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Vectipelta barretti, a new ankylosaurian dinosaur from the Lower Cretaceous Wessex Formation of the Isle of Wight, UK

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The Wealden Group of southern England was deposited by rivers, on floodplains and in lagoons during the Early Cretaceous. Two historically significant ankylosaurs, *Polacanthus* and *Hylaeosaurus*, are currently known from its deposits; *Hylaeosaurus* from the 'lower Wealden fauna' and *Polacanthus* from the 'upper Wealden fauna'. Here, we describe a new genus and species of ankylosaur from the Wessex Formation of the Isle of Wight, which is characterized by numerous postcranial autapomorphies. *Vectipelta barretti* gen. et sp. nov. is 6–8 million years older than *Polacanthus*, and at least 3 million years younger than *Hylaeosaurus*, suggesting a more complicated pattern of faunal turnover in the Wealden Group than previously realized. *Vectipelta* does not appear to be closely related to either of the other Wealden taxa, but instead is found in a clade with two Chinese ankylosaurs, suggesting a complex pattern of dispersal to and from Europe, North America and Asia during the Early Cretaceous. The historic practise of cataloguing all ankylosaur material from the Wessex Formation as '*Polacanthus*' has potentially prevented a diversity of taxa from being discovered, and new and existing material in museum collections should be re-appraised using an autapomorphy-driven approach.

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Keywords: Dinosauria; Ornithischia; Wealden Group; Barremian; osteology; taxonomy

Introduction

Ankylosauria are a diverse clade of ornithischian dinosaurs characterized by a broad body, short limbs and an extensive covering of dermal armour on the head, body and tail. Their remains are known from all continents, but they are best known from the better-sampled former Laurasian continents of North America, Asia and Europe (Arbour & Currie, 2016; Thompson et al., 2012; Vickaryous et al., 2004). The ankylosaurs split from their sister taxon, the stegosaurs, in the late Early or early Middle Jurassic (Maidment et al., 2020, 2021). During the Jurassic, they appear to have been a minor constituent of ecosystems, but they radiated in the Early Cretaceous to become a significant component of terrestrial herbivorous faunas until the end of the Cretaceous, when they went extinct, along with all other non-avian dinosaurs, at the Cretaceous–Palaeogene mass extinction event (Thompson et al., 2012; Vickaryous et al., 2004).

Several ankylosaurs are known from the Jurassic and Cretaceous of the UK, including one of the oldest recorded, *Sarcolestes leedsi*, from the Callovian Oxford Clay Formation (Galton, 1983). British ankylosaurs are

best known, however, from the lower Cretaceous Wealden Group of southern England, from where two valid genera, *Polacanthus foxii* and *Hylaeosaurus armatus*, are known (Raven et al., 2020). *Hylaeosaurus* is of considerable historical importance as one of the three taxa on which Richard Owen founded his new group, Dinosauria (Owen, 1842). Although a large amount of ankylosaur material found in the Wealden Group, and particularly from the Isle of Wight, has been traditionally referred to *Polacanthus* (e.g. Blows, 2015; see Raven et al., 2020 for a detailed account), in a recent review, Raven et al. (2020) concluded that the name should be restricted to the holotype specimen (NHMUK PV R175) and that all other partial skeletons in publicly accessible collections were generically indeterminate.

Although poorly dated, the Wealden Group of the Isle of Wight spans the Barremian and lower Aptian, a time period of at least 8 million years and perhaps significantly longer (Lockwood et al., 2021). The approach of identifying all ankylosaur material from the Wealden Group of the Isle of Wight as *Polacanthus* without appealing to autapomorphies or unique character combinations for identification (e.g. Blows, 2015) may well have obscured

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greater diversity in the ankylosaur fauna over this considerable span of geological time than is currently appreciated. An analogous situation occurs in the island's iguanodontian fauna, where long-held habits of identifying gracile material as *Mantellisaurus* and robust, larger material as *Iguanodon* has hidden diversity that we are only now beginning to reveal (Lockwood *et al.*, 2021).

Early Cretaceous dinosaur faunas are rare worldwide, hindering our attempts to understand a purported mass extinction event that may have taken place at the end of the Jurassic: the paucity of Early Cretaceous terrestrial faunas means that it is difficult to investigate whether this event was a mass extinction or whether it is an artefact of sampling bias and, if a mass extinction occurred, it is difficult to reconstruct how ecosystems recovered following it (Tennant *et al.*, 2017). The Wealden Group, deposited from the Valanginian to Aptian, is one of few dinosaur-bearing rock sequences worldwide that fills this gap, and thus an accurate understanding of its dinosaur diversity and distribution through time is crucial if we hope to shed light on the purported end-Jurassic extinction event and how faunas recovered following it.

Herein, we describe and name a new genus and species of ankylosaur, *Vectipelta barretti*, from the lower Barremian Wessex Formation of the Isle of Wight. *Vectipelta* may be as much as 8 million years older than the holotype of *Polacanthus*, and differs from it in features of the cervical and dorsal vertebrae and the iliosacral block. Our results demonstrate that ankylosaur diversity in the Wealden Group of southern England was higher than previously realized, and that the practice of referring isolated ankylosaur material from the Wessex Formation to *Polacanthus* should cease.

Institutional abbreviations

AMNH, American Museum of Natural History, New York, NY, USA; **BYU**, Brigham Young University Museum, Provo, UT, USA; **DMNH**, Denver Museum of Nature and Science, CO, USA; **IWCMS**, Dinosaur Isle Museum, Sandown, Isle of Wight, UK; **NHMUK**, Natural History Museum, London, UK; **UM2**, Université des Sciences et Techniques du Languedoc, Montpellier, France; **USNM**, National Museum of Natural History, Smithsonian Institution, Washington, DC, USA; **YPM**, Peabody Museum, Yale University, New Haven, CT, USA.

Methods

Photogrammetry

The specimen was recorded using manual photogrammetry, an established and widely used technique (Mallison & Wings, 2014) for creating 3D point clouds and meshes

by taking overlapping photographs that are then processed using specialist software. Photogrammetry is capable of recording detail to sub-millimetre resolution with a high degree of reproducibility (Fahlke & Autenrieth, 2016), with an accuracy superior to that of a hand scanner (Díez Díaz, *et al.*, 2021) and similar to that of LIDAR. Photographs were taken on a Fuji X10 camera mounted on a tripod and the data processed in Agisoft Photoscan and Agisoft Metashape. A detailed account of the methodology used can be found in the [Supplemental material](#).

Histology

A section of the pelvic shield with ilium attached was cut along an existing break, and two thin sections perpendicular to each were prepared in accordance with standard histological practices for fossil bone (Padian & Lamm, 2013). Slides were examined under a Brunel SP-78P polarizing microscope with digital microscope camera attachment (Nikon D70s), using plane polarized (PPL) and cross polarized light (XPL) and with the addition of a lambda filter. Lightbox macrophotography was used to obtain complete images of the thin sections using a Canon EOS 7D camera with a Canon EF100mm f/2.8 lens.

Phylogeny

A new phylogenetic analysis has not been carried out herein, because the specimen was already included in Raven *et al.* (2023), which is a whole-group, species-level phylogenetic analysis of Thyreophora, and the most complete phylogenetic analysis of armoured dinosaurs carried out to date. In that analysis, the specimen was referred to as the “Spearpoint ankylosaur”. Here, we present the preferred topology from the series of analyses carried out by Raven *et al.* (2023), but focus our discussion on the phylogenetic placement of *Vectipelta*, which was not investigated in any detail in that contribution. The character–taxon matrix of Raven *et al.* (2023) comprised 91 taxa and 340 characters. Safe taxonomic reduction was carried out prior to analysis using the R package *Claddis* (Lloyd, 2016). The preferred topology was obtained using an extended-implicit weights parsimony analysis with a k-value of 3, carried out using a New Technology Search in TNT v. 1.5 (Goloboff & Catalano, 2016). Sectorial search, the parsimony ratchet with 20 substitutions, tree fusing with five rounds, and tree-drifting were used, with 100 random addition sequences. Zero-length branches were collapsed. In order to assess clade support, symmetric resampling was applied using 5000 replicates and a New Technology search, and Bremer support was

applied using the BREMER.run script in TNT. The ensemble consistency index, ensemble retention index, ensemble rescaled consistency index and homoplasy index were calculated using the STATS.run script in TNT. A more complete account of methods and their justification can be found in Raven et al. (2023).

