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THE BERRIASIAN–VALANGINIAN AND APTIAN DEPOSITS FROM THE NORTH-WESTERN PART OF THE PIATRA CRAIULUI MASSIF: STRATIGRAPHIC RELATIONSHIPS, FACIES AND DEPOSITIONAL ENVIRONMENTS

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Abstract Study of the breccia clasts and conglomerate pebbles from the Aptian deposits of the north-western part of Piatra Craiului Massif provides a valuable tool for identifying source areas and for reconstructing the original depositional environments which produced these types of sedimentary deposits. Two sections were studied on the western flank of the Piatra Craiului syncline containing Berriasian-Valanginian limestones followed by Aptian breccia and conglomerates.

Between the peritidal Berriasian–lower Valanginian limestones and the overlying upper Valanginian limestones/marly-limestones an unconformity was identified, recognized previously in other areas of the Dâmbovicioara Couloir.

Several characteristics of the Aptian deposits that cover the lowermost Cretaceous limestones/marly-limestones, such as grain size, morphology, and pebble composition were used in order to identify the transport mechanisms and the location of the source area. The monomictic breccia was deposited as debris flows on a shelf slope or toe-of-slope from a proximal source area. The pebbles from the Aptian conglomerates are associated with a fan-delta depositional environment. These clasts are frequently reworked in mass, debris and grain flows associated with slope and toe-of-slope sedimentary areas during the Aptian. Several distinct microfacies types and microfossils were identified in the carbonate pebbles. These data provide information about the age and help to interpret the sedimentary facies of the carbonate rocks in the source area.

Keywords: geology, limestones, conglomerates, breccia, Valanginian, Aptian, microfacies, source area, Piatra Craiului Massif

INTRODUCTION

Study of conglomerate pebbles and breccia clasts, including microfacies and microfossil content, provides important data on their original sedimentary environment, as well as on the source area and the depositional environment of the clast-bearing deposits. In this study we analyzed Aptian deposits located at the contact with Berriasian-Valanginian carbonate rocks from the north-western part of the Piatra Craiului Massif (Fig. 1).

Our aim was to identify the source rocks of these breccia and conglomerates and to infer the position of their exhumation areas during the Aptian. To achieve this goal we studied the lowermost Cretaceous limestones and marly-limestones situated immediately below the breccia and conglomerates, and described the pebble microfacies and the microfossil content (also useful for age constraints) to decipher the depositional environments of the carbonate rocks. These data were used to indicate the location of the source area and the rate of erosion.

The stratigraphic relationships between the Berriasian-Valanginian limestones and the Aptian breccia/conglomerates can be observed in several locations in the Piatra Craiului Massif such as at Prăpăstiile Zărneştilor, Şaua Crăpăturii, Drumul lui Lehmann (located below Şaua Padinei Inchise), Padinile Frumoase (situated below Vârful Ascuţit), and Vârful La Om. Some of the best exposures are located in Padinile Frumoase and Drumul lui Lehmann (Fig. 1). In these locations the transition from the basal Aptian breccia (which is located above the upper Valanginian limestones/marly-limestones) to the Aptian conglomerates can be observed.

GEOLOGICAL FRAMEWORK

The Piatra Craiului Massif is located in the north-eastern part of the Southern Carpathians, in the proximity of the Braşov Depression (Fig. 1) and represents the western component of the Dâmbovicioara Couloir (Patrulius, 1969). This region is part of a larger tectonic unit which was defined as the Getic Nappe (Murgoci, 1905, 1910; Săndulescu, 1984). Balintoni (1997) separated the eastern part of this area into a distinct tectonic unit called the Dâmbovicioara Nappe. The Getic Nappe is part of the Median Dacides, a tectono-stratigraphic unit belonging to Dacia Mega-Unit cf. Csontos & Vörös (2004). This mega-unit was formed during Jurassic times when several blocks were detached from the European margin (Săndulescu, 1984; 1994). The closure of the East Vardar Ocean during the Late Jurassic (Maţenco et al., 2010) was followed by Cretaceous continental collision (Schmid et al., 2008). During this time interval the Getic Unit evolved as a major tectonic unit within the Southern Carpathians (Săndulescu, 1984). The Getic Nappe, that

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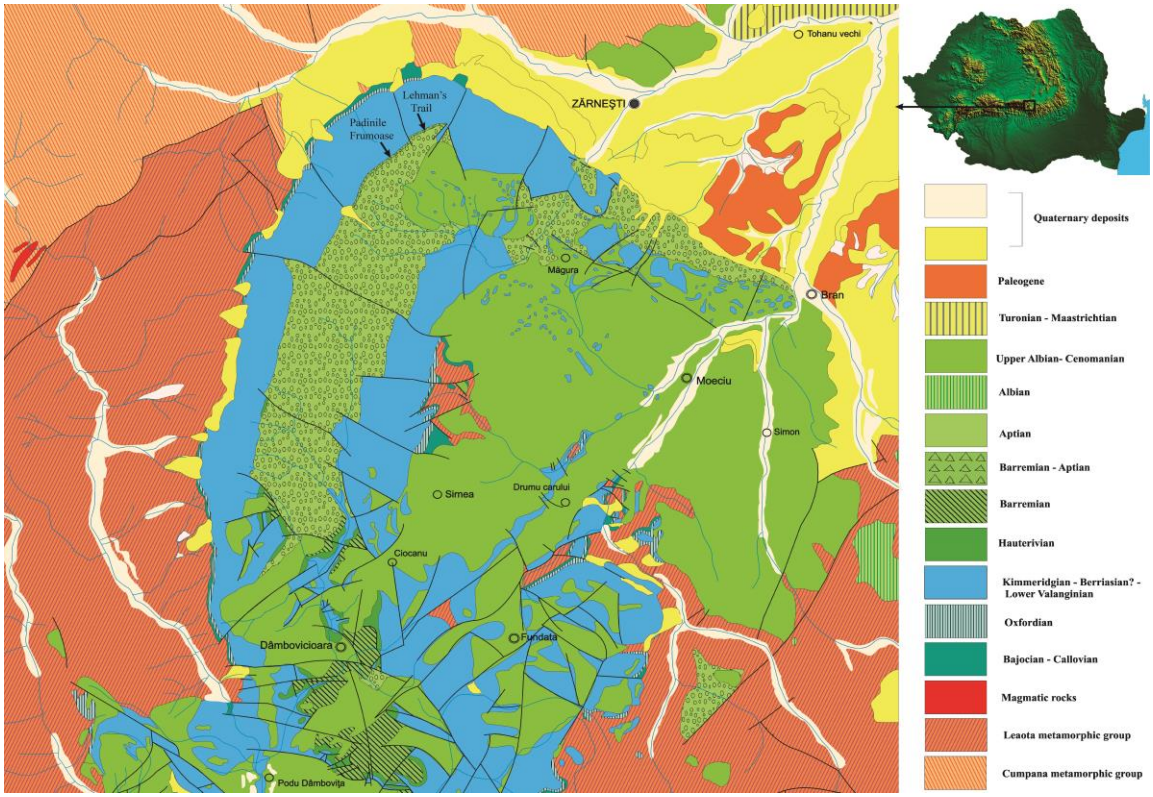

Fig. 1 Location of the Aptian deposits on the geological map of the northern part of the Piatra Craiului Massif [based on the maps 1:50000, sheets110a to 110d (Dimitrescu et al., 1971; Patrulius et al., 1971; Săndulescu et al., 1972; Dimitrescu et al., 1974), redrawn with minor changes]

has the largest outcropping areas within the Median Dacides, was subject of several tectonic phases during the Cretaceous with two important phases (Codarcea, 1940): an intra-Aptian phase and an intra-Senonian (Coniacian–-Maastrichtian) one (Săndulescu, 1984). The first phase (Austric tectonic movements of Patrulius, 1969) produced the thrusting of the Getic Nappe front over the External Dacides (Codarcea, 1940; Săndulescu, 1984). During the first (post-Bedoulian, Patrulius, 1969) phase, in the eastern part of the Getic domain, the central part of the Leaota area was uplifted and an anticline structure was formed. This anticline is bordered on its eastern side by the Bucegi Syncline area and on the western side by the Piatra Craiului Syncline, respectively. These first tectonic movements were followed by the uplift of two units (Leaota and Zamura) which are separated (cf. Patrulius, 1969) by a couloir-type depression. Within this couloir the succession comprises conglomerates, reefal limestones and olistoliths (Patrulius, 1969). The overthrusting plane of the Getic domain over the External Dacides (Ceahlău Nappe) is largely covered by upper Aptian and Albian–Cenomanian sedimentary deposits (Săndulescu, 1984).

On a south-north direction the Dâmbovicioara Zone can be divided in four distinct structural compartments: Dragoslavele, Rucăr-Bran, Tohan-Râșnov, and Holbav-Cristian (Patrulius, 1969). The Piatra Craiului Massif forms the western extremity of the Rucăr-Bran compartment. This region can be associated with an asymmetric syncline that dips 70 ^{0} on the western flank and 30-45^{0} the eastern flank. Jekelius (1938) associated the Piatra Craiului Massif with an overthrown flank of a partially thrusted fold (Fig. 2). This structure was defined during the post-Paleogene tectonic movements since the entire sedimentary succession has been affected (Popescu, 1966). Patrulius (1969) considered that some of the pre-Vraconian tectonic accidents were reactivated after the post-Paleogene movements. This hypothesis further justifiies the amplitude of the folding processes which affected the region of the Piatra Craiului Massif.

