

First record of a polyplacophoran from the Southern Uplands of Scotland.

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Synopsis.

An intermediate sclerite of a paleoloricate chiton (Polyplacophora) collected from the Kirkcolm Formation (Ordovician, Lower Katian) of Kilbucho in the Scottish Borders (formerly Peeblesshire), Scotland represents the first record of the class in the Southern Uplands. The single Kilbucho specimen is morphologically distinct from documented taxa, and is described and figured here but left in open nomenclature.

Introduction.

Polyplacophorans (chitons) are marine molluscs with a long fossil record, ranging from the Cambrian (Yu 1984, 2001) to the Recent. They are represented by over 900 extant species worldwide from shoreline to deep seas, but the total number of fossil species is <400 (Schwabe 2005). They are rare fossils and are mostly known from isolated intermediate sclerites (Cherns *et al.* 2004); many occurrences document only few or, as is the case here, a single sclerite. The poor preservation potential of rocky shore palaeoenvironments also probably contributes to the sparse fossil record (Cherns *et al.* 2004). Palaeozoic polyplacophorans are included in the Order Paleoloricata, which is characterised by the lack of insertion plates and of an intermediate shell layer, the articulamentum. However, a definition based on absence of derived characters is unsatisfactory, and the Palaeoloricata is certainly paraphyletic (Vendrasco & Runnegar 2004; Pojeta *et al.* 2010; Sutton & Sigwart 2012). Recent fossil finds demonstrate some palaeoloricate 'chiton' and new taxa that combine certain polyplacophoran and aplacophoran characteristics, interpreted as more closely related to the aplacophorans than the polyplacophorans (Sutton *et al.* 2012).

Records of fossil polyplacophorans are few in the upper Ordovician rocks of south-east Scotland. The sclerite described here is the first record of the class in the Southern Uplands. It comes from the early Katian Kirkcolm Formation at Kilbucho (see Fig. 1 for geographic position of locality), which has yielded a relatively scarce but very diverse macrofauna including corals (Scrutton &

Clarkson 1991), trilobites (Owen & Clarkson 1992) and brachiopods (Candela & Harper 2010; see faunal list in Clarkson et al. 1992). The fauna represents a broad census of outer shelf and upper slope palaeocommunities around this part of the Laurentian margin, mixed with an assemblage of shallower-water origin (including diploporite cystoids) that lived above storm-wave base. The preservation of some of the shells indicates mass transport of the faunas and deposition of mud probably involving living or recently deceased animals (Clarkson *et al.* 1992). Much of the fauna was transported downslope and is locally preserved in obrution deposits (Clarkson *et al.* 1992). Candela & Harper (2010) identified almost 40 taxa among circa 180 specimens of brachiopods collected, but the assemblage was dominated by relatively small plectambonitoids. The fossil brachiopods are very rarely preserved as conjoined valves.

Ordovician Chitons in Scotland.

All the occurrences of Polyplacophora in Scotland were recorded from Ordovician rocks of the Girvan area. The earliest record may be attributed to Woodward (1885), who listed two species, *Helminthochiton grayiae* Woodward, 1885 and *Helminthochiton (Solenocaris) solenoides* Young, 1868, from the 'Upper Bala Beds' of Threave. This corresponds to the Laggan Member of the Balclatchie Formation (Sandbian). *Solenocaris solenoides* was also found from the same horizon at Dalfask Quarry, about 4 km SE of Girvan. Moreover, *Solenocaris solenoides* is known from the Bellmore Member and Pumphouse Member of the Balclatchie Formation (Sandbian) at Dow Hill and

Balclatchie, respectively.

Rolfe (1981) reassigned *Helminthochiton grayiae* to the genus *Septemchiton* and considered *Septemchiton vermiformis* Bergenhayn, 1955 from the Lady Burn Starfish Bed, as a junior synonym of the species. However, Van Belle (1981) and later Hoare (2002) listed the species *grayiae* as an accepted species of *Helminthochiton*.

Reed (1911) described *Helminthochiton thraivensis* from the Lady Burn Starfish Bed, which is included in the Farden Member of the South Threave Formation (Katian), Threave Glen. *Helminthochiton thraivensis* has been reassigned to the genus *Phthipodoichiton* by Sutton & Sigwart (2012), and is considered as a potential transitional morphology linking aplacophorans with polyplacophoran-like forms (Sigwart & Sutton 2007; Sutton & Sigwart 2012).

The oldest and youngest stratigraphical records of Ordovician polyplacophorans were made by Peach & Horne (1899) with two undetermined species of *Helminthochiton* from the Middle Ordovician (Darriwilian) (upper teretiusculus and gracilis zone) and the Upper Ordovician (Upper Katian) of Girvan.

Chelodes longissimus Bergenhayn, 1955 was described from the middle Bala beds of Shalloch Mill, about 3 km south of Girvan.

