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A long trilobite-trackway, *Cruziana semiplicata* Salter, from the Upper Cambrian of the Holy Cross Mts

ABSTRACT: A long trilobite-trackway, *Cruziana semiplicata* Salter, found in the Upper Cambrian deposits of Wielka Wiśniówka in the Holy Cross Mts, is studied and compared both to previously known specimens from the same ichnotope, as well as to Salter's type-locality forms from North Wales. The trilobites' mode of life, their behaviour when settling on the sea bottom and the resulting ichnoassemblage characterized by a dominance of *Cruziana semiplicata* and *Rusophycus polonicus* forms, were closely comparable in both Polish and Welsh environments.

INTRODUCTION

The purpose of the contribution is to describe an extraordinary long trilobite-trackway, *Cruziana semiplicata* Salter, from the Upper Cambrian (Olenus Beds) exposure at the Wielka (Great) Wiśniówka quarry in the Holy Cross Mts, Central Poland (*cf.* Orłowski, Radwański & Roniewicz 1970, Fig. 1). For a dozen or so years this exposure has yielded a rich assemblage of various trace fossils, the taxonomy as well as paleoenvironmental analysis of which have been the subject of detailed studies (Radwański & Roniewicz 1960, 1963, 1967; Orłowski, Radwański & Roniewicz 1970, 1971; *cf.* also Dżułyński & Żak 1960). The traces were formed herein in a very shallow marine environment, influenced both by waves and bottom currents of various intensity which allowed preservation of the traces in many horizons or lithologic sets distributed through the whole, c. 400 m in thick series of alternate quartzitic sandstones or siltstones and claystones. The collected trackway, as being one of the longest hitherto known, is estimated to be an interesting illustration of the ichnologic variability within the Wielka Wiśniówka ichnocoenose.

ICHNOTOPIC FEATURES

The presented trackway *Cruziana semiplicata* Salter was discovered at the Wielka Wiśniówka quarry, in July 1969, when excavating successive layers of a thin-layered-quartzitic-sandstone set being suspected to bear trilobite traces, similarly as it had previously happened in analogous sets within the profile. During the work, a layer with an indistinct, much over 1 m long, curving swell was found. The layer was covered by more