The study area represents the eastern part of the sedimentary cover of the Getic Nappe, described as the Brașov Series by Patrulius (1969). Its sedimentary succession covers a metamorphic basement composed of rocks belonging to the Cumpăna and Leaota groups. In this area, the Middle Jurassic-Bedoulian deposits are covered by upper Aptian and Albian–Cenomanian conglomerates (Popescu., 1966; Patrulius, 1969; Patrulius et al., 1976). Jekelius (1938) suggested a late Albian–Cenomanian age for the Piatra Craiului Syncline conglomerates. Popescu (1966) and Patrulius (1969) separated two distinct lithological units within these conglomerates: the Aptian "Gura Râului conglomerates" and the "Vraconian–Cenomanian conglomerates".

The first unit is well exposed in the north-eastern part of the Piatra Craiului Massif. It consists of blocks which have been reworked into the Albian Bucegi conglomerates. They were assigned to the upper Aptian because their matrix contains some rare orbitolinids (Popescu, 1966). The uppermost Albian–Cenomanian conglomerates are well exposed on the western flank of this syncline.

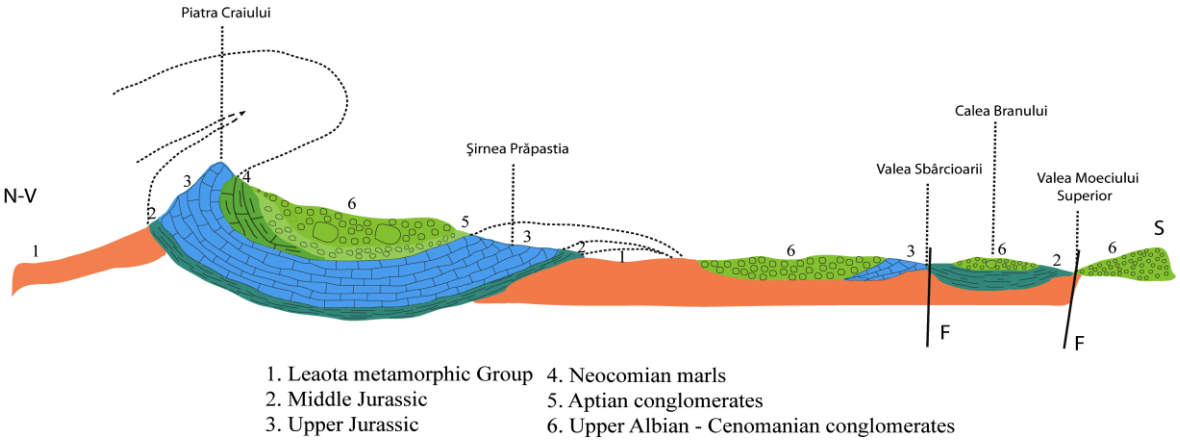

Fig. 2 Geological cross-section through the northern part of Piatra Craiului Massif and Bran Pass (after Jekelius, 1938, redrawn with minor changes).

They comprise olistoliths which are encased in very well-cemented carbonate breccia. The age of these deposits was assigned by the previous authors taking into account the different faunal assemblages found in some locations such as Podul Cheii (Toula, 1897; Simionescu, 1898; Popovici-Hațeg, 1898) and Muntele Ghimbavu (Patrulius, 1969).

METHODOLOGY

The Aptian conglomerates that transgressively overlie the Berriasian–Valanginian limestones were investigated during several fieldwork campaigns in 2013 and 2014. We collected approximately 180 samples and prepared more than 200 thin sections and 30 polished slabs. Several features such as grain size/morphometry, sorting, and pebble orientation were traced in detail within the field. Thin section analysis was used to describe the microfacies and microfossils of the clasts, pebbles and the matrix. Standard classifications of Dunham (1962) modified by Embry & Klovan (1971) and Wright (1992) were used.

BERRIASIAN–VALANGINIAN LIMESTONES AND APTIAN BRECCIA AND CONGLOMERATES

1. Padinile Frumoase

1.1 Berriasian–Valanginian limestones and marly-limestones

Lithology and microfacies.

In the Padinile Frumoase area the limestone and conglomerate beds are almost vertical (Fig. 3a). In this outcrop (Fig. 3a, 5a) the stratigraphic contact between the Berriasian-lower Valanginian limestones and the upper Valanginian limestones/marly-limestones is well visible. The lower Valanginian limestones are well cemented and they form a positive topography (steep sides) if compared with the highly weathered upper Valanginian limestones/marly-limestones (Fig. 5a). The Berriasian-lower Valanginian limestones are stratified in decimetre-metre thick banks while the upper Valanginian limestones / marly-limestones are stratified in thin beds which are centimetre-decimetre thick (Fig. 5a). The Berriasian-lower Valanginian limestones contain mainly bioclastic-intraclastic grainstone and peloidal-bioclastic packstone (Fig. 5b, c). The microfossil assemblage (Fig. 6) consists of small benthic foraminifera (miliolids), rare large agglutinated benthic foraminifera [*Pseudocyclammina lituus* (Yokoyama)] (Fig. 6a), *Lithocodium* nodules, rivularian type cyanobacteria, bivalve fragments, echinoderm plates, dasycladalean algae, and rare ostracods. Other components include peloids, intraclasts and rare oncoids. Fenestral structures and meniscus-type cement are scarce. These limestones were deposited in a shallow peritidal environment belonging to the intertidal and supratidal areas. At their top, the lower Valanginian limestones contain dissolution features and patches of iron oxides (Fig. 5b,c) indicating subaerial exposure. The dissolution cavities were filled with vadous silt (Fig. 5b) or micritic sediments (Fig. 5c).

The boundary between the lower Valanginian limestones and the upper Valanginian limestones/marly-limestones is marked by an unconformity. This unconformity is followed by 3 m of thin, compact marly-limestones and limestones (Fig. 5a). They consist of alternating bioclastic wackestone and peloidal-bioclastic packstone (Fig. 5d-f). Bioclasts are represented by echinoderm fragments, ostracods, rare mollusk fragments, bryozoans, small benthic foraminifera [*Montsalevia salevensis* (Charollais, Brönnimann & Zaninetti) (Fig. 6f-h), *Meandrospira favrei* Charollais, Brönnimann & Zaninetti (Fig. 6l)], very rare calpionellids (Fig. 6p, q) and calcispheres [*Cadosina fusca* Wanner (Fig. 6u), *Crustocadosina semiradiata* (Wanner) (Fig. 6v, w)]. Small peloids and rare clasts of glauconite can be associated with these bioclasts (Fig. 5e).

The bioclastic packstone contains echinoderm fragments with syntaxial overgrowth cement (Fig. 5e, f). These types of cement form angular fragments, of different dimensions which are randomly distributed within the micritic sediment. The texture of the rock is comparable with a heterogeneous “pepper and salt-type texture” (Fig. 5e, f). The associated facies and microfossils identified in

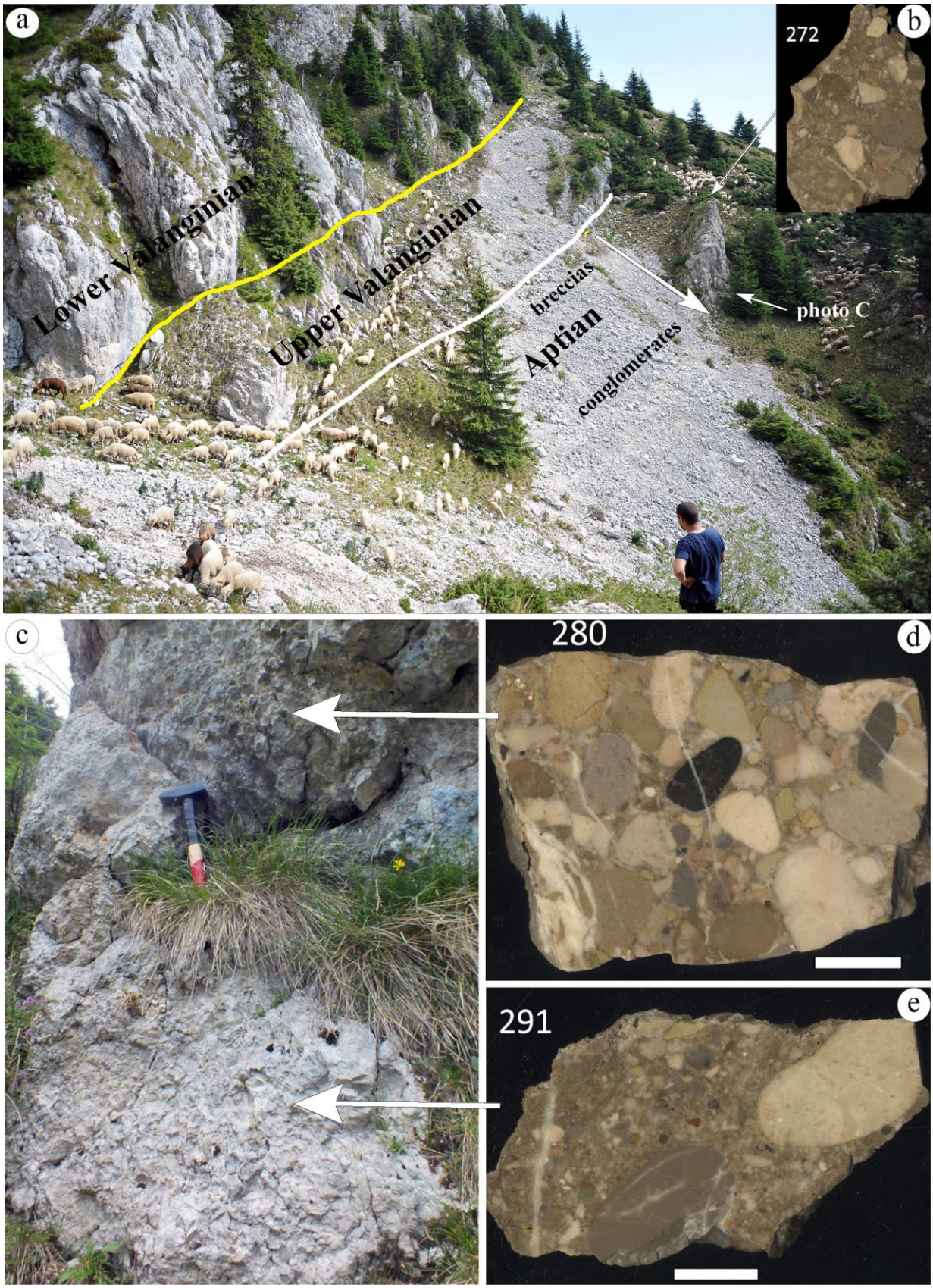

Fig. 3 Padinile Frumoase outcrop **a** The lower Valanginian-upper Valanginian unconformity (yellow line) and the transgressive contact between the Valanginian limestones and the Aptian deposits (breccia and conglomerates) (white line). **b** Monomictic breccia. **c** The first outcrop located above the contact area (~3m). **d** Monomictic orthoconglomerates with common carbonate pebbles. **e** Monomictic paraconglomerates with carbonate pebbles. 272, 280, 291 = sample numbers. Scale bar for b, d, e = 2 cm.

