

# *DICTYOCARIS*, SALTER, A LARGE CRUSTACEAN FROM THE UPPER SILURIAN AND DOWNTONIAN

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(WITH 4 TEXT-FIGURES AND 3 PLATES)

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## Introduction.

Certain facies of the Upper Silurian and Downtonian series have very characteristic fossils consisting chiefly of fish and eurypterid remains. Typical marine organisms are not found in these beds, but in addition to the mentioned groups often occur lamellibranchs, and crustaceans of the order Phyllocarida (=Archeostrata). From British localities, particularly, a number of different species of phyllocarids have been described from well preserved specimens often showing both carapace and the jointed abdomen.

For a long time it has been known that several beds of the Upper Silurian and Downtonian of Scotland contain great quantities of a very peculiar fossil which appear as thin films with a distinct reticulate surface ornamentation. Salter (1860) introduced the new generic name *Dictyocaris* for fossils of this type which he explained as remains of a "giant Phyllopod" with a carapace measuring frequently from 9 inches to a foot in length.

Unfortunately the *Dictyocaris* remains only consisted of irregular fragments which did not offer a possibility of a distinct determination of its zoological position. Jones and Woodward (1888—99, p. 5) in their monograph on British Palaeozoic Phyllocarida, mention *Dictyocaris* as a form of doubtful alliance. Dr. Smith Woodward suggested

it might represent fragments of the exoskeleton of ostracoderm fishes (Campbell 1913, p. 932). The basal layer in the armour of Pteraspidian fishes exhibits a similar reticulation. Dr. Traquar, on the other hand, found this explanation less probable. *Dictyocaris* was even regarded as plant remains by certain authors, an explanation which was denied by Dr. D. H. Scott who received specimens for determination. In spite of the large number of collected specimens the nature of the enigmatic fossil *Dictyocaris* remained unsolved and it had to be listed as one of the many "*incertae sedis*". In a recent comprehensive study of the Phyllocarida, Gürich (1925, p. 63—64) does not find it possible to take a standpoint as to the nature of the genus.

New interest was attributed to the genus after the discovery of *Dictyocaris* in two different regions of Norway, and in a new locality in Scotland. *Dictyocaris* appeared to be a guide fossil for the Downtonian and its occurrence in post-Caledonian sediments of Scotland and Norway was therefore of considerable importance.

In 1909 the late Professor Johan Kiær discovered a very rich and well preserved fossil fauna in the Downtonian sandstone of Rudstangen, Ringerike, Norway. A preliminary report of the fauna which consists of ostracoderms, merostomes and *Dictyocaris* was given by Kiær in 1911. More recently the anaspids were described by Kiær (1924) and the merostomes by the present writer (1934 a). The *Dictyocaris* remains occur in great abundance in the fossiliferous beds. Nearly a thousand pieces have been listed and the number of specimens far exceeds the number of the most common eurypterid *Hughmilleria norvegica*. Professor Kiær very kindly offered me the *Dictyocaris* material for description. The original scheme of the present paper was to describe this material only, but a closer study of the Norwegian specimens and the literature concerning the genus convinced me on the general interest attached to the genus and for these reasons I found it necessary to redescribe some of the earlier collections and to attempt to get the opportunity of studying more recent finds of *Dictyocaris* remains. By studying the various collections and the statements given in the literature as to the stratigraphical occurrence of the different species, I hoped to be able to solve the following questions: 1. the zoological position of *Dictyocaris*, and 2. the stratigraphical range of the different species and their value as guide fossils in determining the age of the Caledonian folding.

In addition to the Rudstangen material, I have described the *Dictyocaris* fauna found by Dr. Hans Reusch in post-Caledonian beds of Hitra off the west coast of Norway, a fauna preliminarily dealt with by Kiær (Reusch 1914).

Dr. Robert Campbell of Edinburgh University has very kindly permitted me to describe the invertebrate fossils found by him (Campbell 1913) in the post-Caledonian beds of Stonehaven, Scotland. *Dictyocaris* is the common fossil in the fauna which also contain eurypterids evidently identical with the leading form of Rudstangen.

I wish to express my thanks to Dr. Campbell also for having read the manuscript.

Through the courtesy of Dr. J. Pringle I have borrowed for description to specimens of *Dictyocaris* from the Geological Survey Museum in Edinburgh.

From the Geological Survey in London I have with the kind permission of Sir John Flett borrowed a larger collection of *Dictyocaris* specimens. Dr. C. J. Stubblefield very kindly selected the collection which also contains some of Salter's types.

Professor O. Holtedahl has permitted me to study some specimens which he collected in Scotland.

Mr. W. W. King has given to me a fragment of *Dictyocaris* which he found in the Downtonian beds of West Midlands in England. I wish to express to him my gratitude also for valuable information with regard to the stratigraphy of the early Downtonian of England.

An American occurrence of a *Dictyocaris*-like fossil is also mentioned in the following account. Dr. Ruedemann offered me valuable assistance in studying the fossils from the Shawangunk grit of New York State.

### General Description of the Genus.

The shape of the carapace. In his original description of the genus Salter (1860, p. 161) pointed out the subtriangular outline of the carapace. The posterior outline particularly was marked by a strong marginal furrow. Text-fig. 1 c shows the holotype of *Dictyocaris ramsayi* Salter (1861, pl. II, fig. 20). A marginal rim is distinct in the ventral part, but at the posterior border several lines parallel to the border have not the characteristics of a marginal furrow. Studying the material from the same locality I noticed one specimen

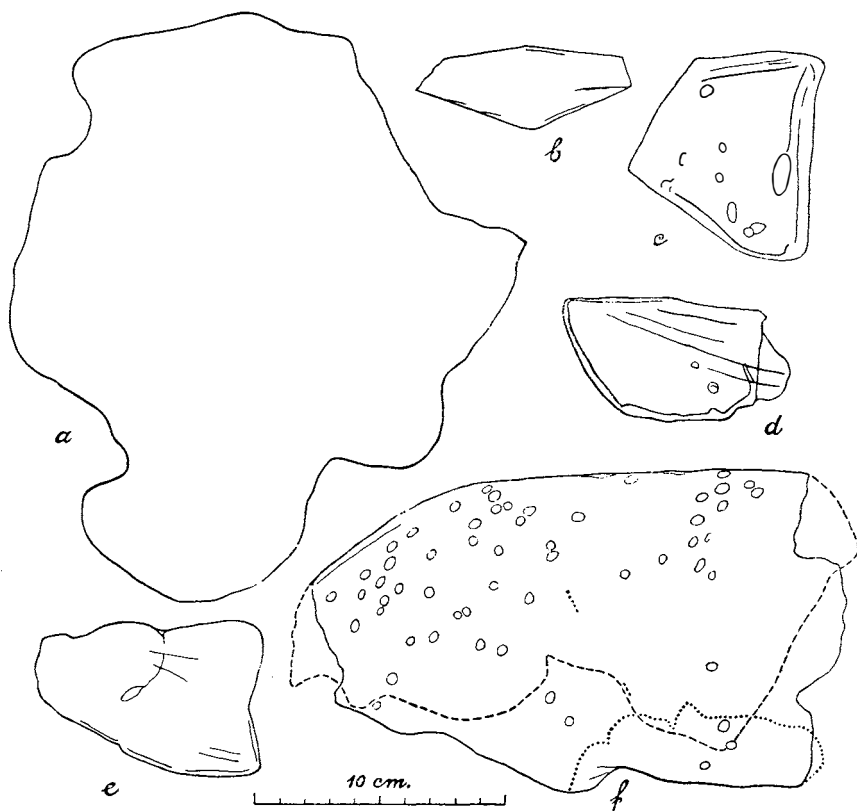


Fig. 1. Outlines of Scottish specimens of *Dictyocaris slimoni*, Salter (a—b, f) from Downtonian (?) sandstone of Logan Water, Lesmahago and *D. ramsayi*, Salter (c—e) from Wenlockian sandstone of North Esk Reservoir, Pentland Hills. c = original of Salter (1861). In fig. f the broken line marks the outline of the right side of the carapace and the dotted line the bent left side. All specimens from the Geol.

Survey Museum in London. Catalog Nos: a = 53429, b = 53433,

c = 7483, d = 53414, e = 53415, f = 53431.

(text-fig. 1 d) which apparently had a very distinct marginal rim, but by following the margin along the border it left the margin and continued at a length of 1,5 cm towards the central part of the carapace. Other specimens from the same locality (No. 53 413) show the same 2 mm wide rims crossing the carapace. The presence of actual marginal rims is therefore very doubtful.

The Norwegian material demonstrates how the "marginal rims" in many cases are nothing but secondary lines of fracture along which the carapace was broken easily into fragments. Pl. II, fig. 1 shows

several lines crossing the carapace. Similar lines are also found on the counterpart showing also other side of the carapace. The lines do not show a regular arrangement and can therefore hardly represent primary lines like those found on the carapace of many decapods. Several specimens show very clearly how the carapace is broken off along one of the broader lines which remain and might be mistaken for natural borders. Pl. II, fig. 4 has both sides of carapace, and at the left side a false border is visible.

For these reasons it is not possible to determine the outline from the "marginal" rims. It is very peculiar that in spite of the rather good preservation indicated by the reticulation of the test, not a single one of the more than a thousand specimens from Norway and Scotland is complete. The outlines of the specimens are very different and may attain even the shape of narrow long pieces. The convex surface of carapace is indicated in the *Dictyocaris ramsayi* material (Salter's type) and in the well preserved Norwegian Rudstangen material of *D. Slimoni*.

