

**EARLY PALEOGENE (?) TECTONICS OF NORTHERN
PIRIN MT., SW BULGARIA (BASED ON PRELIMINARY
PHOTOGEOLOGICAL OBSERVATIONS)**

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Abstract

Carbonatic clastics of probable Early Paleogene age are recognized for the first time in the highest (Vihren) part of Pirin Mountain. They exhibit a complex fold structure: recumbent folds refolded by normal folds, intersected and displaced by shear zones with thrusting movement, and a later generation of uplift, extensional detachment and normal faulting. Fractures and normal faults were superimposed later, too. Several first-order structures may be recognized in the Vihren area: the Vihren Complex Fold, the Main Vihren Shear Zone, and the Vihren Fold Cascade. The whole northern pericline of the Sinanitsa Antiform exhibits an interference pattern: a series of SSW-NNE antiforms along the main ridges of the same direction are crossing WNW-ESE folds as the Koncheto Antiform and the Vihren Synform. Issued from preliminary photogeological observations, the regional interpretations should be verified by field and laboratory sedimentological, stratigraphic, and structural studies. Photogeological and remote sensing research on a modern methodological basis is needed, too.

Key words: Pirin Unit, photogeology, Paleogene tectonics

Introduction. Inspection of own field photographs by the present author hinted at a more complex structure of the northern pericline of the Sinanitsa Anticline than previously recorded [1–3]. Further perusal of numerous videos (published in YOUTUBE) from the high mountain (Vihren-Banderitsa area) revealed

[4] the presence of a previously unknown [1,5–7] carbonatic clastic formation situated above the marble formation of the Rhodopian complex. Thus, new prospects are opened both for the reopening of the problems of Pirin tectonics, and a vast field for implementation of photogeology and remote sensing in the high Bulgarian mountains of alpine relief and scarce vegetation.

The present paper gives a brief report on the preliminary photogeological interpretations of elements of the tectonic structure of the Vihren area. Based mostly on previous field studies, wider conclusions are outlined about the Paleogene tectonic evolution of the Pirin Unit.

Geological setting. The Pirin tectonic unit is the main element of the three units (Pirin, Pangeon, and Thassos) of the Pirin-Pangeon tectonic zone. The difficult accessibility hindered the geological studies. The petrographic composition has been known mostly due to the eminent petrographers G. Bonchev and S. Dimitrov. The metamorphic complex was regarded as Precambrian, and the granite plutons (referred to by S. Dimitrov as “South Bulgarian granites”) as Paleozoic. The metamorphism and internal structure of the unit were considered a result of the granite intrusions (s. [5]) that led to the formation of three plutons: North-Pirin, Central-Pirin, and South-Pirin. The plutons formed four domes, the Central Pirin pluton consisting of two (Spanopole and Hleven) domes divided by a chain of metamorphics of their mantle, and detected also by their internal structure [1, 8, 9].

The modern research is mostly connected to the systematic geological mapping by the national geological survey (known by several different names), in the years 1954–1958 (unpublished, 1:100 000; [5]), 1967–1960 (unpublished, 1:25 000; [1, 8, 9]), and 2006–2009 (published, 1:50 000; [6, 7, 10]). The geological map of the Republic of Bulgaria (map sheet Razlog; [11, 12]) was produced by field and laboratory revisions in 1985–1989 on the 1:25 000 maps of 1967–1969. Numerous isotopic geochronological studies were summarized [3], and continuing research revealed new evidence about the petrology and age of the granite intrusions and the coeval volcanism in the Mesta graben, resp., Southern Bulgaria (s. [9, 13], and numerous recent geochronological publications).

The metamorphic rocks of the Pirin Unit (Fig. 1) belong to the Rhodopian supercomplex (Supergroup) with stratotypes in the Central Rhodope area. In Pirin both the lower (Rupchos complex/Group) and the upper (Bachkovo-Asenovgrad complex/Sinanitsa complex) are present. The problems of the lithostratigraphic nomenclature as applied in Pirin may be found in [6, 7]. This study concentrates on the Sinanitsa antiform (anticline) and mainly, on its northern periphery. The antiform is a tight structure of kilometric dimensions trending SSW-NNE and built entirely from rocks of the *Sinanitsa complex* correlated with the Bachkovo-Asenovgrad complex. Three formations are distinguished [5] and [6, 7]. The lowermost formation (*Vihren gneisses*; Vihren formation *sensu* Boyadjiev) is built of biotite and two-mica banded gneisses, sillimanite and sillimanite-cordierite gneisses,