Geological setting

The Lower Cretaceous strata of the Wealden Group of southern England consists of terrestrial, lacustrine, fluvial and lagoonal deposits (Batten, 2011) that are divided into two distinct sub-basins, the Wessex Sub-basin of the Isle of Wight and the Weald Sub-basin of south-east England (Radley & Allen, 2012).

The coastal exposures of the Wessex Sub-basin on the Isle of Wight comprise the Wessex and Vectis formations (Fig. 1). The Wessex Formation is considered Barremian in age (Austen & Batten, 2018) and consists of variegated mudstones and interbedded sandstones deposited as river channel, floodplain and point bar deposits by a high-sinuosity river system flowing west to east (Sweetman, 2011) across a low-relief valley (Stewart, 1978). Sandstones probably represent sand bar, crevasse splay, levee, and channel infills (Insole et al., 1998) and these often contain casts of the tracks of dinosaurs (Martill & Naish, 2001; Pond et al., 2014). It is estimated around 180 m of the Wessex Formation is exposed on the island, with borehole data indicating a total thickness of approximately 580 m (Sweetman, 2011).

The Wessex Formation is overlain by the strata of the younger upper Barremian/lower Aptian Vectis Formation (Radley & Allen, 2012; Sweetman & Goodyear, 2019) that is considered to have been deposited under shallow lagoonal conditions (Allen & Wimbledon, 1991). On the Isle of Wight, the Wessex and Vectis Formations are exposed along the south-west coast of the island, with less extensive exposures at Yaverland on the south-east coast.

The palaeoenvironment of the Wessex Formation is thought to have had a climate similar to the Mediterranean of today, with distinct arid and wet seasons (Allen, 1998; Haywood et al., 2004; Sweetman, 2011). The Wessex Formation represents a complex riparian system and contains the remains of plants, including logs of gymnosperms at the 'Pine Raft' at Hanover Point (Insole et al., 1998), ichnofossils of invertebrates and vertebrates (Pond et al., 2014), contains a diverse fauna of invertebrates (Radley & Barker, 2000), and is well known for its vertebrates, including bony fish, turtles, crocodilians, pterosaurs and dinosaurs

(Sweetman & Insole, 2010). The mottled red and grey deposits, their colour the result of pedogenic processes (Sweetman, 2011), also contain lenses of organic-rich sediment distributed apparently at random throughout the succession, known as plant debris beds (Fig. 1; Insole et al., 1998; Sweetman & Insole, 2010). These are thought to have formed when the remains of plants and animals were swept up in debris flows by periodic flood events and redeposited on the floodplain in ephemeral ponds (Sweetman & Insole, 2010); these debris flows were strong enough to transport tree trunks and large dinosaur bones over short distances (Sweetman & Goodyear, 2019). The occurrence of abundant fusain in plant debris beds is considered evidence of frequent wildfires (Sweetman & Insole, 2010) and the presence of the coprolites of termites observed in plant debris bed residues indicates termite activity may have played a significant role in the destruction of plant material (Sweetman & Goodyear, 2019). Plant debris beds are the main source of vertebrate fossils, including dinosaurs, on the Isle of Wight (Lockwood et al., 2021).

Discovery, excavation and previous work

The specimen was found approximately 50 m to the west of Chilton Chine (Fig. 2), in an area which forms part of the Compton Chine to Steephill Cove Site of Special Scientific Interest (SSSI), the Compton to Atherfield Geological Conservation Review site, and the Isle of Wight Area of Outstanding Natural Beauty. The SSSI was notified in 2003 for its geological, geomorphological and biological features, including its species-rich chalk grassland, nationally rare plant species, nationally rare invertebrates, the characteristic 'chines' that emerge from the cliffs as waterfalls and are the result of rapid cliff recession preventing the streams from eroding to base level, and its cliff and foreshore exposures of the Wealden Group and overlying Lower Greensand Group between Hanover Point and St. Catherine's Point. The dinosaurian fauna found within the SSSI include the sauropods *Eucamerotus* and *Ornithopsis* (Upchurch et al., 2011), the theropods *Aristosuchus*, *Eotyrannus*, *Neovenator*, *Baryonyx*, *Yaverlandia* (Naish, 2011), *Ceratosuchops* and *Riparovenator* (Barker et al., 2021), the ornithomimids *Hypsilophodon*, *Iguanodon*, *Mantellisaurus*, *Valdosaurus* (Norman, 2011) and *Brighstoneus* (Lockwood et al., 2021), and the thyreophoran *Polacanthus* (Raven et al., 2020), as well as a number of footprints (Pond et al., 2014).

