Research Article

DEŞLI CAIRA (ROMANIA) OLENEKIAN-ANISIAN BOUNDARY SECTION: REVISED STRATIGRAPHY AND NEW FINDINGS

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Abstract – We provide an update on the ongoing investigation of the Deşli Caira section, Dobrogea, Romania, candidate section for the Anisian stage GSSP. We report on a discussion about a fault in the section, which resulted in a comment in a different paper, and demonstrate that the fault is present, cutting the section almost perpendicular and continuing from the lower part to the top of the section. However, as long as the fault's position is recognized, it does not affect research in the section, because there is sufficient room to work on both sides; nevertheless, we recommend that all work be conducted on the same (left) side of the fault throughout the section just to rule out any potential mistakes, even though, when taking it into account accordingly, one can move from one side of the fault to the other without problems. Furthermore, we suspect the occurrence of *Pseudacrochordiceras*, that in Nevada is limited to the uppermost part of the *Neopopanoceras haugi* ammonoid zone, just below the boundary with the overlying *Courtilloticeras stevensi* ammonoid zone are present in the Deşli Caira section. If confirmed, this would enable long-range correlation with data from Nevada (USA) and thus, the Panthalassa realm.

INTRODUCTION

The Deşli Caira section of North Dobrogea, Romania has been under investigation for more than 100 years, beginning with the work of Kittl (1908) and Simionescu (1910, 1911), and later continued by Mirăută (1974) and Mirăută and Gheorghian (1978). Then, in the 1990's, when the Chios section became unsuitable for further consideration as a GSSP for the Anisian stage due to the presence of a fault, the Deşli Caira section became a candidate for the GSSP of the Anisian stage, which resulted in increased scientific activities, mainly lead by Eugen Grădinaru. In 2000 a field workshop conducted at the section resulted in several publications as well as a formal proposal for Deşli Caira as a GSSP candidate (Grădinaru et al., 2006, 2007). However, Grădinaru failed to publish the ammonoid record of the section, which was deemed crucial for the definition of the boundary, and for the next ~10 years little to no progress was made, even though Grădinaru did publish a few additional articles.

Then, in the early 2020's, two more potential candidates were proposed for the GSSP of the Anisian stage, i.e., the Kçira section in Albania and the Wantou section in China, both of which were accompanied by supporting publications (Muttoni et al., 2019, Chen et al., 2020). Meanwhile, a few additional articles were published to further support Deşli Caira's candidate status, e.g., Golding (2021), Grădinaru (2022), Horacek and Grădinaru (2023), and, most recently, Balini et al., (2024) and Golding, (2025). While the work of Balini et al., (2024) was intended to be a continuation of Grădinaru's ammonoid research, which unfortunately was never published, that of Golding (2025) was the continuation of earlier work on Deşli Caira conodonts (Orchard et al., 2007; Golding, 2021). However, both of these latest contributions require further attention. The

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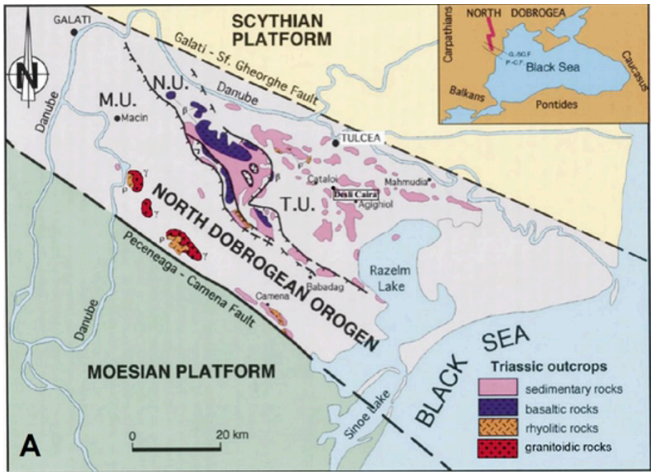