these marly- limestones are characteristic for an open marine environment located probably on the shelf slope or the distal shelf. The accumulation of these hemipelagic deposits over the subaerially exposed lower Valanginian limestones took place during the late Valanginian transgression (Patrulius et al., 1980; Patrulius and Avram, 2004; Grădinaru et al., submitted)]. The boundary between the shallow-water deposits and the hemipelagic limestones/marly-limestones marks a regional unconformity which was formed during the Valanginian. Patrulius (1969) identified this unconformity in several locations from the Dâmbovicioara Zone while Grădinaru et al. (submitted) have studied it in detail in the same area.

These thin-bedded limestones/marly-limestones are overlain by a 2.5 m thick succession of decimetre-thick beds (Fig. 3a, 5a) represented by interbedded bioclastic-intraclastic grainstone, bioclastic-intraclastic packstone (Fig. 5g) and intraclastic-bioclastic floatstone (Fig. 7a, b). Intraclasts are characteristic components in these rocks, mainly as peloidal packstone rich in small foraminifera and echinoderm plates (Fig. 7a-b), together with bioclastic packstone with sponge spicules and coral fragments (Fig. 7a), and encrusted large coral fragments. The sediment between the intraclasts contains *Lithocodium* nodular crusts (Fig. 5g), echinoderm plates, worm tubes, large benthic foraminifera [*Pseudocyclammina lituus* (Yokoyama) (Fig. 6b, c), *Coscinoconus* cf. *cherchiae* (Arnaud-Vanneau, Boisseau & Darsac) (Fig. 6d)], small benthic foraminifera [*Montsalevia salevensis* (Charollais, Brönnimann & Zaninetti) (Fig. 6e, i, j), *Meandrospira favrei* Charollais, Brönnimann & Zaninetti (Fig. 6k, m-o)], very rare calpionellids (Fig. 6r-s), calcispheres [*Cadosina fusca* Wanner (Fig. 6t), *Stomiosphaera echinata* Nowak (Fig. 6x, y)], green algae fragments (*Terquemella* sp.), ostracods, and mollusks. The matrix contains some small peloids and rare clasts of glauconite.

Based on the identified intraclasts and bioclasts one may assume that these deposits were accumulating on the shelf slope or at the base of the slope (Mullins et al., 1984; Mullins & Cook, 1986). The sediment was delivered through several episodes of mass debris flows (Sohn, 2000a, b; Talling et al., 2012). A large number of bioclasts were reworked from the shallow shelf areas (e. g. coral fragments, green algae, large foraminifera).

Age of the limestones

The early Valanginian age of the peritidal limestones was assigned based on the micropaleontological assemblage identified just below the contact with the upper Valanginian limestones/marly-limestones [*Salpingo-porella praturloni* (Dragastan), *Pseudocymopolia jurassica* Dragastan, *Haplophragmoides joukowskyi* Charollais, Brönnimann & Zaninetti, *Montsalevia salevensis* (Charollais, Brönnimann & Zanninetti), *Pfenderina neocomoensis* (Pfender), *Coscinoconus cherchiae* (Arnaud-Vanneau, Boisseau & Darsac), *Coscinoconus delphinensis* (Arnaud-Vanneau, Boisseau & Darsac), *Coscinoconus campanellus* (Arnaud-Vanneau, Boisseau & Darsac)] and correlations with similar deposits from Dâmbovicioara Couloir (Cheile Dâmbovicioarei Formation, Patrulius et al., 1980). The marly-limestones and limestones above the unconformity contain *Meandrospira favrei* and *Stomiosphaera echinata* indicating a late Valanginian age.

1.2 Aptian breccia and conglomerates

Lithology and microfacies

In the Padinile Frumoase area monomictic carbonate breccia have been identified some meters above the upper Valanginian deposits (Fig. 3b). This Aptian breccia is very thin (2-3 m) and it passes into monomictic carbonate-rich ortho- and paraconglomerates (Figs. 3d; 3e), which are overlain by Aptian polimictic conglomerates similar to those from Gura Râului area (Fig. 4A).

The breccia situated above the Valanginian deposits contain clasts of variable dimensions and morphology, as well as a micritic/clay-rich matrix (Figs. 3b, 7c). Clasts are mostly carbonates, bioclasts, and marls with bioclasts (Fig. 7c-h). The carbonate clasts are fragments of coral-rich boundstone (Fig. 7e, f), with *Lithocodium* and sponge crusts (Fig. 7f), peloidal bioclastic grainstone with orbitolinids (Fig. 7g, h), bioclastic packstone with green algae and orbitolinids (Fig. 7h), and peloidal fenestral wackestone (Fig. 7h). The clasts from the marl-rich layers contain small fragments of echinoderms, foraminifera (e.g., *Lenticulina* sp.), ostracods, peloids and glauconite (Fig. 7d). The bioclasts from the matrix are represented by orbitolinids (Fig. 8a-c), coral fragments, rudist fragments, bryozoans and echinoderm plates. The matrix contains silt-sized quartz (Fig. 7c-f).

Both the carbonate and the marly clasts show dissolution structures. Figure 7d documents that the marly clast was dissolved and surrounded by iron oxides. Some of the glauconitic minerals were totally or partially oxidized. By contrast, Figure 7e shows a partially dissolved coral which was replaced by dog tooth-type cement. Other carbonate clasts are characterized by dissolved components, and the newly formed cavities are bordered by a fine crystalline cement. Subsequently these cavities were filled with micritic/clay-rich sediment (Fig. 7f).

The breccia situated above the contact with the Valanginian limestones contain components that have similar microfacies with those identified in the Berriasian-Valanginian and Barremian-Aptian limestones. Orbitolinids are present both in the matrix and in the clasts (Fig. 7c, g-h).

Clasts of the peritidal sediments (peloidal fenestral mudstone/wackestone, peloidal bioclastic packstone /grainstone with large benthic foraminifera) are reminiscent of the Berriasian-lower Valanginian type of facies. They contain *Montsalevia salevensis* (Fig. 8i), *Pfenderina neocomiensis* (Pfender) (Fig. 8k), *Terebella lapilloides* Münster (Fig. 8m), and *Clypeina parasolkani* Farinacci & Radoičić (Fig. 8q). The presence of *Montsalevia salevensis* and *Pfenderina neocomiensis* points to a late Berriasian-early Valanginian age. By contrast, the coral-microbial and grain-rich bioclastic facies are frequently encountered in the Barremian-lowermost Aptian limestones from the Dâmbovicioara Couloir. Associated microfossils are *Neomeris cretacea*