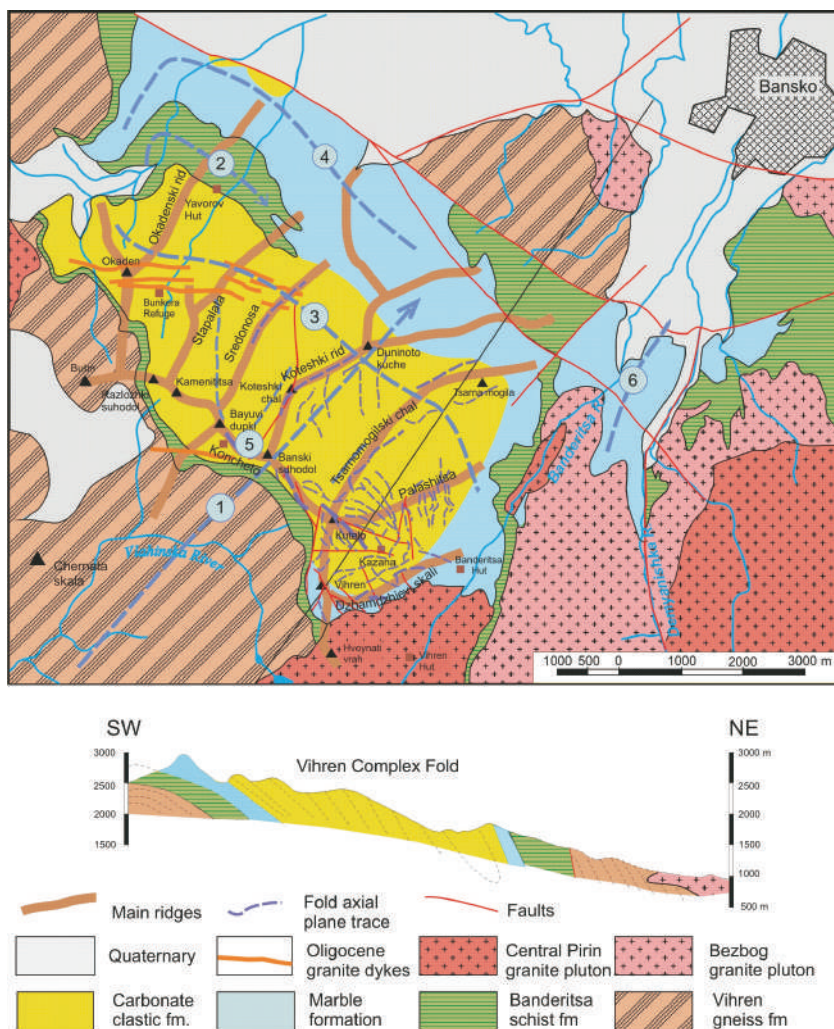


Fig. 1. Geological map of the Vihren area. After Milovanov et al. [6, 7] with revisions. 1 – Sinanitsa Antiform, 2 – Yavorov Antiform, 3 – Vihren Complex Fold, 4 – Yavorov Synform, 5 – Koncheto Antiform, 6 – Banderitsa Antiform

and leucogneisses (leptitoid gneisses), the latter dominant mostly in the upper parts of the formation. The Vihren gneisses are correlated with the Boykovo and Bachkovo Formations (*s. Kozhoukharov*) from the Central Rhodopes. The second formation (*Banderitsa silicatic and carbonatic metamorphics*; Banderitsa formation *s. Boyadjiev*; correlated with the Lukovitsa Formation *s. Kozhoukharov*) has a transitional character [8] and consists of thinly banded biotite gneisses and amphibole-biotite gneisses, leucogneisses, and amphibolite and marble interbeds, in the upper parts dominated by calcareous schists and impure banded marbles. At the top, the Sinanitsa complex ends with the *marble formation*

(Lyalevo formation *s. Boyadjiev*; correlated with the Dobrostan Marble Formation *s. Kozhoukharov*). It is built of grey and white calcitic and dolomitic marbles. Usually they possess a clear layering, often with clear intersection lineation (schistosity vs. primary bedding) and exhibit minor folds. Dolomitic marbles are more massive, whitish, and with fine-grained sugar-like aspect. Interlayers of calcareous schists, micaschists and leucogneisses are observed, mostly in the lower parts. The thickness of the whole complex is estimated at 2000–3000 m; the thickness of the marble formation is about 800–1000 m [8]. Different opinions have been expressed on the problem of the age of the complex: from the traditional Precambrian (Proterozoic) to Mesozoic (Triassic or/and Jurassic) all without definite supporting evidence.