Figure 1– Geology of North Dobrogea, south-eastern Romania, with the position of Deşli Caira section, part of the Tulcea Unit (=T.U., after Grădinaru et al., 2007). The inset shows the position of the Tulcea Unit in the North Dobrogea Orogen.

lithology, which was published in Balini et al., (2024), needs a few minor revisions in the lower part even though this part of the stratigraphic column had not been the focus of the Balini et al., (2024) article. These revisions are in progress and will be published in an article currently in preparation. The work of Golding (2025) contains some serious ambiguities concerning a fault in the Deşli Caira section and the exact positions from which samples were taken. Even though two of the present authors reviewed the Golding manuscript and both independently requested the exact sampling positions with respect to the fault's location, the author and editors, for whatever reason, apparently did not think these requests had merit and the manuscript was published without this crucial information. This situation seemed unacceptable to the present authors, because it could lead to differing views on the presence and position of the fault and the accuracy of the results provided by Golding (2025). Therefore, we have written an article (Balini et al., 2026) commenting on our concerns with Golding (2025) and identified the problems arising from the absence of a description of the fault's position with respect to their sampling locations. Obviously, it must be stressed that in any stratigraphic investigation it is essential that the section be screened for the presence of faults in order to avoid incorrect results (Krystyn et al., 2019, Balini et al., 2026).

In the present article we want to make certain that everyone understands the relevance of the fault running more or less perpendicular to the bedding, resulting in an offset of ca. 0.8 to 1m between the right and left sides of the fault, which causes a serious problem when not identified (or recognized) if samples were collected on both sides of the fault. Also, we want to make clear that the fault in no way disqualifies Deşli Caira as a GSSP candidate (and in our opinion, the best), because there is ample space on both sides of the fault, thus enabling sampling without the need to cross it. Furthermore, as stated by Balini et al., (2026), if the fault is recognized and accounted for appropriately, it is possible to work and sample on both sides. While we have only included published material and data in our comments on Golding 2025 (Balini et al., 2026), we now also present additional evidence on and photographs of the fault in the Deşli Caira section.

LOCALITY

The Deşli Caira section is positioned south of the Danube Delta in North Dobrogea Orogen, in south-eastern Romania, close to the Black Sea coast (Fig. 1). GPS coordinates for the section are as follows: 28°48'08"E, 45°04'27"N (Grădinaru et al., 2007). Paleontological investigations of the locality were first conducted by Kittl (1908) and Simionescu (1910, 1911), and later continued by Mirăuță (1974), and Mirăuță and Gheorghian (1978). Grădinaru et al. (2006, 2007) then published numerous articles in collaboration with an earlier working group, of which the latter work included a partial report on some of the ammonoids as well a report on the Deşli Caira foraminiferas and conodonts. Golding (2021, 2025) recently updated the conodont record, Grădinaru & Gaetani (2019) reported on the brachiopod record and Forel and Grădinaru (2021) reported on the ostracod fauna. The paleomag signal was also investigated by Grădinaru et al., (2007), as was the carbonate $\delta^{13}C$ evolution of the section by Atudorei (1998) and Horacek & Grădinaru (2023).

The Deşli Caira section is composed of the Agighiol Limestone, a medium to thick massive-bedded limestone named after a neighboring hill and nearby village (Grădinaru et al., 2007). It was deposited on a carbonate platform developed in the Tulcea Unit (Fig. 1), which is interpreted as having been located on the distal north-western rim of the Paleotethys (Stampfli & Kozur, 2006). Its lower part, which consists mainly of shallow-water carbonates almost devoid of macrofossils (no ammonoids), is only present in the eastern A-section (Grădinaru et al., 2007).

The fault was recognized in the western Deşli Caira B-section about 150 meters west of section A (Balini et al., 2024; Horacek & Gradinaru 2023: Section A equals section 100/500, section B equals section 810). The first appearance datum (FAD) of *Chiosella timorensis* (Nogami, 1968) was reported between GR6 and GR7 by Grădinaru et al., (2007), Orchard et al., (2007), and later was moved down to level 817 of the Grădinaru numbering by Golding (2021). The first occurrence datum (FOD) of *Stenopopanoceras transiens* Tozer, 1972, the ammonoid that could potentially serve to mark the lowermost Anisian, was identified at the base of bed 822A2 (Balini et al., 2024).