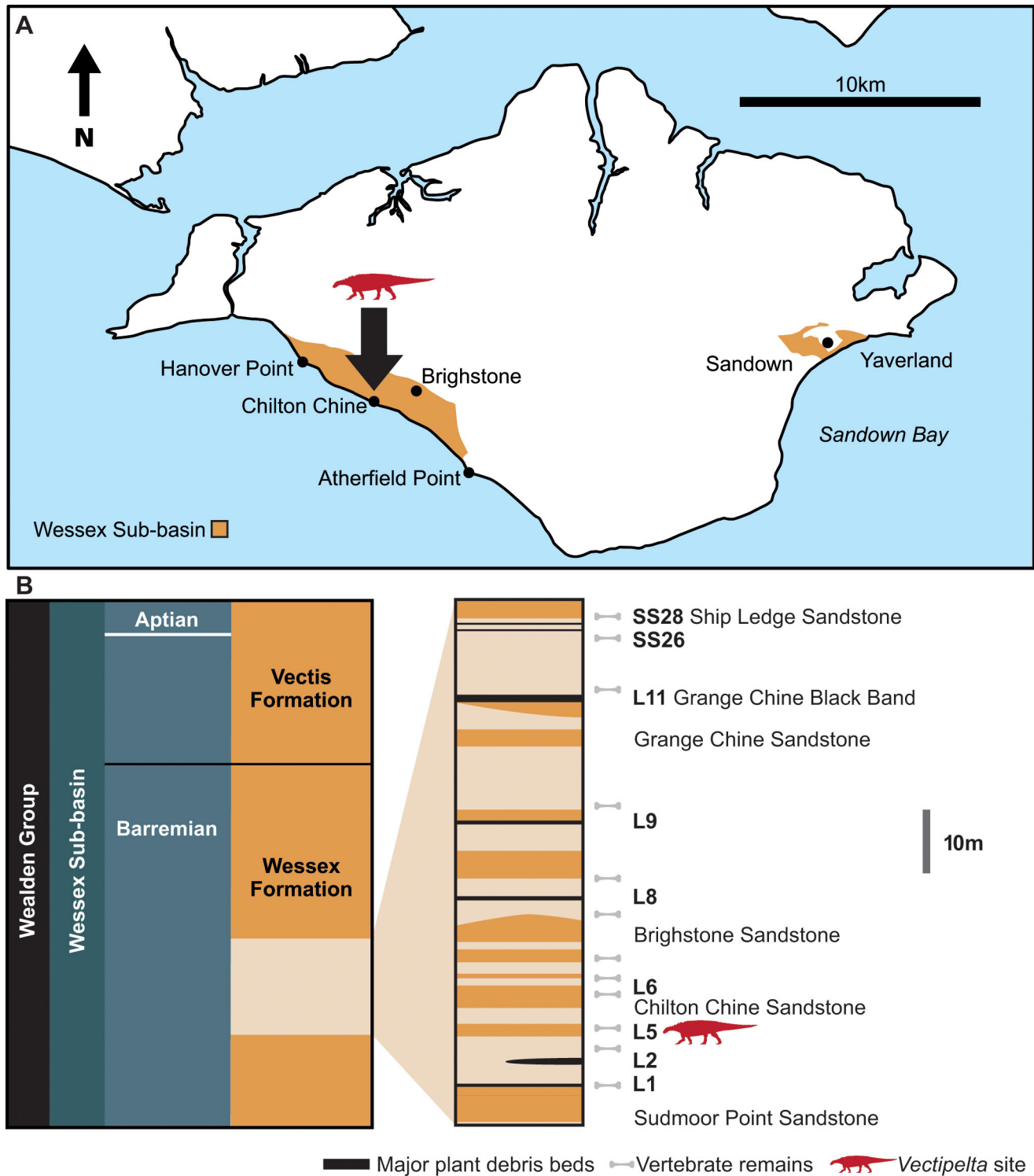


Figure 1. Geological setting and stratigraphy. **A**, map of Isle of Wight with the extent of Wessex Sub-basin marked in orange, and the site of the *Vectipelta barretti* gen. et sp. nov. (IWCMS 1996.153 and IWCMS 2021.75) excavation indicated by the black arrow. Adapted from Pond et al. (2014). **B**, schematic stratigraphical log of the outcrop between Sudmore Point and Ship Ledge showing the approximate stratigraphical location of *Vectipelta barretti* gen. et sp. nov. (IWCMS 1996.153 and IWCMS 2021.75). Adapted from Sweetman and Insole (2010) and Radley and Allen (2012). Bed numbers follow scheme established in Stewart (1978).

Several vertebrae belonging to the specimen were collected from the beach in November 1993 by Gavin Leng, and he later donated them to the collections of Dinosaur Isle Museum. This material is accessioned with the number IWCMS 1996.153. The remainder of the skeleton was found by Lin Spearpoint in March or April of 1994 in cliffs belonging to Richard Fisk (Fig. 2). Richard Fisk gave permission for Lin Spearpoint, Dick Spearpoint and one of us (MIS) to excavate and acquire the specimen. Due to the logistical difficulties of working with tides, poor weather, and on landslipped ground, no complete quarry map was made, but photographs were taken (Fig. 2). MIS noted that the skeleton lay with its anterior facing out to sea, and the dorsal vertebrae were scattered in this area. The pelvis was upside down, indicating that the specimen was probably lying with its dorsal surface downwards. The largest spines were located near the front of the animal. The

tail vertebrae were associated but not fully articulated. The specimen was acquired by the Dinosaur Isle Museum in November 2021 and given the accession number IWCMS 2021.75.

Several years prior to 1993, a beach-rolled braincase was collected from the same locality by David Cooper. This was acquired by the Sedgwick Museum, University of Cambridge (CAMSM X.26242), and subsequently described by Norman and Faiers (1996) as cf. *Polacanthus*. Anecdotally, it has long been considered that this braincase belongs to the same individual, and although it is a possibility, there is no way of independently verifying this. A partial femur and posterior part of an ilium were also collected from the same locality by David Richards some time in the 1990s. These were donated to the Natural History Museum, London (NHMUK PV R16484, R16485) upon his death and were originally registered as *Polacanthus* (although are



Figure 2. Photographs of the site of the excavation of *Vectipelta barretti* gen. et sp. nov. taken at the time. The green crate indicates the approximate location of the specimen in the landslip. **A**, the site as seen from the foreshore at Chilton Chine. The break in the cliffs towards the right of the photograph is the entrance to the chine. **B**, close-up of the dig site.

now considered as *Ankylosauria incertae sedis* and *Dinosauria incertae sedis*; Raven *et al.*, 2020). These specimens may also relate to the skeleton we describe here; of note, the posterior part of the ilium is heavily eroded and beach-rolled, but is not duplicated in the material preserved in IWCMS 2021.75. However, we cannot independently verify that this material comes from the same specimen, and consequently none of these specimens will be considered further herein.

Prior to acquisition by the Dinosaur Isle Museum, the specimen was under study at the University of Southampton, where it formed the subject of various MSci, MRes and PhD projects, including by some of us (SP, SJS, KM). It was also temporarily displayed at the SeaCity Museum, Southampton. Known as the Spearpoint ankylosaur, parts of the skeleton have been figured in Blows (2015) and Lomax and Tamura (2014) as *Polacanthus*, and the specimen was included in the phylogeny of Raven *et al.* (2023).

Systematic palaeontology

Dinosauria Owen, 1842

Ornithischia Seeley, 1887

Thyreophora Nopcsa, 1915 (*sensu* Norman, 1984)

Ankylosauria Osborn, 1923

Vectipelta barretti gen. et sp. nov.

(Figs 3–26)

Holotype. A partial skeleton containing cervical, dorsal, sacral and caudal vertebrae, fragmentary girdle and limb elements, and numerous osteoderms, housed in the Dinosaur Isle Museum, Isle of Wight (Fig. 3). Parts of the specimen were acquired at different times by the Museum and are therefore accessioned under different specimen numbers. The cervical vertebrae and six of the free dorsals have the specimen number IWCMS 1996.153. The remainder of the skeleton is accessioned under the number IWCMS 2021.75.

Locality and horizon. The specimen was discovered in a plant debris bed in a landslipped block that retained original stratigraphy, 50 m west of Chilton Chine on the south-west coast of the Isle of Wight (Fig. 1). Plant debris bed L5 (Gale, 2019), Wessex Formation, Wealden Group. Plant debris bed L5 lies close to the base of the exposed Wessex Formation on the Island, which is thought to be earliest Barremian in age (Lockwood *et al.*, 2021).

Etymology. *Vectipelta* is derived from the Roman name for the Isle of Wight, *Vectis*, and ‘*pelta*’, meaning shield in Latin, referring to the characteristic dermal armour.

‘*Barretti*’, in honour of Prof. Paul M. Barrett, in recognition of his major and ongoing contributions to dinosaurian vertebrate palaeontology, and his importance to SP, TJR and SCRM as a mentor, supervisor, colleague and friend.

Diagnosis. *Vectipelta barretti* differs from other ankylosaurs by the possession of the following autapomorphies: anteriorly projecting lip on the ventral surface of the anterior articular facet of the axis; deep fossa present in the floor of the neural canal, piercing the centrum in cervical and caudal vertebrae; postzygapophyses of cervical vertebrae widely separated by a deep, transversely broad and dorsoventrally elongate fossa containing a midline ridge extending dorsally towards the neural spine; epipophyses present in posterior cervical vertebrae; highly rugose ridges extending ventrally from the parapophyses to the centrum in anterior dorsal vertebrae; anterior centroparapophyseal laminae present on the neural arches in mid-dorsal vertebrae; ischium with elongate, gently curving shaft in lateral view that is straight in anterior view; sacral shield smooth on its dorsal surface with gently undulating low-relief ornamentation.

Osteological description

In what follows, comparative observations followed by a specimen number indicate the observation was made first-hand, while those followed by a citation indicate the observation was made from the literature.

