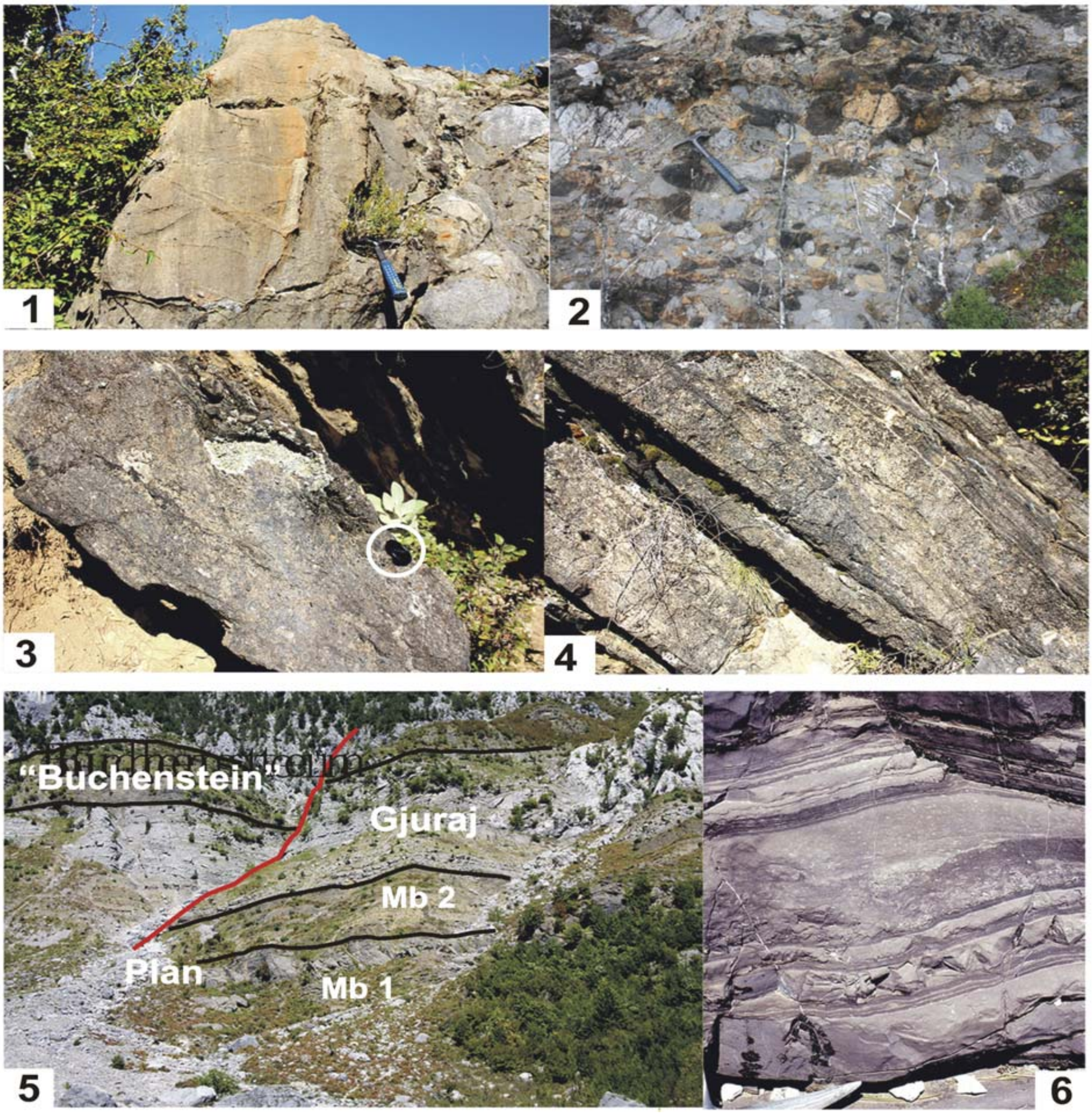
1 – Cobble from the lowest conglomerate horizon, Boks Formation; sample AA665; hammer as a scale; the microfacies from this sample is figured on Pl. 4, Fig. 1.

2 – Base of the second conglomerate horizon, polymictic and bimodal. The smaller pebbles are better rounded, while the largest are angular. Hammer for scale. Boks Formation; sample AA669. Microfacies reported in Pl. 4, Fig. 5.

3, 4 – The fine conglomerate and coarse sandstone sequence from the fine conglomerate and arenite layer between the first two conglomerate horizons. Note the oblique lamination and possibly some hummocky crossing laminae. Boks Formation; lens cover for scale in Pl. 4, Fig. 3.

