

Ichnofacies Interpretation of Trace Fossils Occurrences in the Paleocene-Lower Eocene Deposits of the Borjomi Canyon

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The results of recently conducted integrated ichnological-sedimentological studies of the Paleocene-Lower Eocene deposits in the central part of the Achara-Trialeti Fold-and-Thrust Belt and in particular within the Borjomi canyon are presented. Three sections containing trace fossils have been investigated, i.e. the Papa, Ardagani 1 (Paleocene) and Ardagani 3 (Lower Eocene) sections. The analysis of trace fossil assemblages and sedimentological features helped to interpret depositional environments of these sections. The Papa section represents a part of the outer deep-sea fan. The Ardagani-1 section belongs to the distal part of deep-sea turbiditic depositional system. The lower and the upper part of the Ardagani-3 section represents the channel off-axis (intra-channel or the channel-lobe transition) and a part of the deep-sea fan environment (such as the channel margin, depositional lobe or fan fringe), respectively. It has been assumed that Paleocene–Lower Eocene deposits of the Borjomi canyon represent a deep-sea turbiditic depositional environment within the Achara-Trialeti rift basin. © 2023 Bull. Georg. Natl. Acad. Sci.

Paleocene-Lower Eocene, trace fossils, ichnofacies, graphoglyptids

Combined ichnological-sedimentological studies of the Paleocene-Lower Eocene Borjomi Flysch in the Borjomi region were made in 2019–2020. Their results are presented in this paper. The study area is a part of one of the major tectonic units of Georgia

– the Achara-Trialeti Fold-and-Thrust Belt (ATFTB), which is located within the northernmost part of the Lesser Caucasus and is associated with the Arabia-Eurasia convergency [1]. The Paleocene-Lower Eocene flysch deposits ("Borjomi

Suite” or ”Borjomi Flysch”) are traced as a latitudinal zone/belt in the central and eastern segments of the ATFTB. Several outcrops of the flysch containing trace fossils have been detected in the Borjomi canyon. This flysch represents the western distribution area of the Paleocene-Lower Eocene sedimentary formations. The trace fossils were studied in three sections for the first time. Several ichnotaxa have been identified, described and interpreted. On the basis of trace fossil assemblages and sedimentological analysis, sedimentary depositional environment was interpreted for the sections.

Geological Setting

Deposits constituting the ATFTB accumulated in the Achara-Trialeti Trough (rift), which was formed within the Transcaucasian Massif (island arc) during Late Cretaceous-Eocene times. Aptian and Albian volcanogenic-sedimentary formations are the oldest units of the trough [2-4]. They are overlain by Cenomanian-Maastrichtian alternations of volcanogenic and carbonate rocks and Paleocene (Danian) marls. The upper Paleocene (Thanetian) and lower Eocene (Ypresian) stages are mainly represented by clastic turbidites, which are ascribed as the Borjomi Flysch or the Borjomi Suite [5, 6].

The Borjomi area is typical of the Paleocene-Lower Eocene Borjomi Flysch or the Borjomi Suite. The Borjomi Suite is subdivided into the Tusrebi, Boshuri and Bolevani subsuites. The Paleocene (Thanetian) Tusrebi Subsuite constitutes nearly three-quarters (900-1000 m) of the entire thickness of the Borjomi Flysch. According to recent field observations by the author's team, it can be subdivided into three lithofacies units: 1) the lower Tusrebi shaly unit formed by packages composed of mudstones, siltstones and very fine-grained sandstones; 2) the middle Tusrebi sand-rich unit consisting of sandy packages separated by shaly intercalations, and 3) the upper Tusrebi shaly unit. The volcanogenic-sedimentary Boshuri Subsuite contains deformed (slumped) deposits rich in volcanic material and related debris-flow deposits,

graded sandstones (typical turbidites) and amalgamated massive sandstones interbedded with mudstones and siltstones. In some cases, thick intervals of amalgamated sandstones comprise thin intercalations of locally laminated mudstone or siltstone. Some silty laminae mark amalgamation surfaces. The shaly Bolevani Subsuite is formed by deep-sea heterolithic deposits (thin alternations of mudstones and siltstones with pelagites/hemipelagites). The latter two members are dated to the Lower Eocene (Ypresian) [7].

Occurrences and Trace Fossils

Three occurrences of trace fossils have been identified for the first time within the Paleocene-Lower Eocene deposits of the Borjomi region in the Papa, Ardagani-1 (Paleocene) and Ardagani-3 (Lower Eocene) sections. Below, we present the brief descriptions of these sections (Fig. 1).