Cervical vertebrae (Figs 4, 5, Supplemental material Fig. S1). Parts of four cervical vertebrae are preserved. The axis (Fig. 4A–F) is more-or-less complete, although the centrum is cracked and offset transversely. The anterior part of the odontoid process is broken (Fig. 4E), and fragments of CV 3 adhere to the posterior articular surface (Fig. 4F). The anterior articular facet of the centrum is strongly dorsoventrally compressed in anterior view (Fig. 4E). The surface is flat, but ventrally it bears a small anteriorly projecting lip that is convex on its dorsal surface (Fig. 4C–E, lip). The posterior articular facet is shallowly concave and rounded in posterior view (Fig. 4F, posart), and is offset ventrally relative to the anterior articular facet. In lateral view, transverse cracking of the centrum obscures its true shape. A rounded parapophysis is located slightly posterior to the anterior articular facet and is angled posterolaterally (Fig. 4C, D, para). The ventral margin of the centrum is upwardly concave in lateral view (Fig. 4C, D). The neural arch is mostly preserved. It is slightly deformed so that it is crushed to the right side. The neural spine is triangular in lateral view (Fig. 4C, D, ns), sloping steeply posterodorsally. Its dorsal margin

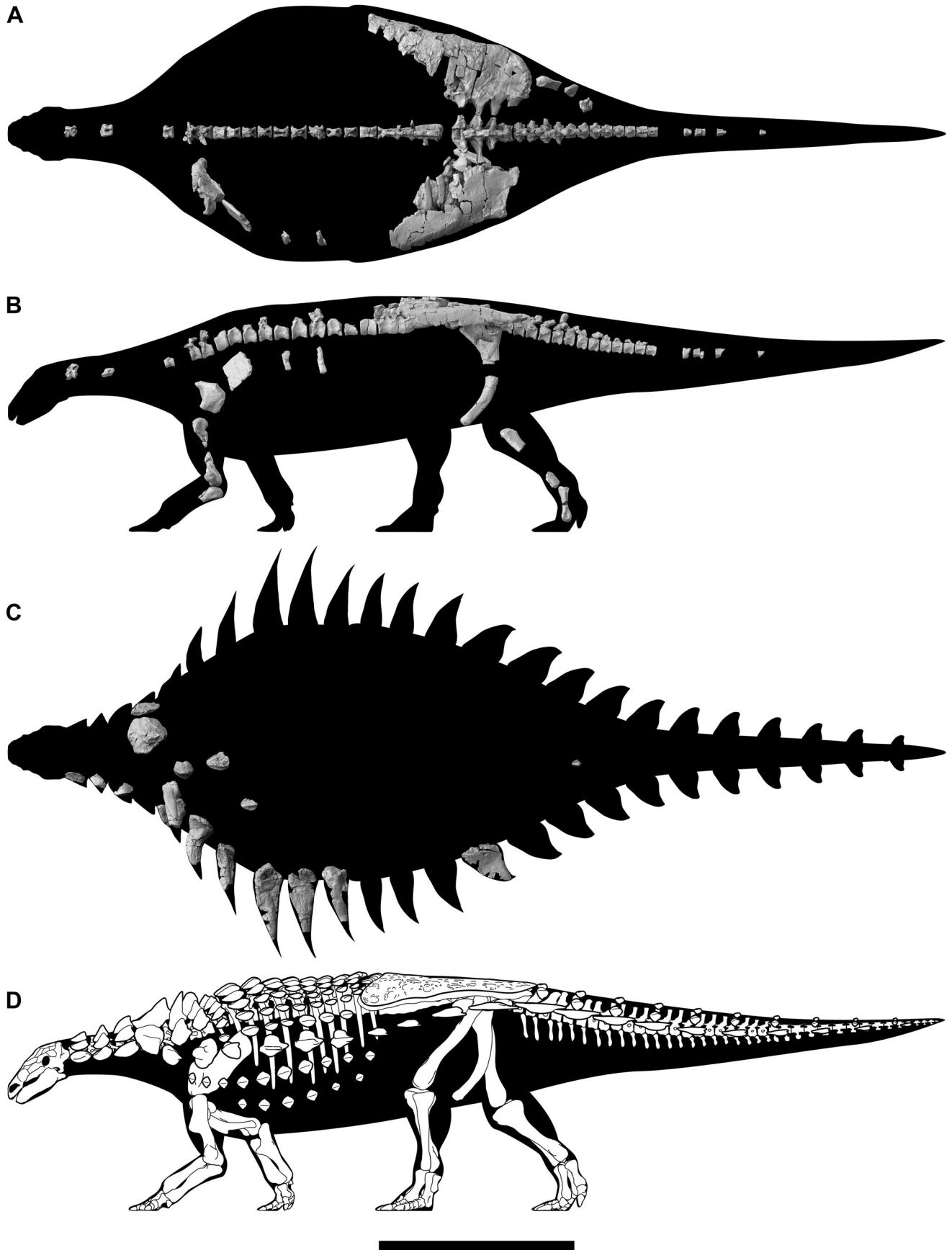
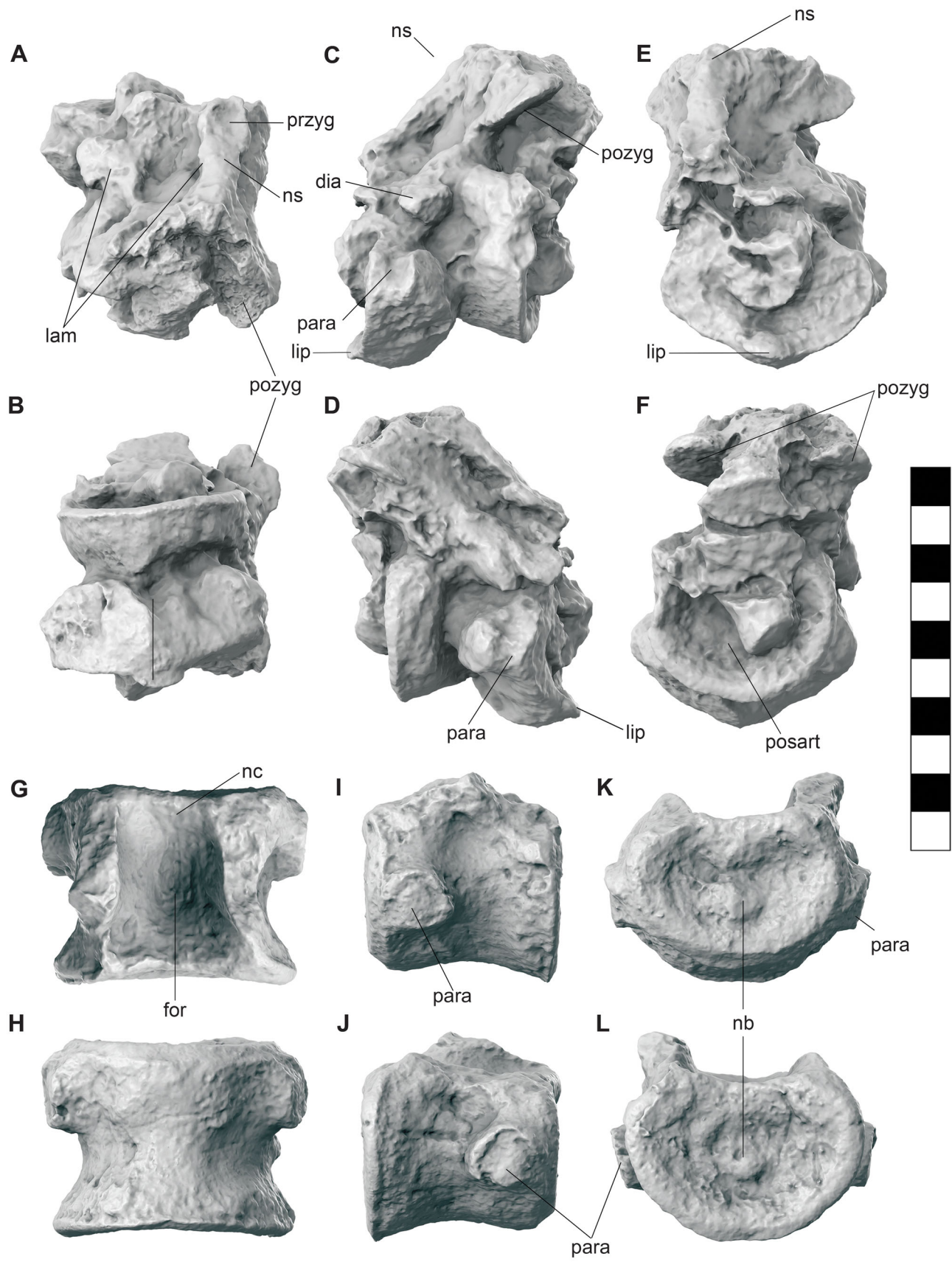