RESULTS AND DISCUSSION

The fault, once its presence is recognized, is quite prominent and easy to follow, as it runs more or less perpendicular to the bedding (Fig. 2A-C, 3, 4), with an offset of 80 to 100 cm. As excavation and cleaning of the outcrop (an old quarry) progressed (see Fig. 4), we have provided new photos that show the improved accessibility (due to excavation and cleaning) of the individual beds in the section, and thus, also the visibility of the fault, which now can be followed more or less continuously from the top of the section (bed 836) down to bed 812. It is now obvious that several beds were labeled incorrectly by Grădinaru (as also

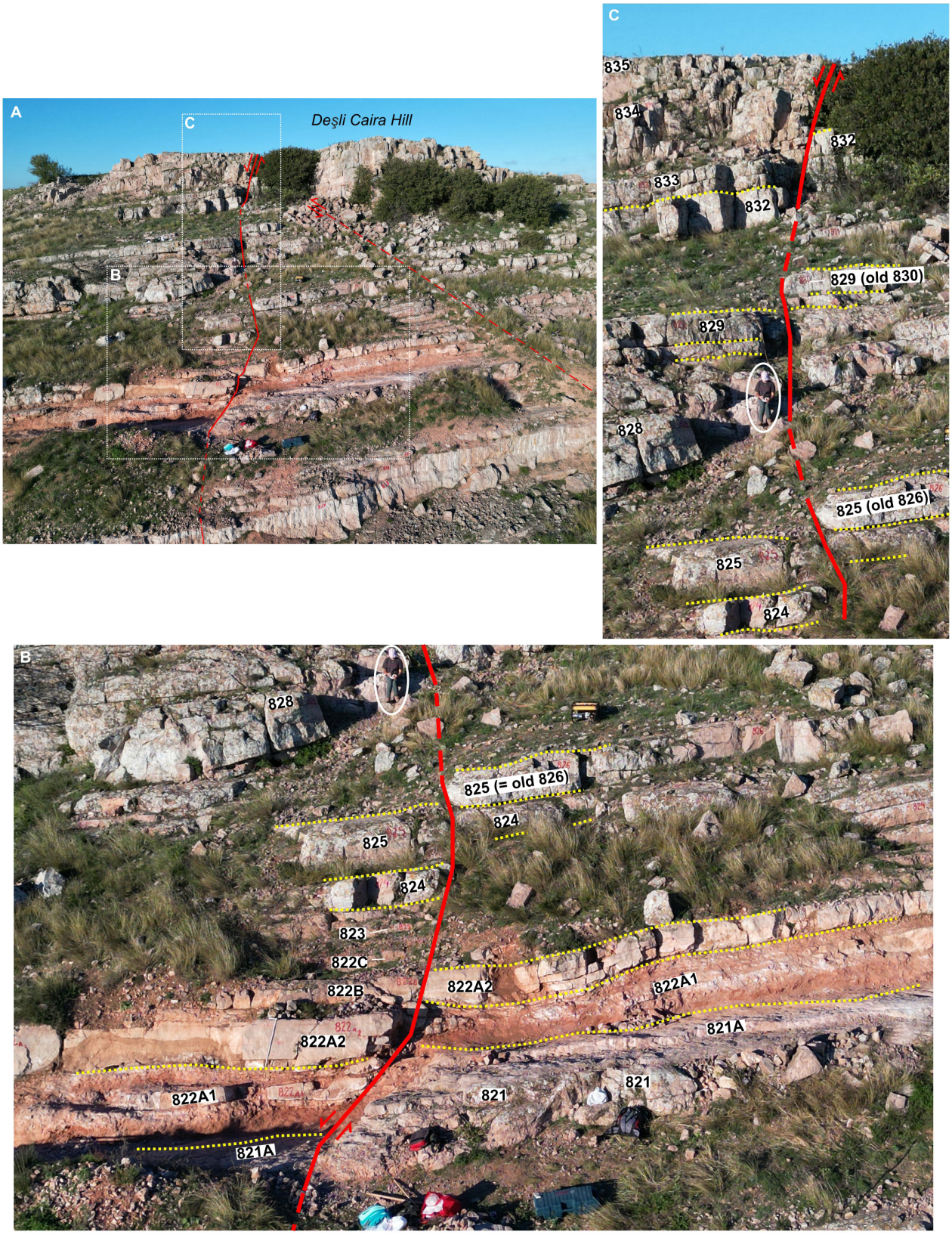

Figure 2 – Overview of middle and upper part of Deşli Caira B-section, showing the uppermost Olenekian – lowermost Anisian succession and the two faults originally identified in Balini et al., (2024 see fig. 4), and shown again in Balini et al., (2026). A) General view of the upper part of the succession; B) Detail of the proposed boundary interval (Balini et al., (2024, 2026) of the section; C) Detail of the uppermost part of the section. Note that the direction of movement of the (assumed) right/eastern fault (dashed red line) has been changed. White ellipse encircles Alexandra Lăcătuş who provides scale for the photo (ca. 160 cm). See text and Balini et al. (2024, 2026) for additional explanations. Photo taken by a drone.