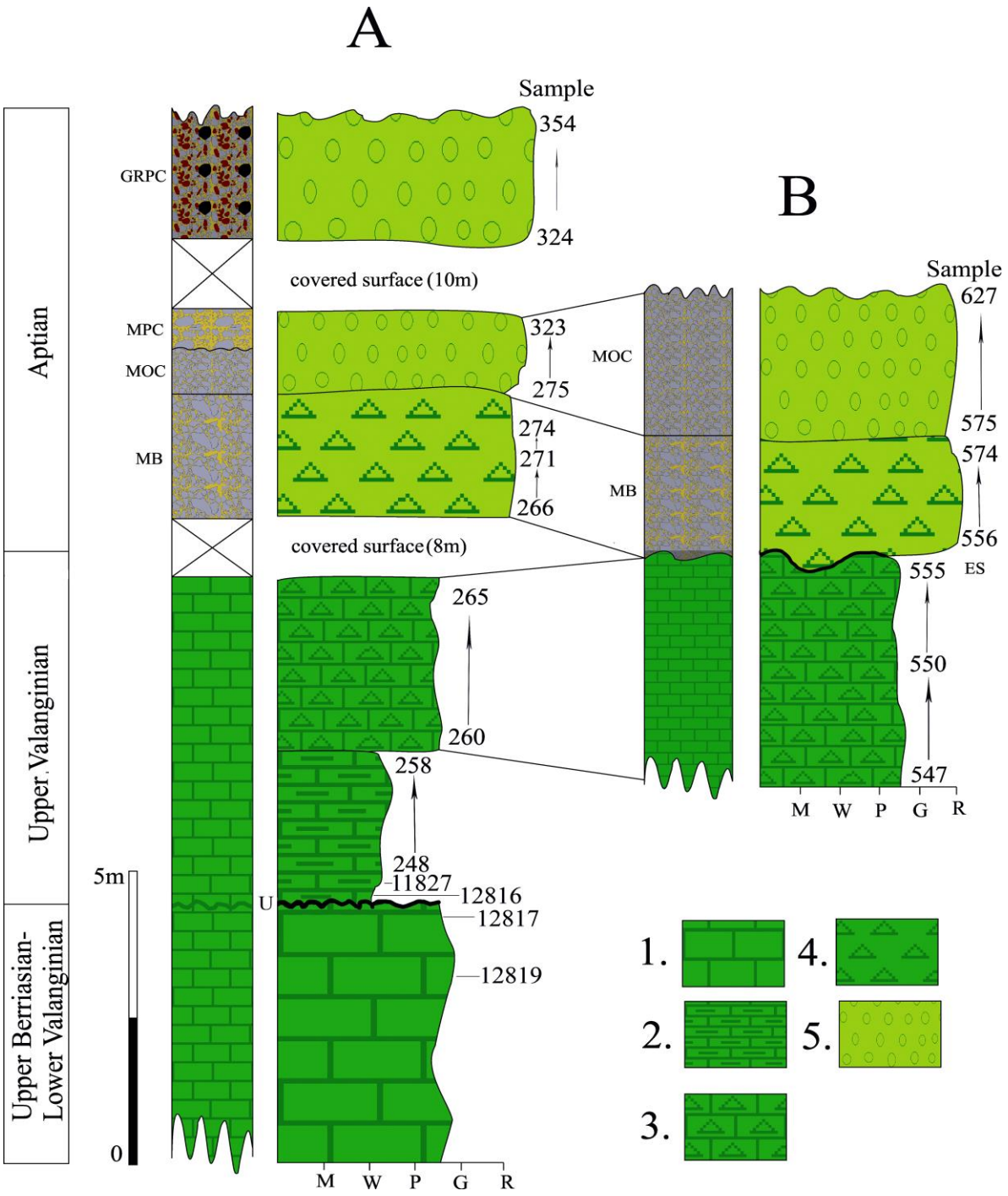

Fig. 4 Stratigraphic logs of the **A** Padinile Frumoase succession; and the **B** Drumul lui Lehman succession. Legend: 1, massive limestone; 2, marly limestone; 3, allodapic limestone; 4, breccia; 5, conglomerate; ES, erosional surface; GRPC, Gura Râului Paraconglomerates; MB, monomictic breccia; MOC, monomictic orthoconglomerate; MPC, monomictic paraconglomerate; U, unconformity. M, W, P, G, R = mudstone, wackestone, packstone, grainstone, rudstone in Dunham's (1962) limestone classification.

Steinmann (Fig. 8n), *Carpathoporella occidentalis* Dragastan (Fig. 8p), *Coscinophragma cribrosa* (Reuss) (Fig. 8s), and *Lithocodium aggregatum* Elliott (Fig. 8r). The limestone fragments-bearing monomictic breccia are followed by monomictic conglomerates, similarly rich in limestone pebbles (Fig. 3c-e). Microfacies and micropaleontological analysis has shown that, similar with the breccia components, the most important microfacies and microfossils of the pebbles are characteristic for the Berriasian-Valanginian and Barremian-Aptian intervals. The Berriasian-Valanginian pebbles consist of a wide range of microfacies such as fenestral mudstone, peloidal bioclastic packstone or peloidal bioclastic packstone/grainstone. The micropaleontological assemblage contains foraminifera [*Ammobaculites* sp., *Montsalevia salevensis* (Charollais, Brönnimann & Zaninetti) (Fig. 8), *Meandrospira* sp., *Protopeneroplis ultragranulata* (Gorbatchik), *Pfenderina neocomiensis* (Pfender)] and dasycladalean algae.

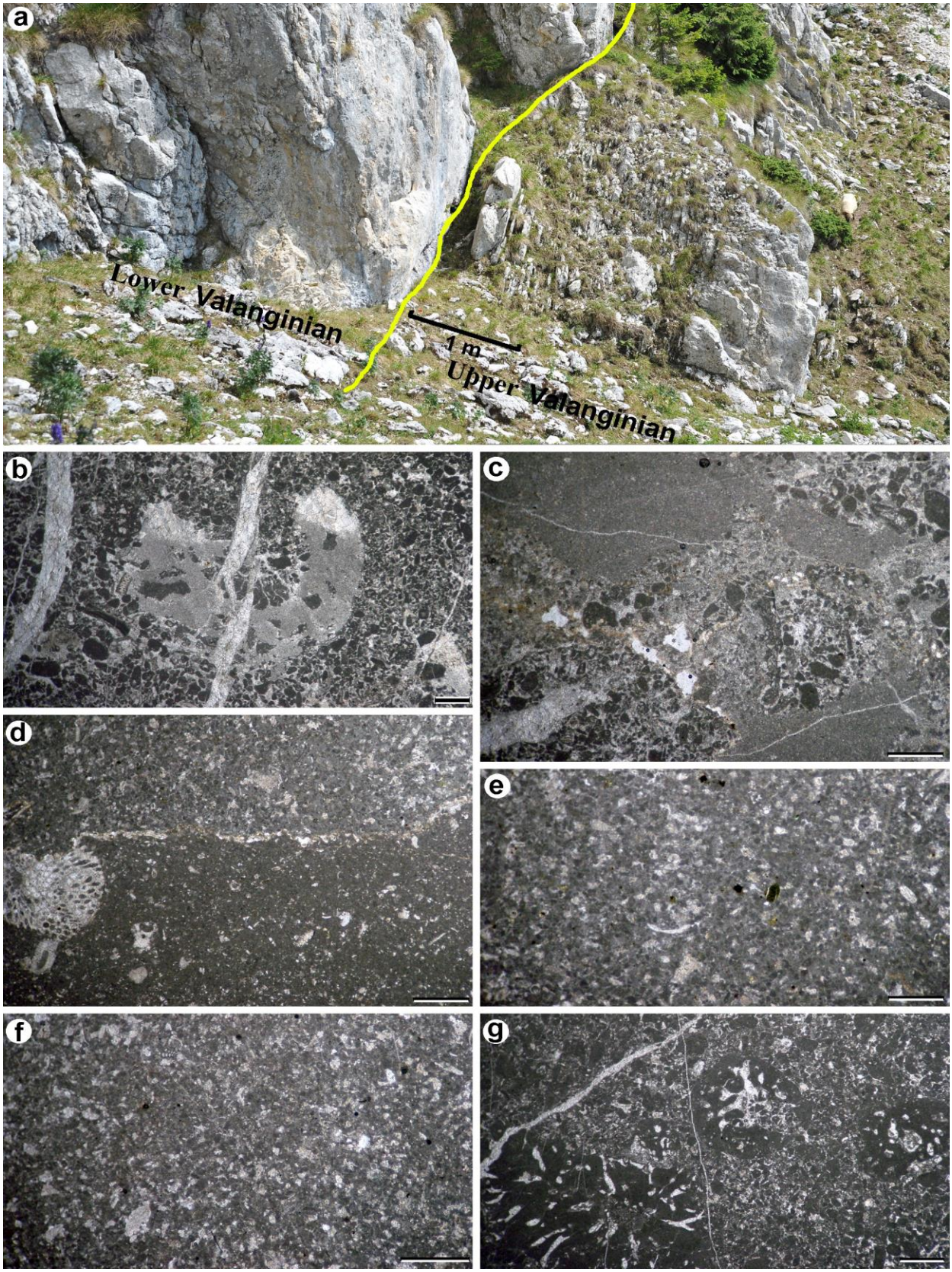

Fig. 5 Lower Valanginian limestones and upper Valanginian limestones/marly-limestones (enlargement view of the left area in Fig. 3a). **a** The unconformity between the lower Valanginian limestones and upper Valanginian limestones/marly limestones (yellow line). The thin-bedded upper Valanginian carbonate beds are lying over thick-bedded shallow-water lower Valanginian limestones. **b** Bioclastic intraclastic grainstone; note the presence of dissolution structures filled with vadous silt. **c** Peloidal bioclastic packstone with dissolution structures. **d** Bioclastic wackestone passing to a peloidal bioclastic packstone. **e**, **f** Peloidal bioclastic packstone, with sintaxial overgrowth cement being developed on the echinoderm plates. **g** Peloidal bioclastic packstone/grainstone with *Lithocodium* nodules. b, c, sample 12817; d, e, sample 12816; f, sample 11827; g, sample 12819. Scale bar = 1 mm (b-g).

