

Trace fossil *Cruziana tenella* from the Furongian (Upper Cambrian) deposits of Poland

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ABSTRACT:

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A minute, bilobate ribbon-like trace fossil, assigned to the ichnospecies *Cruziana tenella*, is recorded for the first time from Furongian (Upper Cambrian) strata of the Wiśniówka Formation exposed in the Wiśniówka Wielka quarry, Holy Cross Mountains, central Poland. The collected material of *C. tenella* is interpreted as arthropod *pascichnia* trails. A significant gap in size distribution and morphology between *C. tenella* and other *Cruziana* trails from Wiśniówka Wielka suggests that the former cannot be regarded as produced by juveniles of the biotaxa responsible for the latter. *C. tenella* from Wiśniówka Wielka was most probably produced by arthropods reaching a small adult size.

Key words: Trace fossil; *Cruziana*; Furongian; Cambrian; Wiśniówka Formation; Poland.

INTRODUCTION

Furongian (Upper Cambrian) deposits are well exposed in the Wiśniówka Wielka quarry located in the western part of the Łysogóry Block, in the Holy Cross Mountains, central Poland (Text-fig. 1). This locality has yielded numerous well preserved trace fossils attributed to trilobites (Dżułyński and Żak 1960; Radwański and Roniewicz 1960, 1963, 1972; Orłowski *et al.* 1970, 1971), aglaspids (Radwański and Roniewicz 1967) and several soft-bodied animals, including sea-anemones and priapulids (Radwański and Roniewicz 1963; Orłowski and Żylińska 1996; see Żylińska and Radwański 2008 for the most recent review).

To date, only medium-sized to large *Cruziana* traces were recorded from the Furongian strata exposed at Wiśniówka Wielka, as exemplified by *Cruziana semiplicata* Salter, 1853 (Radwański and Roniewicz 1960, 1963, 1972; Orłowski *et al.* 1970,

1971; Seilacher 1970). No minute *Cruziana* trails have so far been recorded from these deposits. The present paper fills this gap by recording, for the first time, minute specimens of *Cruziana tenella* (Linnarsson, 1871) from the Wiśniówka Formation. The palaeological implications of this record are discussed.

STRATIGRAPHY AND PALAEOENVIRONMENT

The trace fossil-bearing deposits exposed in the Wiśniówka Wielka quarry belong to the Wiśniówka Formation, which is Late Cambrian (Furongian) in age, as indicated by trilobites and acritarchs (Żylińska 2002; Żylińska *et al.* 2006; Text-fig. 1C herein). The Wiśniówka Formation consists mainly of quartzitic sandstones and siltstones. The unit rests on the Pepper Mountains Formation of Middle–Late Cambrian age, and is followed upwards by the Furongian

Klonówka Shale Formation (Jaworowski and Sikorska 2006; Żylińska *et al.* 2006). The trace fossil-bearing deposits of the Wiśniówka Formation originated in shallow water, turbulent marine environments (Dżułyński and Żak 1960; Radwański and Roniewicz 1960), ranging from the inner to the outer shelf (Żylińska *et al.* 2006; see Jaworowski and Sikorska 2006). The sandstones that originally were fine grained and well sorted and had well-rounded, loosely packed grains (Żylińska *et al.* 2006), are strongly recrystallised (Sikorska 2000).

MATERIALS AND METHODS

The material discussed herein forms part of the Upper Cambrian trace fossil collection housed in the Institute of Paleobiology of the Polish Academy of Sciences in Warsaw, Poland (collection abbreviation: ZPAL Tf. 4/). All of the described specimens come from the lower part of the succession exposed in the