Llandeiloichiton ashbyi Bergenhayn, 1955 was described from the Llandeilo of Balclatchie (Darriwilian) of Girvan. A single intermediate valve was described and used as the type specimen. Van Belle (1981) and Smith & Hoare (1987) rejected this taxon from the Polyplacophora on the basis of morphological features considered peculiar for the class.

Technical summary.

Backscattered micrographs were recorded with a 4 quadrant fluorescence backscatter electron detector (BSC) of a CamScan 2500 Scanning Electron Microscope (SEM), working in controlled pressure mode with fully open lower aperture (Envac, 40 Pa). The micrographs were recorded at the analytical working distance of 15 mm with an accelerating voltage of 20 kV working with a 5 spot size. Surface topography was enhanced by selectively switching off some of the quadrants of the BSC detector.

Systematic Palaeontology.

Specimen repositied in the Invertebrate Palaeontology Collection of the National Museum of Scotland. Digital photography by YC; SEM imaging by LT.

Class Polyplachophora de Blainville, 1816

Order Paleoloricata Bergenhayn, 1955

Gen. et sp. nov.

Figure 2a–g

Material. – One almost complete intermediate sclerite, preserved as a mould of the dorsal surface; Kilbucho, 5 km SSE of Biggar, Scottish Borders

(formerly Peeblesshire), Scotland; Kirkcolm Formation (Early Katian), NMS G.2005.109.75.

Description. – Sclerite subcarinate, about 90% as wide as long; lateral margins sub-parallel to expanding gently anteriorly, rounded anterior margin with jugal embayment (Fig. 2a, c); prominent narrow jugal fold (Fig. 2c), becoming less elevated towards the anterior; jugal fold 10% of sclerite width, flanked by broad pleural and lateral areas; shallow radial depression (indicated by an arrow, Fig. 2c) delimiting gently convex pleural area from lateral area that becomes flatter to slightly concave dorsally (Fig. 2d); jugal angle obtuse (110° - 120°). Posterior apex (Fig. 2e); posterior margin short, straight to obtuse in dorsal view (Fig. 2c).

Ornament pustular, regular, consisting of about 30 concentric rows; on the jugal area rows normal to the antero-posterior axis (Fig. 2f, g); pustules 24 to 80 μm in diameter (Fig 2b, e); larger pustules and wider spacing of rows (200 μm) outwards towards anterior and antero-lateral margins (40 μm); approximately 25 pustules per row.

Measurements (in mm) of specimen NMS G.2005.109.75; Length (max) L = 5; length of jugal ridge = 4.25; width (max) = 5; width of jugal ridge = 0.5.

Discussion. – The posterior margin of the sclerite is not clearly defined therefore its exact shape cannot be ascertained without doubt. Nevertheless, as both right and left sides of the posterior margins appear symmetrical with

respect to the sagittal axis it is likely that the posterior apex and short, straight to obtuse margin are morphological features rather than a taphonomic artefact.

The Kilbucho sclerite differs in its posterior margin from intermediate sclerites of *Phthipodochiton thraivensis* (Reed, 1911) and also lacks growth lines Reed (1911; p. 337) described his new species as “ornamented with two (or sometimes more) strong regular concentric striae parallel to anterior and outer edges of plates, one being situated usually at about one-fourth the length and the other at one-half the length, with finer concentric striae between them”.

The Kilbucho specimen does not possess these strong concentric striae on the external surface of the sclerite, but has well developed pustular ornament. Moreover, the posteriorly tapering jugal ridge in *P. thraivensis* is diagnostic of the genus (“posterior margins pinched at the midline fold, forming a pronounced point but not a significant projecting beak” (Sutton & Sigwart 2012, p. 404)), whereas in the present sclerite, which does not show any signs of post-mortem breakage, maintains a constant width throughout its length . However, the new specimen is similar to *P. thraivensis* in the subrectangular intermediate sclerite and in the distinctly bilobed anterior margin with median embayment (Reed 1911, pl. 15, fig. 4; Sutton & Sigwart 2012, p. 407) *Helminthochiton grayiae* Woodward from Girvan has intermediate sclerites that are broadly similar in outline, but differ from the Kilbucho specimen in possessing both concentric and radiating lines and lack pustules. The Kilbucho sclerite is also different from *H. griffithii* Salter, 1847 from the Lower Silurian of the west of Ireland, which is devoid of ornamentation. Pojeta *et al.* (2010) regarded regular pits on the interior surface of the

tegumentum of silicified sclerites of upper Cambrian *Aulochiton*, seen in latex moulds as pustule like projections, as the ends of vertical aesthete canals and not valve ornament. On *Hemithecella eminensis* sclerites aesthete canals emerge as small, irregular 'pustule like markings' on the external tegumentum (Pojeta et al. 2010, pl.15). Hoare *et al.* (1972) had observed that pores present in the tegumentum of a Middle Carboniferous polyplacophoran from Ohio, USA were expressed externally as small granules. The Kilbucho sclerite is an external mould preserving strong, regular pustular ornament on the tegumentum outer surface (although not interpreted here, as related to aesthete canals). The intermediate sclerites of *Aulochiton*, which are mucronate, elongately rounded and have an anterior snout-like projection, also differ in shape, growth form and profile from the Kilbucho sclerite.