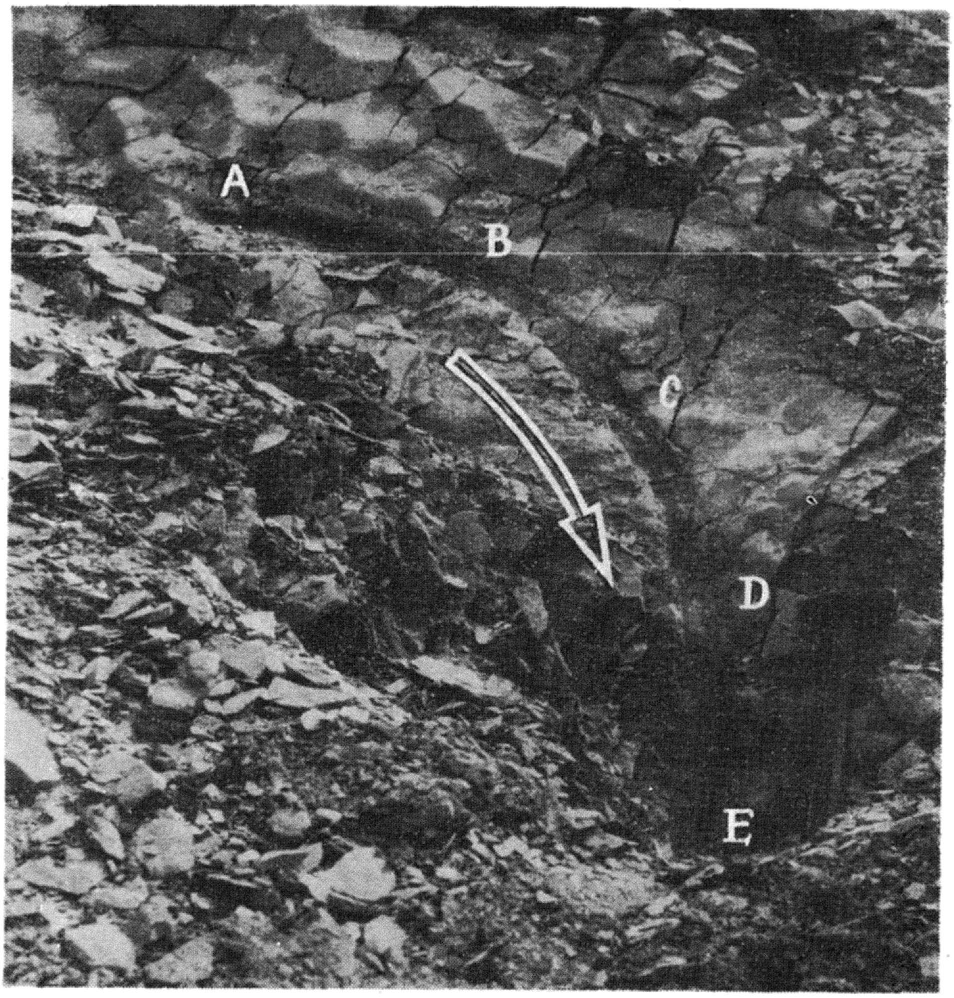

Fig. 1

Natural furrow made by a crawling olenid on a thin layer of fine-grained, ripple--marked sand; the furrow appeared after taking-off the overlying layer with *Cruziana semiplicata* Salter on its sole

A-B-C-D-E correspond to segments of the infilling of the furrow, i.e. *Cruziana semiplicata* Salter, presented in Pl. 1; arrow shows direction of the olenid's motion (*cf.* Text-fig. 2) or less linguoid ripples and cracked by weathering joints to the same extent as that underlying one presented in Fig. 1. The taking-off the cracked slabs revealed a high trilobite trackway along the whole swell, and a corresponding deep furrow on the topside of underlying layer (Fig. 1; *cf.* Orłowski, Radwański & Roniewicz 1970, Pl. 2c). The trackway, being an infilling of the curving furrow, continued along the whole length of the latter and exhibited a rather undifferentiated structure (*cf.* Pl. 1, description below). In a sector of the furrow there appeared small, herringbone oriented grooves imprinted by trilobite's walking legs (Fig. 2).

A preservation of the trilobite furrow underneath the covering trackway, *Cruziana semiplicata* Salter, resulted from a firm consistency of fine-grained sand which formed a temporary sea-bottom material. Such a situation in the discussed ichnotope (*cf.* Radwański & Roniewicz 1970) was rather sporadical, as mostly it was clay material which was sufficiently firm to enable shaping of the bottom by a trilobite and retain the

Fig. 2

Detail of the furrow presented in Text-fig. 1 (hammer in the same place): visible are imprints of the olenid's walking legs — the furrowing motion of the trilobite is evidenced as downward in the photo (see arrow in Text-fig. 1) imprints up to the time of their burial by a successively deposited sand material. These only conditions (heterogenic material in a definite layer and its overlier) led to the formation of a distinct infilling of the true trace, *i.e.* to the formation of the hieroglyph (infilled mould). The sets composed of following clay layers were as a rule strongly affected by compaction pressure and tectonic folding; consequently, the trilobite traces in these sets of layers are mostly obliterated and usually unrecognizable. The better preserved true traces of trilobite activities in the discussed ichnotope are therefore preserved only in some fine-grained sandstones or in siltstones (*cf.* Orłowski, Radwański & Roniewicz 1971, Pl. 6, Fig. 1*a*).

The effect of compaction in the trilobite-trace-bearing sequence, consists in a swell which appeared over this layer that contained the presented trackway. The sand, being ununiformly shaped by ripples and only a few millimeters thick under the grooves of the ripples (no more than 1 cm under the crests respectively), was too thin whereas the deep infilling of the furrow (attaining 1.3 to 1.6 cm) was too thick to be compacted without any differentiation. As a result, a swell has been impressed throughout the whole thin layer and reproduced the *Cruziana* outline on the topside. An analysis in the exposure shows that the along-the-length fluctuations of height of the discussed *Cruziana* (invisible in the vertical photo, Pl. 1) have been caused mostly by a changeable depth of the furrow being ploughed by a trilobite across the successive crests and grooves of the ripple-marked bottom (*cf.* Figs 1 and 2); the effect of uneven loading along the trackway is here of smaller importance.