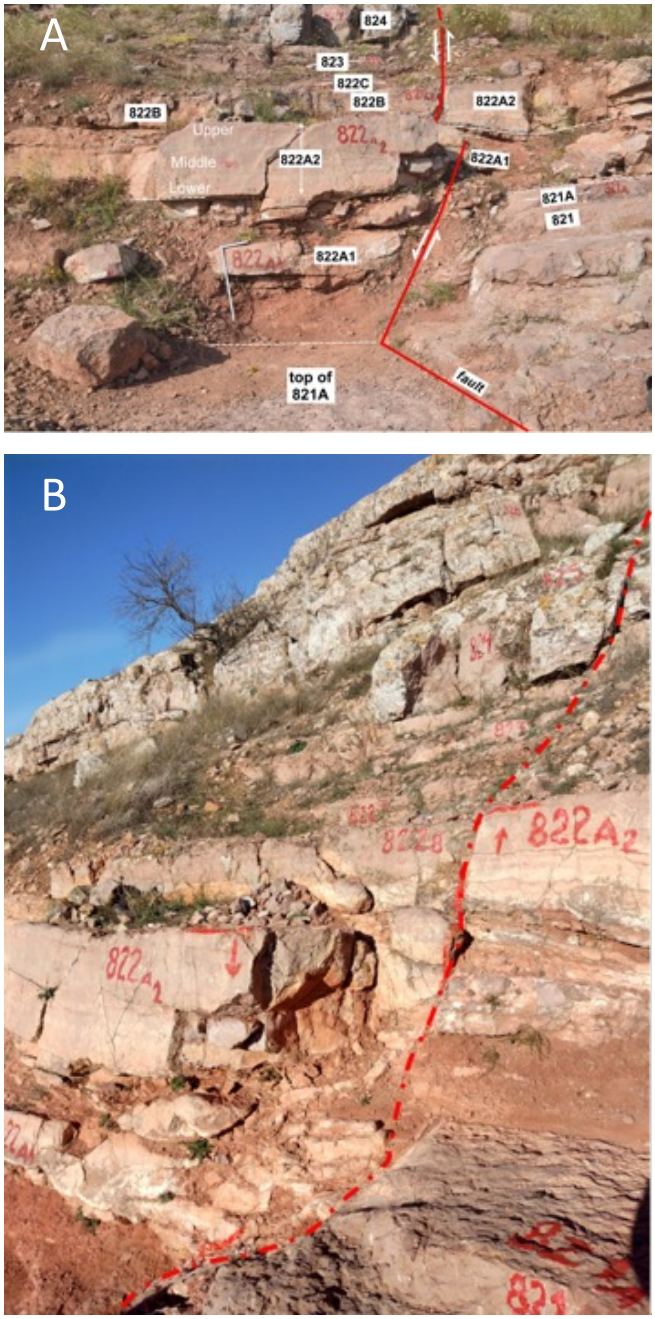

Figure 3 – A, B: Detail of the boundary interval, as proposed in Balini et al., (2024, 2026). A: as indicated in Balini et al., (2026), B: with the displacement by the fault indicated in the section by the horizontal lines representing the top of 822A2. The two red arrows in the photograph on both sides of the fault indicate the relative movement with respect to the other side of the fault.

mentioned in Balini et al., 2024, Balini et al., 2026) e.g. right side (old) 830 is left side 829, right side (old) 826 is left side 825, right side (old) 824 is left side 823, right side (old)819 is (approximately)left side 817 (see Fig. 4 and Fig. 5). Below bed 817 (see Fig. 4), the situation is not completely clear and still under investigation. These results will be published in a future article. As seen in the lower part of the B-section after cleaning and excavating (Fig. 4), correlation between both sides of the fault is still under investigation, and until complete correlation is achieved, we recommend that ongoing work be conducted only along the left (western) side of the section to rule out any errors due to the fault. As can be seen on the photos, there is more than sufficient space on both sides of the fault. To provide an impression of the good fit of both sides of the fault when the offset is taken into account, we show for a part of the section the logs from both sides (Fig. 5).

Meanwhile, ammonoid investigations are progressing and the latest results suggest that *Pseudacrochordiceras*, whose range is restricted to the uppermost part of the *Neopopanoceras haugi* Zone and the *Courtilloticeras stevensi* Zone of the North American scale, both latest Olenekian, may be present in bed GR7. If this occurrence is confirmed, the late Olenekian of Deşli Caira will be correlatable with the Nevada ammonoid scale, and thus, with the Panthalassa realm.