Figure 3. Holotype material of *Vectipelta barretti* gen. et sp. nov., IWCMS 1996.153 and IWCMS 2021.75 in **A**, dorsal view; **B**, left lateral view; **C**, dorsal view of the osteoderms only; **D**, complete skeletal reconstruction, in left lateral view. Scale bar = 1 m.



is transversely thickened and rugose. Anteriorly the neural spine is flat on top and becomes slightly convex extending posteriorly. Posteriorly, the dorsal surface of the neural spine divides in two laminae which extend over the postzygapophyses (Fig. 4A, lam). The articular facets of the postzygapophyses face ventrally and are widely separated (Fig. 4F, pozyg). They are rounded in outline in ventral view. Short, oval diapophyses extend from about half-way down the neural arch as small nubbins on either side (Fig. 4C, dia).

Two centra appear to be proximal cervicals based on the similarity of their size to the centrum of the axis. One is beach rolled and obliquely crushed (Fig. S1); the other is better preserved (Fig. 4G–L). Articular facets are flat to shallowly concave and both bear small notochordal bosses centrally (Fig. 4K, L, nb). They are dorsoventrally compressed so that the articular facets are wider transversely than they are tall dorsoventrally, as is usually the case in ankylosaurs (Raven et al., 2020 and references therein). Laterally the centra are saddle-shaped (dorsoventrally convex, anteroposteriorly concave), lacking the anteroposteriorly extending ridge present in *Hylaeosaurus* (Raven et al., 2020) and *Gargoyleosaurus* (Kilbourne & Carpenter, 2005) and the ventral margin is gently upwardly concave (Fig. 4I, J), as in *Hylaeosaurus* (Raven et al., 2020) and *Europelta* (Kirkland et al., 2013), but in contrast to *Gargoyleosaurus* (Raven et al., 2020), which has a straight ventral margin. A ventral keel is not present (Fig. 4H), in contrast to *Hylaeosaurus* (Raven et al., 2020), *Gargoyleosaurus* (Kilbourne & Carpenter, 2005) and *Pinacosaurus* (Burns et al., 2015). A large and deep foramen is present in the floor of the neural canal (Fig. 4G, for), differing from *Texastes*, in which there is an elongate groove (Coombs, 1995). A deep foramen has not previously been described in any ankylosaur to our knowledge, and thus appears autapomorphic for the taxon.

A posterior cervical vertebra (based on size) is well preserved (Fig. 5). The centrum is wider transversely than it is long anteroposteriorly, as in most ankylosaurs but in contrast to *Struthiosaurus*, *Stegopelta* and *Hungarosaurus*, in which the centra are elongate (Carpenter & Kirkland, 1998; Ősi, 2005; Pereda Suberbiola & Galton, 1997, 2001). The anterior and posterior articular facets are shallowly concave (Fig. 5E, F). The anterior centrum facet has broad and shallow a notochordal boss (Fig. 5E). In lateral view (Fig. 5C, D)

the centrum is flat ventrally, bearing a transversely broad, slightly rugose ridge extending from anterior to posterior articular facet (Fig. 5B). The lateral surfaces of the centrum are saddle-shaped (Fig. 5C, D). There is a small foramen located centrally on the left lateral surface (Fig. 5D, for). The parapophyses are rounded, located just posterior to the anterior articular facet, supported on slightly raised processes, and are gently concave (Fig. 5C, D). The neural canal is wider transversely than it is tall dorsoventrally (Fig. 5E, F). The left prezygapophysis is preserved; the right is broken off. An anteroposteriorly narrow intraprezygapophyseal shelf separated the prezygapophyses (Fig. 5E, ipps); such a shelf does not appear to be present in *Ankylosaurus* (Brown, 1908), *Euoplocephalus* (AMNH 5404), *Gastonia burgei* (BYU 16425), *Hungarosaurus* (Ősi, 2005) or *Sauropelta* (YPM 5166, 5167, 5168) but a similar feature is present on the posterior cervicals of *Europelta* (Kirkland et al., 2013). The preserved prezygapophysis is rounded in outline and angled dorsally and slightly medially (Fig. 5E, pryzg). In lateral view, the transverse processes arise from the lateral surfaces of the prezygapophyses (Fig. 5C, D, tp); this differs from the condition in *Ankylosaurus* (Carpenter, 2004), *Euoplocephalus* (AMNH 5404), *Pinacosaurus* (Burns et al., 2015) and *Hungarosaurus* (Ősi, 2005) where the transverse processes project from the neural arch ventral and posterior to the prezygapophyses, but is similar to *Sauropelta* (YPM 5166, 5167, 5168), *Europelta* (Kirkland et al., 2013) and *Gastonia burgei* (BYU 16452). Transverse processes are rounded in cross-section and angle laterally (Fig. 5C, D), as in *Ankylosaurus* (Brown, 1908), *Gastonia burgei* (BYU 16452), *Europelta* (Kirkland et al., 2013), *Hungarosaurus* (Ősi, 2005) and *Sauropelta* (YPM 5166, 5167, 5168). Ventral to the diapophyses, a deep fossa is present and is bordered posteriorly by a posterior centrodiaepophyseal lamina that is well pronounced and extends posteroventrally to the presumed location of the neurocentral suture and the posterior articular facet (Fig. 5C, D, cdpl). Such a marked lamina does not appear to be present in *Sauropelta* (YPM 5166, 5167, 5168), *Europelta* (Kirkland et al., 2013), *Hungarosaurus* (Ősi, 2005) or *Euoplocephalus* (AMNH 5404), but is present in *Gastonia burgei* (BYU 16452). In posterior view, the right postzygapophysis is preserved (Fig. 5F, pozyg). It is oval in outline with the long-axis anteroposterior, and projects only a very small amount beyond the posterior

Figure 4. *Vectipelta barretti* gen. et sp. nov., IWCMS 1996.153. A–F, axis and G–L, anterior cervical centrum in A, G, dorsal; B, H, ventral; C, I, left lateral; D, J, right lateral; E, K, anterior, and F, L, posterior views. **Abbreviations:** dia, diapophysis; for, foramen; lam, lamina; lip, lip on ventral part of anterior articular facet; nb, notochordal boss; nc, neural canal; ns, neural spine; para, parapophysis; posart, posterior articular facet; pozyg, postzygapophysis; pryzg, prezygapophysis. Scale bar = 10 cm.