In order to obtain a fairly correct impression of the outline of the carapace, I have studied a large number of specimens and outlined on text-figs. 1 and 2 some of the most complete specimens from Scottish and Norwegian localities. Some of the largest specimens (1 *a*) form only irregular patches without any distinct shape. If we compare most of the other specimens, however, we notice a certain uniformity in shape. At least one side is fairly straight and the outline is sub-triangular as pointed out by Salter. Generally it seems possible to distinguish right-sided (text-fig. 2 *a—d*) and left-sided specimens of the carapace. The specimen on pl. I, fig. 1 and text-fig. 2 *h* seems to present a nearly complete outline of the carapace according to the impression obtained from a large number of specimens. The well preserved carapace on pl. I, fig. 2 and text-fig. 2 *o*, has also a sub-triangular outline, but is more narrow probably because the test is crumpled together. According to the figures the two posterior angles appear to be about equal. Each side of the carapace forms hence an isosceles triangle. Fig. 2 *n* indicates that the rostral position was pointed. The posterior border was probably more rounded. Text-fig. 2 *j* shows possibly the posterior outline which has a slight concavity. The specimen H 1261, text-fig. 2 *d*, which was figured by Kiær (1924) does not have the anterior portion preserved. In several specimens the dorsal line is secondarily concave.

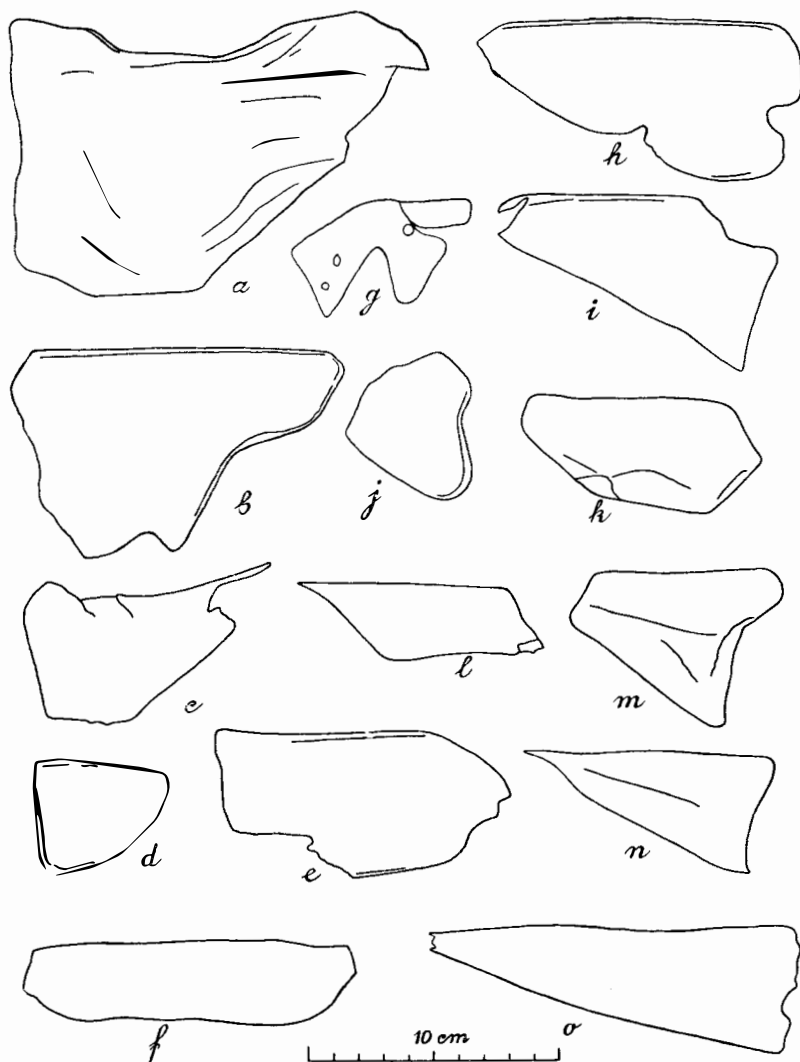


Fig. 2. Outlines of Norwegian specimens of *Dictyocaris slimoni* Salter and *D. s.* var. *tuberculata* n. var., (d), from Downtonian sandstone of Rudstangen, Ringerike. Both sides of the carapace are preserved in specimen on fig. k, and indicated in those on fig. b, e, i, j, l, n and o (not marked in the drawings). Specimens collected by Kiær and belong to the Paleont. Museum Oslo collection. Catalog Nos: a = H 2074, b = H 2159, c = H 2070, d = H 1261, e = H 2063, f = H 1357, g = H 2149, h = H 1147, i = H 2143, j = H 2077, k = H 1260, l = H 2147, m = H 2098, n = H 1503, o = H 2095.

As pointed out by Salter the carapace of *Dictyocaris* is not bivalved as in *Ceratiocaris*, but consists evidently of one continuous shield bent along a dorsal line and thus forming a right and left side as suggested from the outlines. In many specimens it has been possible to study both sides of the carapace. The great carapace demonstrated on text-fig. 1 *f*, has both sides preserved, the right side is shown by the broken line and the dotted line shows how the left side of the carapace is bent over again. Among the Norwegian specimens some (text-fig. 2 *k*, *l*) have both sides equally preserved even when the outline is rather aberrant.

**Remains of body-segments.** During the preparation of the Norwegian material I succeeded in excavating one specimen (pl. II, fig. 3 and text-fig. 3) which has some body-rings preserved. Parts of both sides of the carapace are preserved and the two sides meet at a straight dorsal line. The characteristic reticulate surface of the test is not preserved, but yet there can be no doubt that the specimen represents *Dictyocaris*. As shown in the illustrations the lower half of one side of the carapace carries the imprint of four segments. The two to the left are preserved a little (1 mm) below the surface of the carapace. The segments are separated from each other by three distinct transverse joints. The width of the segments is more difficult to establish, but according to the counterpart it was slightly broader than on the photographed specimen, and the two segments to the right might also have been wider, as suggested by the dotted line in the text-figure. The segments which have a rectangular outline evidently represent body-rings of the abdomen, body-rings of the type found among the phyllocarids.

In addition to these segments four others occur which evidently belong to the same specimen. One has a trapezoid outline and might possibly represent one of the body-rings or part of it. The three remaining are of another type and their distinct outline seems to exclude the possibility that they are the ventral part of the other side of the body-rings. The nature of these elongate segments (the left one is incomplete) is uncertain, but since they are separated by distinct joint-lines they hardly belong to caudal appendages or styles, and may possibly form fragments of appendages.

**The test and its sculpture.** The test of *Dictyocaris* is always preserved as thin films and a microscopic thin section is

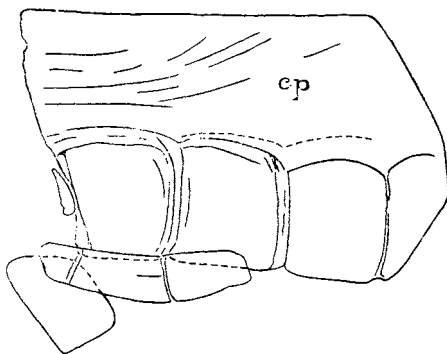


Fig. 3. *Dictyocaris slimoni* (?) Salter. Specimen showing body-segments inside the carapace (cp). (Comp. pl. II, fig. 3). Nat. size. No. H 2117 of the Pal. Mus. Oslo Coll. Excavated from material collected by Kiær in Downtonian Sandstone of Rudstangen, Ringerike, Norway.

therefore unable to demonstrate any shell structure. On account of the considerable size of the remains it is very unlikely that the thin films represent the original thickness of the crustacean shell. Since the *Dictyocaris* remains generally are preserved in sandstones and grits, it is possible that an originally calcareous shell was dissolved before or during the diagenesis. Vertebrate remains maintaining more or less the original thickness of the exoskeleton are often associated with the *Dictyocaris* faunas and it is therefore possible that a selective diagenesis had taken place as pointed out by

Richter (1931) for the Devonian Hunsrück shale in Germany and by the present author (1934 *b*) from the Downtonian of Spitsbergen.

The *Dictyocaris* remains, which are often found together with complete specimens of other organisms, always occur as fragments generally devoid of the original borders demonstrating the outline of the animal. This might be due partly to a dissolution of the test during the diagenesis. But the fact that so many of the studied specimens have a strongly crumpled test which might be bent as e. g. in the specimen text-fig. 1 *f*, suggest that the test was thin even before the imbedding in the sediment. The most reasonable explanation of this seems to be that the calcareous shells remained uncovered for some time on the bottom, and the fresh or brackish water (which has a greater ability than salt water in dissolving lime) succeeded in dissolving and destroying parts of the shells, a process which was completed later during the diagenesis.

