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Cruziana traces from the Late Silurian (Pridoli) carbonate shelf of Saaremaa, Estonia

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Abstract. Late Pridoli *Cruziana* traces have recently been found in carbonate shelf sediments of the Ohesaare Formation on Saaremaa Island, Estonia. *Cruziana* isp. is interpreted here as a locomotory trace (repichnia) of an arthropod, possibly a trilobite. *Cruziana* traces previously known from the Silurian of Baltica differ from *Cruziana* isp., indicating that the diversity of *Cruziana* traces in the late Silurian of Baltica was higher than previously thought.

Key words: trace fossils, Late Silurian, carbonate platform, *Cruziana*, trilobites, Baltica.

INTRODUCTION

Trace fossils of the Silurian of Estonia and the eastern Baltic in general are poorly studied. A few reports are devoted to borings in the hard substrates of the Silurian of Estonia (Vinn & Wilson 2010a, 2010b). Even less is known about the softground substrate trace fossils. Only *Skolithos* burrows have previously been described from the late Pridoli of Saaremaa (Vinn & Wilson 2013). However, Silurian rocks of Estonia are rich in trace fossils, which are usually mentioned as worm traces and bioturbation in the geological literature (Kaljo 1970).

Ichnospecies of *Cruziana* are typically associated with shallow-water marine facies (Seilacher 1985). *Cruziana* ranges from the lower Cambrian to the Triassic (Zonneveld et al. 2002; Metz 2013) and is both of stratigraphic (i.e. different ichnospecies of *Cruziana* have a different stratigraphic distribution; Magwood & Pemberton 1990) and palaeoenvironmental significance (i.e. different ichnospecies of *Cruziana* have a different facies distribution; Seilacher 2007). On the basis of their age and co-occurrence with the body fossils of the probable trace-maker, most of Palaeozoic *Cruziana* traces have been attributed to trilobites (Seilacher 1970), but some *Cruziana* are considered as produced by aglaspidids (Fischer 1978), brachiopods (Bromley & Asgaard 1979), as well as vertebrates (Shone 1978). In contrast, *Cruziana problematica* has often been found from non-marine sediments and was produced by other arthropods than trilobites (e.g. Bromley & Asgaard 1972; Trewin 1976; Pollard 1985).

The *Cruziana* ichnofauna was less diverse in the Silurian than in the Cambrian or Ordovician. Silurian *Cruziana* traces have mostly been restricted to specific palaeogeographic regions and localities (Seilacher 2007). *Cruziana kufraensis* has been described from Lower Silurian rocks of Libya and *C. acacensis* from the Lower Silurian of North Africa and South America (Seilacher 2007). *Cruziana pudica* has a wide distribution in the Upper Ordovician and Lower Silurian of North America (Garlock & Isaacson 1977; Seilacher 2007). Records of *Rhusophycus pudicum* and *Rhusophycus pudica* should presumably also be included in *C. pudica*. The Upper Silurian sections contain *Cruziana quadrata* in North Africa, *C. pedroana* in North Africa and Spain and *C. retroplana* in Spain (Seilacher 2007). In contrast to the Silurian, in the lower Palaeozoic several *Cruziana* species had a global distribution (Seilacher 2007).

The record of *Cruziana* traces in the Silurian of Baltica is poor. No *Cruziana* traces have previously been reported from the Silurian of Estonia and the eastern Baltic. Rare late Pridoli *Cruziana* traces have recently been found from the Ohesaare cliff on Saaremaa Island, Estonia, and are described here.

The aims of the paper are to (1) describe *Cruziana* traces from the Silurian of Estonia and the eastern Baltic for the first time, (2) interpret the ethology of the trace-maker and (3) discuss the palaeobiogeographic distribution of *Cruziana* traces in the Late Silurian.

GEOLOGICAL BACKGROUND AND LOCALITY

An epicontinental basin covered most of the area of Estonia in the Silurian. During the Late Silurian the Baltica palaeocontinent was located in equatorial latitudes

and was drifting northwards (Cocks &Torsvik 2005). A wide range of tropical environments and diverse biotas characterized the Silurian Baltic palaeobasin (Hints et al. 2008). Five main facies belts have been recognized in that basin: tidal flat/lagoonal, shoal, open shelf, basin slope and a basin depression (Nestor & Einasto 1977). The first three facies belts comprise a carbonate platform succession (Raukas & Teedumäe 1997). The rocks exposed at the Ohesaare cliff mostly represent the open shelf facies belt, but the upper part of the section, which formed during a considerable shallowing event (Hints et al. 2008; Vinn & Wilson 2013), represents the shoal facies belt.