The **Papa** section (GPS coordinates: 41°83.734'N, 043°38.165'E) is located on the southern periphery of the town Borjomi, nearby the railway tunnel in the lower part of the lower Tusrebi shaly unit formed by packages composed of mudstones, siltstones and very fine-grained sandstones. These deposits contain the trace fossils *Avetoichnus luisae* Uchman & Rattazzi, *Chondrites intricatus* (Brongniart), *Ch. targionii* (Brongniart), *Planolites* isp. and *Zoophycos* isp.

The section **Ardagani-1** (GPS coordinates: 41°82.637'N, 043°40.587'E) is located on the steep, southern flank of the Borjomi Anticline, in the environs of the Ardagani settlement, along the Borjomi-Bakuriani road. It is composed of dark grey and grey calcareous siltstones and mudstones intercalated with very fine- and fine-grained calcareous sandstones. They belong to the uppermost part of the lower Tusrebi unit dated on the basis of microforaminifers to the upper Paleocene (Thanetian). The trace fossil assemblage here consists of *Avetoichnus luisae* Uchman & Rattazzi, *Chondrites intricatus* (Brongniart), *Ch. stellaris* Uchman, *Ch. targionii* (Brongniart), *Halimedes*

isp., *Nereites* isp. *Ophiomorpha annulata* (Książkiewicz), *Oph. rudis* (Książkiewicz), *Phycosiphon incertum* Fischer-Ooster, *Planolites* isp., *Polykampton georgianum* Uchman et al., *Scolicia prisca* de Quatrefages, *Sc. strozzii* (Savi & Meneghini), *Scolicia* isp., *Spirophyucus bicornis* (Heer), *Thalassinoides* isp., *Trichichnus* isp. and *Zoophycos* isp. It should be mentioned, that the Ardagani 1 is the type locality of *Polykampton georgianum* [7].

The section **Ardagani-3** (GPS coordinates: 41°81.888'N, 043°41.311'E) is located along the Borjomi-Bakuriani road as well, SE of the Ardagani 1 section and represents the Lower Eocene Boshuri and Bolevani subsuites. In the

Boshuri subsuite deposits, *Chondrites intricatus* (Brongniart), *Ch. targionii* (Brongniart), *Nereites irregularis* (Schafhäütl), *Ophiomorpha annulata* (Książkiewicz), *O. rudis* (Książkiewicz), *Planolites* isp., *Scolicia strozzii* (Savi & Meneghini), *Spirophyucus bicornis* (Heer), *Thalassinoides* isp. and *Trichichnus linearis* Frey have been identified.

Trace fossils of the Bolevani subsuite include: *Belorhaphé zickzack* (Heer), *Chondrites intricatus* (Brongniart), *Ch. targionii* (Brongniart), *Cochlichnus* isp., *Halimedides* isp., *Helminthopsis* isp., *Helminthorhaphé* isp., *Megagraption aequale* Seilacher, *Megagraption submontanum* (Aspetia Mo-