5 – The Gjuraj section, looking NNE. The section was measured north of the Gjuraj houses, along the gully on the right, up to the top of the Gjuraj Formation. The “Buchenstein” facies and the overlying succession were measured on the west side of the west gully.

6 – A typical graded sequence in the Theth Formation. Head of the hammer for scale. Theth section, second part, around 75 m from the base of this part.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"Buchenstein"
Gjuraj
Mb 2
Plan
Mb 1
5
6

PLATE 4

Conodonts from Anisian

1 – *Nicoraella kockeli* (Tagte, 1956) vs *Triassospathodus ggermanicus* (Kozur, 1972), lateral view. Gjuraj section, sample AA87.
2 – *Nicoraella kockeli* (Tagte, 1956) vs *Triassospathodus germanicus* (Kozur, 1972), lateral view. Gimaj section, sample G8.
3 – *Nicoraella kockeli* (Tagte, 1956) vs *Triassospathodus germanicus* (Kozur, 1972), lateral view, Gjuraj section, sample AA87.
4 – *Nicoraella kockeli* (Tagte, 1956) vs *Triassospathodus germanicus* (Kozur, 1972), lateral view. Gjuraj section, sample AA61.
5 – *Paragondolella bifurcata* (Budurov and Stefanov, 1972), lateral view. Gimaj 1 section, sample G7.
6 – *Paragondolella bifurcata* (Budurov and Stefanov, 1972), lateral view. Theth section, sample AA331.
7 – *Paragondolella bifurcata* (Budurov and Stefanov, 1972), upper view. Gjuraj section, sample AA91.
8 – *Paragondolella bifurcata* (Budurov and Stefanov, 1972), lateral view. Gjuraj section, sample AA79.
9 – *Paragondolella bifurcata* (Budurov and Stefanov, 1972), lateral view. Theth section, sample AA331.
10 – *Paragondolella bulgarica* (Budurov and Stefanov, 1975), lateral view. Gimaj 1 section, sample G6.
11 – *Paragondolella hanbulogi* (Sudar and Stefanov, 1979), lateral view. Gimaj 1 section, sample G7.
12 – *Paragondolella bifurcata* (Budurov and Stefanov, 1972), lateral view. Gimaj 1 section, sample G7.
13 – *Paragondolella bulgarica* (Budurov and Stefanov, 1975), lateral view. Gjuraj section, sample AA61.
14 – *Paragondolella hanbulogi* (Sudar and Stefanov, 1979), lateral view. Gimaj 1 section, sample G9.
15 – *Paragondolella excelsa* (Mosher, 1968), lateral view. Gimaj 1 section, sample G9.
16 – *Budurovignathus mungoensis* (Diebel, 1956), upper view. Gjuraj section, sample AA101.
17 – *Budurovignathus mostleri* (Kozur, 1972), lateral view. Gjuraj section, sample AA 101.
18 – *Budurovignathus diebeli* (Kozur and Mostler, 1971), upper view. Gjuraj section, sample AA101.
19-21 – *Budurovignathus mungoensis* (Diebel, 1956), lower view. Gjuraj section, sample AA 101.
22 – *Paragondolella inclinata* (Kovacs, 1983), lateral view. Gjuraj section, sample AA 101.
23 – *Paragondolella foliata* (Budurov, 1975), lateral view. Gjuraj section, sample AA 101.