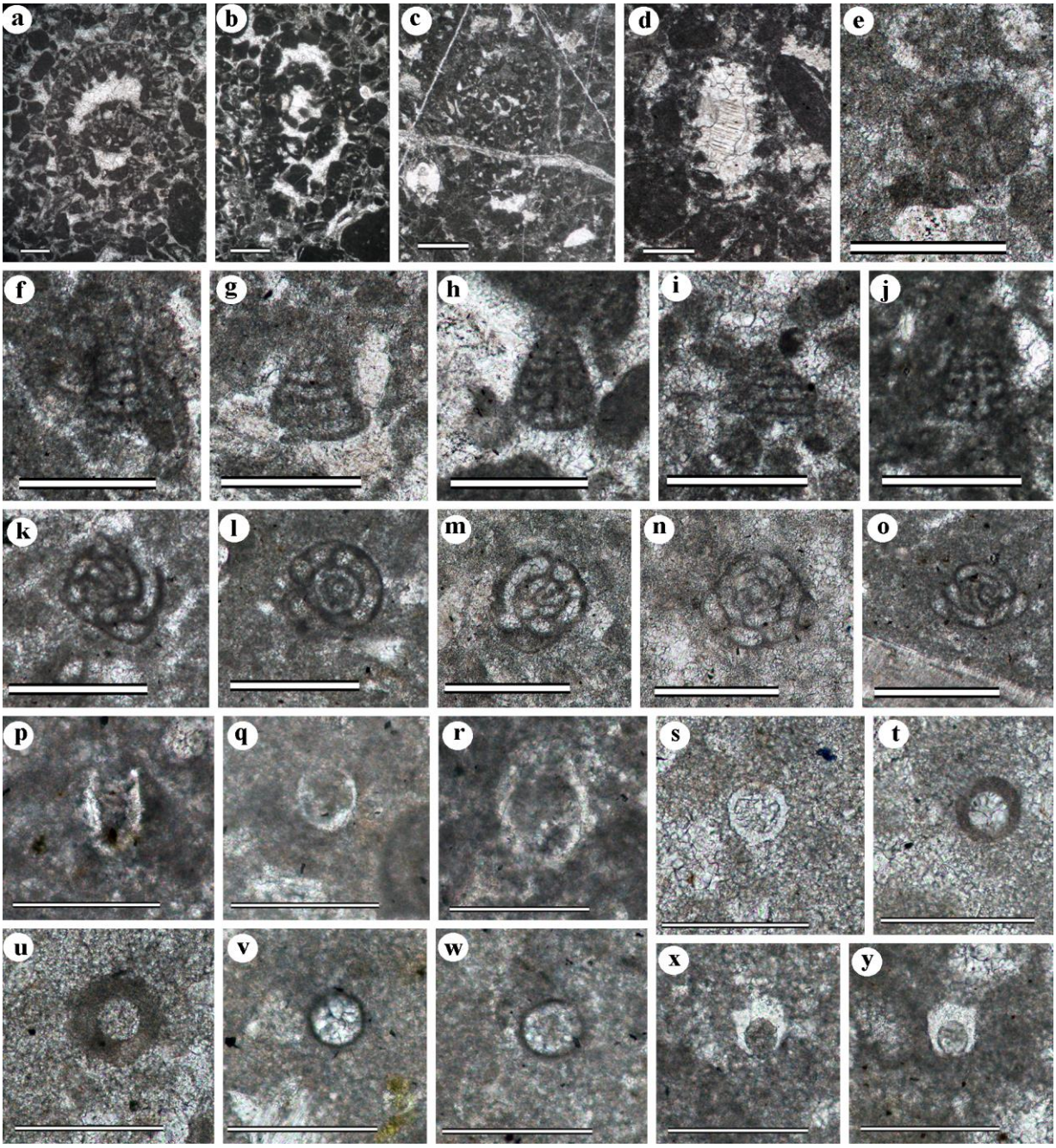

Fig. 6 Microfossils from the lower Valanginian limestones and the upper Valanginian limestones/marly-limestones. **a-c** *Pseudocyclammina lituus* (Yokoyama); **d** *Coscinoconus* cf. *cherchiae* (Arnaud-Vanneau, Boisseau & Darsac); **e-j** *Montsalevia salevensis* (Charollais, Brönnimann & Zaninetti); **k-o** *Meandrospira favrei* (Charollais, Brönnimann & Zaninetti); **p-s** Unidentified calpionellids; **t**, **u** *Cadosina fusca* Wanner; **v**, **w** *Crustocadosina semiradiata* Wanner; **x**, **y** *Stomiosphaera echinata* Nowak. a, h, sample 12817; b, i, sample 256; c, d, sample 257; e, sample 260; f, g, p, u, sample 12818; j, x, y, sample 249; k, r, sample 252; l,q, v, w, sample 12816; m, n, o, s, t, sample 258. Scale bar = 0.5 mm (a-b); 0.25 mm (c-o); 0.125 mm (p-y).

The Barremian-Aptian pebbles contain the following microfacies types: bioclastic grainstone/packstone, sponge-rich microbial boundstone, bioclastic packstone with glauconite and microbreccia. The micropaleontological assemblage includes foraminifera [*Coscinophragma cribrosa* (Reuss), *Pseudolituonella* sp., biserial aglutinated foraminifera, ?involutinid-type foraminifera], worm tubes, dasycladalean algae [*Neomeris cretacea* Steinmann, *Griphoporella* sp. (Fig. 8o), *Cylindoporella elliptica* Bakalova, *Carpathoporella occidentalis* Dragastan, *Salpingoporella muehlbergii* (Lorenz)], microproblematic organisms [*Lithocodium aggregatum* (Elliott)], and red algae (*?Sporolithon* sp.).

Age of breccia and monomictic conglomerates

Although the thin sections did not cut the embrionic aparatus of the most orbitolinids, their structure indicates that they belong to Barremian-Aptian orbitolinid group (*Palorbitolina-Mesorbitolina*) (Fig. 8a-c, f, g). The very rare identified species belong to *Rectodyctioconus*

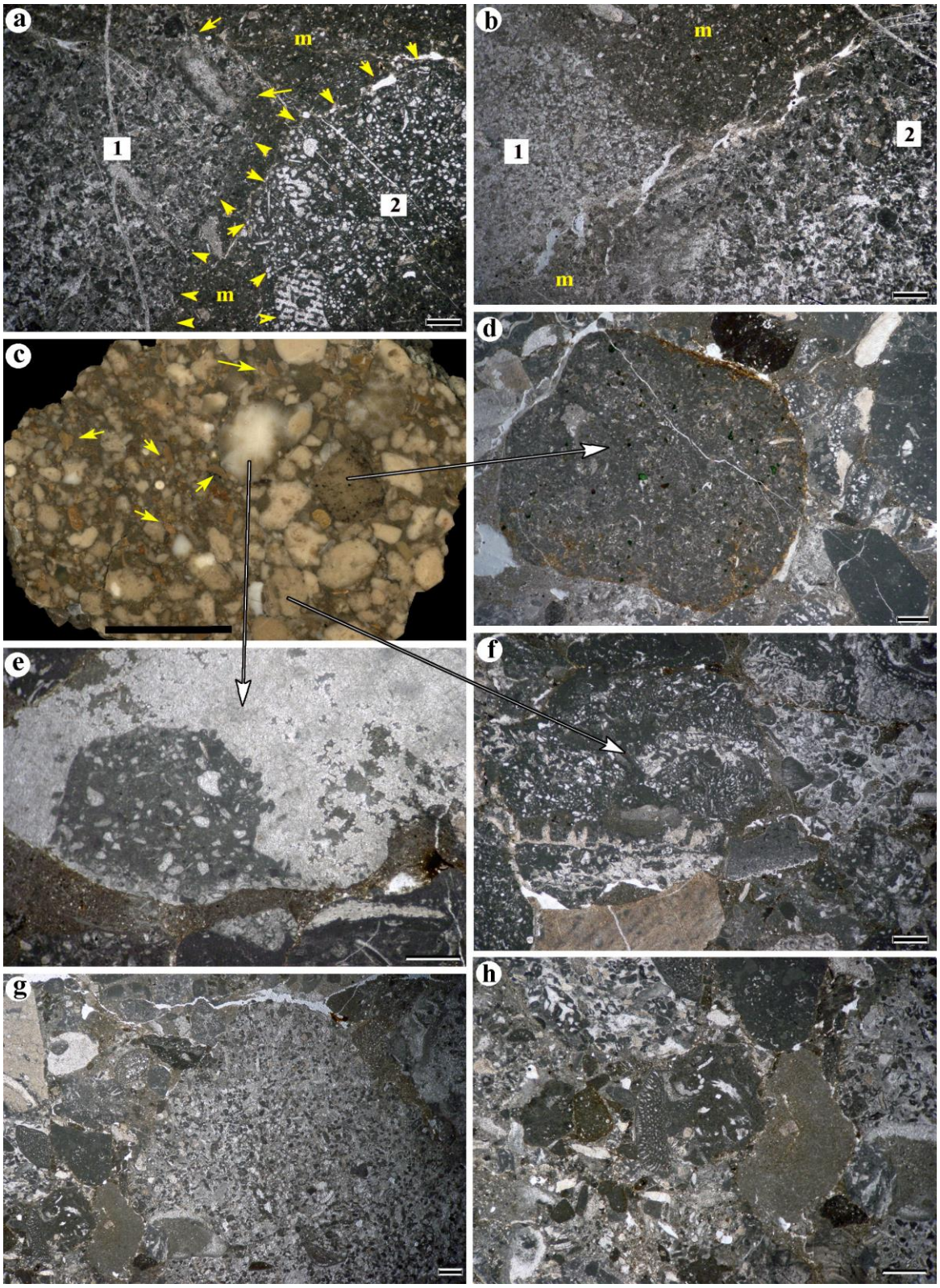

Fig. 7 Facies and microfacies from the upper Valanginian (a-b) and Aptian (c-h). **a-b** Bioclastic intraclastic floatstone. Intraclasts consist of peloidal packstone with echinoderms (a1, b1), bioclastic packstone with sponge spicules and coral fragments (a2), and peloidal packstone with small foraminifera (b2). The matrix (m) contains calpionellids and calcispheres. The arrows in **a** are delineating the shape of the intraclasts. **c** Limestone-rich breccia. Clasts are embedded in a micritic/clay-rich matrix that contains silt-sized quartz. The matrix contains orbitolinids (indicated by the small yellow arrows). **d** Marly clast with bioclasts and glauconite. **e** Coral-rich bioconstruction with dissolved corals. **f** Clast containing abundant sponge and *Lithocodium* crusts (center). In the upper right corner the carbonate components of the clast are dissolved. **g** Clasts from an orbitolinid-rich peloidal bioclastic grainstone; orbitolinids are present both in the matrix and the clasts. **h** Clast composed of an orbitolinid/green algae-bearing packstone (left) and clast that contains peloidal fenestral wackestone (right) (detail from photo g). a, b, sample 258; c-f, sample 266; g, h, sample 272. Scale bar =1mm (a, b, d-h); 2 cm (c).

giganteus Schroeder (Fig. 8d) and *Mesorbitolina parva* (Douglass) (Fig. 8e). These two orbitolinids are indicative for the age of the monomictic breccia. Following Schroeder at al. (2010), *M. parva* has a stratigraphical range from the early Gargasian to the early Clansayesian (Middle–Late Aptian), while *R. giganteus* has an early Bedoulian (Early Aptian) range. However, Schlagintweit et al. (2012) found *R. giganteus* associated with *Mesorbitolina texana* in limestones dated as Gargasian-early Clansayesian. Consequently the *Mesorbitolina parva-Rectodictyoconus giganteus* association indicates a Gargasian age for the monomictic breccia from Piatra Craiului (Middle Aptian, if we adopt a tripartite subdivision of the Aptian, or the early part of the Late Aptian in a bipartite subdivision).