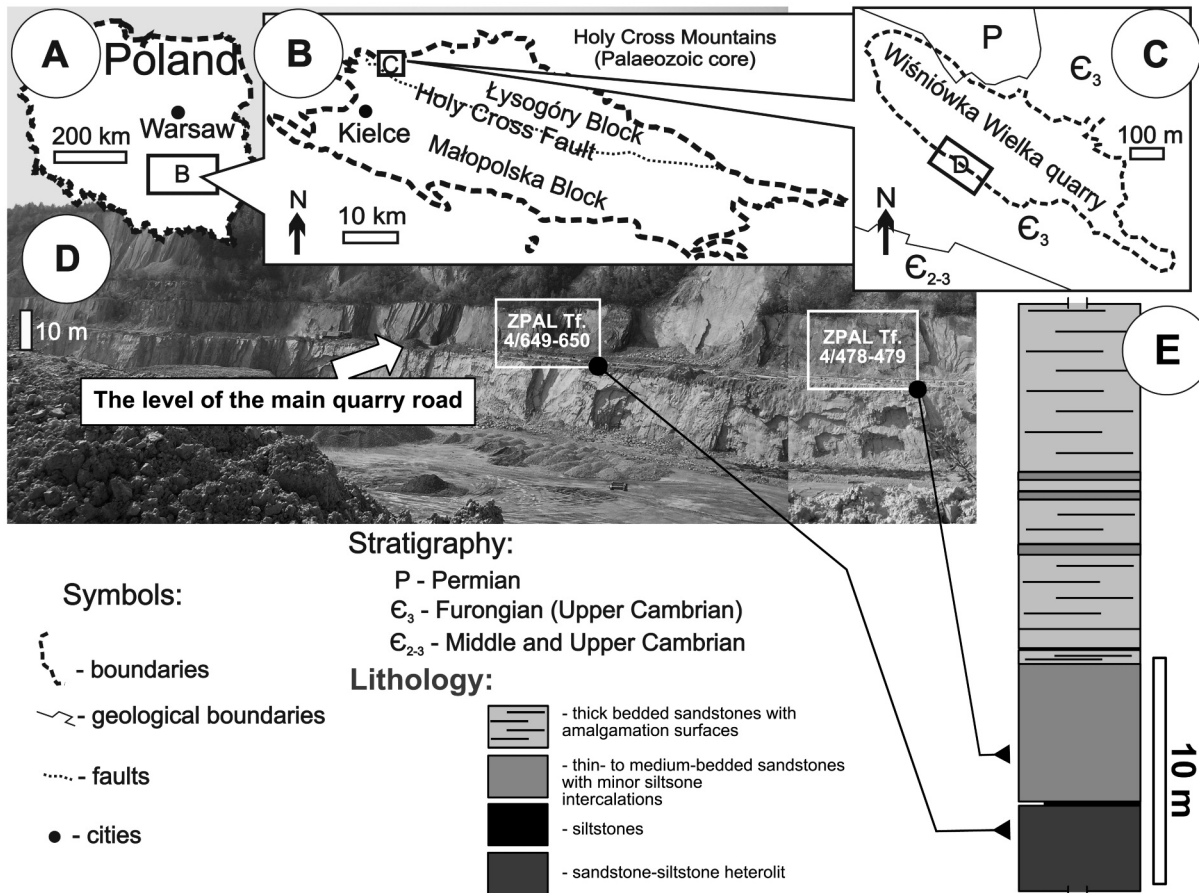
Wiśniówka Wielka quarry (Wiśniówka Formation) and were collected at the level of the main quarry road in the central part of the southern wall (Text-fig. 1D–E).

Specimens ZPAL Tf. 4/649 and 4/650 were collected from sandstone-siltstone heterolitic deposits (Text-fig. 1D–E). Two further specimens, ZPAL Tf. 4/478 and 4/479, come from a slightly higher part of the succession dominated by thin- and medium-bedded grey quartzitic sandstone beds with minor siltstone intercalations. The slabs containing the latter specimens display various additional trace fossils produced by arthropods, mainly scratches (not considered in the present paper). All photographs were taken with low-angle illumination from the upper left corner.