Scale bar 100 μm

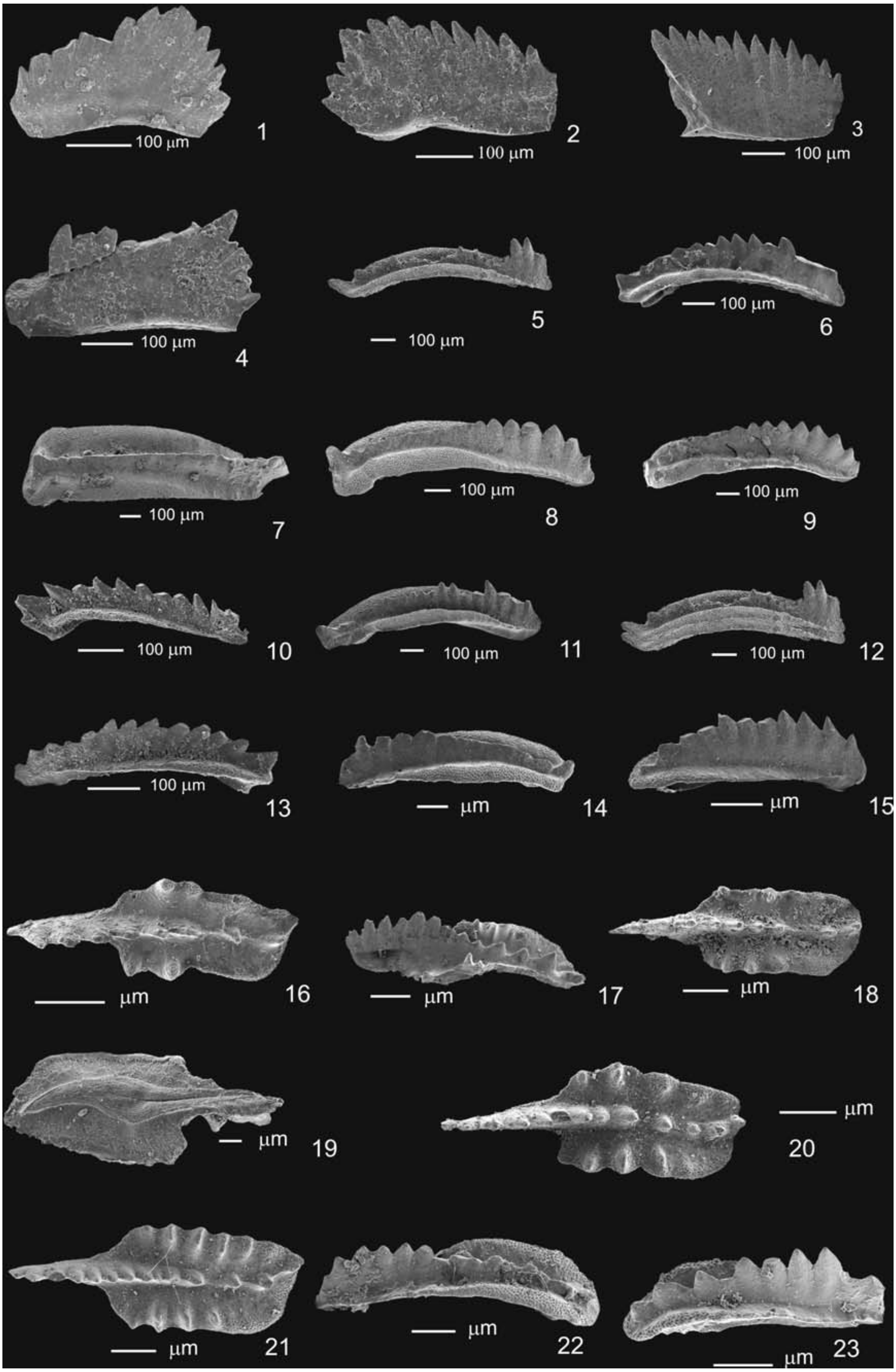

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PLATE 5

Foraminifers from the Early Triassic and Anisian

1 – *Lasiotrochus* cf. *L. tatoiensis* Reichel, 1946; Gjuraj section, sample AA22; Permian species reworked in the Lower Triassic sediments.
2, 3 – *Meandrospira pusilla* (Ho, 1959); Gjuraj section, samples AA22; AA26.
4, 5 (left) – *Pilammina densa* Pantic, 1965; Gjuraj section, sample AA623.
5 (right) – *Meandrospira dinarica* Kochansky-Devidé and Pantic, 1965; Gjuraj section, sample AA623.
6 – *Meandrospira dinarica* Kochansky-Devidé and Pantic, 1965. Gjuraj section, sample AA623.
7, 8 – *Aulotortus*? *eotriasicus* Zaninetti, Rettori and Martini, 1994. Gimaj 1 section; samples AA412 and AA427 respectively.
9 – *Pilamminella semiplana* (Kochansky-Devidé and Pantic, 1965). Gjuraj section, sample AA72.
10 – *Palaeolituonella meridionalis* (Luperto, 1965). Gimaj 1 section, sample AA412.
11, 12 – Duostominidae. Gimaj 1 section, sample AA431 and Gjuraj section, sample AA622.
13 – *Endoteba* sp.; Gjuraj section, sample AA30.
14 – Lagenid, Gjuraj section, sample AA623.
15 – *Endotebanella* sp., Gjuraj section, sample AA30.