The Ohesaare Cliff (58°00′02″N, 22°01′10″E) is located on the western coast of the Sõrve Peninsula of southwestern Saaremaa Island (Estonia) near Ohesaare village (Fig. 1). The cliff is over 600 m long and up to 4 m high (Fig. 2). On average, about 3.5 m of bedrock is exposed. The thicknesses of individual beds (lenticular and slightly wavy) vary throughout the outcrop (Nestor 1990; Hints et al. 2008; Vinn & Wilson 2013). The Ohesaare section is characterized by the intercalation of thin-bedded limestones and marlstones of normal marine shelf origin (Fig. 2; Vinn & Wilson 2013). Only one *Cruziana* specimen was collected from the section. The other two specimens were obtained from loose material. The beds with rare *Cruziana* traces are situated in the upper part of the cliff below the hardground (Figs 2, 3; for description see Vinn & Wilson 2010b). The *Cruziana* traces were found in the beds of open shelf origin where they occurred as hyporelief along bed junctions. The bed surface with *Cruziana* has a wavy relief.

The figured specimens are deposited at the Geological Museum, Museum of Natural History, University of Tartu (TUG). Their collection number is 1670.

SYSTEMATIC ICHNOLOGY

Ichnogenus *Cruziana* d'Orbigny, 1842
Cruziana isp.
Figure 4

Material. One long trace and two short traces.

Locality. Ohesaare cliff, Saaremaa, Estonia (Figs 2, 3).

Stratigraphy. 0.55 m from the top of the Ohesaare cliff, Ohesaare Formation, upper Pridoli, uppermost Silurian.

Notes. The longest, bilobate trace is up to 23 cm long. It is characterized by well-developed relatively deep linear scratch marks on both sides of the wide median groove. The median groove is about 1/3 as wide as the trace. Scratch marks form a V-shaped pattern. The angle between scratch marks and the median groove is 42–44 degrees. Six to seven scratch marks per 10 mm occur on both sides of the trace. The scratch marks are 0.5–0.7 mm deep. The trace has variable width and can be divided into sectors with increasing diameter (in one specimen). The minimum width of the trace is 6.0 mm and the maximum width is 11 mm. The scratch marks are less developed in the widest parts of the trace.

Remarks. The specimens described here resemble *Cruziana pudica* because of their somewhat similar V-shaped scratch marks pattern. However, *Cruziana* isp. has a more V-shaped scratch marks pattern than *C. pudica*. It also has a wider median furrow and lower relief than *C. pudica*. It is possible that these *Cruziana* isp. traces may belong to a new ichnospecies.

DISCUSSION

Cruziana isp. of the Ohesaare Formation is interpreted here as a locomotory feeding trace (repichnia), presumably formed by an arthropod which excavated sediments by scarping its endopodites towards its midline. During this movement the trace-maker may have filtered food from the disrupted sediment (Seilacher 1985, 1990, 1994). Ohesaare *Cruziana* may have formed as a surface furrow, since it occurs on a bedding plane. This is an unusual example as it was found on the sole of a limestone bed, while mostly *Cruziana* occur on the soles of sandstones. This is because sand has cast the bottom of the furrow during a sedimentation event such as a storm. It is known that sedimentation, particularly in shelf settings, appears to enhance the preservation of shallow-tier and interface structures such as *Cruziana* (Crimes 1975). Three sections of the trace with an increasing diameter are interpreted here as episodes of faster movement of the trace-maker separated by two episodes of rest or slower movement. During the initial phase or episode of movement the trace-maker probably moved higher above the bottom and was less in contact with the sediment (the narrowest part of the trace). At the end of the moving episode the trace-maker dug deeper into the sediment. The widest part of the trace at the end of the movement was presumably left by the head shield of the trace-maker, because the shape of that part of the trace resembles the shape of the trilobite head shield.

Trilobites were the most likely *Cruziana* trace-makers in the Palaeozoic (Seilacher 2007). They also are the most common fossilized arthropods in the Ohesaare Formation. Several trilobites of the Ohesaare Formation, such as *Calymene*, had a suitable body size for the *Cruziana* isp. traces. The trilobite fauna of the Ohesaare