The characteristic reticulation of the test in *Dictyocaris* is preserved in most cases. The Rudstangen material demonstrates clearly the transition between well preserved specimens (pl I, fig. 2) and those in which the reticulation is partly or completely lost on account of a less favourable preservation (pl. I, fig. 1). The most common reticulation consists of narrow rims or ridges bordering five or six-sided



polygonal areas. Salter assumed that the raised ridges occurred on the inside of the test, the presence of a small *Beyrichia* on the inside of the test of one of Salter's types (pl. III, fig. 12) might have led to this assumption, but the Norwegian specimens have shown clearly (pl. III, fig. 4) that they are present on the outer surface. The constancy of the size (0,8 mm in width) of the polygonal areas is rather remarkable. The reticulation seems therefore to be the same at different growth stages. Since only one type of reticulation may be found among numerous specimens of a fauna, it is also probable that the reticulation is the same on different parts of the same arthropod. The typical polygonal reticulation is shown on the specimens depicted on pl. I, figs. 1—2, pl. II, figs. 1, 2, 4, 8, 9, and pl. III, figs. 6, 10, 12, 13.

In the Rudstangen fauna, where practically only the ordinary type of reticulation is found, I noticed one specimen (pl. II, fig. 2). which deviates from the ordinary type in having a small tubercle in the centre of each polygonal area. Also a single specimen with elongate meshes (pl. II, fig. 6) was noticed which points to the older type of reticulation characteristic of the Wenlockian species.

The characteristic Wenlockian species described by Salter as *Dictyocaris ramsayi*, has not according to the present, rather badly preserved material a reticulated surface, but an ornamentation consisting of broader ridges separated by smaller circular or elongate depressions (pl. III, fig. 8). This sculpture is found on convex carapaces and therefore evidently represent the outer surface of the test.

From the same region in Scotland, and probably the same horizon another type of reticulation was found which is shown on pl. III, fig. 9. The fragments do not show which is the upper surface of the test, but a comparison with the common *Dictyocaris slimoni* indicates that narrow raised ridges form the ornamentation. *D. slimoni* (pl. III, fig. 9) occurs with it and certain specimens show a tendency to form regular polygonal areas. Nevertheless I have found it appropriate to erect a new species since the characteristic meandering reticulation is never found along with the other common *slimoni*-faunas.

A tendency to form elongate rounded meshes is noticed as an exception among the later faunas. Pl. II, fig. 6, pl. III, figs. 7, 10, 11 demonstrate structures which must be regarded as belonging to *D. slimoni* in spite of the slightly irregular reticulation.

The fossil specimens of *Dictyocaris* often show peculiar circular holes in the test. Specimens both from Scotland and Norway (text-

figs. 1 *c—f*, 2 *g* and 4 *g*) exhibit these openings, generally 3—5 mm in diameter. They are found only in bodily preserved specimens, and it is not possible to decide whether they were made by borrowing invertebrates or are due to other causes.

**Zoological position.** The large number of specimens of *Dictyocaris* which has been available for the present study has corroborated the opinion of Salter of the phyllocarid nature of the genus. The carapace consists of one symmetric shield bent along a straight dorsal line and each side of the carapace has in lateral view a subtriangular outline. Remains of body-segments have been found on the inside of the carapace. The common Silurian genus *Ceratiocaris*, which accompanies *Dictyocaris* in certain faunas, has a bivalved carapace and therefore belongs to another suborder although the general outline and size of the carapace is not very different in many of the species. The Cambrian (and Ordovician?) genus *Hymenocaris* has a carapace bent along the back and resembles in shape also the present genus. The difference in age, size and sculpture denies a closer relationship, but with our present knowledge it seems natural, as did Salter, to place them in the same group of the order Phyllocarida, the suborder Hymenocarina according to the classification applied by van Straelen and Schmitz (1934) in the Fossilium Catalogus.

A reticulation of the test is found in many different Paleozoic arthropods. It occurs in trilobites such as *Wanneria* and *Tretaspis*, and in the latter it has been possible to show that it evidently comprises a supporting structure where the test is especially thin such as on the glabella (Størmø 1930, p. 104). Among crustaceans reticulate structures have been described rather commonly in ostracods and phyllocarids. The Cambrian *Tuzoia* (Resser 1929) and the Silurian *Emmelzoe* (Clarke 1900) show an approximate *Dictyocaris* ornamentation. Of interest in this connection is the undetermined phyllocarid described by Klohn (1928, p. 285) from the Carboniferous of Germany. In spite of its small size it resembles *Dictyocaris* in having on a small scale the same kind of reticulation.

The comparison has shown that *Dictyocaris* known through numerous remains from Silurian and Downtonian beds, evidently was a big crustacean belonging to the order *Phyllocarida* as originally suggested by Salter.

**Classification.** The material is too incomplete to allow a closer determination of the relationship to other phyllocarids. As above mentioned it seems in accord with our present knowledge to include the genus provisionally in the suborder Hymenocarina and leave to judge from future studies whether it belongs to a new family or the one already established. In the following a diagnosis of the genus is presented. With regard to species and varieties the difference in reticulation has suggested the presence of those presented below. The reticulation alone might seem insufficient as a specific character, especially when we know that phyllocarids such as *Emmelzoe* have a decidedly different ornamentation on the carapace and abdomen, but on the other hand the occurrence of the various types in separate faunas and the lack of continuous transitions between the different types of ornamentation seem to justify the creation of several species. In the following only the original descriptions are listed, a complete list of papers in which *Dictyocaris* is mentioned is given by van Straelen and Schmitz (1934) and a recent by Campbell (1935) has to be added.

## Order *PHYLLOCARIDA* Packard.

### ? Suborder *Hymenocarina* Clarke.

#### Genus *Dictyocaris* Salter.

1860. Genus *Dictyocaris*, J. W. Salter. Ann. Mag. Nat. Hist. Ser. 3, 5, pp. 161—162.

**Diagnosis.** Carapace large, consisting of one continuous shield bent along a straight dorsal line. Outline in lateral view sub-triangular with anterior angle about 30 degrees and post-dorsal nearly 90 degrees. Outline not known in detail. Length of carapace up to 23 cm, one fragment 33,3 cm. Body-rings apparently narrow. Test with distinct ornamentation, varying from regular polygonal areas bordered by raised rims to broader ridges separating narrow depressions.

Upper Llandoveryan-Downtonian ..... Scotland,  
England, Norway and North America (?).

*Dictyocaris slimoni* Salter.

Pl. I fig. 1, 2; pl. II fig. 1—4, 6, 8, 9; pl. III fig. 6, 7, 10—13;  
text-figs. 1 *a—b*; 2 *a—c*, *e—o*; 3; and 4 *g*.

1860. *Dictyocaris slimoni*, J. W. Salter. Ann. Mag. Nat. Hist. Ser. 3, 5, p. 162, fig. 2—4.

1861. *Dictyocaris slimoni*, J. W. Salter. In H. H. Howel a. A. Geikie. The Geology of the Neighbourhood of Edinburgh (Map 32). Appendix. — Mem. Geol. Surv. Gr. Brit. 32, Scotland, Pl. II fig. 20 *b—c*.

**D i a g n o s i s.** Carapace and body-rings as in generic diagnosis. Test with distinct reticulation consisting of raised narrow rims or ridges bordering level 5—6-sided polygonal areas. Diameter of meshes rather constant with an average of 0,8 mm. In certain cases the areas may be somewhat elongate.

Upper Llandoveryan(?)—Downtonian ..... Scotland,  
England and Norway.

**L e c t o t y p e.** No. 7482 (pl. III, fig. 12) Coll. Geol. Surv. Great Britain Museum London. From upper Ludlowian or Downtonian of Logan Water, Lesmahagow, Lanarkshire, Scotland. In his two papers describing *Dictyocaris* Salter (1860, 1861) presents drawings of the carapace and surface reticulation. In the former three specimens of the genus are figured without specific determination, while in the later publication one of the specimens, the carapace (l. c. pl. II, fig. 20) is referred to as *D. ramsayi* and the details of test (fig. 20 *b—c*) not referred to species. The Geol. Survey Collection contains three specimens marked as originals. One is easily identified as the type of *D. ramsayi* (1861, pl. II, fig. 20), and evidently also fig. 1 from 1860 which has the same structure and outline although it is reversed. Of the two others (pl. III, figs. 11, 12) the one with the low catalogue number and the regular reticulation seems to have been the type of figs. 2 and 3 (1860) and 20 *b* (1861). Whether the two remaining figures represent the counterpart of this or belong to the other marked specimen, is not possible to decide.

*Dictyocaris slimoni* Salter, var. *tuberculata* n. var.

Pl. II fig. 5, text-fig. 2 *d*.

1924. *Dictyocaris* sp. J. Kiær. Vidensk.-Selsk. Oslo Skr. I. M.-N. Kl. 1924. No. 6, text-fig. 6.

**D i a g n o s i s.** Reticulation of test consisting of regular polygonal areas with diameter about 1 mm and with a central tubercle or elevation.

Downtonian. .... Norway.  
 H o l o t y p e. No. H 1261, Coll. Pal. Mus. Oslo. From Downtonian, Rudstangen, Ringerike, Norway.

*Dictyocaris ramsayi* Salter.

Pl. III fig. 8, text-fig. 1 c—f.

1860. *Dictyocaris ramsayi* J. W. Salter. Ann. Mag. Nat. Hist. Ser. 3, 5, p. 162, fig. 1.  
 1861. *Dictyocaris ramsayi* J. W. Salter. In H. H. Howel a. A. Geikie: The Geology of the Neighbourhood of Edinburgh (map 32). Appendix. Geol. Surv. Gr. Brit., Scotland. Pl. II fig. 20.