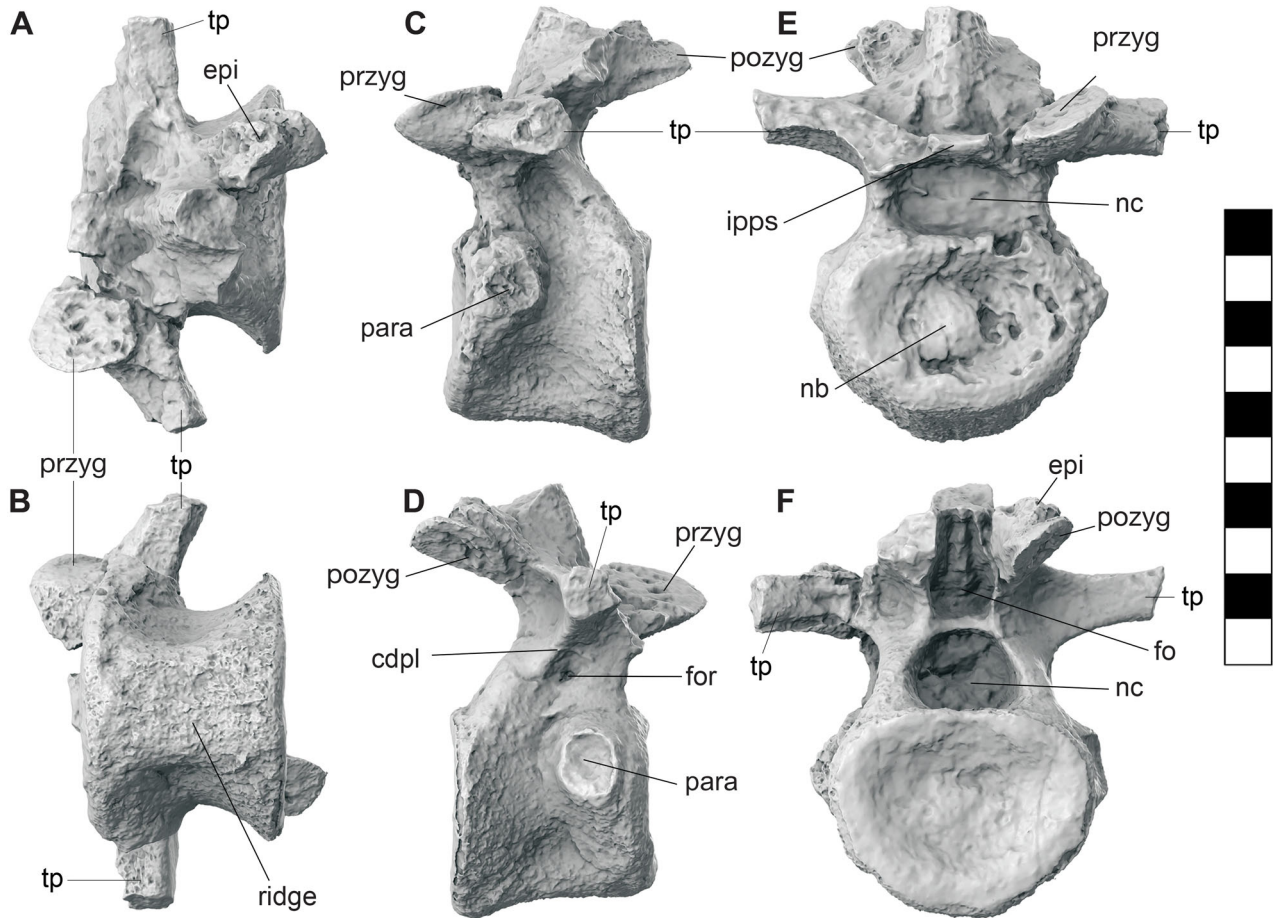


Figure 5. *Vectipelta barretti* gen. et sp. nov., IWCMS 1996.153. Posterior cervical vertebra in **A**, dorsal; **B**, ventral; **C**, left lateral; **D**, right lateral; **E**, anterior and **F**, posterior views. **Abbreviations:** **cdpl**, centrodiapophyseal lamina; **epi**, epipophysis; **fo**, fossa; **for**, foramen; **ipps**, intraprezygapophyseal shelf; **nb**, notochordal boss; **nc**, neural canal; **para**, parapophysis; **pozyg**, postzygapophysis; **przyg**, prezygapophysis; **tp**, transverse process. Scale bar = 10 cm.

articular facet of the centrum (Fig. 5D). The postzygapophyses were distinctly separated; between them is a deep, transversely broad and dorsoventrally elongate fossa with a ridge that extends from the dorsal margin of the neural canal (which is developed into a shelf extending posteriorly) dorsally to the point where the neural arch is broken (Fig. 5F, fo). This differs from the condition in *Europelta* (Kirkland et al., 2013) and *Hungarosaurus* (Ősi, 2005) where the postzygapophyses appear to be closer together, and *Ankylosaurus* (Brown, 1908), *Gastonia burgei* (BYU 16452) and *Sauropelta* (YPM 5166, 5167, 5168) where the postzygapophyses are far apart but no fossa is present. Such a deep and broad fossa does not appear to have been described previously for any ankylosaur, suggesting that it is autapomorphic for *Vectipelta*. Dorsally, the dorsal surface of the postzygapophysis bears a rugose epipophysis (Fig. 5F, epi). Epipophyses have not been previously described in ankylosaurs to our knowledge, and indeed

they are rare in ornithischian dinosaurs beyond the proximal-most cervicals. Their presence here is probably autapomorphic for *Vectipelta*. The neural spine is broken.

Dorsal vertebrae (Figs 6–8, Supplemental material S2–S10). Eleven free dorsal vertebrae and five dorsal vertebrae that are fused together to form the presacral rod are preserved, indicating that *Vectipelta* possessed at least 16 dorsals. None of the free dorsal vertebrae are completely preserved, and most preserve only the centrum and neural canal (Figs 6, 7; Supplemental material Figs S2–S10). Eleven free dorsals are also known for *Ankylosaurus* (Carpenter, 2004).

The articular facets of the centra of anterior dorsals (Fig. 6E, F) are heart-shaped in anterior and posterior views, and flat to slightly concave with small notochordal bosses. The centra are anteroposteriorly longer than they are dorsoventrally tall and they are wider