The granitoids are the other basic group of rocks that build the Pirin Unit. With the geological mapping on the scale 1:25 000 (1967–1969) they have been differentiated as several magmatic bodies with intrusive contacts or with preserved septa of metamorphic rocks between them, each one with own internal domal characteristics superimposed also on the earlier structure of the metamorphic complex. Different ages have been suggested, the older group being of Paleozoic age, and the youngest ones (North-Pirin, Central-Pirin and South-Pirin) referred to Late Cretaceous – Paleogene [1,3,9]. The youngest Pirin-type granitoids were assumed to be coeval and co-genetic with the late Eocene – (Early) Oligocene volcanics at the two sides of the Pirin Unit: in the Padesh-Piyanets graben complex and the Mesta complex. This has been later confirmed with petrological, geochemical, and isotopic studies. Discrepancies exist between the results obtained with different isotopic geochronological methods. However, three independent groups of researchers determined a Paleocene age (55–58 Ma) for the Spanchevo granite pluton, and a latest Eocene (Priabonian) – Rupelian (35–32 Ma), for the Pirin-type granitoids.

Carbonatic clastic formation in Northern Pirin. The carbonatic clastic (calclastic, carbonaticlastic) formation is reported for the first time by [4] and the present paper. The formation consists of calcarenites, calcirudites, calcareous conglomerates, breccias and olistostromes. Concretions and probable microbialites (stromatolites, thrombolites, oncolites, etc.) are detected. Carbonatic clastics differ from the underlying marbles by the following principal features: a) the marbles possess continuous foliation and schistosity, and form layers of distinct and continuous composition and structure whereas similar carbonatic breccias have distinct mosaic-like structure, the layering being outlined by layers of different composition and structure – polymictic conglomerates, calcarenites, limestones with separate distinct pebbles; b) the carbonatic clastics are not affected by regional metamorphism but in discrete zones of concentrated deformations (shear zones) exhibit gradual deformation – flattening of the pebbles and transition to clear local shear schistosity with the appearance of low-grade metamorphic calcareous schists; c) some calcirudites show gradual spotty and flaky recrystalliza-

tion; in cases of similar composition of pebbles/rock fragments and the carbonate cement, the rocks obtain the appearance of a spotty or flaky limestone or dolomite with ghostly fragment outlines. The carbonatic clastic formation differs from the younger Quaternary sediments of colluvial or eluvial origin (rockfalls, slope breccias, glacial sediments, ravine rubble) by the good cementation and clear layering often intensively affected by folding and shear. Nevertheless, the field mapping of the carbonatic clastic formation meets considerable difficulties not only because of the hardly accessible steep alpine terrain but also due to apparent similarities to older or younger rocks including the presence of olistostromes and of large (decametric to hectometric) olistoliths. Thus, the delimitation from the marble basement may be excessively difficult. The boundaries and outcrop area shown in Fig. 1 have only a preliminary and approximate character. The lower contact with the marble basement is very irregular. Carbonate breccias and conglomerates fill lows of the ancient relief so typical for calcareous terrains, very often with large development of karst. Huge rock fragments and masses of marble collapse from the rock cliffs, and during their fall down crush into numerous smaller blocks often retaining their original structure outlines. Finally, finer calcirudites and calcarenites may fill in open cracks both in the fractured basement rocks and in huge blocks and olistoliths forming neptunian clastic dykes. Such cracks may be filled also by recrystallized limestone or dolostone identical with the breccia cement. Some of the outcrops remain unresolved.