D i a g n o s i s. Carapace as in generic diagnosis. Test ornamented with small circular of elongate, more or less curved, depressions between broader raised ridges.

Wenlockian-Ludlowian? ..... Scotland.

L e c t o t y p e. No. 7483 (text-fig. 1 c) Coll. Geol. Surv. Gr. Brit. Museum London. From Wenlockian (?) of North Esk Reservoir, Pentland Hills, Scotland. (Salter's types discussed under *D. slimoni*).

*Dictyocaris salteri* n. sp.

Pl. III fig. 9.

D i a g n o s i s. Outline of carapace unknown. Surface of test, or counterpart of it, ornamented with narrow raised ridges bordering elongate meandering depressions with an average width of 0,9 mm.

Wenlockian. .... Scotland.

H o l o t y p e. No. A 17248 (pl.III, fig.9) Coll. Pal. Museum Oslo. From Gutterford Burn, Pentland Hills, Scotland.

## Geological Distribution.

Remains referable to the genus *Dictyocaris* have been found in Scotland, Norway, England and probably also in North America. In the following the different occurrences are mentioned as far as possible in stratigraphical sequence. In the last part of the chapter the facies of *Dictyocaris* and the vertical distribution of the species and the relation to the Caledonian orogenesis is discussed. The information regarding the geological distribution has been gathered mainly from the monograph of Peach and Horne (1899) and the data collected by O'Connel (1916).

Llandoverian or early Wenlock. Peach and Horne (1899, p. 208) and O'Connel (1916, p. 128) mention the occurrence of fragments of *Dictyocaris* in the Tarannon series near the southern border of the Central Belt NE of Selkirk in Scotland. The fragments were found in: "grey-blue calmy shales and flagstones" probably of the Hawick series and were associated with a telson of *Eurypterus* and crinoid stems. The latter author discusses the connection between the Tarannon series and the Birkhill beds of England and concludes that the structural relation is that of a replacing overlap and the age therefore must be Llandoverian (probably upper). The terrestrial Tarannon sediments are regarded as delta deposits from rivers originating in the eastern Highlands according to Peach and Horne (l. c., p. 210).

The Shawangunk Grit of New York State bears resemblance to the above-mentioned formations of Scotland not only in age which was probably lower Silurian, but also in being alluvial fan formations. Besides a rich eurypterid fauna these beds have yielded some specimens which very probably belong to the genus *Dictyocaris*, although the surface ornamentation is not preserved.

Wenlock. In the Pentland Hills, Scotland, the lower Wenlockian is developed as graptolite shales containing *Monograptus priodon*, *M. vomerinus* and *Retiolites geinitzianus* (Jones 1929, p. 107). At Gutterford Burn the beds have also yielded a rich fauna of eurypterids, a fauna which besides these fossils also contained a very large amount of fragments of *Dictyocaris ramsayi* and a single specimen of a scorpion and xiphosuran. The fossils occur in "an irregularly fissile fine-grained sandstone, containing a considerable amount of carbonaceous matter distributed in thin layers" (Laurie 1892, p. 151). Although the fossil list includes several typical marine species it seems hardly probable, as strongly argued by O'Connel, that the eurypterid-*Dictyocaris* layers represent typical marine conditions. Evidently brackish or freshwater faunas alternated with marine.

Peach and Horne (1899, p. 591, 605) mention also some other occurrences in the Pentland Hills of *Dictyocaris ramsayi* or *D. sp.* in strata with apparently Wenlockian fossils. *D. slimoni* and *D. salteri* have been determined in material collected by Campbell and Høltedahl in the Wenlock of the Pentland Hills.

Ludlow and Downtonian. Lanarkshire and Pentland Hills have furnished numerous *Dictyocaris* remains from the strata at the transition between the Ludlowian and Downtonian. The most complete section is demonstrated at Lesmahagow, Lanarkshire where Peach and Horne (1899, p. 570—581) distinguished eleven divisions of which the lowest ones belong to the Ludlowian and the uppermost to the basal Old Red (Dittonian King), Div. 3, the *Ceratiocaris*-beds, has yielded *Dictyocaris ramsayi* together with *Beyrichia kloedeni*, *Platyschisma (Trochus) helicites* etc. in the blue greywackes and shales of Long Burn. From Div. 4, the *Pterygotus*-beds, both *D. ramsayi* and *D. slimoni* are listed in association with a number of eurypterids, viz: *Hughmilleria* (= *Eurypterus*) *lanceolata*, *Pterygotus bilobus*, *Slimonia acuminata*, *Carcinosoma* 3 sp. etc. The flaggy shales have also *Ceratiocaris papilio* and the other fossils mentioned for Div. 3.

In divs. 5—6 which are evidently closely connected with the preceding, the green shales, sandy mudstones and greywackes contains *Dictyocaris* sp. associated with *Beyrichia kloedeni*, *Platyschisma (Trochus) helicites* etc. Above Div. 6 a conglomerate (Div. 7) is found in certain localities. Div. 8 consisting of red and yellow sandstones, is succeeded by Div. 9, the Fish-beds, which includes the well-known "Downtonian fish-band". *Dictyocaris* sp. has been found associated with *Mixopterus* (= *Eurypterus*) *dolichoschelus*, *Pachytheca* sp. etc. and numerous fishes belonging to the genera *Lanarkia*, *Birkenia*, *Lasanius*, *Thelodus* and *Atelaspis*.

A quartzite-conglomerate (Div. 10) and chocolate-coloured sandstones (Div. 11), the latter containing *Cephalaspis lyelli* characteristic of the Dittonian (the base of the Old Red), finish the section.

Peach and Horne (1899, p. 576) regard the local conglomerate in Div. 7 as representing the oldest Downtonian. The age of the divisions has been subject to discussion. Stamp argued that the lowest zones should also be assigned to the Downtonian, while Jones (1929, p. 112) is inclined to, with our present limited knowledge of the distribution of the Silurian molluscs, to assign most of the divisions to the Ludlowian. Mr. W. W. King has kindly informed me that he is inclined to draw the border as Peach and Horne did. Dr. J. Pringle has also kindly expressed his opinion on the subject to me (Størmer 1934 a, p. 71) and mentions that he has found certain evidence of

a palaeontological break between Divs. 2 and 3, and correlates Div. 3 with the Ludlow Bone Bed of Shropshire.

For the present the age of the Lesmahagow divisions is not conclusively determined, but if the Div. 3 is equivalent to the Ludlow Bone Bed it seems natural to regard these beds either as the basal ones of the Downtonian (Jones 1929) or the top of the uppermost Ludlow, according to the division applied by King (1934).

In the Pentland Hills (Peach and Horne 1899, p. 599) the section is not very complete. The upper Ludlovian seems to be absent. The disconformity is marked by a band of red conglomerate above which we find a conformable red sandstone series. Above these sandstones *Dictyocaris* occurs in "green and blue shales and mudstones with bands of flaggy greywacke" evidently corresponding to Div. 9 of Lesmahago. Further up in the section *Birkenia*, *Lasanius* and *Atelaspis* are found. Between the Downtonian and the Lower Old Red Sandstone, there exists a complete discordance.

A very interesting post-Caledonian occurrence of *Dictyocaris* was discovered by Campbell (1913) at Cowie, Stonehaven south of Aberdeen. Numerous specimens of *D. slimoni* were found in "green and grey sandy mudstones and shales" which rest with a marked discordance on strongly folded and deeply eroded ? upper Cambrian rocks. Campbell (l. c. p. 934) points out that the presence of *Dictyocaris*, *Ceratiocaris* and a cyathaspidian fish (*Traquiraspis campbelli* Kiær), besides the lithological character of the sediments, show conclusively the Downtonian age of the Stonehaven beds. He points out the striking similarity between the Stonehaven fauna and the Rudstangen fauna discovered by Kiær in Norway.

Dr. Campbell has very kindly offered me the opportunity of describing the interesting fossil material. My studies (p. 292) have strongly corroborated the views presented by him. In addition to *Dictyocaris slimoni* occur specimens of a *Ceratiocaris* cf. *papilio* and an eurypterid which seems to be identical with the common *Hughmilleria norvegica* (Kiær) of Rudstangen and probably also identical with the small specimens of *H.* (= *Eurypterus*) *lanceolata* which accompanies *Ceratiocaris papilio* in the Div. 4 at Lesmahagow. The palaeontological evidence indicates strongly a basal Downtonian or possibly uppermost Ludlovian age for the Stonehaven fossils.

Recent detailed investigations of the Downtonian of England by King have among others also revealed a few specimens of *Dictyocaris*.



In the classical region of Shropshire, King (p. 295) has found a single specimen of *Dictyocaris slimoni* at the top of his stage I, 5 of the Downtonian, a find which establishes the presence of the species in the Middle Downtonian. The fragment occurred in a green mudstone, about 1380 feet above the upper Ludlow, and was associated according to information by Mr. King, with "*Pterygotus*, *Didymaspis grindrodi*, *Leperditia*, many scales, teeth and spines and jaws of *Ischnacanthus kingi*, *Modiolopsis complanata* var. *trimpleyensis*, *Leptodesma? downtonia*, *Grammaysia? anceps* and *Modiolopsis nilsoni*".

