Sedimentary and faunal evidence for the Late Devonian Kellwasser and Annulata events in the Balkan Terrane (Bulgaria)

Iliana Boncheva¹, Valeri Sachanski¹, ², Ralph Thomas Becker³

¹ Geological Institute, Bulgarian Academy of Sciences, Acad. G. Bonchev St., Bl. 24, 1113 Sofia, Bulgaria; e-mail: boncheva2005@yahoo.com
² University of Mining and Geology, Department of Geology and Geo-Information, Sofia, Bulgaria; e-mail: v_savhanski@geology.bas.bg
³ Westphälische Wilhelms-Universität, Institut für Geologie und Paläontologie, Corrensstr. 24, D-48149 Münster, Germany; e-mail: thomas.becker@rz.hu-berlin.de

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Abstract. The global Upper Kellwasser (Frasnian–Famennian boundary interval) and Annulata Events (base of upper Famennian, Upper Devonian IV-A) are recorded for the first time in deep marine sedimentary successions of western Bulgaria. Within the upper Parchar Formation of the Lyubash-Golo Bardo Unit, a distinctive black shale unit yielded frequent, partly still articulated bivalves (Guerichia) and a Platyclymenia-fauna, including the name-giving Pl. annulata, although smooth platyclymeniids are more common. This interval reflects within a thick Eovariscan flysch succession an episode of starved sedimentation, increased organic productivity, oxygen deficiency, and bloom of opportunistic specialists. The event biofacies agrees with a basinal setting far away from land and its nutrient input. The Upper Kellwasser interval is recognized within the thick flysch sequence of the Katina Formation in the Svoge Unit. It is characterized by an interruption of carbonate deposition, as it is typical for other basal settings, for example, of the Rhenish and Thuringian basins of Germany.

INTRODUCTION

Late Devonian global events include a sequence of sudden biotic changes and various kinds of drastic environmental perturbations. There were fast transgressions and regressions (eustatic sea-level pulses) as well as catastrophic sedimentary events, well documented by intervals of anoxic marine sediments with elevated organic content, and changes in the geological record of stable isotopes and rare elements. The sequence of global black shale events of variable intensity, which were connected with small-scale to mass extinctions, eustatic fluctuations, have been summarized by Walliser (1984, 1996), House (1985, 2002), and Becker (1993). Their explanation requires a profound knowledge of the distribution of event beds in time and space, their palaeoecology, and a comparison between events of different magnitude. Therefore, the recognition of some of the well-known specific events in the Balkan region adds to the knowledge of their spatial distribution and, possibly, of their nature and origin.

This study concerns Bulgarian flysch successions, where sedimentary and faunal indications of two important Late Devonian global events, the Upper Kellwasser Event at the Frasnian–Famennian boundary and the basal upper Famennian Annulata Event, can be observed. There is a very high amount of publications on the Upper Kellwasser Event, with a last general review by Racki (2005) and a summary of comparable European strata and facies trends by Gereke, Schindler (2012). The global distribution and characteristics of the Annulata Events have previously been summarized by Becker (1992a, b), Becker et al. (2004), and Hartenfels (2011). Regionally, Spassov (1960) published for the first time finds of the bivalve Posidonomya cf. venusta (now the genus Guerichia) and the presence of undeterminable goniatites in black shales of the Parchar Formation. Our new data enable to identify this black shale unit as Annulata Event beds.
GEOLOGICAL SETTING

The Devonian flysch accumulation in western Bulgaria marks the final stage of the regional Palaeozoic marine basin development, related to compression and the onset of Variscan orogeny. It is characterized by turbiditic siliciclastic successions, with carbonate lenses as members within the sequence, and such conodont-bearing layers provided age data. They indicate flysch deposition from within the Early Devonian (Emsian) until the Early Carboniferous (Tournaissian). This interval is unconformably overlain by Late Carboniferous and Permian molasses.

Devonian outcrops of flysch sediments are related in Bulgaria to three tectonic units – the Lyubash-Golo Bardo Unit, Morava Unit, and the Svoğe Unit (Boncheva et al., 2010; Fig. 1). The most complete Late Devonian sections of the Lyubash-Golo Bardo and Svoge units are situated in the western part of the Srednogorie tectonic zone.