THE TRACKWAY

The presented (Pl. 1) trackway *Cruziana semiplicata* Salter fully fits in its shape and morphologic features to all the *Cruziana* forms previously reported from the Wielka Wiśniówka ichnotope (Radwański & Roniewicz 1960, Pl. 29, Fig. 2; 1963, Pls 4—7; Orłowski, Radwański & Roniewicz 1970, Pl. 4*a*—*c*; 1971, Pl. 1; *cf.* also Dżułyński & Żak 1960, Pl. 24, Figs 1—2). Its ichnospecific assignation results from its identity with the forms being recently included to this ichnospecies (*cf.* Seilacher 1960, 1970; Seilacher & Crimes 1969), especially with the forms occurring in Salter's type locality on Mt. Carnedd-y-Filiast (slopes of Cwm Graianog) in North Wales, which were the subject of detailed studies by Crimes (1968, 1969, 1970a, b).

The complete length of the presented trackway is unknown. The unearthed part, from its beginning (point *A* in Fig. 1) down to the quarry floor (point *E* in Fig. 1), was 152 cm long, a 3-cm segment of which was crushed (at point *D* in Fig. 1; a piece missing between segments *C-D* and

D-E in Pl. 1). The best preserved part (segments *B-C*, *C-D* and *D-E* in Fig. 1 and Pl. 1) attains 121 cm in length at the average width c. 4.2 cm.

The maximal length of *Cruziana semiplicata* Salter, recorded in the referenced bibliography, is more than a metre as noted by Crimes (1970a) for the type-locality forms. The average length in the latter area is however much smaller, being of about 15 cm (Crimes 1970a). The longest form previously reported from the Wielka Wiśniówka ichnotope attained 24 cm and bore only one natural termination (*cf.* Radwański & Roniewicz 1963, Pl. 7 — a trackway right in the photo). The collected specimen bears no natural terminations; at its beginning (point *A* in Fig. 1), the trackway is however so obliterated that it was omitted in the presented photo (Pl. 1).

The structure of the discussed long *Cruziana* and its morphologic features distributed along the whole trackway are generally the same as of the previously reported and interpreted forms (Radwański & Roniewicz 1963). The features worth to be mentioned are characterized as follows:

The trackway is mostly shaped by the endopodal lobes (*cf.* Seilacher 1970, Fig. 3) counterparting the grooves ploughed by trilobite's walking legs (endopodites). Their pattern consists of herringbone-oriented ridges counterparting the scratches made by individual legs of the trilobite. The *V*-angle of the herringbone is more or less constant along the trackway pointing to a similar speed and mode of digging by the trilobite (*cf.* Crimes 1970a, Seilacher 1970).

The exopodal lobes of the trackway (*cf.* Seilacher 1970, Fig. 3) are weakly developed or missing: trilobite's exopodal brushings are marked only in some fragments of the trackway (*e.g.* at point *B* in segment *B-C* in Pl. 1). Nevertheless, it seems that the exopodites (exites *sensu* Bergström 1972) might have been well developed in the Wielka Wiśniówka trilobites and been touching the bottom, as it is evidenced by external parts, marked with small beaded imprints, of the resting places of trilobites, *i.e.* the rusophyci, from the same ichnotope (*cf.* Orłowski, Radwański & Roniewicz 1971, p. 345). A herein suggested identity of the furrowing and resting trilobites is discussed below.

The external ridges of the trackway, counterparting the pleural grooves (*cf.* Seilacher 1970, Fig. 3), are similarly pronounced and more or less continuous. In some places these are indistinct or locally vanish, although they are detectable along the whole trackway. In places of interrupting, they happen to overlap in an imbricating manner, which correspond to a local rotation of the trilobite body during furrowing. Such places (*e.g.* before point *D* in segment *C-D* in Pl. 1) do not mark, however, stronger bendings of the trackway which is uniformly bordered along its curvature (*cf.* Fig. 1 and Pl. 1).

The coxal part of the trilobite's body (*cf.* Seilacher 1970, Fig. 3) is not imprinted in the trackway. Its morphology may be inferred only from the rusophyci occurring in the same ichnotope (Orłowski, Radwański & Roniewicz 1970, 1971).