CONCLUSIONS

A fault runs more or less perpendicular to the bedding in the center of section B at Deşli Caira, resulting in a displacement of 80 to 100 cm between both sides of the fault. However, about 30 m of room exists on each side of the fault, leaving sufficient space to work, thus enabling a sampling study of the section without having to cross the fault. In most parts of the section (except the lower part) one can even move from one side of the fault to the other without problem, because the fault and its displacement are easily recognized, and bed thicknesses on both sides of the fault show a very good fit when the offset is taken into account. For the sake of clearness, we propose to only work on the left side of the fault, to avoid any problem of correct correlation. The Deşli Caira section possesses rich ammonoid and conodont faunas and has been investigated for several other fossil groups, as well as paleomag and carbon isotopes. Furthermore, a detailed lithologic accounting is available and will be extended further downwards in the near future, thus enabling very detailed investigations of the entire succession and most importantly, the boundary interval. Ongoing ammonoid investigations suggest the occurrence of the ammonoid *Pseudacrochordiceras* in the late Olenekian of Deşli Caira section. This taxon is crucial for long range correlation with the succession of the late Olenekian *Neopopanoceras haugi* and *Courtilloticeras stevensi* ammonoid zones of Nevada and beyond. Finally, in our opinion, the Deşli Caira section is best suited for eventual selection as the GSSP for the Olenekian-Anisian Boundary.