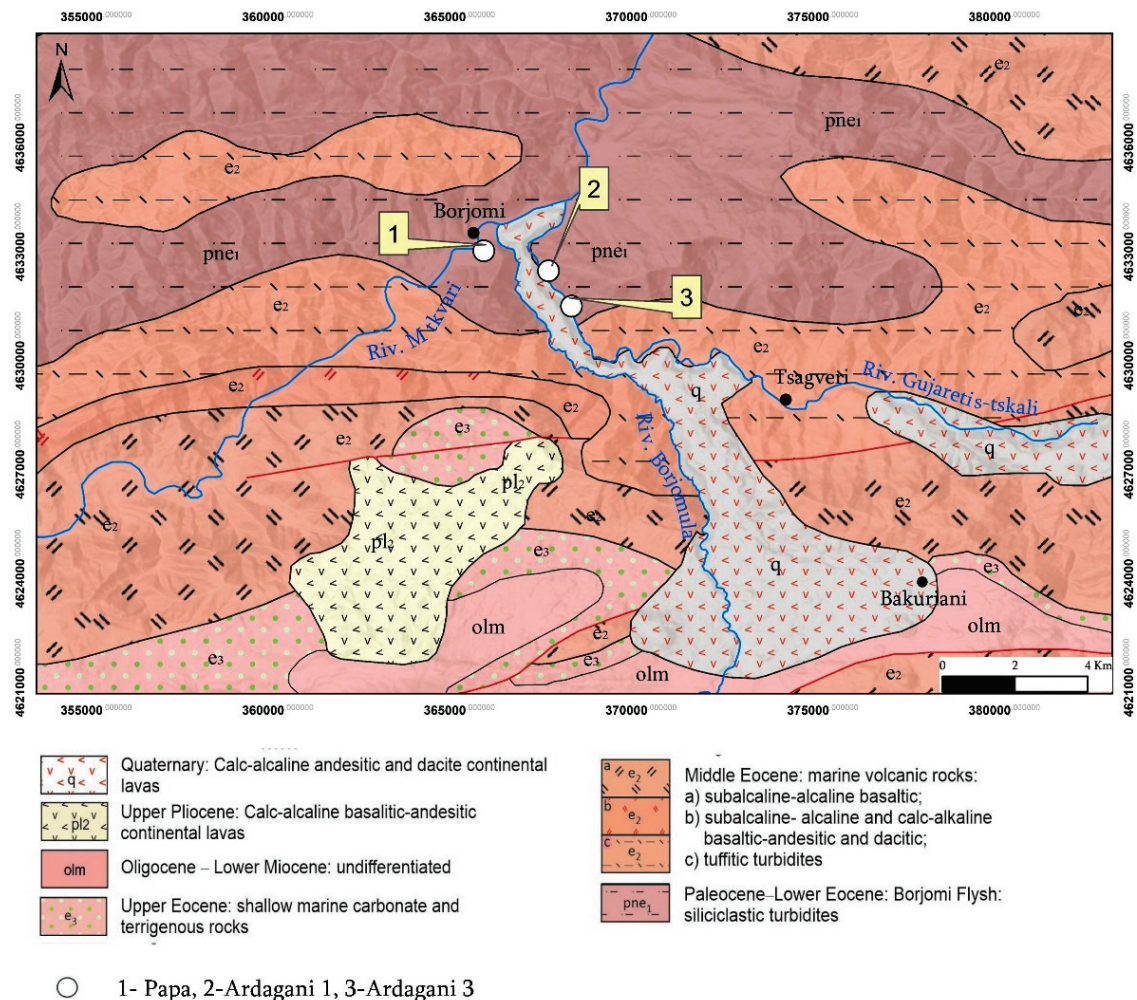


Fig. 1. geological map of the Borjomi area, showing the Papa, Ardagani-1 and Ardagani-3 sections (based on Adamia, 2004).

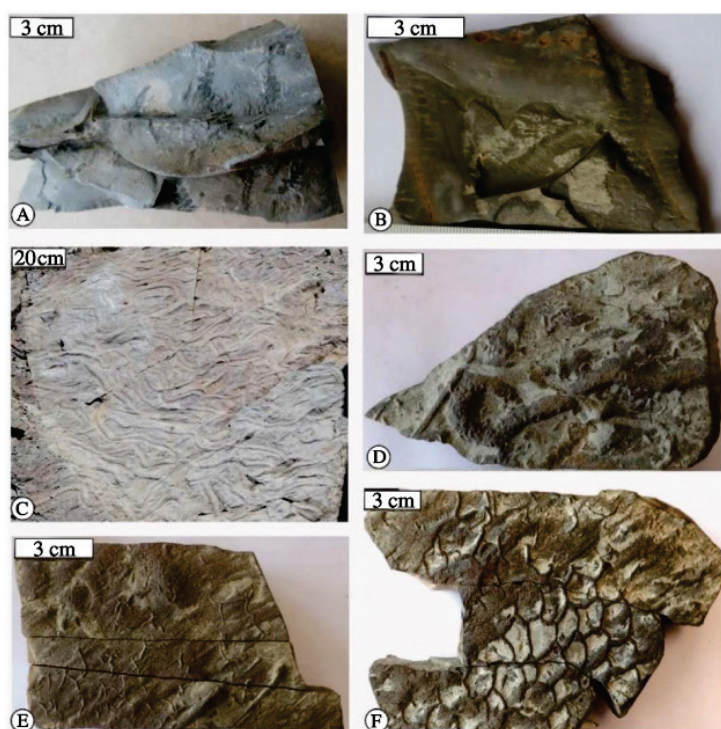


Fig. 2. Some Trace Fossils of the Paleocene-Lower Eocene deposits of the Borjomi Canyon: **A.** *Avetoichnus luisae*, **Papa**, Paleocene, **B.** *Polykampton georgianum*, **Ardagani-1**, Paleocene, **C.** *Scolicia* isp., **Ardagani-1**, Paleocene, **D.** *Spirophycus bicornis*, **Ardagani-3**, Lower Eocene, **E.** *Megagraption submontanum*, **Ardagani-3**, Lower Eocene, **F.** *Megagraption aequale*, **Ardagani-3**, Lower Eocene.