The Kilbucho specimen shows some morphological similarities with *Helminthochiton? baueri* Hoare & Pojeta, 2006 from the Late Sandbian of Wisconsin, USA, in the outline and profile of the intermediate sclerites with anterior margin embayed and bilobed, posterior margin concave and lateral margins subparallel. However, the concave posterior margin shown in some specimens is not a consistent feature as others possess a convex apex. They differ in the absence of pustular ornament and concentric lines, and in having a posteriorly tapering jugal ridge.

Other Ordovician and Silurian genera with comparable features to the Kilbucho specimen include *Alastega* Cherns, 1998, *Amblytochiton* Hoare & Pojeta, 2006, *Chelodes* Davidson & King, 1874 and *Gotlandochiton* Bergenhayn, 1955. Although these are characterised by a bilobed and embayed anterior margin, further comparison is limited by the broadly

triangular shape of intermediate sclerites, combined with a convex posterior apex.

Thairoplox Cherns, 1998 from the Silurian of Gotland, Sweden possesses a similar intermediate sclerite shape to the present specimen, with a bilobed, embayed anterior margin and subparallel lateral margins. However, this genus lacks pustular ornament and is characterised by a longitudinally flexed sclerite and a posterior apex, pointed and acute, not characteristic of the Scottish sclerite.

Kindbladochiton Van Belle, 1975 possesses a dovetail-shaped posterior margin, but differs from the present specimen in strongly carinate intermediate sclerites, flat pleural and lateral areas and a slightly pointed apex, and lack of pustular ornament.

In summary, several genera of Ordovician polyplacophorans show some morphological similarities with the Kilbucho specimen but not diagnostic characters for a confident identification. Diagnostic characters such as the broad jugal embayment, prominent narrow jugal fold, broad pleuro-lateral areas becoming slightly concave outwards, the short, straight to obtuse posterior margin and strong pustular ornament combine to point clearly towards a new genus and species. The unique specimen hinders positive taxonomic assignment before more material is collected, and thus in the meantime it is left in open nomenclature.

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References.

Bergenhayn, J. R. M. 1955. Die Fossilen Schwedischen Loricaten nebst einer vorläufigen Revision des Systems der ganzen Klasse Loricata. *Lund Universitet, Årsskrift*, n. f., **2**, 1–41.

Blainville, H. M. D. de. 1816. Prodrome d’une nouvelle distribution systématique du règne animal. *Bulletin des Sciences par la Société Philomathique de Paris*, 105–124.

Candela, Y. & Harper, D. A. T. 2010. Late Ordovician (Katian) brachiopods from the Southern Uplands of Scotland: biogeographic patterns on the edge of Laurentia. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, **100**, 253–274.

Cherns, L. 1998. Silurian polyplacophoran molluscs from Gotland, Sweden. *Palaeontology*, **41**, 939–974.

Cherns, L., Rohr, D. M. & Frýda, J. 2004. Polyplacophoran and symmetrical univalve mollusks. *In* Webby, B. D., Droser, M. L., Paris, F., & Percival, I. (eds) *The Great Ordovician Biodiversification Event*. New York, Columbia University Press, 179–183.

Clarkson, E. N. K., Harper, D. A. T., Owen, A. W. & Taylor, C. M. 1992. Ordovician faunas in mass-flow deposits, southern Scotland. *Terra Nova*, **4**, 245–253.

Davidson, T. & King, W. 1874. On the Trimerellidae, a Palaeozoic family of the palliobranchs or Brachiopoda. *Quarterly Journal of the Geological Society*, **30**, 124–173.

Hoare, R. D. 2002. European Paleozoic Polyplacophora, Multiplacophora, and Turridae in United States repositories. *Journal of Paleontology*, **76**, 95–108.

Hoare, R. D. & Pojeta Jr., J. 2006. Ordovician Polyplacophora (Mollusca) from North America. *Paleontological Society Memoirs*, **64**, 1–27.

Hoare, R. D., Sturgeon, M. T. & Hoare, T. B. 1972. Middle Pennsylvanian (Allegheny Group) Polyplacophora from Ohio. *Journal of Paleontology*, **46**, 675–680.

Owen, A. W. & Clarkson, E. N. K. 1992. Trilobites from Kilbucho and Wallace's Cast and the location of the Northern Belt of the Southern Uplands during the late Ordovician. *Scottish Journal of Geology*, 28, 3–17.