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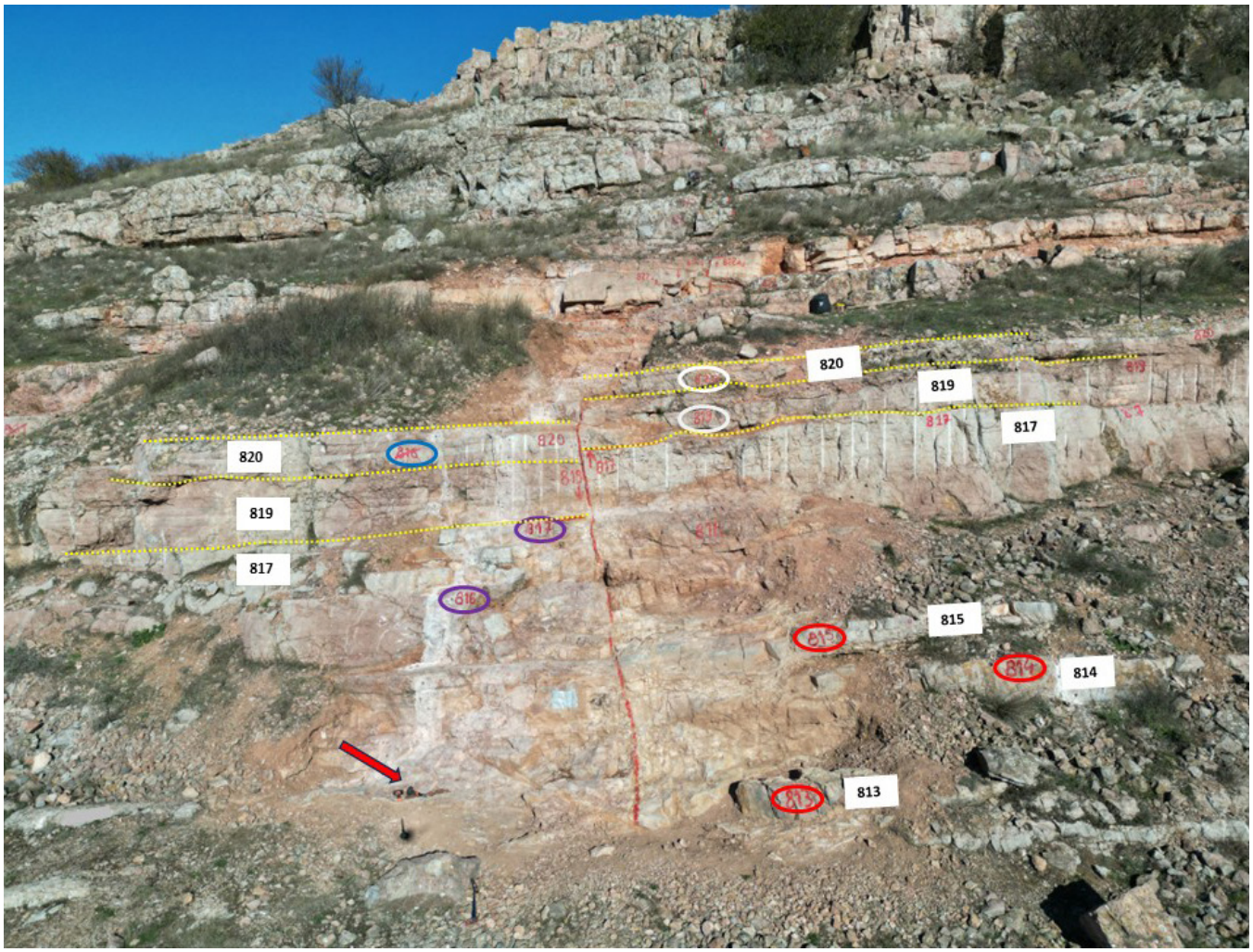

Figure 4 – Photograph of the lower (excluding the lowermost) to middle part of the B-section, which was excavated and cleaned in 2025. Red line represents the fault. Red ovals on right side of fault indicate numbers by E. Grădinaru, which need to be corrected with respect to the left side of the fault. Violet ovals represent E. Grădinaru's numbers to the left side of the fault, which are regarded as references in the section. White ovals show E. Grădinaru's numbers on the right side, which are presently in use and have been correlated accordingly to the left side of the fault. Blue oval indicates one of Grădinaru's numbers on the left side, which has been abandoned for the number on the right side of the fault. Other red numbers are of recent age, taking the fault into account. Thin dashed yellow lines represent individual beds. The black chisel (red arrow) next to the black-and-orange hammer in the lower left center (left of the fault) is ~30cm long. The two red arrows in the center of the photograph on both sides of the fault represent the relative movement with respect to the other side of the fault.