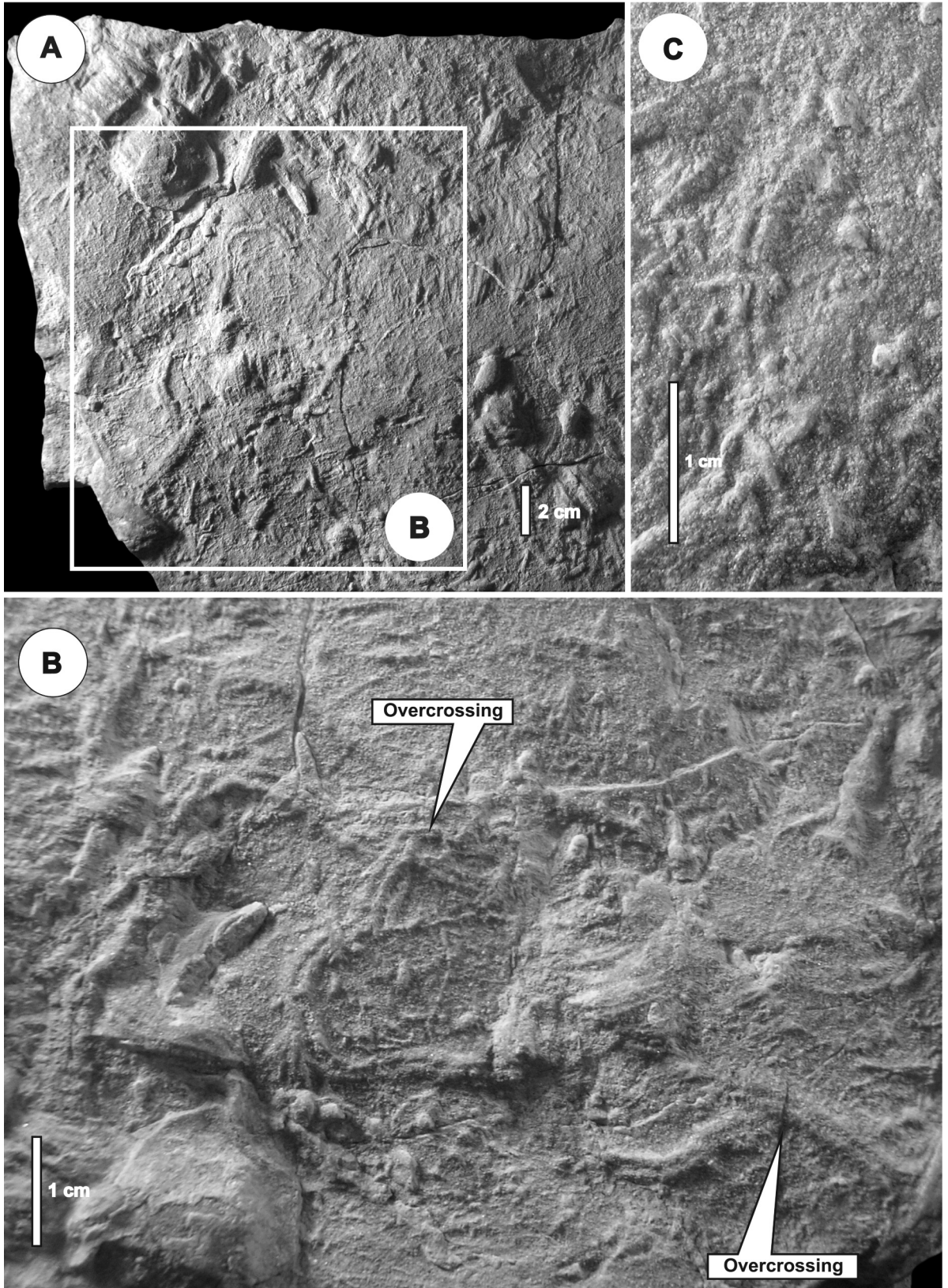
SYSTEMATIC ICHNOLOGY

Ichnogenus: *Cruziana* d'Orbigny, 1842

Ichnospecies: *Cruziana tenella* (Linnarsson, 1871)
(Text-figs 2 and 3)