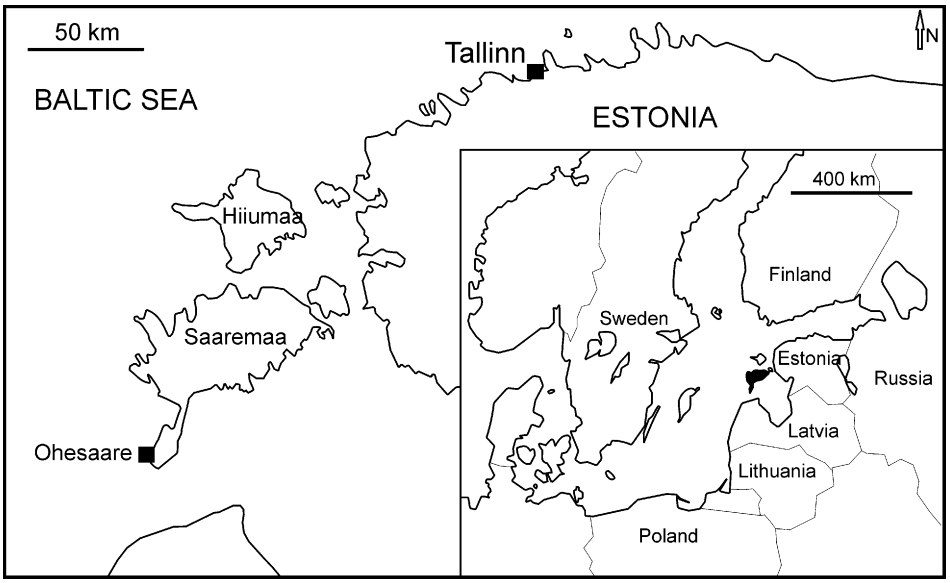

Fig. 1. Location of the Ohesaare cliff with *Cruziana* traces.

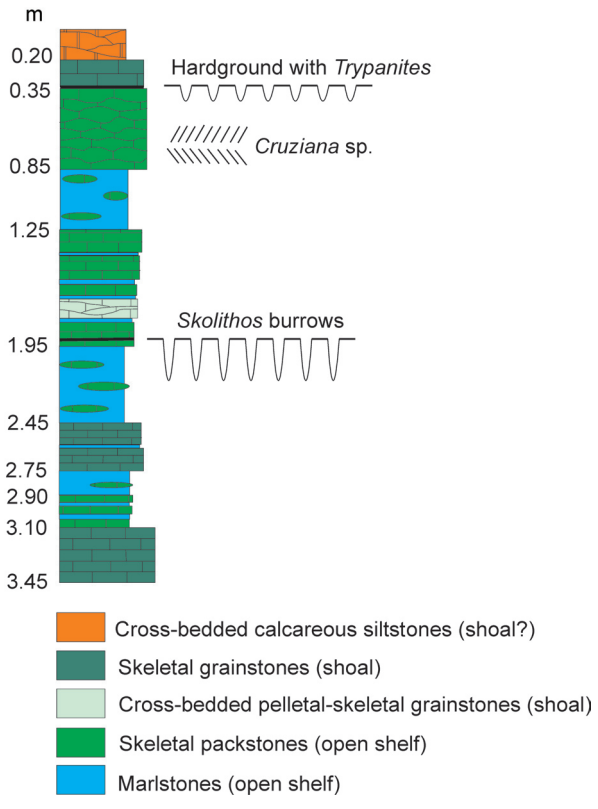

Fig. 2. Section of the Ohesaare cliff, Pridoli, Late Silurian (Modified after Vinn & Wilson 2010b).

Formation includes *Proetus conpersus*, *Calymene blumenbachii*, *C. conspicula*, *C. laevigata*, *C. soervensis* and *Acaste dayiana* (Kaljo 1970; Hints et al. 2008). The

Fig. 3. Ohesaare cliff. The arrow points to beds with *Cruziana*.

most common trilobites at the Ohesaare cliff locality are *Calymene conspicula*, *C. soervensis* and *Acaste dayiana* (Hints et al. 2008).

The occurrences of *Cruziana* drop off after the Ordovician, due to changes in global diversity (Seilacher 2007). The highest diversity of Silurian *Cruziana* traces is associated with North Africa and Spain (Seilacher 2007). Most of the Silurian *Cruziana* traces have been found in Gondwana (Seilacher 2007). *Cruziana pudica* had a slightly wider distribution in the Early Silurian (Garlock & Isaacson 1977; Seilacher 2007). The diversity and stratigraphic distribution of *Cruziana* traces are poorly understood in the Silurian of Baltica. There are

Fig. 4. *Cruziana* isp., Pridoli, Ohesaare Formation, Saaremaa. Scale bar division = 1 cm. TUG 1670-1.

records of two types (A and B) of *Cruziana* traces from the Late Silurian of Norway (Davies et al. 2006). Both of these traces differ from *Cruziana* isp. of the Ohesaare Formation, indicating that the diversity of *Cruziana* traces in the Late Silurian of Baltica was higher than previously known.

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Cruziana jäljed Saaremaa Hilis-Siluri (Pridoli) karbonaatse šelfi setenditest

Olev Vinn

Ohesaare pangalt leiti hiljuti haruldased *Cruziana* jäljed. Need on ebatavalised, kuna ei esine liivakivis, vaid lubjakivikihis. *Cruziana* isp. kujutab endast tõenäoliselt lülijalgsete, arvatavasti trilobiitide toitumisel jäetud jälge. Varem Baltika ürgmandri Silurist teada olevad *Cruziana* jäljed erinevad Ohesaarest leitutest. Baltika Siluri *Cruziana* jäljed võisid olla mitmekesisemad, kui varem arvati.