![Image](https://example.com/image.png)

**Fig. 1.** Location of Lyubash-Golo Bardo and Svoge units in the simplified tectonic sketch of Bulgaria (after Dabovski, Zagorchev, 2009).

The Lyubash-Golo Bardo Unit is a fault-bounded structure. The Devonian consists regionally of black graptolitic shales (Gradishte Formation, Lochkovian), a lydite series at the base of the Parchar Formation, and a subsequent rhythmic succession of shales, siltstones, and sandstones. Accumulation of turbiditic sediments started during the Emsian–Eifelian, prior to the two other regions with Devonian sedimentation, and lasted into the Early Carboniferous. This succession is unconformably overlain by Permian continental clastic rocks.

In the Svoğe Unit turbiditic accumulation occurred since the Givetian, characterized by siliciclastics and cherty rocks at the beginning (Katina Formation). A typical basinal trough development during the Late Devonian led to the accumulation of a thick flysch succession of conglomerates, sandstones, shales, and siltstones. Based on sedimentological investigations by Yanev (1985), there was regionally a tendency towards deeper water conditions in the middle part and a regression towards the end of the Devonian.

**Lyubash-Golo Bardo Unit**

The 1400 m thick Late Devonian flysch sediments of this unit are subdivided into three formations: Parchar, Tumba, and Propalnitsa (Yanev, Spassov, 1985).

The **Parchar Formation** represents an irregular alternation of black, grey to rusty grey or greenish-grey argillites, siltstones and sandstones. Locally there are interbedded granular and pebbly conglomerates. The thickness varies between 250 to 770 m. Intercalations of less than 1 m thick, dark grey nodular or black, massive, aphanitic limestones occur predominantly in the lower part of the section. Single intercalations of lydites are also observed. The limestones yielded late Emsian to earliest Famennian conodonts. Sachanski, Boncheva (2002) and Boncheva et al. (2010) documented the following zones and stages: late Emsian–early Eifelian (serotoninus to parctica zones), top Eifelian–Givetian (ensensis and varcus zones), middle–late Frasnian (hassi and rhenana zones), early Famennian (Lower triangularis Zone). A miospore association from the terrigenous matrix at the base of the rhythmic alternation confirms a late Emsian–early Eifelian age for the onset of turbiditic deposition. The Kellwasser event falls in a level right below the Frasnian–Famennian stage boundary and triangularis Zone.

In the upper part of the Parchar Formation, ca. 615 m above its base, there is a distinctive black shale unit, which yielded frequent bivalves (Guerichia venusta, Figs 3.7-9) in association with clymeniids (involute, Figs 3.1-2, and evolute, Fig. 3.4, morphotypes of Platyclymenia cf. subnautilina, Pl. annulata, Figs 3.5-6, and Protactoclymenia sp., Fig. 3.3). It clearly represents one or both of the Annullata Black Shales, first recognized in the Rhenish Massif of Germany (Schmidt, 1924; detailed data in Becker, 1992b; Korn, 2004; and Hartenfels, 2011). It indicates a sudden eutrophication of the basin, with increased organic productivity (accumulation of high amounts of organic matter), and oxygen deficiency at least near the sea-floor and possibly with fluctuating intensity (Racka et al., 2010). Guerichia was an opportunistic bivalve, which was specialized to low-oxygen (exaerobic) conditions. Still articulated (bivalved) specimens that were not attached to any algae (Figs 3.7 and 3.9) confirm their benthic mode of life. They occur widely in the Annulata Event beds of Germany, Poland, Czech Republic, and Morocco, and also in other Famennian black shale units, such as those of the global Dasberg and Hangenberg Crises (e.g., Rzebak, 1910; Bless et al., 1988; Racka et al., 2010; Hartenfels, 2011). The Annulata Event falls in the top part of the Upper *Trachytera* Zone and, in the ammonoid zonation, at the base of Upper Devonian IV-A (Pl. annulata Zone). It has been proposed to define the base of a future, formal upper Famennian substage (Hartenfels et al., 2009).