No specific orbitolinids were identified in the matrix of the monomictic conglomerates, but taking into account the age of their pebbles and the stratigraphic position above the breccia their age should be late Aptian.

2. Drumul lui Lehman

The Drumul lui Lehman succession (Fig. 5B) is important because this is the location where the direct contact between the Berriasian-Valanginian limestones and the monomictic limestone-rich breccia can be observed (Fig. 9).

2.1 The Valanginian limestones

The Valanginian limestones contain peloidal bioclastic packstone and fine-grained peloidal bioclastic packstone/grainstone. They are rich in small benthic foraminifera, small echinoderm fragments (some with syntaxial cement), and peloids. These limestones contain Valanginian microfossils such as *Protopeneroplis ultragranulata* (Gorbatchik), *Montsalevia salevensis* (Charolllais, Brönnimann & Zaninetti), *Haplophragmoides* sp. and *Meandrospira* cf. *favrei* (Charollais, Brönnimann & Zaninneti).

2.2 Aptian breccia and conglomerates

The Valanginian limestones are overlain by 1-2.5 m thick monomictic limestone-rich breccia. The breccia has a massive structure and the clasts are randomly distributed within a micritic matrix (Fig. 9b-d). The matrix contains orbitolinids (Fig. 10a), echinoderm, rudist and coral fragments (Fig. 10d), and silt-sized quartz (Fig. 10a, b). Intraclasts consist of coral and chaetetid fragments (Fig. 10c, d), peloidal bioclastic packstone with ?*Vercorsella* sp. (Fig. 10e), fenestral mudstone/packstone with foraminifera (Fig. 10a, b, g), wackestone/packstone with foraminifera, and grainstone with large foraminifera.

The breccia is overlain by monomictic paraconglomerates rich in limestone pebbles. Clasts of breccia and conglomerate pebbles display dissolution features and structures (Fig. 10f-h), which evidence subaerial exposure of the source limestones.

The conglomerate pebbles reveal microfacies and microfossils that indicate both the Berriasian-Valanginian and the Barremian-Aptian intervals. The micropaleontological assemblage from the upper Berriasian-lower Valanginian pebbles is largely composed of foraminifera (Fig. 11): *Pseudocyclamina lituus* (Yokoyama) (Fig. 1h), *Scythiolina* sp., *Scythiolina camposauri* (Sartoni & Crescenti) (Fig. 11v), *Coscinoconus* sp., *Coscinoconus delphinensis* (Arnaud-Vanneau, Boisseau & Darsac), *Montsalevia salevensis* (Charollais, Brönnimann & Zaninetti), ?*Pfenderina sp.*, *Pfenderina neocomiensis* (Pfender) (Fig. 11r), *Protopeneroplis ultragranulata* (Gorbatchik) (Fig. 11t, u) *Everticyclamina* sp. (Fig. 11i), *Gaudryina* sp. (Fig. 11k), ?*Nautiloculin*a sp. (Fig. 11w), ?*Vercorsella* sp. (Fig. 11m-o), ?*Arenobulimina* sp. (Fig. 11q), *Mohlerina basiliensis* (Mohler) (Fig. 11s), *Paracoskinolina*? *jourdanensis* (Foury & Moullade) (Fig. 11x), ?involutinid foraminifera (Fig. 11y), and rare calcareous algae: *Salpingoporella pygmaea* (Gümbel) (Fig. 11c), *Pseudocymopolia jurassica* (Dragastan) (Fig. 11d), ?*Banatocodium* sp. (Fig. 11a, b, e, f), and *?Nipponophycus* sp (Fig. 11g).

The pebbles of Barremian-Early Aptian age contain frequent *Lithocodium-Bacinella*-type structures, *Chaetetopsis favrei* Denninger, *Charentia cuvillieri* Neumann, and *Palorbitolina lenticularis* (Blumenbach) (Fig. 8l).

DISCUSSIONS

Clast analysis performed on the Padinile Frumoase and Drumul lui Lehman breccia and conglomerates indicates that the exhumation of the Barremian-lowermost Aptian shallow-water reefal limestones and Berriasian-Valanginian peritidalites occurred during the Aptian. The monomictic breccia from the basal part of the Aptian succession was deposited as debris flows on the shelf slope or toe-of-slope (Mullins et al., 1984; Mullins & Cook, 1986). The angular to subrounded shape of the clasts suggests that the source area was proximal. The occurrence of orbitolinids within the matrix is indicative for a shallow marine depositional environment. The presence of quartz in a micritic/clay-rich matrix supports a terrigenous influx. The overlying conglomerates (Fig. 3c-e) also contain in their carbonate-rich silty-sandy matrix some orbitolinids sugestive of the Aptian. These massive deposits have an erosional base (Fig. 3c) and were deposited as grain flows. The grain and mass debris flows are characteristic for fan delta depositional environments (Nemec & Steel, 1988; Postma, 1990). Thus, we can presume that during Aptian times these shelf areas were routing sediments through a series of submarine alluvial fans. The sediment input from the continent was high. This indicates that the source areas were located in the proximity of the shoreline and the erosion rate was high. Most probably these fan-delta systems started to produce sediments after the Aptian uplift of the basin margin (Patrulius, 1969).

Nowadays, the Barremian-lowermost Aptian carbonates and marly limestones are outcropping only in the Dâmbovicioara Zone (Sasului Hill, Muierii Valley) (Patrulius, 1969; Patrulius & Avram, 1976: Patrulius et al., 1980; Bucur et al., 2011; Gradinaru et al., submitted). The source area of the Berriasian-Valanginian clasts was the Piatra Craiului Massif since the outcrops are located in the proximity of the western flank of the massif. Barremian-lowermost Aptian reefal limestones are not present in the Piatra Craiului Massif. We presume that the