Structural geological data and interpretations. An analysis of about 30 own photographs (Fig. 2) from the last ten years directed me to videos published on the YOUTUBE platform. Each of the principal routes and traverses has been covered with five to ten videos of good quality, and all of them have been carefully studied. More than one hundred frames with typical geological features are extracted (Fig. 3).

The photos clearly exhibit coarse breccia partially passing into megabreccia, with interbeds of carbonatic conglomerates and calcarenites. The bedding is highly irregular and even chaotic due to mass gravity-driven debris flow which has been the principal sedimentation process. Occasional big rock fragments (olistoliths) may substantially disturb the bedding in cases of finer calcirudites and calcarenites. Slumping is a frequent phenomenon. Many of the thicker beds possess an internal structure consisting of numerous contorted and chaotic folds of obvious synsedimentary origin. They can be confounded with tectonic flow folds. The sedimentation processes, the formation of synsedimentary folds, and the interrelations with the superimposed tectonic folds could be a subject of separate studies.

Superimposed schistosities of different origin are clearly visible both on the field outcrop photos and photopanoramas, and on the airborne and satellite photos. They developed either in the limbs of the tectonic folds or formed in and close to shear zones. Some shear zones have a thickness of several hundred meters and



Fig. 2. Photogeological interpretation of the panorama from Vihren Hut. Photo and interpretation Ivan Zagorchev. A, B, C – conventional lithostratigraphic units. VS1, VS2 – Vihren Synform 1, etc. Vsz1, Vsz2 – Vihren shear zone 1, etc. LVF – Lower Vihren Folds. In the bottom row – enlarged original parts of the panorama

may be confounded in the field with interlayers of calcareous schists and low-grade to greenschist-facies calcareous micaschists.

Folds are abundant and spectacular. Several fold generations may be observed almost in every outcrop, sometimes in complex interrelations with the shear zones, one of the last generations being a result of the evolution of the shear zones themselves. The majority of the folds observed are non-cylindrical, with curvilinear hinges both vertically and horizontally, with non-planar axial surfaces. According to the interlimb angle the folds vary from isoclinal to tight (for the first generations) to open normal folds. The folds' orientation is variable, too. Recumbent and reclined folds, sheath folds, and vertical folds both with vertical, inclined or horizontal hinges are often observed. Very complex interference patterns between the folds of the same or of two or three consecutive generations are visible. They cover the whole range of patterns studied by RAMSAY and HUBER [15] and described in their classification. Boudinage is frequent. Its products may be misinterpreted and confounded with cases of big platy rock fragments that disintegrated during their fall and slide in the basin.