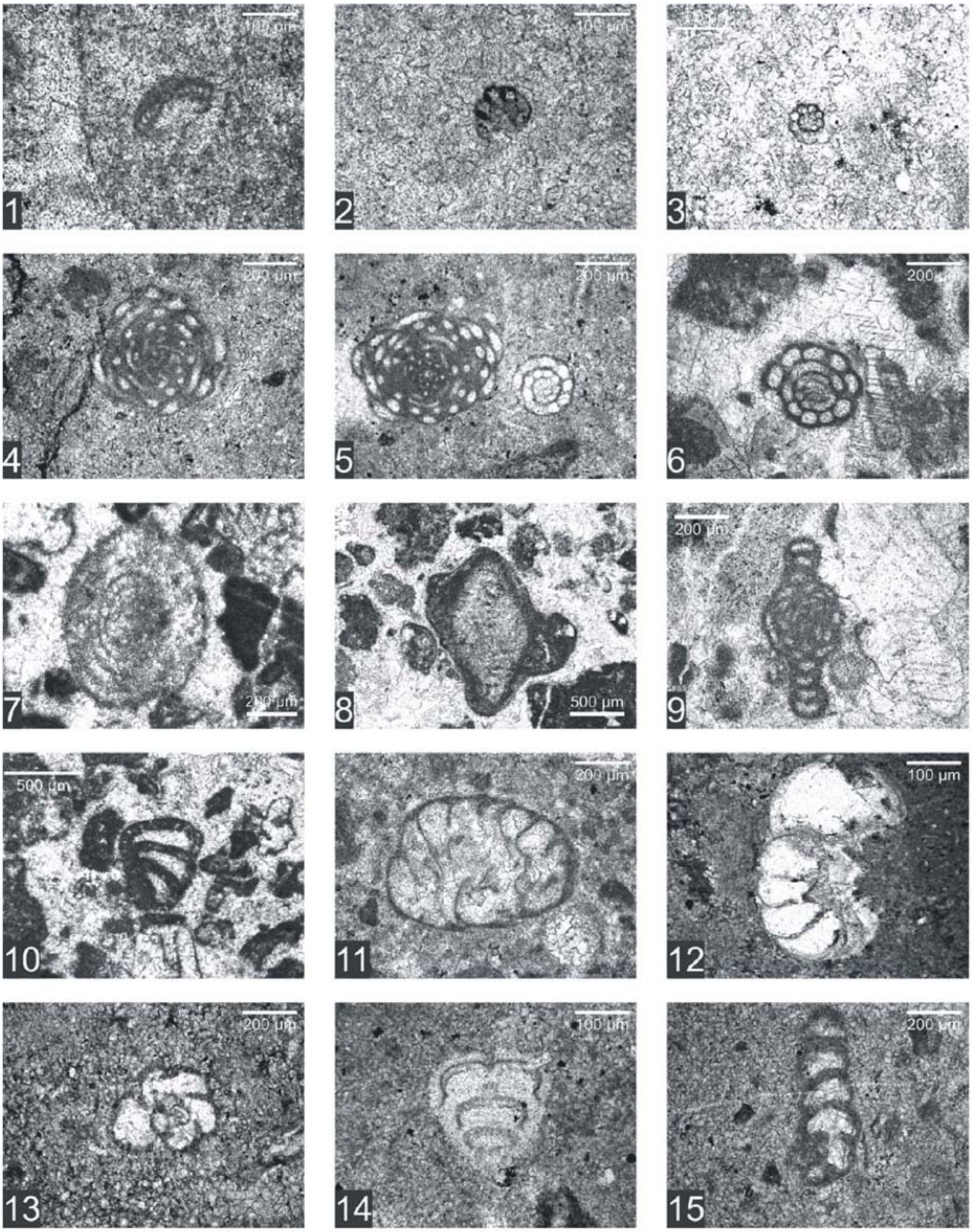
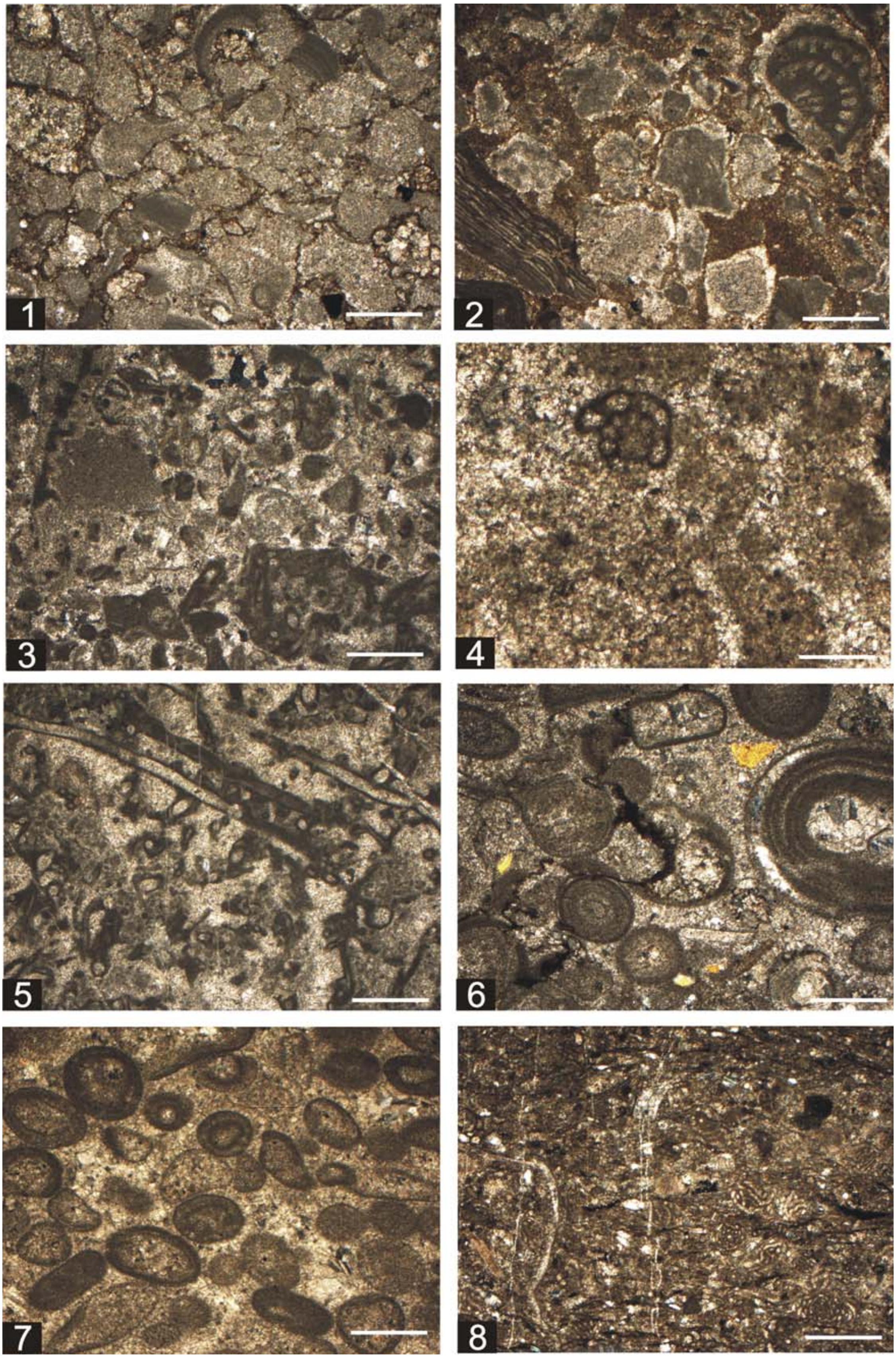