King (1934, p. 540) mentions also *Dictyocaris* from the lower Downtonian stage I, 2 in Freshwater Bay, Penibrokeshire, South Wales. In this stage was also found *Lingula minima*, *L. squamiformis*, *Orbiculoidea nitida?*, Acanthodian jaws and spines, *Pachytheca*, an eurypterid coxal joint, and fragments of cephalaspidae and *Pterygotus*. In this region the basal zone of the Downtonian (stage I, 1) rests with a clear unconformity on Ludlow Rocks. In Shropshire the basal stage rests on the Ludlow Bone Bed.

In Norway *Dictyocaris slimoni* occurs in great abundance in the bluish-grey fine sandstone of Rudstangen, Ringerike about 30 km NW of Oslo. A single specimen of the variety *D. s. tuberculata* has also been found. The rich and well-preserved fauna discovered and in parts described by Kiær (1911, 1924), consists of eurypterids and vertebrates belonging to the groups anaspida, thelodonti and cephalaspidae related to, but evidently not identical with the Scottish Downtonian species. The most common eurypterid, *Hughmilleria norvegica*, is perhaps identical with *H. (=Eurypterus) lanceolata* (comp. Størmer 1934 a, p. 90—91) of Div. 4 of Lesmahagow and the great *Mixopterus kieri* has its relative in *M. (=Eurypterus) dolichoschelus* in Div. 9.

The age of the Rudstangen is probably basal Downtonian or possibly uppermost Ludlow as indicated by Kiær (1931).

On the west coast of Norway Reusch (1914) made an important find of *Dictyocaris slimoni* in post-Caledonian dark, fine-grained sandstones at Balsnesaune on the island Hitra off the inlet of the Trondheimsfjord. The fossils were very rare and the specimens badly preserved, but it has been possible to determine the present species and establish the occurrence of several eurypterids (p. 289) probably of the genus *Hughmilleria*, but hardly the same as the Rudstangen form.

Like the Stonehaven series, with which the Hittra beds have been compared by several authors, the west Norwegian sediments rest on strongly folded and eroded older Palaeozoic rocks. On the neighbouring island Smøla Lower Ordovician fossils of Artie type, similar to those of Durness in Scotland, have been described by Høltedahl and Strand (1932) from the basement complex.

With regard to the age of the *Dictyocaris*-beds of Hittra, the present studies have affirmed the current opinion that these sediments are of Downtonian age. It is, however, also possible that they may belong to the Ludlow, but younger than Downtonian is very unlikely. In younger parts of the post-Caledonian series Vogt (1929) has found on islands further north *Psilophyton princeps* indicating typical Lower-Middle Devonian.

#### Conclusions on the Facies and vertical Range of *Dictyocaris*.

If we compare the various occurrences of *Dictyocaris*, it becomes apparent that a greater abundance of the species is found in green, grey or dark fine-grained sandstones and greywackes. These types of sediments are especially typical of the Scottish and Rudstangen (Norway) occurrences. As pointed out to me by Mr. King the almost complete absence of *Dictyocaris* in the fossiliferous Downtonian series of Shropshire and Wales is probably due to facies. In England the marls and silts constitute 84% of the sediments and this, probably in connection with a somewhat higher degree of salinity, evidently accounts for the absence of *Dictyocaris* in the central mud belt.

When judging the habitat of the genus we have to be cautious not to draw too definite conclusions from the faunal lists, which often include fossils from different layers in one series. It seems reasonable to assume as pointed out by O'Connell that the rich Wenlockian eurypterid fauna of Lesmahagow was fluviatile and had little to do with the marine species (graptolites) listed from the same group. According to the faunal lists *Dictyocaris* is often associated with ostracods, gastropods and lamellibranchs, indicating probably brackish water. Especially the faunas with ceratiocarids, eurypterids (in certain cases also scorpions and myriapods) and anaspid fishes suggest strongly brackish or fresh water conditions.

An alluvial habitat of *Dictyocaris* is indicated by the presence of specimens in the Shawangunk Grit (?) and the Tarannon which both have been regarded as alluvial delta deposits.

The typical *Dictyocaris*-occurrences have shown that the fossil is found in fine, not red, sandstones and grey wackes, in sediments deposited in lakes, rivers (or possibly lagoons and estuaries). This is of importance in determining the upper limit of the vertical distribution of the genus. Most of the Old Red sediments do not seem to furnish favourable conditions for the presence of *Dictyocaris*, but in certain cases the facies seems to have been the same. In Kincardineshire Campbell (1913) distinguishes several groups of the Lower Old Red Sandstone above the basal (Downtonian) one at Stonehaven. In the third group (Garvock), which consists of: "purplish sandstones, with which are intercalated grey and chocolate-coloured sandstones with grey and olive-tinted sandy shales", occur in the shale remains of eurypterids, ostracoderms (among others *Cephalaspis lyelli* and *Thelodus pagei*) and myriapods. Both the lithological and palaeontological characters are apparently similar to the *Dictyocaris*-bearing Downtonian sediments of the same sequence. Although we have to be cautious in judging from negative evidence, it seems therefore reasonable to assume that the absence of *Dictyocaris* in beds above the Downtonian (or above the lower part of it) is not only due to facies, but is probably due to a disappearance of the genus.

The vertical range of *Dictyocaris* is, so far as we know, from the uppermost Llandovery to the middle Downtonian. Determination of species has only been carried out for the Wenlock and Ludlow-Downtonian forms. Of the two important species; *D. ramsayi* and *D. slimoni*, the first occurs in great abundance in the Wenlock and has also been recorded from divs. 3 and 4 in Lanarkshire, e, g at the transition between Ludlow and Downtonian, but is absent in the higher zones representing the typical Downtonian. *D. slimoni* occurs sparingly in the Wenlock, is recorded together with *D. ramsayi* from the Div. 4 at the transition between the Ludlow and Downtonian, but is very abundant in and may be regarded as characteristic of the Downtonian as shown also by the singular occurrences in the well-known sections in England.

In spite of the considerable vertical range of the genus *Dictyocaris*, it seems possible to distinguish *D. ramsayi* as characteristic of the non-

marine Wenlock, and *D. slimoni* largely as a guide fossil for the non-marine Downtonian. The latter particularly, seem to represent an important guide fossil on account of its widespread occurrence and great abundance.

### ***Dictyocaris* and the Caledonian Folding.**

There seems to exist an intimate connection between the occurrence of *Dictyocaris* and the emergence associating the formation of the Caledonian Mountain ranges. The crustacean seem so to speak to have inhabited the drainage and estuaries along the flanks of the rising land.

When Campbell (1913, p. 935—36) discovered the post-Caledonian, Downtonian strata at Stonehaven, he naturally arrived at the conclusion that the folding along the highland border took place earlier than further south where the Downtonian rests on the Ludlowian without unconformities and both have taken part in post-Downtonian orogenic movements. The Stonehaven section (Downtonian resting disconformably on strongly folded ? upper Cambrian) does not allow a closer determination of the age of the disturbances, but the present study of the fossils which indicate a lower Downtonian and possibly uppermost Ludlowian age of the sediments, has strongly pointed out a pre-Downtonian age of the folding of the older rocks.

As pointed out by several authors, the Hittra occurrence forms a Norwegian parallel to the Scottish one above mentioned. Little altered sediments with *Dictyocaris slimoni* rest on a folded metamorphic bed-rock complex. Reusch (1914, p. 47) who discovered the fossils, concluded that: "the Caledonian folding had in this part of the world a first stage ending in the Silurian". Holtedahl (1920, p. 9) points out that both in western Norway and Spitsbergen Downtonian unmetamorphosed sandstones rest unconformably on deeply eroded remnants of Caledonian mountain ranges. He assumes that the deformation began "rather early in the Silurian", that is after Llandovery time. Vogt (1928, p. 108) is inclined to place the Caledonian folding of the Hittra district between Ludlow and Downtonian. The present studies have corroborated the general opinion on a pre-Downtonian age of the folding in this region. The Hittra sediments seem to have been deposited in Downtonian or possibly upper Ludlowian time.

In Scotland the Downtonian beds further south in Lanarkshire, rest conformably on Ludlowian rocks and are folded together with those. The fossils have shown that the disturbances in this region are younger than further north. The Ludlowian and Downtonian are lacking in several places in southern Scotland, suggesting upheavals at that time. The occurrence of the none-marine *Dictyocaris* in alluvial sediments of the uppermost Llandovery suggests similar emergencies already in the middle Silurian.

In Norway the Downtonian of the Oslo Region rests conformably on the Ludlowian and is here, like in southern Scotland, folded contemporaneously with the older rocks. The folding is regarded as having taken place shortly after the deposition of the Downtonian sandstone, but a closer determination of the age is not possible. (The presence of lower Devonian above folded Cambro-Silurian at Røragen, a considerable distance to the north of the Oslo Region, gives a certain hold for the determination of the age).

A more detailed study of the *Dictyocaris* faunas has corroborated the assumptions set forth by earlier authors, of an earlier, pre-Downtonian phase of the Caledonian folding in the NW part of Scotland and Norway, and a younger late Downtonian or younger disturbance in the SE of the same countries.

### Remarks on the *Dictyocaris* Faunas studied.

1) Downtonian of Rudstangen, Ringerike, Norway. The present description and discussion of the genus *Dictyocaris* is based mainly on the large number of (more than a thousand specimens) and in several respects well-preserved material from this locality. The occurrence was discovered by Professor Kiær who gives a list of the fauna (1911, 1924) and a more detailed description of the sequence in the locality. The merostome list has been revised by the present author (1934 a).