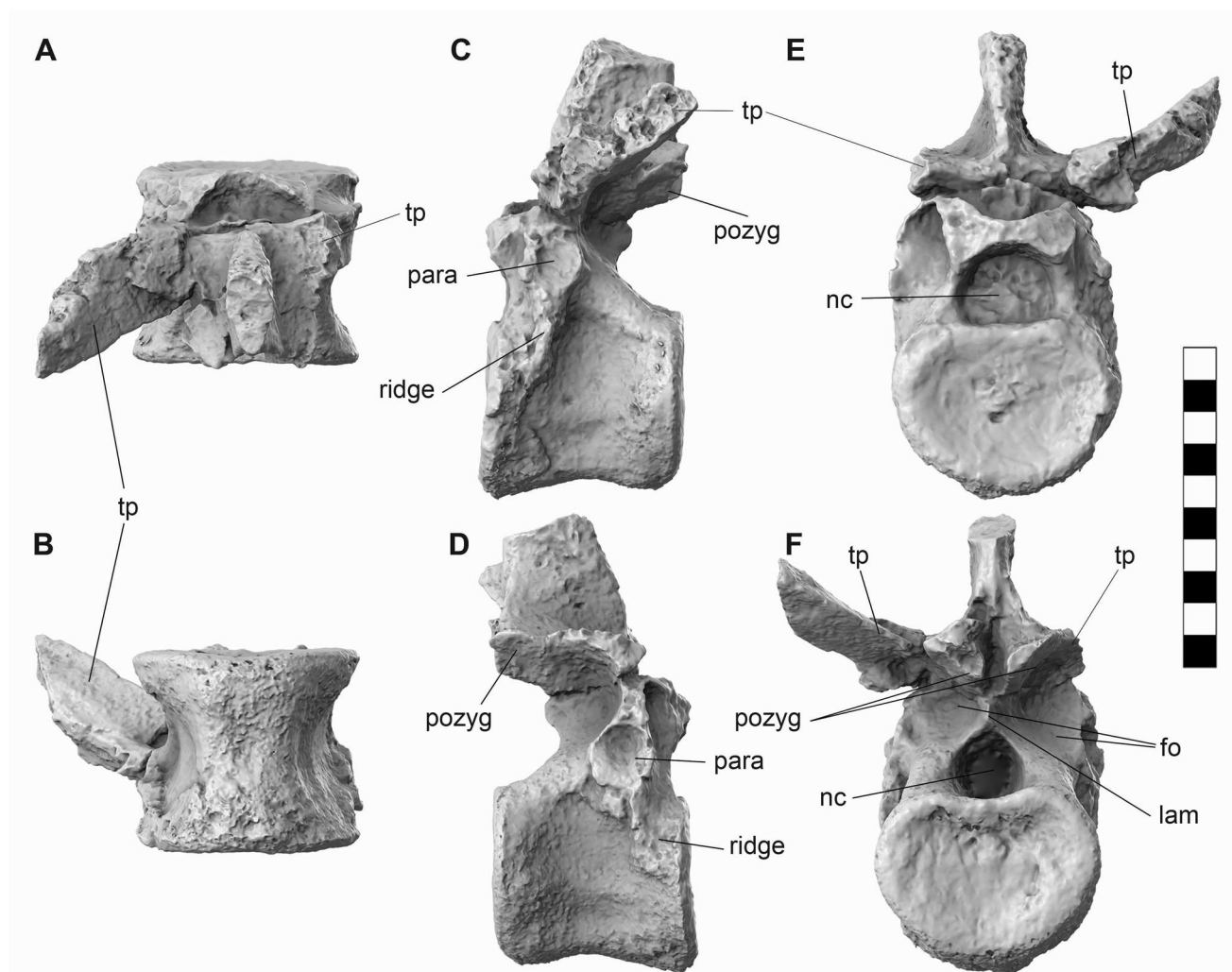


Figure 6. *Vectipelta barretti* gen. et sp. nov., IWCMS 1996.153. Anterior dorsal vertebra in **A**, dorsal; **B**, ventral; **C**, left lateral; **D**, right lateral; **E**, anterior and **F**, posterior views. **Abbreviations:** fo, fossa; lam, lamina; nc, neural canal; para, parapophysis; pozyg, postzygapophysis; ridge, rugose ridge; tp, transverse process. Scale bar = 10 cm.

transversely than they are tall dorsoventrally. Extending down the column, the centra become more anteroposteriorly elongate, the articular facets become narrower transversely, and notochordal bosses are reduced or absent (Fig. 7E, F). In lateral view, the ventral surfaces of the centra are concave dorsally (Figs 6C, D; 7C, D). Ventrally, anterior dorsal centra possess a broad, gentle ridge that becomes less distinct extending posteriorly along the column (Figs 6B, 7B). This differs from the condition in *Hylaeosaurus* (Raven et al., 2020) and *Struthiosaurus languedocensis* (Garcia & Pereda Suberbiola, 2003), which both possess a keel ventrally on dorsal centra (Raven et al., 2020).

In anterior dorsals, the neural canal is circular (Fig. 6E, F, nc), but it becomes more elliptical extending down the column (Fig. 7 E, F, nc). No free dorsal

vertebra preserves a complete neural arch. One dorsal, which is perhaps the first or second based on the morphology of the centrum and location of the parapophysis (Fig. 6), possesses rounded, concave parapophyses elevated on pedestals and level with the neural canal (Fig. 6C, D, para). Rugose ridges extend from the anteroventral margin of the parapophyses ventrally, and merge with the lateral surface of the centrum just posterior to the anterior articular facet (Fig. 6C, D, ridge). Such rugosities extending ventrally from the parapophyses are unknown in other ankylosaurs (e.g. *Polacanthus*, NHMUK PV R175; *Sauropelta*, YPM 5154, 5495; *Euoplocephalus*, AMNH 5337; *Gastonia burgei*, BYU 11640; *Europelta*, Kirkland et al., 2013) and represent an autapomorphy of this taxon. Extending down the column the parapophyses migrate dorsally to a location at

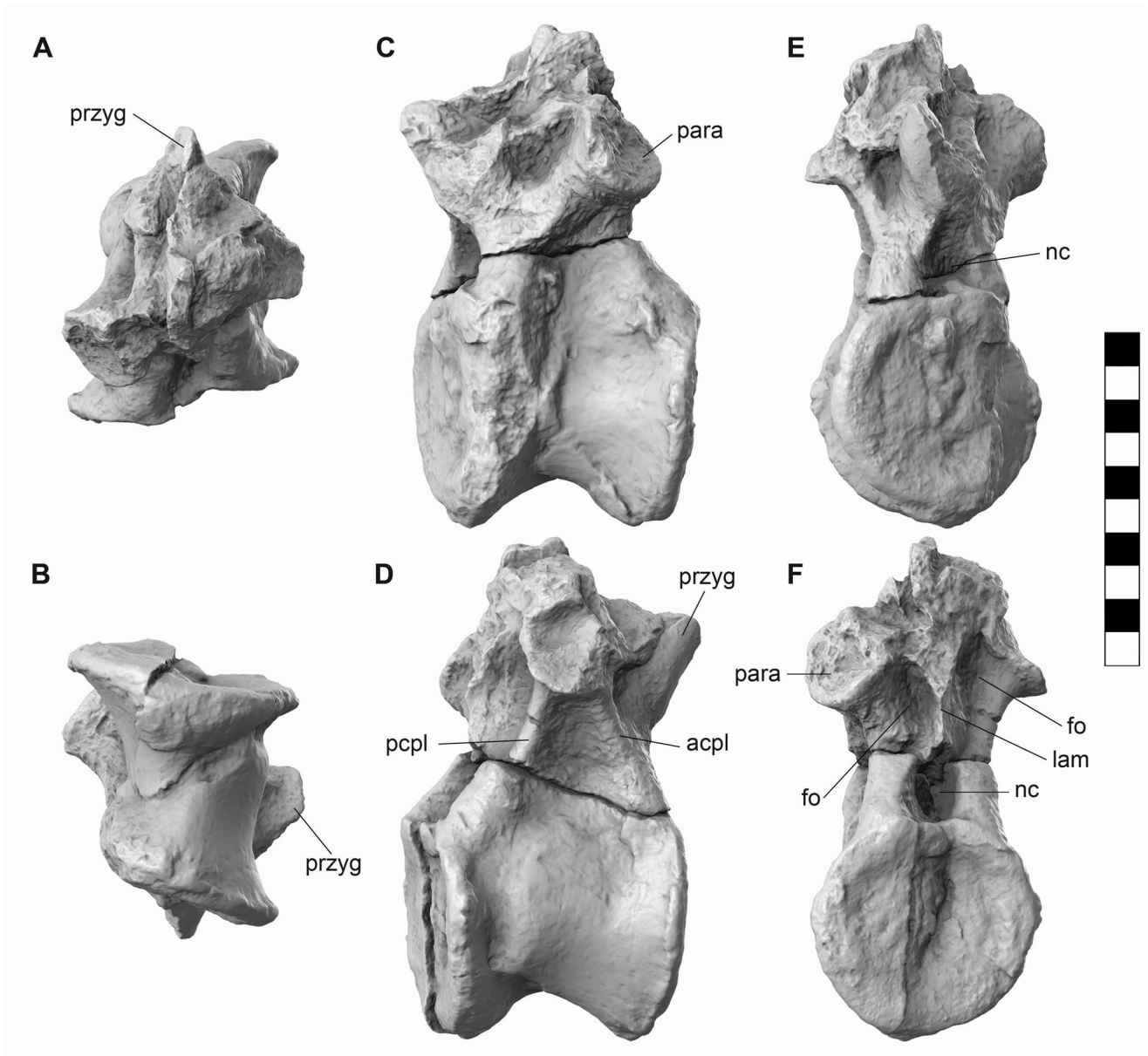


Figure 7. *Vectipelta barretti* gen. et sp. nov., IWCMS 1996.153. Mid-dorsal vertebra in **A**, dorsal; **B**, ventral; **C**, left lateral; **D**, right lateral; **E**, anterior; **F**, posterior views. **Abbreviations:** **acpl**, anterior centroparapophyseal lamina; **fo**, fossa; **lam**, lamina; **nc**, neural canal; **para**, parapophysis; **pcpl**, posterior centroparapophyseal lamina; **przyg**, prezygapophysis. Scale bar = 10 cm.