The ammonoid assemblage from the upper Parchar Formation resembles in its composition the black, main Annulata Shales of Germany and Poland, where smooth platyclymeniids are by far dominant. In slightly better oxygenated settings, indicated by
Fig. 2. Lithological columns and stratigraphical position of Kellwasser and *Annulata* events in the studied sections (after Boncheva, Yanev, 1993; Yanev, Spassov, 1985).
green shales or marls, other ammonoids, especially *Prionoceras* and *Erfoudites*, are more common, and these are associated by different benthos, such as small orthids and/or small gastropods (Becker, 1992a; Becker *et al.*, 2004; Hartenfels, 2011; Hartenfels, Becker, 2013). In other regions, basinal *Annulata* shales may be dominated by cyrtoclymeniids (Kowala, Holy Cross Mountains, Hartenfels, 2011) or yielded
a rather unusual juvenile *Gundolficeras-Erfoudites-Platyclymenia-Protactoclymenia* assemblage (southern Maider, Morocco, Webster et al., 2005). Contemporaneous black *Annulata* Limestones of Germany (Korn, 2002) and southern Morocco (Korn et al., 2000; Hartenfels, 2011) are also characterized by higher ammonoid diversity, although platyclymeniads are rather dominant. In summary, the new Bulgarian assemblage is characteristic for a rather deep and strongly oxygen-deficient setting, which was hostile to benthos apart from *Guerichia* and to various ammonoid groups named above.

**The Tumba Formation** crops out only in the range of the Lyubash-Golo Bardo Unit as a thin strip. It overlaps with lithologic transition the Parchar Formation and grades into the subsequent Propalnitsa Formation. The thickness does not exceed 250 m. It is characterized by alternating lydites and shales, with minor sandstones and siltstones with land plant fragments. Fine-grained, dark grey to black argillites with indistinct lamination predominate and pass locally into siltstones. Very typical is the presence of lydites with poorly preserved radiolarians, locally in the form of banded alternations. The age of the formation is tentatively assumed based on its position between the Parchar and Propalnitsa Formations: The radiolarian microfauna does not indicate any precise age; it only refer the rocks to the Late Devonian.

**The Propalnitsa Formation** is built up of irregularly alternating siltstones, sandstones, and conglomerates. This lithological composition is similar to the Parchar Formation. Various sandstones and granular to pebbly conglomerates predominate. The unit thickness ranges between 250 and 500 m. It is covered with angular discordance by Late Permian red-beds. Biostratigraphic data are based on land plants, such as *Cyclostigma hercynium*, *C. ursinum*, *C. kitkorkense*, *Sphenophyllum subtenerrium*, *Bowmanites tumbana*, *Archaeopteris* cf. *halliana* (Remy, Spassov, 1959; Yanev, Spassov, 1985), and *Sphenophyllostachys tum bana* (Tenchov, Yanev, 1987). These are assigned to the late Famennian–Early Carboniferous but *Archaeopteris* is not known from the Carboniferous.

**Svoge Unit**

The succession consists of three Devonian formations, the Ogradishte Formation (black shales), Romcha Formation (greenish-grey shales; Angelov et al., 2010), and Katina Formation (Tenchov, 1965).

**The Romcha Formation** consists of predominant greenish and grey-greenish, crudely bedded argillites plus subordinate silty argillites in the lower part. A characteristic lithologic feature is the presence of lenticular nodules and „dark spots”. The lower boundary is a gradual transition from the rocks of the Ogradishte Formation. The formation is overlain with a short lithologic gradation by the Katina Formation. On the basis of chitinozoans (Lakova in Yanev et al., 2005) and its stratigraphic position below the Katina Formation, it has been assumed that the unit covers parts of the Emsian (Early Devonian) and parts of the Middle Devonian (Angelov et al., 2010). The unit thickness is 300–350 m.

The grey-green argillites are built of a microflake groundmass containing small amounts of quartz and mica silt. Under the microscope lamination is observed as dark-coloured layers enriched in organic matter. The silty argillites build a 60–70 m thick package at the base of the sequence. These rocks display an indistinct laminated structure, which disappears upwards in the section.