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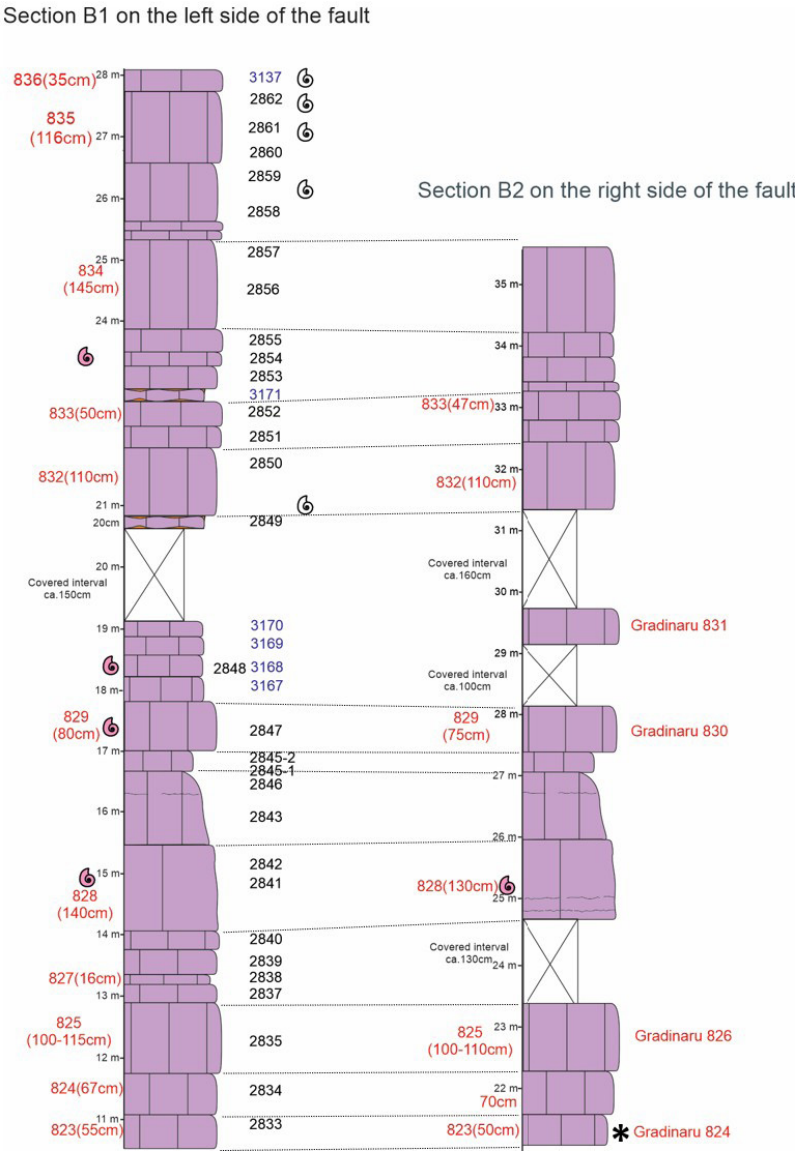

Figure 5 – Lithologs from both sides of the fault with the offset (0.8-1.0m) taken into account, demonstrating a good comparability of thicknesses. Note that only the upper part (Bed 823 to 836) of the section is shown here, both logs continue downwards. The logs were measured ca. 0.5–2m away on each side of the fault. Note that on the left side Bed 836 has been added with respect to earlier logs. Red ammonoid symbol shows presence of Aegean ammonoids, white ammonoid symbol identifies layers containing ammonoids undetermined up to now. Asterisk on the east side log identifies bed 823, which is not exposed directly at the fault but in the "eastern trench" (Balini et al., 2024), ca. 20m east of the fault.

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