The general structure of the discussed trackway suggest the trilobite to have been tail-down (opisthocline) ploughing the bottom (*cf.* Seilacher 1970, Fig. 4). The same mode of digging was previously inferred also from the rusophyci in the Wielka Wiśniówka ichnotope (Orłowski, Radwański & Roniewicz 1971).

A direction of motion of the discussed furrow-making trilobite is concluded on the herringbone apex being oriented backward in the furrow (*cf.* Fig. 2 and the arrow in Fig. 1). Such an orientation of the herring-boned imprints of the trilobite's walking legs was already claimed by Seilacher (1959) and afterwards it was fully accepted when orientation of the rusophyci was recognized (Crimes 1970a, b; Orłowski, Radwański & Roniewicz 1971) and evidenced by the latter when found continuous with the *Cruziana* trackways (Crimes 1970a, Pl. 12*a, b*; 1970b, Pl. 5*e*). Detailed studies of the action of trilobite's walking legs in furrowing the bottom (Crimes 1970a, Seilacher 1970, Birkenmajer & Bruton 1971, Bergström 1972) have solved and explained the problem which previously was not sufficiently clarified (*cf.* Radwański & Roniewicz 1963, Birkenmajer & Bruton 1971, p. 313). A generally undifferentiated structure of the presented trackway and its relatively small *V*-angle (*cf.* Pl. 1, and Crimes 1970a) suggest that the trilobite furrowed the bottom uniformly, using mainly its walking legs, with no checking or hesitation, and, as appears in consequence — swiftly [1].

The producer of the discussed trackway was one of the olenids to which all the traces from the Wielka Wiśniówka ichnotope may be attributed; as the most probable tracemaker a representative of the endemic species, *Olenus rarus* Orłowski, being close to such Scandinavian species as *O. scanicus* Westergård and *O. alpha* Henningsmoen (*cf.* Orłowski 1968), is to be suggested (*cf.* also Orłowski, Radwański & Roniewicz 1970, 1971).

COMPARATIVE REMARKS

The presented trackway as well as other specimens of *Cruziana semiplicata* Salter from the Wielka Wiśniówka ichnotope are mostly similar in their shape, morphologic features, and even their length, to the type-locality forms from North Wales. Also, the suggested tracemakers, being generally the olenid trilobites are the same; consequently, the stratigraphic occurrence of the ichnocoenoses from both localities is nearly identic, *viz.* the Ffestiniog Stage or the Olenus Beds (*cf.* Crimes 1970a, b). What about the tracemakers, within the Wielka Wiśniówka ichnotope a definite olenid species is suggested, as this is the only, similar-in-size trilobite species hitherto known in that environment. Under other conditions, however, it is possible that various trilobite species, even more than one in a single locality, may be responsible for making the traces, as it was suggested by Crimes (1970a, p. 66). At Wielka Wiśniówka, the

[1] An interpretation of the *Cruziana semiplicata* forms from Wielka Wiśniówka, presented by Birkenmajer & Bruton (1971, Figs 11*A*—*B*, 12*A*, *B*, *C* and 13*B*) and based on a photo of the specimen figured by Dżułyński & Żak (1960, Pl. 24, Fig. 2), cannot be accepted as to the nature of imprint-making parts of the trilobite body, and to the character of furrowing as an intrastratal burrowing; in the light of all the hitherto known data both on the *Cruziana* from Wielka Wiśniówka and on the trilobite appendages and mode of furrowing, presented in the herein referenced bibliography, this interpretation is highly improbable.

postulated species, *Olenus rarus* Orłowski, was certainly the producer of all abundant resting-traces of the *Rusophycus polonicus* type (*cf.* Orłowski, Radwański & Roniewicz 1970, 1971). Similar resting traces do accompany *Cruziana semiplicata* trackways, in some cases even interrupting them, in the comparable ichnotope in North Wales (*cf.* Crimes 1970a, b). It therefore appears that the *Cruziana semiplicata* — *Rusophycus polonicus* ichnoassemblage does reflect a definite olenid trilobites' community and may be regarded as stratigraphically important (*cf.* Crimes 1968, 1969, 1970a, b; Seilacher & Crimes 1969; Seilacher 1970; Orłowski, Radwański & Roniewicz 1970, 1971).