Peach, B. N. & Horne, J. 1899. The Silurian rocks of Britain, 1: Scotland. *Memoir of the Geological Survey, U.K.*, xviii, 749 p.

Pojeta Jr., J., Vendrasco, M. J. & Darrough, G. 2010. Upper Cambrian chitons (Mollusca, Polyplacophora) from Missouri, USA. *Bulletins of American Paleontology*, **379**, 1–82.

Reed, F. R. C. 1911. A new fossil from Girvan. *Geological Magazine*, **8**, 337–339.

Rolfe, W. D. I. 1981. *Septemchiton* – a misnomer. *Journal of Paleontology*, **55**, 675–678.

Salter, J. W. 1847. Description of a fossil chiton from the Silurian rocks, with remarks on the fossil species of the genus. *Quarterly Journal of the Geological Society of London*, **3**, 48–54.

Schwabe, E. 2005. A catalogue of Recent and fossil chitons (mollusca: Polyplacophora) Addenda. *Novapex*, **6**, 89–105.

Scrutton, C. T. & Clarkson, E. N. K. 1991. A new scleractinian-like coral from

the Ordovician of the Southern Uplands, Scotland. *Palaeontology*, **34**, 179–194.

Sigwart, J. D. & Sutton, M. D. 2007. Deep molluscan phylogeny: synthesis of palaeontological and neontological data. *Proceedings of the Royal Society B*, **274**, 2413–2419.

Smith A. G. & Hoare, R. D. 1987. Paleozoic Polyplacophora: a checklist and bibliography. *Occasional Papers of the California Academy of Sciences*, **146**, 1–71.

Sutton, M. D. & Sigwart, J. D. 2012. A chiton without a foot. *Palaeontology*, **55**, 401–411.

Sutton, M. D., Briggs, D. E. G., Siveter, David J., Siveter, Derek J. & Sigwart, J. D. 2012. A Silurian armoured aplacophoran and implications for molluscan phylogeny. *Nature*, **490**, 94–97.

Van Belle, R. A. 1975. Sur la classification des Polyplachophora: II. Classification systématique des Lepidopleurina (Neoloricata), avec la description des Helminthochitoninae nov. subfam. (Lepidopleuridae) at de *Mesochiton* nov. gen. (Helminthochitoninae). *Informations de la Société Belge de Malocologie*, **6**, 135–145.

Van Belle, R. A. 1981. *Catalogue of fossil chitons*. Dr. W. Blackhuys,

Rotterdam, 84 pages.

Vendrasco, M. J. & Runnegar, B. 2004. Late Cambrian and Early Ordovician stem group chitons (Mollusca: Polyplacophora) from Utah and Missouri. *Journal of Paleontology*, **78**, 675–689.

Woodward, H. 1885. On a new species of *Helminthochiton* from the Upper Bala (Silurian) of Girvan, Ayrshire. *Geological Magazine*, **22**, 353–355.

Young, J. 1868. On new forms of Crustacea from the Silurian rocks at Girvan. *Proceedings of the Natural History Society of Glasgow*, **1**, 169–173.

Yu, W. 1984. Early Cambrian molluscan faunas of Meishucun Stage with special references to Precambrian-Cambrian boundary. In *Contribution to 27th International Geological Congress*. Science Press, Beijing, 21–35.

Yu, W. 2001. The earliest Cambrian Polyplacophorans from China. *Records of the Western Australia Museum*, **20**, 167–185.

Fig. 1. a, Location of Kilbucho in the context of the Northern Belt of the Southern Uplands. HBF = Highland Boundary Fault; IS = Iapetus Suture; KB = Kilbucho; MV = Midland Valley; OBF = Orlock Bridge Fault; SU = Southern Uplands; SUF = Southern Upland Fault; WC = Wallace's Cast. Redrawn from Owen & Clarkson (1992) and Candela & Harper (2010). b, Map of the fossil locality (indicated by a circled asterisk) at Kilbucho. Redrawn from Clarkson *et al.* (1992b) and Candela & Harper (2010).

Figure 2. Ordovician paleoloricate (Polyplacophora) gen. et sp. nov., intermediate sclerite, Kilbucho, Scotland (Kirkcolm Formation, Lower Katian); NMS G.2005.109.75. **a, c**, external mould and latex cast; note narrow, elevated, slightly expanding jugal fold, broad lateral field flexed at shallow radial ray, rows of pustular ornament. **b**, detail of ornament on the anterior part of the sclerite. **d**, left lateral view of the latex cast. **e**, detail of arched posterior margin and pustular ornament. **f, g**, SEM images of the whole sclerite (f), note arched posterior margin, and detail of the jugal ridge crossed by rows of pustules at mid sclerite (g). Scale bar: a, c, d, f: 1 mm; b, e, g: 200 μ m.