*Dictyocaris* was found in great abundance in the "Fish Horizon" associated with vertebrates (*Pterolepis nitidus*, *Pharyngolepis*, *oblongus*, *Rhyncholepis parvulus*, *Aceraspis robustus*, *Micraspis gracilis*, *Thelodus* sp.) and merostomes (*Hughmilleria norvegica*, *N. (?) lata*, *Pterygotus holmi*, *P. sp.*, *Stylonurus pentagonalis*, *S. ruedemanni*, *S. dolichopteroides*, *Mixopterus kiæri*, *Bunodes* sp., *Kiæria* sp.). Kiær also records *Ceratiocaris* sp., but I have not been able to establish its

presence. The specimens of *Dictyocaris* are preserved partly in relief and the reticulate surface sculpture is traceable in the greater part of them.

*Dictyocaris* occurs in still greater abundance in the "Dictyocaris Horizon" five meters below the "Fish Horizon". The specimens are, however, badly preserved, showing only in a few cases the surface reticulation. Some tests have circular holes quite similar to those found in specimens from Hittra and Scotland.

Besides *Dictyocaris slimoni*, one specimen of *D. s. var. tuberculata* is known from the Rudstangen locality. The size of the specimens appears from text-fig. 2.

2) Downtonian of Hittra. In 1913 Dr. Hans Reusch made an important discovery of fossils in the post-Caledonian sandstones of Balsnesaune on the island of Hittra near the inlet of the Trondheimsfjord.

The fossils were found in a dark, fine-grained, argillaceous sandstone. The specimens were very rare and rather badly preserved. Thanks to the enthusiasm and patience of the brilliant collector Dr. Reusch who spent five days collecting in the locality, we have got our present material.

Among the fossils Professor J. Kiær (Reusch 1914, p. 8—10, pl. I, fig. 1) identified *Dictyocaris*. He also mention specimens recalling deformed plant remains. A few also resembled the abdominal segments of eurypterids. In the following a new description of the fossil material is given.

### Order *Phyllocarida* Packard.

#### *Dictyocaris slimoni* Salter.

Pl. II fig. 8—9, text-fig. 4 g.

I have not been able to find the originally figured specimen. Only a few of the specimens available show traces of the *Dictyocaris*-sculpture.

No. 39 414 (and counterpart 39 407) and 39 416 show the characteristic sculpture very distinctly. The first mentioned fragment (pl. II, fig. 8) measures 50 mm in length and 31 mm in width. The sculpture consists of numerous, rather regular polygons. The polygons which are five or six-sided generally are in the present specimen more regular than in the previously figured one. The average width of the areas amount to about 0,8 mm. In No. 39412 of *Dictyocaris* the

areas are almost obsolete, but the test shows a few peculiar circular perforations (text-fig. 4 *g*) which resemble those from Rudstangen (text-fig. 2 *g*) and England (text-fig. 1 *c, d, f*).

A small fragment No. 39 426 and the counterpart, has a minute sculpture of numerous small knots which in a certain way resembles the *Dictyocaris* sculpture, but differs in being only 0,4 mm wide as an average and in apparently lacking the straight sides of the areas. The sculpture might also possibly represent, the test of a merostome or vertebrate. From the Shawangunk grit Clarke and Ruedemann (1912, p. 313 and pl. LIII, fig. 6 and 9) describe similar fragments.

### *Eurypterid Remains.*

*Hughmilleria* (?) sp.

Pl. II fig. 7 and text-fig. 4 *a, d, e*.

The eurypterid nature of the three figured specimens can hardly be doubted. On account of the fragmentary preservation, a closer determination of the fossils is not possible. The figured specimens represent the prosoma of an eurypterid. They might belong to one species.

No. 39 416 (text-fig. 4 *a*) shows distinctly the semi-elliptical anterior outline of the prosoma. On the right side a narrow rim is indicated. The outline of the lateral eyes is not well defined. A smaller portion of the eye forms an elevation. The eyes are intramarginal but have a typical anterior position. The length of the right eye is less than one fourth the length of prosoma. No. 39 446 (text-fig. 4 *d*) has a rather complete outline although the anterior is partly destroyed. The ratio length-width of prosoma is a little more than 3 : 4. The lateral eyes are indicated near the antelateral margin. The length of the eye is one fourth the length of prosoma. The small markings might represent the median ocelli.

No. 39 445 (text-fig. 4 *e*) resembles a phyllocarid with two body segments, but represents evidently a laterally compressed prosoma with parts of the two anterior abdominal tergites on account of a rather small ovate elevation probably belonging to the lateral eye. The eye has the same intramarginal, antelateral position as in the two other specimens. The length of the eye is about one fifth to one sixth the length of prosoma, a length which is comparatively smaller than in the other specimens. The three specimens have in common the intramarginal and antelateral position of the rather small lateral eyes.

The width of prosoma indicated in two specimens is probably exaggerated on account of the compression.

**Dimensions:** The length of prosoma No. 39 416, 39 446 and 39 445, is 13,5 mm, 10 mm and 17,1 mm.

**Relationship:** A similar intramarginal position of the lateral eyes is common in the genus *Hughmilleria* and appears occasionally also in other genera. Among the Stylonuridae *Dolichopterus otisus* Clarke (Clarke and Ruedemann 1912, pl. XLVI) shows occasionally indications of a similar arrangement of the eyes. These specimens (l. c. pl. XLVI, figs. 2 and 8) are not typical and might perhaps belong to another group. The stylonurid nature is generally pointed out in the shape of the prosoma and the well marked imprints of the doublure two characters not present in the Hitra specimens. The known species of *Hughmilleria* have a more posterior position of the lateral eyes. In *H. norvegica* (Kier) (Størmer 1934 a) the position of the eyes is not very different. The prosoma is more narrow in the species from Ringerike, but the Hitra specimens were certainly flattened to a certain extent. The position of the lateral eyes denies the possibility of an identity of the two forms. If the median imprints of No. 39 446 are remains of the ocelli they are more like those of the *Dolichopterus* than *Hughmilleria*.

With our present material it is not possible to identify the described eurypterid remains. It is probable, however, that they belong to the genus *Hughmilleria* although the genus *Dolichopterus* is indicated in certain characters.

*Stylonurus* (?) sp.

Text-fig. 4 b, c (?).

The figured specimen is badly preserved. A pentagonal outline of the prosoma is indicated. A pair of dorsal imprints might represent the lateral eyes although the structures might be accidental. Species of the subgenus *Ctenopterus* of the genus *Stylonurus* has the same outline and a similar central position of the eyes (comp. Clarke and Ruedemann 1912, pl. XLVII and XLIX). The fragment No. 39437 might represent two segments of one of the posterior walking legs of one of the Stylonuridae. The lack of sculpture does not exclude the possibility of plant remains.

**Dimensions:** Length of prosoma 15 mm, original width probably 14 mm.



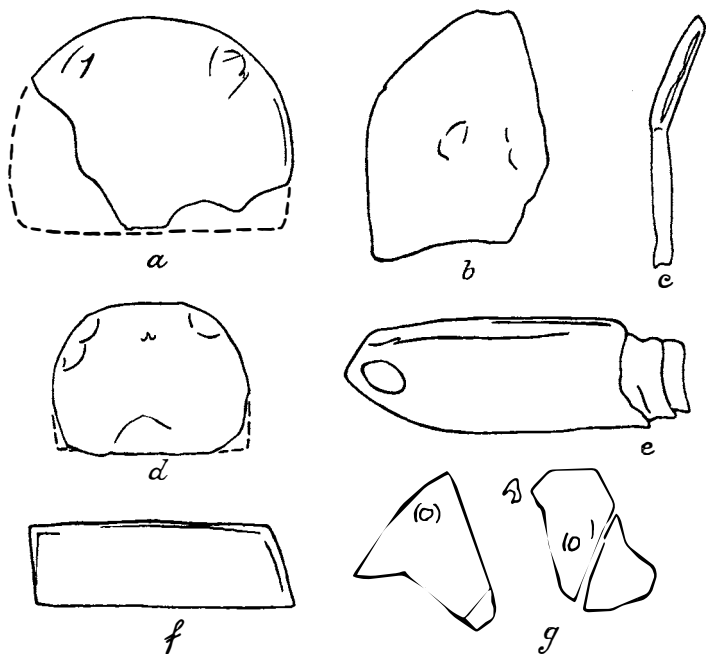


Fig. 4. Arthropod remains from Downtonian beds of Hitra. *a*, *b*, *d*, *e*, evidently eurypterid remains, *e* resembles a prosoma of phyllocarid, but is probably a laterally compressed *Hughmilleria* with three segments of mesosoma. *c*, *f* might also be eurypterid fragments. *g* = *Dictyocaris slimoni* (?) *a*–*e* magnified  $2\times$ , *f*, *g*  $\frac{2}{3}\times$ .  
*a*=39416, *b*=39435, *c*=39437, *d*=39446, *e*=39445, *f*=39402, *g* -39412.

*Genus indet.*

Text-fig. 4 *f*.

The figured plate is rather well preserved. The trapezoid outline is distinct. The anterior (?) border is broadest on the right side and bent in a ventral direction. It is not possible to decide whether the plate represents an eurypterid or crustacean abdominal segment.