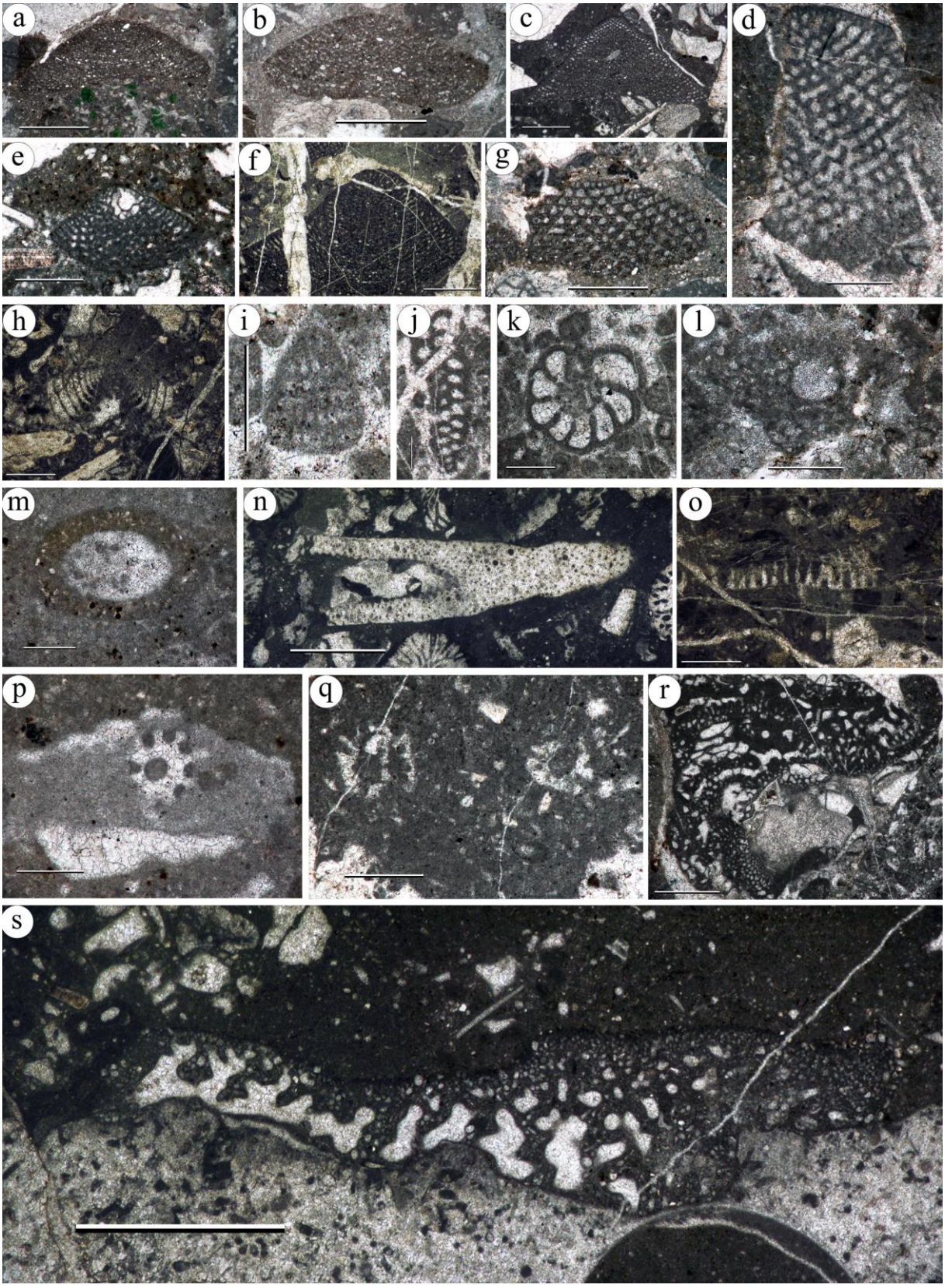

Fig. 8 Microfossils from the Aptian breccia and conglomerate pebbles in the Padinile Frumoase area. **a-c, f, g** Unidentified orbitolinids. **d** *Rectodyctioconus giganteus* Schroeder. **e** *Mesorbitolina parva* (Douglass). **h** Unidentified ?involutinid foraminifer. **i** *Montsalevia salevensis* (Charollais, Brönnimann & Zaninetti). **j** unidentified biserial foraminifer. **k** *Pfenderina neocomiensis* (Pfender). **l** *Palorbitolina lenticularis* (Blumenbach); **m** *Terebella lapilloides* Münster. **n** *Neomeris cretacea* Steinmann. **o** *Griphoporella* sp. **p** *Carpathoporella occidentalis* Dragastan. **q** *Clypeina parasolkani* Farinacci & Radoičić. **r** *Lithocodium aggregatum* Elliott. **s** *Coscinophragma cribrosa* (Reuss). a, b, sample 266; c, e, m, n, p, s, sample 271; d, i, j, k, q, r, sample 275; f , h, o, sample 279; g, sample 272; l, sample 568. Scale bar = 1 mm (a-c, f); 0.5 mm (d, e, g, h, o, q); 0.25 mm (i-m, p).

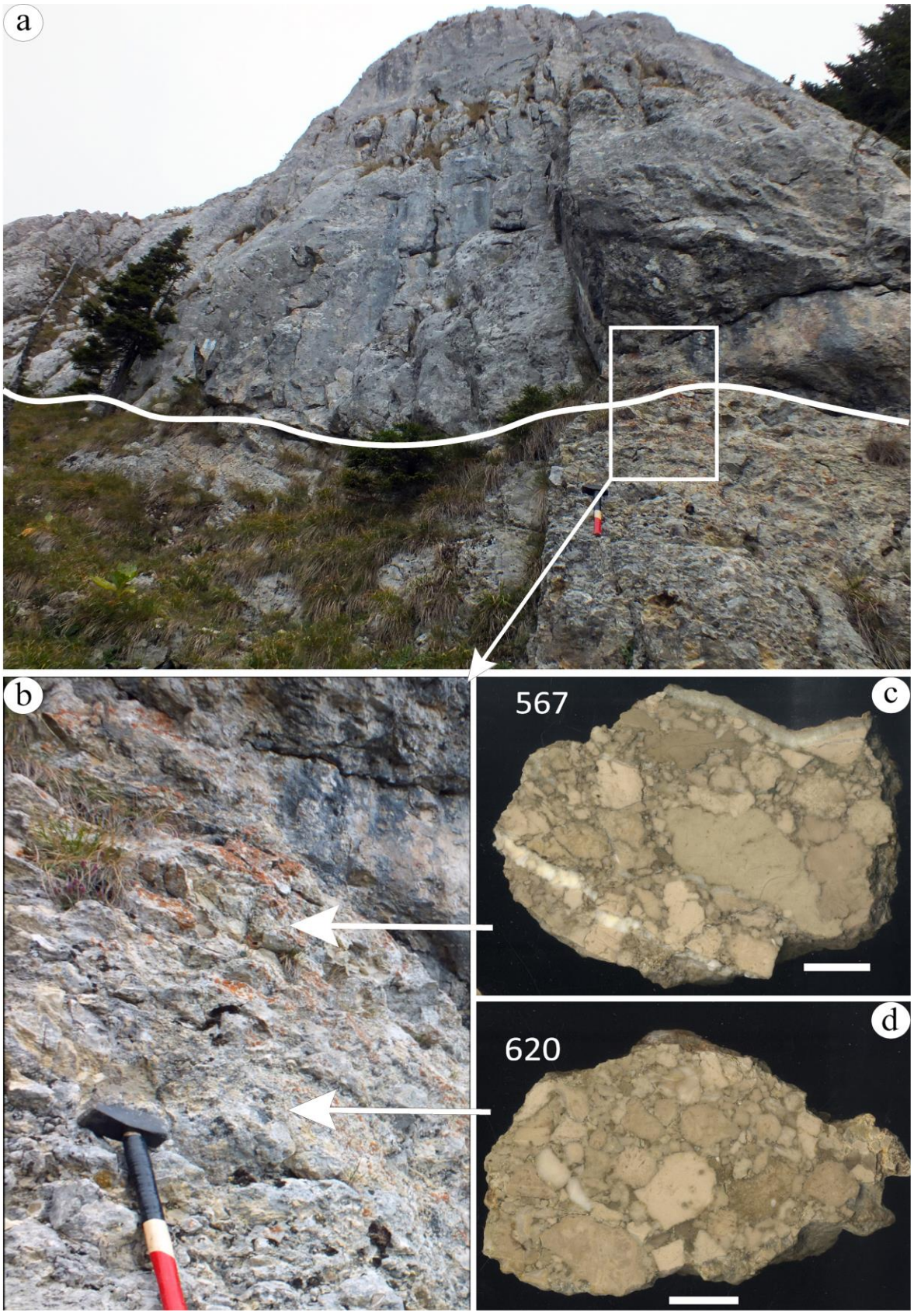

Fig. 9 Drumul lui Lehman. **a** The stratigraphic contact between the Valanginian limestones and the monomictic Aptian breccia (marked by white line). **b** Detail from the contact area. **c, d** Monomictic breccia. 567, 620 = sample numbers. Scale bar for **c** and **d** = 2 cm.

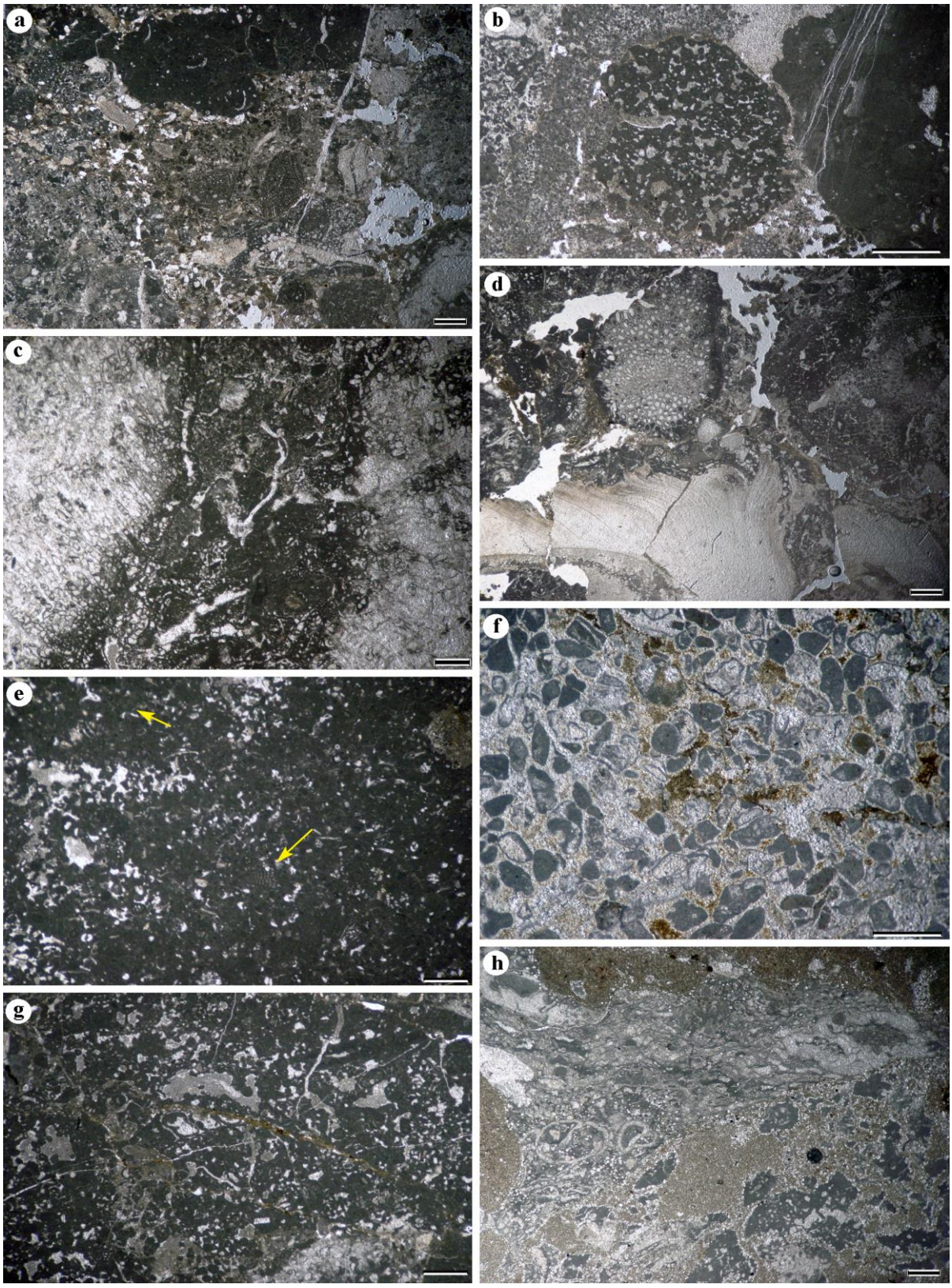

Fig. 10 Microfacies and microfossils identified in the limestone pebbles of the Aptian breccia and conglomerates from the Drumul lui Lehman section. **a** Bioclastic intraclastic floatstone with intraclasts of bioclastic wackestone; the matrix contains orbitolinids, echinoderm plates and silt-sized quartz extraclast. **b** Intraclasts composed of fenestral wackestone and peloidal fenestral grainstone. **c** Pebbles originating form reefal bioconstructions. The corals are encrusted by microproblematic organisms. **d** Rudist fragment and sponges (chaetetids). **e** Pebble consisting of a peloidal bioclastic packstone with ?*Vercorsella* sp. (indicated by the arrows). **f** Carbonate pebble with dissolution structures; cavities are bordered by fine crystalline, schalenoedric cements. The interior is filled with clay minerals and iron oxides. **g** Pebble consisting of a peloidal fenestral packstone; the fenestral structures are filled with vadous silt and sediment derived from the breccia's matrix. **h** Intensely dissolved carbonate clasts; the clasts and the cavities are bordered by fine crystalline, schalenoedric cement. a, sample 568; b, sample 566; c, e, sample 620 d, sample 575; f, sample 624; g, sample 564; h, sample 594. Scale bar = 1mm.