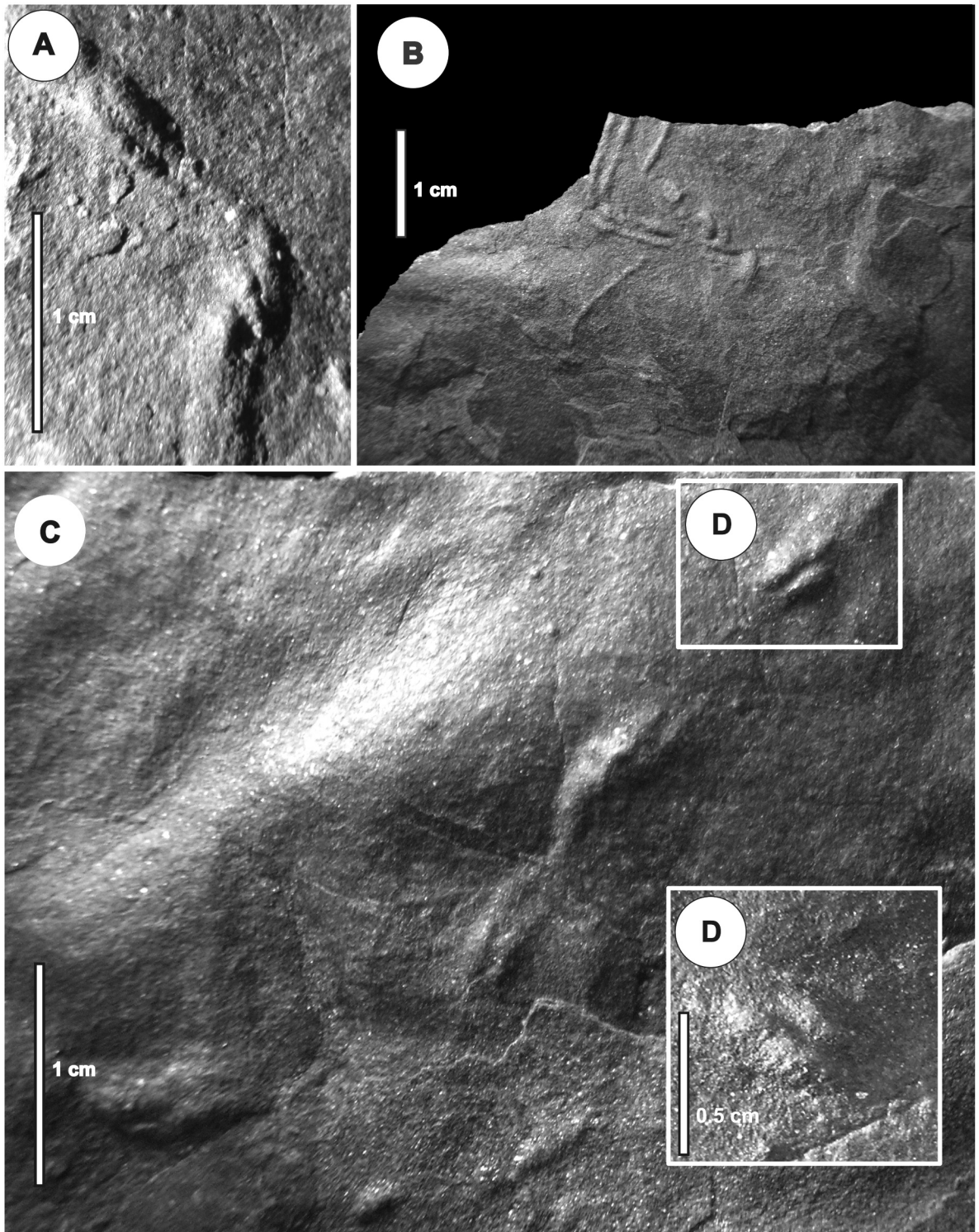
Text-fig. 1. Location of the study area, A – position of the Holy Cross Mountains within Poland; B – position of the Wiśniówka Wielka quarry within the Holy Cross Mountains; C – outline of the Wiśniówka Wielka quarry and general stratigraphical settings (note: tectonics are omitted, A–C based on Żylińska *et al.* 2006 – modified); D – middle part of southern wall of the Wiśniówka Wielka quarry with collecting site (E) indicated; E – partial section of the lowest part of the succession exposed in Wiśniówka Wielka quarry with relative position in the section of the collecting site indicated



Text-fig. 2. *Cruziana tenella* from the Furongian (Upper Cambrian) Wiśniówka Formation of the Holy Cross Mountains, central Poland, A – ZPAL Tf. 4/478; B – magnified detail of ZPAL Tf. 4/478; C – detail of ZPAL Tf. 4/479

MATERIAL: Four specimens in total, preserved in four slabs. Specimens ZPAL Tf. 4/478 (Text-fig. 2A–B) and ZPAL Tf. 4/479 (Text-fig. 2C) are preserved

on 3–4 cm thick slabs of quartzitic sandstone. Specimens ZPAL Tf. 4/649 (Text-fig. 3B–D) and ZPAL Tf. 4/650 (Text-fig. 3A) are preserved on ca 1 cm thick



Text-fig. 3. *Cruziana tenella* from the Furongian (Upper Cambrian) Wiśniówka Formation of the Holy Cross Mountains, central Poland, A – ZPAL tf. 4/650; B – partial view of ZPAL Tf. 4/649, note the 90° side turn; C – partial view of ZPAL Tf. 4/649, note the undulation of the trace fossil; D – magnified and counter-clockwise rotated area of C, note the scratch marks

slabs of a sandstone-siltstone heterolite with wavy bedding on a millimetre scale.

DESCRIPTION: All of the specimens studied are preserved as hypichnial ridges up to 3 mm wide, divided by a median furrow. The ridges are very low (up to 1 mm), and their course is variable (Text-fig. 2A–B). An almost 90° turn is visible in specimen ZPAL Tf. 4/649 (Text-fig. 3B), and sporadic overcrossing of the ridges occurs in specimen ZPAL Tf. 4/478 (Text-fig. 2B). There is some undulation in the horizontal plane of the ridges; thus, the depth of the trace fossil changes along its course and it disappears gradually in one case (Text-fig. 3C). Rare intergradational *Rusophycus*-like structures (Text-fig. 3C–D) and weakly developed transverse striae on the surface of the ridge (Text-fig. 3D) are present in specimen ZPAL Tf. 4/649.