A characteristic lithologic feature of the Romcha Formation is the presence of lenticular nodules and discrete, thin (1–5 cm), discontinuous but normally bedded sandy-clayey layers. They are predominant in the upper levels of the sections and are distinguished as intervals of 50–70 cm thickness (locally 10–15 cm). Beds with thicknesses of 10-20 cm, extending laterally for several meters, are rarely encountered, too. They are strongly deformed and crumpled by dense ripples (interpreted as cone-in-cone structure) on their surfaces. In the case of good preservation, such “cones” have a height of 1–8 cm and a width of 3–4 cm at their base.

**The Katina Formation** starts with a ca. 380 m thick pre-flysch series of thick bedded, greenish lydites, grey shales, and siliceous shales, which grade upwards into grey-greenish shales. Thin layers of fine-grained sandstones with laterally variable thickness are interca-

![Fig. 3. Devonian ammonoids and bivalves from the Parchar Formation. Scale bar 5 mm. The specimens are stored in the Laboratory of Geocollections, Geological Institute, Bulgarian Academy of Sciences.](image-url)
lated. The pre-flysch succession does not contain fossils and is tentatively assigned to the Middle Devonian. Conformably, a flysch succession follows, up to 1000 m thick, consisting of sandstones and shales. It belongs to the Late Devonian–Visean (?), based on macroflora and on conodonts from single carbonate layers. Its upper boundary is an erosional surface covered by terrigenous sediments of the Late Carboniferous, Permian, and Triassic.

In the lower part of the flysch section a 15–20 cm thick lydite package is observed. The succession above consists of deep-water argillaceous sediments and turbiditic sandstones. The latter are very fine or grainy and consist of variable amounts of quartz and rock fragments with 10% cement. Silstone are grey to dark grey, finely stratified, and clayey to slightly sandy. The monomineralic terrigenous grains make up 80–85% of the rock. Shales are dark to black, with a microband-structured texture. They contain fine dispersed organic matter, iron hydroxides, siliceous material, and insignificant amounts of fine terrigenous detritus. There are rare siderite concretions up to 5–15 cm in diameter. Lydites and silicified shales are dense and brittle, light grey, dark grey or black, and consist of micro- to crypto-grained quartz and a variable amount (0–50%) of clay minerals. They form layers of 1–2 cm to 10–15 cm thickness. Some layers are interbedded by lenses of organic matter. The structure of the flysch succession is rhythmic, with 0.5–1.5 m thickness of individual rhythmes. Typical turbidite sedimentary structures are present, such as parallel and transversal lamination and convolute bedding.

Boncheva, Yanev (1993) provided evidence for the topmost Frasnian linguiformis Zone and the earliest Famennian Lower triangularis Zone from the Katina Formation. Based on subsequent progress in conodont taxonomy and stratigraphy across the F/F boundary (e.g., Schülke, 1995; Girard et al., 2005; Klapper, 2007a; 2007b; Ovnatanova, Kononova, 2008), conodont identifications can be updated. The Frasnian samples 1006-1008 yielded a broken Ancyrognathus sp., Palmateolepis layoiolensis (originally identified as Pa. hassi), a more slender, rather smooth and subhombic but incomplete form (originally identified as Pa. ederi), Pa. eureka (originally identified as Pa. subrecta), a specimen that is somewhat transitional between Pa. anzhelae and Pa. bogartensis (= Pa. rotunda), and an incomplete specimen, which was previously identified as Pa. cf. linguiformis. This suggests the Upper rhenana to linguiformis zones (MN 13-a-b zones of Girard et al., 2005). Records from the basal Famennian (samples 970, 982, 988) include Pa. triangularis s.l. (sensu Klapper, 2007 = Pa. praeter-ita Schülke, 1995, with relatively short side lobe; but not sensu the holotype, triangularis s. str., a more elongate form with posteriorly directed side lobe), Pa. delicatula, Pa. clarkei, and an icrioid with very regular, partly bulbous nodes, which was regarded as a rather extreme variant of I. deformatus.