3) Wenlock of the Pentland Hills. From this series I have had the opportunity of studying three different collections belonging to the Geological Survey Museum in London, the Geological Survey collection in Edinburgh and the Palaeontological Museum in Oslo.

The old London collection contains 16 specimens including Salter's type of *Dictyocaris ramsayi*, from the North Esk Reservoir. The fossils occur in grey, not very fine-grained sandstone. The

specimens of *D. ramsayi* are preserved in relief often showing both sides of the carapace, but the surface sculpture is generally not very distinct. The tests are often pierced by circular holes just as in the Norwegian specimens of the genus. Peach and Horne (1899, p. 593—595) give a list of the comprehensive fauna of the Wenlock series in this locality.

Of the two specimens borrowed from Edinburgh, one is from the North Esk and the other from Monks Burn. The latter is quite similar to those of North Esk and has a wellpreserved sculpture (pl. III, fig. 8).

The Palaeontological Museum in Oslo has some specimens of *Dictyocaris* collected by Dr. R. Campbell and Professor O. Høltedahl from the Gutterford Burn in the Pentland Hills. The grey-greenish sandstone and mudstone contain fragments partly preserved in relief of *D. slimoni* and *D. salteri*. The surface sculpture is rather well preserved.

4) Upper Ludlow-Downtonian of Lesmahagow, Lanarkshire. From the Geological Survey in London I have borrowed for description 16 specimens of *D. slimoni* evidently including the type figured by Salter. The specimens are preserved in darker grey, fine-grained sandstone resembling somewhat that of Rudstangen, Norway, but the tests are generally flattened out. Several very large specimens are found in this locality. The reticulate structure is traceable in most of the films and the circular holes also occur (text-fig. 1 f). Only the one species *D. slimoni* is present in the material.

5) Downtonian of Stonehaven, Scotland. Dr. Robert Campbell very kindly offered me the opportunity of describing the interesting fossil arthropods discovered by him at Cowie, Stonehaven. A detailed description of the occurrence and a preliminary list of the fossils are given by Campbell (1913).

The fossils which occur in a fine-grained grey and green sandy mudstone, are not very well preserved, but the surface sculpture of *Dictyocaris* is usually distinct.

The fossils listed by Campbell (1913, p. 931—932) had partly been given provisional determinations by Traquair (fishes) and Peach (arthropods). The list contains: Plant remains, *Dictyocaris*, *Ceraticaris*, *Archidesmus* and a new genus of Myriapod, (?) larval form of

insect, *Eurypterus* sp. nov., and fragments of scorpion, *Cyathaspis campbelli* (described as *Traquairaspis campbelli* by Kiær 1932) and cephalaspidian fragments. Besides these forms Campbell mentions that certain fish remains were suggestive of *Birkenia*. Mr. Macconochie had in 1881 collected the following fossils in the "Stonehaven Beds": *Dictyocaris*, fragments of *Pterygotus*, *Eurypterus* and (?) *Kampecaris*. In the following is described the arthropods, with the exception of most of the myriapods which are being studied by Dr. S. G. Brade-Birks.

### Order *Phyllocarida* Packard.

#### *Dictyocaris slimoni*, Salter.

Pl. III fig. 6, 7.

A considerable number of *Dictyocaris*-fragments is present in the material. The fragments are generally rather small. The largest one measuring 75 mm in length. No fragments show indications of natural borders. Neither have I noticed any specimen with both sides of the carapace preserved. The reticulation is very distinct as shown in the figures on the plate. The polygonal areas are generally five or six-sided but in one specimen (pl. III, fig. 7) we find a gradual transition from regular polygonal areas to more elongate meshes.

#### *Ceratiocaris* sp.

Pl. III fig. 4, 5.

Several rather fragmentary carapaces probably represent this genus. The *Ceratiocaris*-remains have a red colour in contradiction to the dark grey *Dictyocaris*-films. It is hardly possible that the smooth carapaces are badly preserved remains of *Dictyocaris*. which occurs well preserved on the same slabs. The preserved carapaces have apparently a subovate outline, but the borders are not clearly defined.

Pl. III, figs. 4—5, show two small plates which evidently belong to the rostrum of *Ceratiocaris*. The plates seem to have a semicircular distal border and a more truncate proximal. Distinct concentric lines or stria are present on the surface of the test.

**Dimensions:** Max. length of carapace = 57 mm, max. width = 30 mm, max. length of rostrum = 15 mm, width = 6,7 mm.

**Relationship:** Jones and Woodward (1888—1899, pl. XII, fig. 2) figure a similar rostrum of *Ceratiocaris stygia* Salter, from the

lower Ludlow of Logan Water, near Lesmahagow, Scotland. *C. Stygia* is closely allied or perhaps identical with *C. papilio*. *C. papilio* also occurs in Downtonian beds. It is probable that the described form belongs to one of these species.

### Order *Eurypterida*.

#### *Hughmilleria norvegica* (Kiær).

Pl. III fig. 1, 2.

The present material contains two almost complete specimens of this interesting eurypterid. The preservation is not very good; especially the dorsal characters of the prosoma have been difficult to establish.

**General description:** The prosoma has a semi-elliptic outline and the ratio length—width is 4 : 5 (No. 71) and nearly 1 : 1 (No. 70). The variation is due to preservation. In No. 71 traces of the lateral eyes are visible especially on the right side. The lateral eye is intramarginal and removed from the margin at a distance equal to the width of the eye. The length of the eye is not well shown. A central depression indicates the lobe with the median ocelli. Both specimens have parts of the appendages preserved. No. 70 (pl. III, fig. 2) shows the second (?) walking leg and the large coxae of the swimming legs.

The shape of the abdomen is well defined although the length might have been shortened by a dislocation of the mesosomal segments. The width of mesosoma is only a little larger than that of prosoma. The operculum and the four succeeding gill-bearing appendages are well illustrated in No. 70.

The first segment of the metasoma shows in both specimens the characteristic post-lateral horns or spines. No. 71 has six metasomal segments preserved and thus lacks only the telson. The shape of the segmental rings is the same as in the Norwegian specimens.

**Dimensions:** For No. 71 and 70 are the probable length of body about 85 mm and 80 mm, length of prosoma: 16 mm and 15—16 mm, width: 20 mm and 16 mm, length of prosoma, mesosoma and first segment of metasoma 40 mm and 38 mm.

**Relationship:** A comparison between the Stonehaven and Ringerike form shows a close correspondence. The dimensions are distinctly the same. The length of the lateral eyes, one of the

distinguishing characters of the present species, is not well shown in the Cowie specimens. The common position of the eyes, however, and the correspondence in a number of various characters seem to justify the establishment of the identity of the Scottish and Norwegian species of *Hughmilleria*. As pointed out in my description of the Norwegian species (1934, p. 90—91) the small form of *Hughmilleria lanceolata* (= *Eurypterus lanceolatus* Salter) from the Downtonian beds of Lesmahagow, Lanarkshire, Scotland might also belong to the same species.

### Class *Diplopoda*.

#### *Kampecaris* (?) sp.

Pl. III fig. 3.

According to the provisional identifications of the arthropod fossils from Cowie, the myriapods were represented by: "*Arcidesmus* and a new genus of Myriapod" (Campbell 1913, p. 932). In the present material I have only found one specimen which might be referred to this group. As will be seen from the photograph the specimen is preserved in a fragmentary condition. It is possible to distinguish 12 dorsal segments. The width of the fossil tapers slightly towards the posterior (?) end (top of the photograph). The lateral borders of the segments are not very distinct. Apparently the ring-shaped segments have a rectangular outline.

**Ornamentation:** The surface of the segments has a distinct sculpture consisting of close-set, flat, granula.

**Dimensions:** Length of preserved part of body = 24 mm, largest width = 7 mm. Length of one segment = 2,2 mm.

**Relationship:** The width of the dorsal scutes and the lack of large lateral lamellae separate the present form from the genus *Archidesmus*. *Kampecaris* on the other hand is more related. *K. forfarensis* Page has according to Peach 1882, p. 179, pl. II, figs. 1 and 1 a—g) a smaller size, but the general shape of the dorsal scutes of *K. forfarensis* . . "is granular and in places is raised into papillae . ." (l. c. p. 181). The size of the Cowie specimen suggests another species. On account of the fragmentary preservation a closer determination is hardly possible.

6) Downtonian of West Midlands, England. Mr. W. W. King most kindly sent me a specimen of *Dictyocaris slimoni* found by him in green mudstone at the top of group I, 5 of the

Downtonian, about 1380 feet above the uppermost Ludlow, at Man Brook, Trimpey, near Kidderminster. The associating fauna is mentioned above. The small rectangular fragment shown on pl. III, fig. 13, exhibits a distinct and regular reticulation characteristic of the species.

7) Upper Llandovery (?) of Otisville, New York State, U. S. A. Clarke (1907) and Clarke and Ruedemann (1912) have described the interesting eurypterid fauna from these beds. During my studies in New York State Museum in Albany, N. Y., I had, thanks to the kindness of Dr. C. C. Adams and Dr. Rudolf Ruedemann, the very best opportunities for studying the interesting collections.