REMARKS: The trace fossil *Cruziana* is discriminated from other, similar bilobates, e.g. ichnospecies of *Didymaulichnus* Young, 1972 (see Jensen and Mens 2001), by the presence of striation on the lobes (Keighley and Pickerill 1996). However, the weakly developed striation or even its total lack may be an effect of poor preservation, especially as far as the small forms of *Cruziana* are concerned (Bromley and Asgaard 1979). This makes the differentiation from didymaulichnids problematic in some instances (see Jensen 1997 and Jensen *et al.* 2005). The present trace fossils are, however, too narrow and have too low a relief to be considered as *Didymaulichnus* (compare Hofmann *et al.* 1994; Jensen and Mens 2001; Weber *et al.* 2007; Davies *et al.* 2009; Alfred Uchman, written communication 2009).

The present material shows similarities to *Cruziana tenella* as described from the Middle Cambrian Mickwitzia Sandstone of Sweden by Jensen (1997) in its small size, rarely occurring scratches, overcrossing of paths and sporadic intergradations with *Rusophycus*-like structures (compare section *Synonymy* and *Discussion* in Jensen 1997; see also Bromley and Asgaard 1979; Schlirf *et al.* 2001). The present specimens of *Cruziana tenella* are slightly wider than those described by Jensen (1997), but they fall into the size range of the ichnospecies as given by Bromley and Asgaard (1979). The overcrossing of the earlier paths by the later ones without disturbances (Text-fig. 3B) may indicate origin below the sediment-water interface (Jensen 1997). The variable course, the undulations in the horizontal plane and the supposed origin below the sediment-water interface suggest foraging behaviour of the producers (see Jensen 1997 and Gaillard *et al.* 2005). Thus, the present trace fossil probably belongs to the category of shallow

subsurface or surface grazing trails (*pascichnia sensu* Frey and Pemberton 1984).

Other Cambrian occurrences of *Cruziana tenella* (often recorded as *C. problematica*) are, in stratigraphically ascending order, those from the Lower Cambrian of California, USA (Alpert 1976), Lower Cambrian of Sweden (Jensen 1997), Middle Cambrian of Jordan (Hofmann *et al.* 2008), Upper Cambrian of Argentina (Manca 1986) and from the Upper Cambrian of Newfoundland, Canada (Bergström 1976).

PALAEOECOLOGY

The ichnogenus *Cruziana* is commonly considered as a product of the life activity of arthropods in both the marine and non-marine realms (Seilacher 1970; Bromley and Asgaard 1972; Pollard 1985; Gradziński and Uchman 1994). An arthropod origin is suggested by the presence of scratches on the lobes, which are best interpreted as produced by arthropod appendages (e.g. Seilacher 1970). However, in the case when the sculpture is not well developed, additional clues to an arthropod origin are provided by the associated *Rusophycus*-like structures (Jensen 1997). The present material of *Cruziana tenella* shows both scratches and *Rusophycus*-like structures, and hence arthropods were its most probable producers. It cannot be decided, however, whether the traces studied were produced by trilobites or other arthropods.

According to Żylińska and Radwański (2008), the forms of *Cruziana* from Wiśniówka Wielka are on average 2.5–3.5 cm wide; the smallest specimen reported by these authors is 1.5 cm wide. The present specimens of *Cruziana tenella* are ca five times narrower. There is thus a significant size gap between the present material and the sample described by Żylińska and Radwański (2008). This, and the morphological differences between the present specimens of *Cruziana tenella* and other ichnospecies of *Cruziana* from the same site (e.g. *Cruziana semiplicata*), suggest that small arthropods distinct from the producers of the larger *Cruziana* produced the trace fossil under consideration.

SUMMARY

The specimens of *Cruziana tenella* described herein represent the first record of this very small, up to 3 mm wide bilobate, ribbon-like trace fossil from the Furonian (Upper Cambrian) Wiśniówka Formation in the Holy Cross Mountains, central Poland. These specimens are best interpreted as shallow subsurface or sur-

face grazing trails (*pascichnia*) produced by minute arthropods, possibly not related to the producers of the larger *Cruziana* trails from the same strata.

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