PLATE 6

Microfacies from Boks, Plan and Gjuraj formations

1 – Boks Formation, first conglomerate horizon. Packstone with fragments of ooids. Sample AA665, from the block figured in Pl. 3, Fig. 1.
2 – Boks Formation, first conglomerate horizon. Pebble of a calcarenite with abraded fragments of fusulinid and *Hemigordiopsis renzi* Reichel. 1945. Some of the clasts have a calcitic rim. Sample AA664/A.
3 – Boks Formation, first conglomerate horizon. Pebble of a packstone with micritized grains and fragments of microproblematic organism. Sample AA664/4.
4 – *Meandrospira pusilla* (Ho, 1959) in the matrix of a thin packstone bed, below the second conglomeratic horizon. Sample AA 666, × 50 µm.
5 – Boks Formation, Second conglomerate horizon. Pebble with a microproblematic organism with long thin tubes, recalling *Vangia* sp., sample AA669/f.
6 – Oosparite, with mature oolites and coated grains. Oolitic shoal lateral equivalent of the Third conglomeratic horizon. Sample AA670.
7 – Oosparite, with surficial oolites and coated grains. From a pebble in the upper part of the Plan Formation, Gjuraj section, sample AA19.
8 – Wackestone/packstone crowded with *Pilammina densa* Pantic, 1965. Plan Formation, sample AA688.

Scale bar 200 µm, except Fig. 4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