Both sampled carbonate layers are separated by black shales, which fall in the interval of the Frasnian-Famennian boundary or of the black Upper Kellwasser level of the Rhenish (German) type region (e.g., Buggisch, 1972; Schindler, 1990; Gereke 2007; Gereke, Schindler, 2012). Locally, the organic-rich sediments lack macrofauna, which indicates high organic productivity and anoxic (oxygen-deprived) conditions, at least of bottom waters. Regional anoxia were probably caused by the bacterial degradation of C cell, which consumes the diluted sea-water oxygen. So far there are no geochemical investigations, as they have been conducted in other European F-F successions (e.g., Pujol 2005), which could give more precise insights into oxygen levels, changes of detrital input, or nutrient availability. But the regionally strong tectonic overprint is rather unfavourable for such studies. The decrease of carbonate deposition in the Upper Kellwasser interval is typical for basinial settings, for example in the “Cyprinenschiefer” facies of the Rhenish Slate Mountains (Piecha, 1993; Gereke, 2007) or of Thuringia (e.g., Bartzsch et al., 1999, 2001).

REMARKS ON THE AMMONOID FAUNA

Becker (1992) and more recently Zong et al. (2014) commented on the partly difficult taxonomy of smooth platyclymeniids, especially when squashed. The Platyclymenia subnautilina Group includes Pl. ruedomanni as a subjective synonym, but also the poorly known, more evolute Pl. quringi. Korn (2002) documented the considerable intraspecific variability of umbilical width (uw) in a supposed subnautilina population from Kattensiepen in the Rhenish Massif. This suggests that only very evolute forms, with uw/diameter > 0.5 should be assigned to Pl. quringi. Within the forms with uw/diameter varying between 0.40 to 0.48, the conch thickness or ratio between whorl width (ww) and whorl height (wh) seems to be more significant to separate species or subspecies. Since this feature is not preserved in the Bulgarian material, it is identified as Pl. cf. subnautilina. However, there are clearly two different morphotypes with uw/diameter ratios between 0.40 and 0.42 (Figs 3.1-2) and near 0.48 (Fig. 3.4). The latter resembles the Polish Pl. glabra, which Korn (2002) kept as a different species.

A coarsely ribbed platyclymeniid (Fig. 3.5) can be identified as Pl. annulata. The ribbing persists longer than in typical Pl. anulata richteri but the poor preservation prevents a subspecies assignment. A second specimen (Fig. 3.6) shows more subdued ribbing and is identified as Pl. cf. annulata.

The single Protactoclymenia falls in the rather widely umbilicate (uw/dm near 0.35) and ribbed species group around Pr. pseudarietina, Pr. teniocostata, and Pr. enkebergensis. Without knowledge of the cross-section and of ornament details, a species identification is not possible. All three ammonoid taxa are widely known from the Pl. annulata Zone (UD IV-A).

CONCLUSIONS

The global Upper Kellwasser Event can be recognized within the Katina Formation of the Svoge Unit based on black shales intercalated between topmost Frasnian (linguiformis Zone) and basal Famennian (Lower triangularis Zone) limestones. Lithology and the lack of macrofauna suggest an anoxic, basinal setting.
The global *Annulata* Event is clearly marked within the Parchar Formation of the Lyubash-Golo Bardo Unit by a black shale, which yielded abundant guerchiids and a typical *Platyclymenia* fauna of Upper Devonian IV-A. The faunal composition agrees with the anoxic, deeper pelagic event biofacies of the Rhenish Massif (Germany) and Holy Cross Mountains (Poland). This may reflect plate tectonic connections.

The development of both the Upper Kellwasser and *Annulata* events in rather thick flysch basins suggest episodes of condensation/sediment starvation and eutrophication far away from land. Both events were probably triggered by palaeceanographic changes, not by land-derived influences.

The new Bulgarian *Annulata* Event record closes within the Prototethys the gap between previously known European (Czech Republic, Poland) and Asian (Iranian) occurrences.

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**REFERENCES**