ros), *Ophiomorpha annulata* (Książkiewicz), *O. rudis* (Książkiewicz), *Paleodictyon minimum* Sacco, *Planolites* isp., *Protopaleodictyon incompositum* Książkiewicz, *Scolicia strozzii* (Savi & Meneghini), *Spirophycus bicornis* (Heer), *Thalassinoides* isp., *Trichichnus linearis* Frey and *Urohelminthoidea appendiculata* (Heer) [8] (Fig. 2).

Discussion

The trace fossils assemblage of the Papa section is similar to the distal muddy and silty turbidites (outer fan) of fine-grained turbidite systems, e.g. in the Eocene Bystrica Formation at Zbludza, The Carpatian Flysch, Poland [9]. Therefore, the depositional environment of the Papa section can be the same.

The Ardagani-1 section trace fossil assemblage is not typical of any well-defined ichnofacies. However, it is closest to the *Nereites* ichnosub-

facies of the *Nereites* ichnofacies, which is typical of mudstone-dominated deposits in the distal parts of deep-sea turbiditic depositional systems [10, 11]. This is supported by the dominance of horizontal feeding and feeding-locomotion traces (*Polykampton*, *Scolicia*, *Phycosiphon*, *Nereites*, *Spirophycus*) and chemichnia (*Trichichnus*, *Chondrites*). This matches to the mud-silt dominated facies of the Ardagani 1 section [7].

The Boshuri member of the Ardagani-3 section is characterized by low ichnodiversity and domination of post-depositional trace fossils, which could be indicative of the channel off-axis (intrachannel or the channel-lobe transition) environment. The dominance of graphoglyptids in the Bolevani member indicates the *Paleodictyon* subichnofacies of the *Nereites* ichnofacies, which is most common in deep-sea fan environments, such as the channel margin, depositional lobe or fan fringe [11].

Conclusions

The results obtained through the recent ichnological-sedimentological studies, allow us to assume:

- The Papa section (Paleocene) represents a part of the outer fan depositional environment;
- Deposits of the Ardagani-1 (Paleocene) section accumulated in the distal part of deep-sea turbiditic depositional system;
- The lower part of Lower Eocene Ardagani-3 section represents the channel off-axis (intra-channel or the channel-lobe transition) environment, while its upper part represents the

deep-sea fan environment, such as the channel margin, depositional lobe or fan fringe.

- Palaeocene-Lower Eocene deposits of the Borjomi canyon represent the deep-marine turbiditic sedimentation in the Achara-Trialeti rift basin.

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ჭრილი ნამარხი ნაკვალევების ადგილსაპოვებლებით: ფაფა, არდაგანი-1 (პალეოცენი) და არდაგანი-3 (ქვედა ეოცენი). გამოვლენილი იქნოკომპლექსების და სედიმენტოლოგიური თავისებურებების ანალიზით შესაძლებელი გახდა ამ ჭრილებისთვის ნალექდაგროვების გარემოს ინტერპრეტირება. ადგილსაპოვებელი ფაფა წარმოადგენს ღრმა ზღვის გამოტანის კონუსის გარე ნაწილს. ადგილსაპოვებელი არდაგანი-1 მიეკუთვნება ღრმა ზღვის ტურბიდიტული ნალექდაგროვების სისტემის დისტალურ ნაწილს. არდაგანი-3-ის ქვედა და ზედა ნაწილები წარმოადგენს, შესაბამისად, არხის ღერძის გარე ნაწილს (არხის შიდა ან გარდამავალი არხი-ენა ზონები) და ღრმა ზღვის გამოტანის კონუსის ნალექდაგროვების გარემოს (არხის კიდე, არხის ენა ან გამოტანის კონუსის კიდე) ნაწილს. დადგინდა, რომ ზორჯომის ხეობის პალეოცენ-ქვედაეოცენური ნალექები ასახავს ღრმა ზღვის ტურბიდიტული ნალექდაგროვების გარემოს აჭარა-თრიალეთის რიფტული აუზის ფარგლებში.

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