Out of the referenced authors, Seilacher (1970, pp. 461 and 473) emphasizes the *Cruziana semiplicata* — *Rusophycus polonicus* association, but makes a reservation that the latter form "... is probably produced by a different trilobite species because it has no exopodal markings in spite of being deeply impressed, and because it does not occur in all *semiplicata* occurrences" (Seilacher, p. 473). The quoted reservations are however not acceptable: exopodal markings are evidently expressed in many *Rusophycus polonicus* forms, recently illustrated (Orłowski, Radwański & Roniewicz 1971, p. 345 and figures enumerated on the same page); a co-occurrence of both the discussed trace fossils may be affected by environmental conditions under which a layer or a smaller set of layers were formed, it may therefore be detectable mostly in thicker sequences such as *e.g.* in the Holy Cross Mts or North Wales. Seilacher (1970) claims also an ichnogeneric identity of *Rusophycus* and *Cruziana*, which however has not been commonly accepted and, contrary to that, a separateness of these ichnogenera is held further on (Osgood 1970, p. 303; Orłowski, Radwański & Roniewicz 1971, p. 344; Birkenmajer & Bruton 1971).

An interesting problem arises when dimensions of the rusophyci and associated *Cruziana* forms are compared. At Wielka Wiśniówka, there appear only wide *Cruziana* forms (2.5—3.5 cm in average width, 1.5 cm minimal, and a little over 4.0 cm maximal in the trackway presented herein), whereas the rusophyci of much smaller dimensions, down to beneath 1.0 cm in width, are common; on the other hand, the latter forms are much more frequent in the environment. This phenomenon was previously interpreted (Radwański & Roniewicz 1963) as resulting from life behaviour of the trilobites considered as generally free-swimming forms, some of which had been settling on the bottom for rest. In North Wales, *Cruziana semiplicata* forms are also only of larger width than rusophyci, and attributed therefore to adult trilobites (Crimes 1970b). According to Crimes' deduction (1970b) the trilobite behaviour was changing at different stages in the life cycle: planktonic after hatching, and afterwards swimming, accompanied successively by resting on the sea bottom, later walking and finally furrowing[2]. Such a conclusion may also be drawn when studying the Wielka Wiśniówka ichnotope: no

[2] This suggestion points to the *Cruziana semiplicata* forms being usually wider than the trace-makers' and other common paleontologic material which supposedly consists mostly of moults successively cast-off (*cf.* Crimes 1970a, p. 67; Orłowski, Radwański & Roniewicz 1970, p. 357).

The best preserved part of *Cruziana semiplicata* Salter taken out of the furrow illustrated in Text-fig. 1; position of the presented segments *B-C, C-D* and *D-E* the same as in the furrow (*cf.* Text-fig. 1)

The specimen collected in July 1969 at the Wielka Wiśniówka quarry (Upper Cambrian, Olenus Beds), Holy Cross Mts; the photo slightly reduced (0.9), taken by B. Drozd, M. Sc.

traces of the first developmental stage of the trilobites — a subsequent appearance of the *Rusophycus polonicus* forms continuing up to the greatest diameters — finally the *Cruziana semiplicata* forms attributable to the adults, presumably after their last moulting. It may therefore be inferred that also in their life behaviour and activities, the Holy Cross olenids were closely comparable to their North Welsh relatives.

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REFERENCES

BERGSTRÖM J. 1972. Appendage morphology of the trilobite *Cryptolithus* and its implications. — Lethaia, vol. 5. Oslo.

BIRKENMAJER K. & BRUTON D. L. 1971. Some trilobite resting and crawling traces. — *Ibidem*, vol. 4.

CRIMES T. P. 1968. *Cruziana:* A stratigraphically useful trace fossil. — Geol. Mag., vol. 105, no. 4. Hertford.

— 1969. Trace fossils from the Cambro-Ordovician rocks of North Wales and their stratigraphic significance. — Geol. J., vol. 6, part 2. Liverpool.

— 1970a. Trilobite tracks and other trace fossils from the Upper Cambrian of North Wales. — *Ibidem*, vol. 7, part 1.