The black shales intercalated between the conglomerate beds of the Shawangunk contain the following fauna: *Dolichopterus otisius*, *D. stylonurides*, *Eurypterus maria*, *Carcinosoma* (= *Eusarcus*) *cicerops*, *Hughmilleria shawangunk*, *Pterygotus globiceps*, *Stylonurus cestrotus*, *S. myops*. In addition to these species Clarke and Ruedemann (1912, pl. LIII) figure a number of "problematica". The surface sculpture in pl. LIII, fig. 9, hardly belongs to an eurypterid. The sculpture resembles those found in certain ostracoderms or, when we have in mind the rather bad preservation, resembles specimens of *Dictyocaris*. Bryant (1926) pointed out that certain specimens figured by Clarke (1907) were cyathaspidian fishes. The fragments were found "only in the grey shale lying at the top of the grit and black shale series", and it is therefore not impossible that they be of a younger age. Thus in the Guymard Quartzite above the Shawangunk formation, more complete specimens of cyathaspids have been found, which recently have been given the generic name *Eoarchegonaspis* by Kiær. The fragments of cyathaspids described from the Shawangunk have been lost.

*Dictyocaris* (?) sp.

Pl. I fig. 3.

Looking through the Shawangunk collections in New York State Museum, I became aware of two specimens which showed a remarkable resemblance to certain of the badly preserved specimens of *Dictyocaris* from Rudstangen, Norway.

The large, figured specimen has a distinct dorsal line, which is partly distinguished as a marginal rim. The dorsal line is secondarily

concave, as in many of the Norwegian specimens (comp. text-fig. 2 c). A posterior margin is also indicated on the left side. The shell probably represents the right side of a carapace. The subtriangular outline is not very well defined. The smooth surface has no sculpture preserved, but the general character of the shell is resembling closely the Norwegian specimens. The considerable size, length along dorsal line = 125 mm and the largest width = 10 mm, is also typical for the genus. Another specimen, a smaller fragment measuring 60 × 45 mm, has the same surface.

**Relationship.** It is not possible to assume an inorganic origin (slickenside) for the described fossil. The presence of a distinct dorsal line, as well as the shape and large size of the fossil strongly suggest a close relationship to *Dictyocaris*. Although I am almost convinced that the described American specimens represent the genus *Dictyocaris*, a definite determination is hardly possible as long as the typical reticulate ornamentation is not observed.

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## PLATES

## Plate I.

Not retouched.

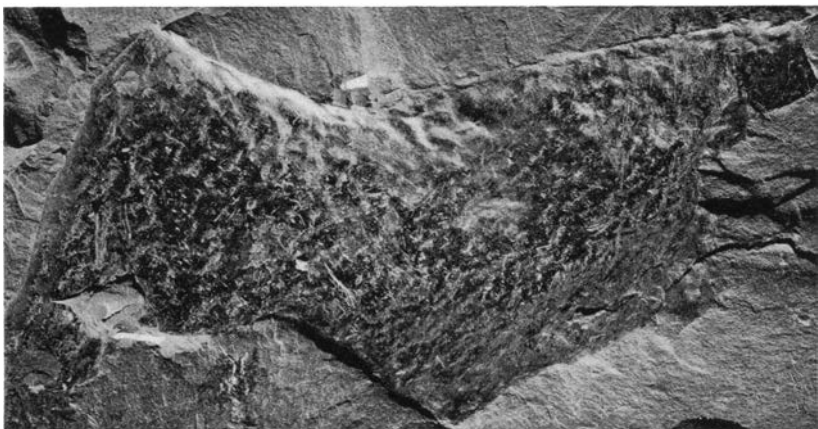
- Fig. 1. *Dictyocaris slimoni* Salter. Impression of right side of carapace. Reticulation partly preserved.  $\times \frac{3}{4}$ . Downtonian Sandstone Rudstangen, Ringerike, Norway. No. H 1147. Paleont. Mus. Oslo. Coll. Comp. text-fig. 2.
- » 2. *Dictyocaris slimoni* Salter. Carapace with well preserved reticulation.  $\times \frac{3}{4}$ . Same loc. and coll. No. H 2095. Comp. text-fig. 2.
- » 3. *Dictyocaris* (?) sp. Silurian Shawangunk Grit, Otisville, New York State, U. S. A.  $\times \frac{3}{4}$ . New York State Museum, Albany, Coll. J. Stein phot.



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## Plate II.

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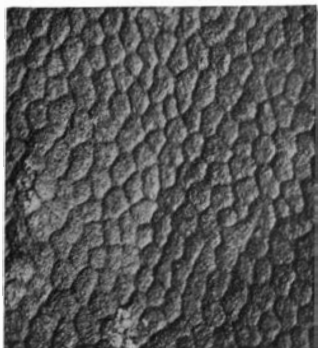
Figs. 1—6 from the Downtonian Sandstone of Rudstangen, Ringerike, Norway, 7—9 from the Downtonian Sandstone of Hitra, Norway. All specimens belong to the Paleont. Mus., Oslo.

Fig. 1. *Dictyocaris slimoni* Salter. Specimen showing primary fracture lines which might be mistaken for natural borders.  $\times 1.5$ . No. H 1166.

- » 2. *Dictyocaris slimoni* Salter. Reticulate structure.  $\times 5.5$ . No. 1193.
- » 3. *Dictyocaris slimoni* Salter. Specimen showing parts of carapace and several abdominal segments. Comp. text-fig. 3.  $\times 1.1$ . No. H 2117.
- » 4. *Dictyocaris slimoni* Salter. Both sides of carapace.  $\times 1.5$ . No. H 1167.
- » 5. *Dictyocaris slimoni* var. *tuberculata* n. var. Polygonal meshes with central tubercles.  $\times 5.5$ . No. H 1261.
- » 6. *Dictyocaris slimoni* Salter. Elongate meshes.  $\times 5.5$ . No. H 2101.
- » 7. *Hughmilleria* (?) sp. Prosoma.  $\times 1.5$ . No. 39446.
- » 8. *Dictyocaris slimoni* Salter.  $\times 3$ . No. 39414.
- » 9. *Dictyocaris slimoni* Salter.  $\times 3$ . No. 39416.



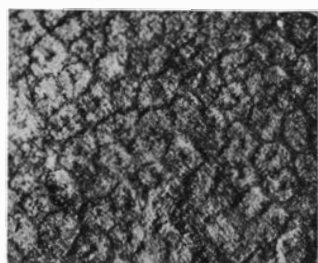
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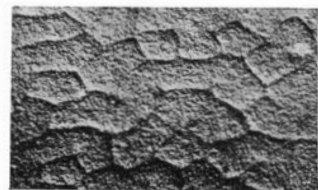
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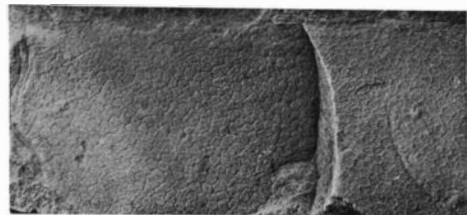
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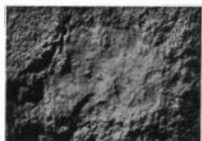
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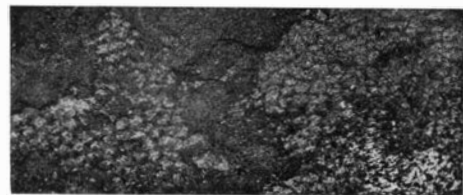
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### Plate III.

Figs. 1—2 slightly retouched.

Figs. 1—7 from the Downtonian Sandstone of Stonehaven, Scotland. Figs. 8—10 from the Wenlockian Sandstone of Munks Burn (8) and Gutterford Burn (9—10), Pentland Hills, Scotland. Figs. 11—12 from the Downtonian Sandstone (or upper Ludlowian) of Logan Water, Lesmahagow, Lanarkshire, Scotland. Fig. 13 from Downtonian Sandstone of Trimpey, West Midlands, England. Specimens on figs. 1—7 belong to Geol. Lab. Edinburgh Univ., that on fig. 8 to the Geol. Survey Museum in Edinburgh, those on figs. 11—12 to the Geol. Survey Museum in London, and the specimens on figs. 9, 10, 13 to the Paleont. Museum in Oslo.

Fig. 1. *Hughmilleria norvegica* (Kiær). Almost complete specimen.  $\times 1.3$ . No. 71.

» 2. *Hughmilleria norvegica* (Kiær). Specimen lacking the posterior abdominal segments.  $\times 1.3$ . No. 70.

» 3. *Kampecaris* (?) sp.  $\times 1.3$ . No. 75.

» 4. *Ceratiocaris* sp. Rostrum.  $\times 2.6$ . No. 72.

» 5. *Ceratiocaris* sp. Rostrum, laterally compressed.  $\times 3$ . No. 73.

» 6. *Dictyocaris slimoni* Salter.  $\times 2.6$ . No. 48.

» 7. *Dictyocaris slimoni* Salter.  $\times 2.6$ . No. 66.

» 8. *Dictyocaris ramsayi* Salter.  $\times 2.6$ . No. 1011.

» 9. *Dictyocaris salteri* n. sp.  $\times 2.6$ . No. A 17248.

» 10. *Dictyocaris slimoni* Salter.  $\times 2.6$ . No. A 17247.

» 11. *Dictyocaris slimoni* Salter.  $\times 2.6$ . Counterpart of surface. No. 53435.

» 12. *Dictyocaris slimoni* Salter.  $\times 2.6$ . Counterpart of surface. No. 7482.

» 13. *Dictyocaris slimoni* Salter.  $\times 2.6$ . No. A 17249.