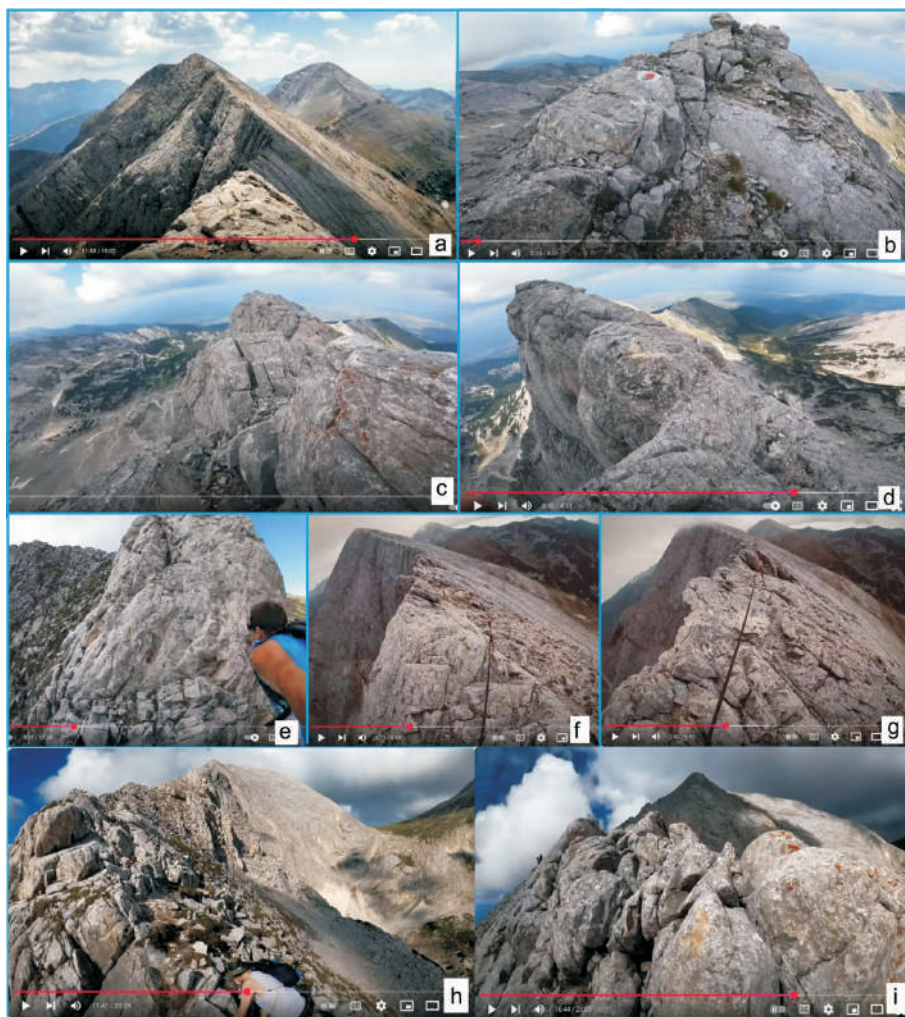


Fig. 3. Frames from videos (YOUTUBE) depicting layers of the carbonatic clastic formation and their structures. (a) View from Dzhamdzhiev rab towards Vihren and Kutela. At the foreground – antiform Photo **Elitsa**. (b) Normal antiform outlined by a thick limestone layer with numerous fragments. Koncheto. Photo **K. Ivanov**. (c) Almost perpendicular crossing of two antiforms trending NNE and WNW. Koteski chal. Photo **Nature and animals Bulgaria**. (d) Inclined antiform contorted at 90° ; in the centre – rotated core of the antiform with complex internal structure. Koteski chal. Photo **Nature and animals Bulgaria**. (e) Recumbent fold with core almost closed from all sides in an oval shape; possible ending of a sheath fold. Dzhamdzhiev rab. Photo **Plamen Petkov**. (f) Inclined antiform; in the right limb schistified conglomerate; in the core, at the left of the steel rope – fold with almost vertical axis and axis-parallel lineation after deformed pebbles. Koncheto. Photo **K. Ivanov**. (g) Two fold generations in the carbonatic clastics. Koteski chal. Photo **Nature and animals Bulgaria**. (h) Vihren from Dzhamdzhiev rab. Slightly inclined antiform at the foreground. Vihren Peak at the background, with a south-vergent synform and very steep and almost isoclinal antiform at the background; to the right – Kazanite with almost chaotic, mostly synformal folds in schists and strongly deformed calcareous conglomerate. Photo **evilmais**. (i) Complex antiform in conglomerate. Dzhamdzhiev rab. Photo **evilmais**

Thrusts and low-angle normal faults are represented usually either by single discrete surfaces with thin gauge or by distinct shear zones. The same is valid for the normal faults and strike-slip faults that intersect and displace the earlier structures.

General structure of the Vihren-Banderitsa part of the Pirin Unit.

The overall ideas about the structure of the Vihren-Banderitsa area (Fig. 1) are based mostly on the photo material (not oriented towards the specificity of geology), and on general deductions and ideas rather than on firm geological evidence. The general picture suggested is a probable hypothesis that should be verified through complex and often painstaking field and laboratory studies. Between the numerous unknowns we should mention: 1) the unknown age of the carbonatic clastic formation – early Paleogene (Paleocene – Middle Eocene) seems most probable but any other age within the range of late Mesozoic and early Cenozoic should be considered; 2) the not yet observed relations with the basement; 3) lack of laboratory sedimentological and paleontological studies; 4) lack of precise geodetical orientation of the photogeological evidence; 5) hardships of the steep and often inaccessible alpine terrain.