— 1970b. The significance of trace fossils in sedimentology, stratigraphy and palaeoecology with examples from Lower Palaeozoic strata. *In:* T. P. Crimes & J. C. Harper (*Eds.*) — Trace Fossils (Geol. J. Special Issues, No. 3). Liverpool.

DŻUŁYŃSKI S. & ŻAK C. 1960. Sedimentary environment of the Cambrian quartzites in the Holy Cross Mts (Central Poland) and their relationship to the flysch facies. — Rocz. P. T. Geol. (Ann. Soc. Géol. Pol.), vol. 30, no. 2. Kraków.

ORŁOWSKI S. 1968. Upper Cambrian fauna of the Holy Cross Mts. — Acta Geol. Pol., vol. 18, no. 2. Warszawa.

— , RADWAŃSKI A. & RONIEWICZ P. 1970. The trilobite ichnocoenoses in the Cambrian sequence of the Holy Cross Mountains. *In:* T. P. Crimes & J. C. Harper (*Eds.*) — Trace Fossils (Geol. J. Special Issues, No. 3). Liverpool.

— , — & — 1971. Ichnospecific variability of the Upper Cambrian *Rusophycus* from the Holy Cross Mts. — Acta Geol. Pol., vol. 21, no. 3. Warszawa.

OSGOOD R. G., Jr. 1970. Trace fossils of the Cincinnati area. — Palaeontogr. Americana, vol. 6, no. 41. Ithaca.

RADWAŃSKI A. & RONIEWICZ P. 1960. Ripple marks and other sedimentary structures of the Upper Cambrian at Wielka Wiśniówka (Holy Cross Mountains). — Acta Geol. Pol., vol. 10, no. 3. Warszawa.

— & — 1963. Upper Cambrian trilobite ichnocoenosis from Wielka Wiśniówka (Holy Cross Mountains, Poland). — Acta Palaeont. Pol., vol. 8, no. 2. Warszawa.

— & — 1967. Trace fossil *Aglaspidichnus sanctacrucensis* n. gen., n. sp., a probable resting place of an aglaspid (Xiphosura). — *Ibidem*, vol. 12, no. 4.

— & — 1970. General remarks on the ichnocoenose concept. — Bull. Acad. Pol. Sci., Sér. Sci. Géol. Géogr., vol. 18, no. 1. Varsovie.

SEILACHER A. 1959. Vom Leben der Trilobiten. — Naturwissenschaften, Jg. 46, H. 12. Berlin — Göttingen — Heidelberg.

— 1960. Lebensspuren als Leitfossilien. — Geol. Rundschau, Bd. 49. Stuttgart.
— 1970. *Cruziana* stratigraphy of "non-fossiliferous" Palaeozoic sandstones. *In:* T. P. Crimes & J. C. Harper (*Eds.*) — Trace Fossils (Geol. J. Special Issues, No. 3). Liverpool.
— & CRIMES T. P. 1969. "European" species of trilobite burrows in eastern Newfoundland. *In:* Amer. Assoc. Petroleum Geol. Memoir 12 (North Atlantic — Geology and Continental Drift). Tulsa.

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HIEROGLIF ORGANICZNY *CRUZIANA SEMIPLICATA* SALTER Z GÓRNEGO KAMBRU WIELKIEJ WIŚNIÓWKI

(Streszczenie)

Przedmiotem pracy jest analiza wyjątkowo długiego hieroglifu organicznego *Cruziana semiplicata* Salter, będącego wypełnieniem śladu pełzania trylobita po dnie morskim, a znalezionego w osadach górnego kambru Wielkiej Wiśniówki w Górach Świętokrzyskich (*por.* fig. 1—2 oraz pl. 1). W nawiązaniu do wykształcenia poprzednio znanych stąd mniejszych form tego typu (Radwański & Roniewicz 1960, 1963; Orłowski, Radwański & Roniewicz 1970, 1971), oraz do nowszych prac poświęconych analizie ruchu trylobitów górnokambryjskich i sposobu rozgrzebywania przez nie osadu (Crimes 1970a, b; Seilacher 1970) omówiono w pracy także zagadnienia związane z trybem życia trylobitów zamieszkujących środowisko sedymentacji osadów Wielkiej Wiśniówki.

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