block which forms the northern part of the massif was uplifted during this time interval. After analyzing the contact between the Valanginian limestones and the Aptian breccia and conglomerates we can state that the carbonate sedimentation in the Piatra Craiului Massif ended in the late Valanginian. This break in sedimentation was followed by an uplift of the entire region as a consequence of an incipient tectonic activity. The intensified tectonic activity and the uplift of the surrounding areas led to an increase in material input and slope angle. This explains why the incipient grain- and debris flows in the conglomerates are characterized by well rounded, small pebbles (1-3 cm). The identified orbitolinids place these events into the middle-late Aptian. These flows are characterized by different hydrodynamic fluctuations. The monomictic paraconglomerates were deposited when the flow velocity started to decrease concomitant with an increase of the viscosity. The monomictic character of the components clearly indicates that during the Aptian the source areas were providing only carbonate material. The polimictic conglomerates which follow in the succession of the Cretaceous deposits from the Piatra Craiului Syncline (Ungureanu, PhD thesis, in preparation) contain Middle Jurassic-Aptian carbonate pebbles, silicolitic material and metamorphic pebbles, with the carbonate fraction still dominant. Nevertheless, the presence of other clast lithologies indicates that the Aptian tectonic events belonging to the first Getic tectonic phase uplifted a wide range of carbonate deposits thus providing diverse material for the breccia and conglomerates.

CONCLUSIONS

1. Two sections were studied in the northern part of the Piatra Craiului Massif (Padinile Frumoase and Drumul lui Lehman). These contain breccia and conglomerates laid over Berriasian-Valanginian limestones. In the Padinile Frumoase area we identified the main unconformity which marks the lower Valanginian/upper Valanginian boundary. The uppermost part of the peritidal limestones containing *Salpingoporella praturloni*, *Pfenderina neocomiensis* and *Montsalevia salevensis* was subaerially exposed at the end of the early Valanginian. They are covered by upper Valanginian marly-limestones with *Meandrospira favrei* and *Stomiosphaera echinata*. The succession continues with limestones containing reworked bioclasts and intraclasts. This regional unconformity was identified in several other locations from the Dâmbovicioara Couloir (Grădinaru et al., submitted).

2. The upper Valanginian hemipelagic deposits are characteristic for an open marine, distal shelf environment. These deposits were accumulated during the late Valanginian transgression. The limestones following in the succession represent debris flows with components reworked from a shallow-water shelf environment.

3. In both sections, the upper Valanginian limestones are overlain by monomictic limestone-rich breccias. These are covered conformably by monomictic limestone-rich conglomerates of the the same age. The pebble analysis has indicated that the main source of the pebbles was represented by Berriasian-Valanginian limestones/marly-limestones and Barremian-lowermost Aptian limestones exhumed during the early-middle Aptian. The orbitolinid-bearing matrix of these conglomerates (including *Rectodictyoconus giganteus* and *Mesorbitolina parva*) allowed us to constrain the Aptian age of these deposits.

4. During the middle-late Aptian the shelf areas were receiving sediment from a system of submarine alluvial fans, while the sedimentary input from the continent was very high. This suggests that the source areas were located in the proximity of the shorelines. The fan-delta systems started to develop when the basin margin was uplifted, during the Aptian.

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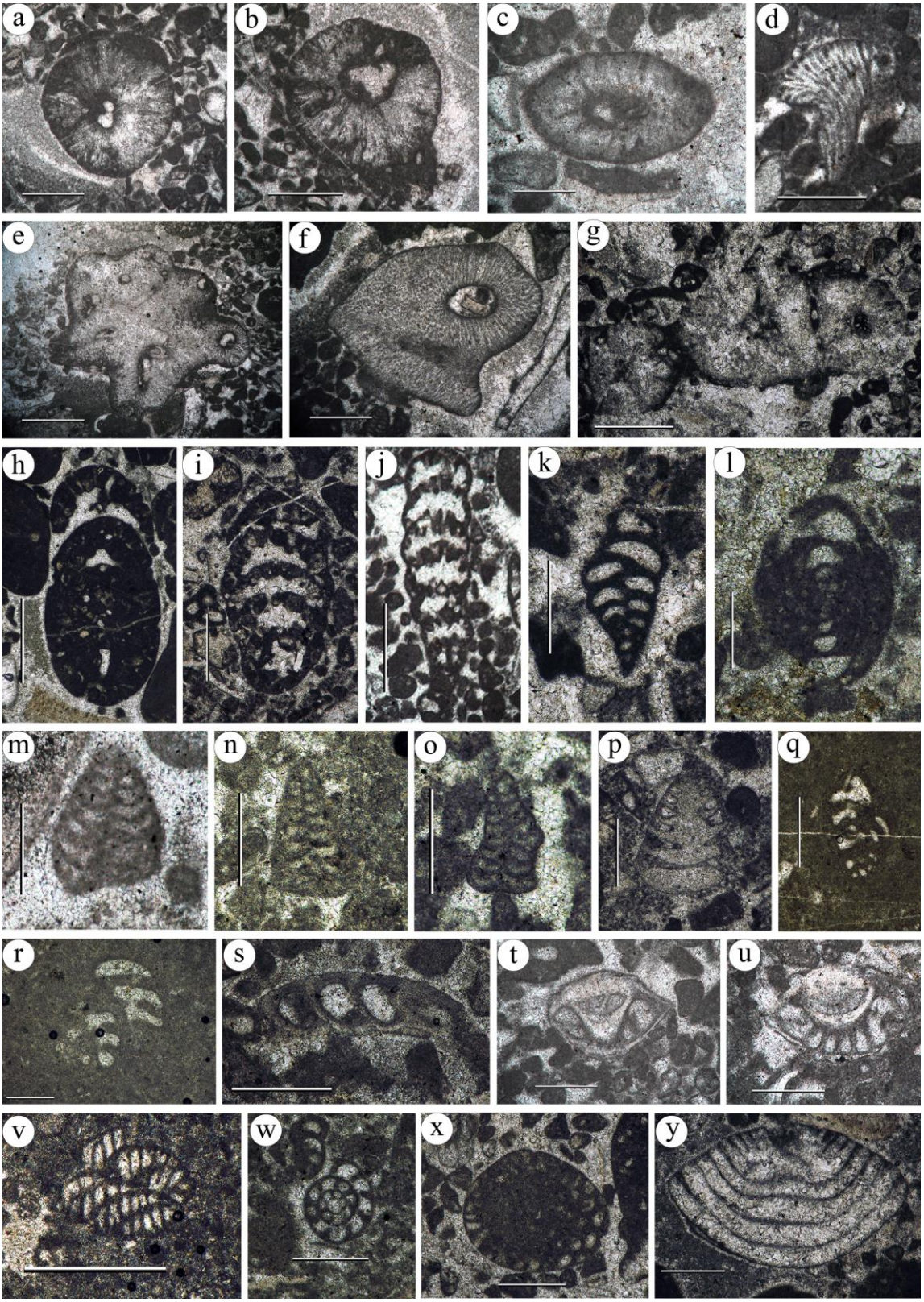

Fig. 11 Microfossils from the limestone pebbles of the Aptian breccia and conglomerates outcropping in the Drumul lui Lehman section. **a, b, e, f** *?Banatocodium* sp. **c** *Salpingoporella pygmaea* (Gümbel). **d** ?*Pseudocymopolia jurassica* Dragastan. **g** ?Ni*pponophycus* sp. **h** *Pseudocyclamina lituus* (Yokoyama). **i** ?*Everticyclamina* sp**. j** Unidentified agglutinated foraminifer. **k** *Gaudryina* sp. **l, w** ?*Nautiloculi*na sp. **m, n, o** ?*Vercorsella* sp. **p** *Coscinoconus delphinensis* (Arnaud-Vanneau, Boiseau & Darsac). **q** ?*Arenobulimina* sp. **r** *Pfenderina neocomiensis* (Pfender). **s** *Mohlerina basiliensis* (Mohler). **t, u** *Protopeneroplis ultragranulata* (Gorbatchik). **v** *Scythiolina camposauri* (Sartoni & Crescenti). **x** *Paracoskinolina*? *jourdanensis* (Foury & Moullade). **y** Unidentified ?involutinid foraminifer. a-f, m, j, o, s, t, u, sample 618; g, sample 597; h, x, sample 604; i, sample 588; k, sample 626; l, sample 613; n, sample 563; p, sample 589; q, r, sample 558; v, sample 564; w, sample 600; y, sample 594. Scale bar = 1mm (e, g, h, p); 0.5 mm (a, b, d, f, i, j, k, q, s, x, y); 0.25 mm (l, n, o, w); 0,125mm (m).

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