The carbonatic clastics are characterized by extreme deformation in several phases and represent a real tectonic conundrum. In general, the following evolution may be suggested: 1) rapid formation of a graben-type basin at or near the sea level, with a previously very uneven karstic relief, and erosion and sedimentation of large masses of debris from the upper level of the metamorphic complex; 2) lithification of the formation; 3) uplift and thrusting over the basement, with formation of numerous isoclinal recumbent folds and schistosity; 4) further uplift with folding and interference pattern of SSW-NNE and WNW-ESE trending folds; the main compression may be related to the intrusions of the Oligocene granitoid plutons (forced folds); an unknown episode of superposition of strike-slip movements with formation of vertical folds (with subvertical axial planes and hinges); 5) last phases (Neogene to Present) of uplift with faulting (including low-angle faults) and extreme fracturing; 6) glacial erosion.

The main structures of the area (Fig. 1) remain the previously established [1,2] Sinanitsa Antiform (Anticline) and several parallel folds, and the cross (WNW-ESE) SW-vergent Yavorov Anticline (Antiform). The Vihren Syncline [1, 6, 7] is specified as a Vihren Complex Fold that consists of a complex system of WNW-ESE folds with complicated interference patterns. The principal elements of this structure (Fig. 1, 2) are the Vihren Synform *s.s.* and the Vihren Slope Fold Cascade, separated by a Main Vihren Shear Zone. Among the most important WNW-ESE cross folds from the interior of the Vihren-Banderitsa area we should mention the highly irregular narrow Koncheto Antiform. A number of similarly irregular longitudinal (SSW-NNE) antiforms are visible on the photos (Fig. 3) and coincide with the principal ridges of the same trend (Fig. 1): Stapalata, Sredonosa, Koteski rid, Tsarnomogilski rid, Palashitsa. They have been formed

most possibly during the intrusion of the Oligocene plutons (forced folds), with shear strain concentration and formation of thick schistose zones in the limbs. Thus, they became more resistant to the later erosion processes and still hold the narrow ridges.

The exact location and character of the supposed Main Vihren Thrust remain unspecified. However, at the base of the “marbles” of Vihren peak the Banderitsa schists and “leptynites” are folded into tightly pressed isoclinal recumbent folds, and a big recumbent fold is well visible within the Banderitsa schists on the whole length of the slopes of Vihren and Kutelo. If the carbonatic clastic formation covered the whole Vihren-Banderitsa area south of the Yavorov Antiform, this presumed Main Vihren Thrust could coincide with the “Banderitsa schist formation”. Thus, the whole structure and evolution of the Pirin Unit has to be revisited and reconsidered.

Conclusions. The present paper exposes preliminary photogeological observations on the previously unknown carbonatic clastic formation in the highest (Vihren-Banderitsa) parts of the Pirin Unit. Numerous videos and photos accessible to the public exhibit important geological features previously unknown but essential to the geological knowledge on this fascinating mountain. My sincere thanks to all ardent mountaineers who produced these excellent videos!

The new information may radically change the knowledge about the tectonic structure and Alpine evolution of this unit with key role in the central parts of the Balkan Peninsula. New lines of research are open, and especially the following ones: 1) complex photogeological, remote sensing, and precise geodetic measurements for obtaining an exact 3D picture; 2) sedimentological, geochemical and paleontological exploration for determination of the age and sedimentary conditions; specialized sedimentological research for elucidation of the evolution and transformation of carbonatic clastics into spotty and flaky limestones and dolomites; 3) specialized structural studies on the deformation processes in highly heterogeneous sedimentary formations with multiple superposition of deformation events; development of 3D interference patterns in conditions of continuous and repeated rotational deformation; development of complex structures at the boundaries of folds with different relative age and orientation; interrelations between the structure of the cover (carbonatic clastic formation) and its basement (Sinanitsa complex); 4) a new synthesis of the Pirin structure and evolution.

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INTERNET RESOURCES

Elitsa:

<https://www.youtube.com/watch?v=MrTl7sf443w&t=253s>

Krassimir Ivanov:

<https://www.youtube.com/watch?v=nKx0-GSkHqs>

Nature and animals Bulgaria:

<https://www.youtube.com/watch?v=kfqMajHHujY&t=38s>

<https://www.youtube.com/watch?v=rYyIgvNDzQ>

Plamen Petkov:

<https://www.youtube.com/watch?v=FzQak-tsVJg>

<https://www.youtube.com/watch?v=UBne9d3yoRU&t=292s>

Evilmais:

<https://www.youtube.com/watch?v=1ZUB5UPv3Cw>

<https://www.youtube.com/watch?v=fzP5Skxzo8M>

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