the base of the transverse processes, and on the more posterior of the free dorsals, are elevated on stalks (Fig. 7C, para). The ventrally extending rugose ridge is replaced on more posterior dorsals by an anterior centroparapophyseal lamina (*sensu* Wilson, 1999) which terminates level with the presumed location of the neurocentral suture and the anterior articular facet (Fig. 7D, acpl). An anterior centroparapophyseal lamina is not present in *Sauropelta* (YPM 5154, 5495), *Polacanthus* (NHMUK PV R175) or *Gastonia burgei* (BYU 11640), but is very prominent in an indeterminate

ankylosaur previously referred to *Polacanthus* (NHMUK PV R9293; Blows, 1987), also from the Isle of Wight. Transverse processes are only preserved on two of the anterior dorsals; these project dorsolaterally, and are triangular in cross-section with a flat dorsal surface and a ventral lamina that extends to the top of the parapophysis (Fig. 6, tp), as in *Pinacosaurus* (Burns *et al.*, 2015) and *Sauropelta* (YPM 5154, 5495). A single prezygapophysis is preserved on a more posterior free dorsal; it is elliptical, faces ventromedially and would have been joined to its counterpart ventrally (Fig.

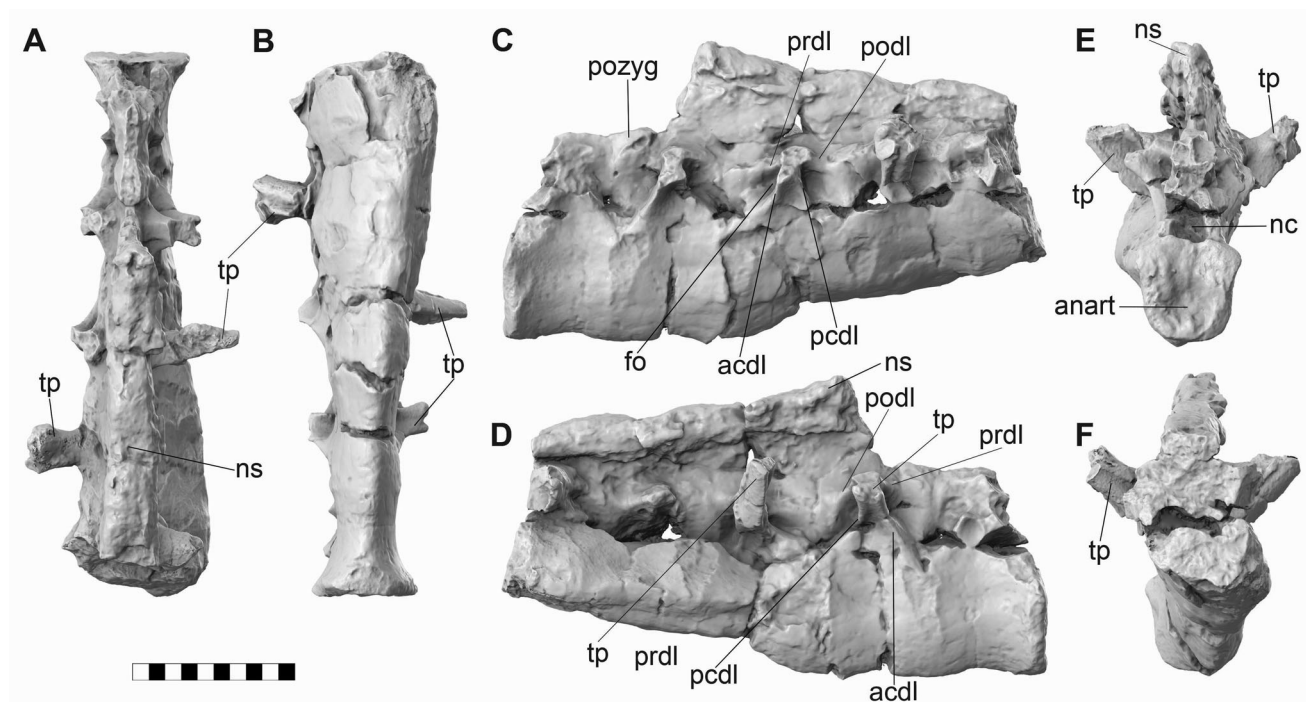


Figure 8. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. Presacral rod in **A**, dorsal; **B**, ventral; **C**, left lateral; **D**, right lateral; **E**, anterior; **F**, posterior views. **Abbreviations:** **anart**, anterior articular facet; **acdl**, anterior centrodiapophyseal lamina; **fo**, fossa; **nc**, neural canal; **ns**, neural spine; **pcdl**, posterior centrodiapophyseal lamina; **pozyg**, postzygapophysis; **podl**, postzygodiapophyseal lamina; **prdl**, prezygodiapophyseal lamina; **tp** transverse process. Scale bar = 10 cm.

7A, D, pryzg), as in *Ankylosaurus* (Brown, 1908), *Pinacosaurus* (Burns et al., 2015), *Euoplocephalus* (AMNH 5337), *Struthiosaurus languedocensis* (Garcia & Pereda Suberbiola, 2003), *Polacanthus* (Raven et al., 2020) and *Sauropelta* (YPM 5154, 5495). In posterior view, a sharp, very prominent lamina arises dorsal to the neural canal and extends to the base of the postzygapophyses (Figs 6F, 7F, lam). Each side of the lamina is a deep fossa (Figs 6F, 7F, fo). This is similar to the condition in *Gastonia burgei* (BYU 11640) and *Hylaeosaurus* (Raven et al., 2020), but a sharp ridge and fossae are not present in *Sauropelta* (YPM 5154, 5495), *Polacanthus* (Raven et al., 2020) or *Euoplocephalus* (AMNH 5337), which have a ridge but no fossae. Postzygapophyses are only preserved on the anterior-most free dorsal (Fig. 6F, pozyg); they are rounded in outline, face ventrally and slightly laterally, and are separated at their bases by a deep slit-like fossa, similar to *Sauropelta* (YPM 5154, 5495), *Struthiosaurus languedocensis* (Garcia & Pereda Suberbiola, 2003), *Mymooropelta* (Kirkland & Carpenter, 1994), *Europelta* (Kirkland et al., 2013) and *Gastonia burgei* (BYU 11640). This contrasts with the condition in *Ankylosaurus* (Brown, 1908) and *Euoplocephalus* (AMNH 5337), in which the postzygapophyses are joined ventrally. Neural spines are not preserved.

Five complete or partial dorsal vertebrae are fused together to form a presacral rod (dorsosacral vertebrae; Fig. 8). The posterior-most dorsosacral vertebra in the rod is broken (Fig. 8F), so the total number of dorsosacral cannot be determined. In *Polacanthus* (Raven et al., 2020), *Zhejiangosaurus* (Lü et al., 2007), *Europelta* (Kirkland et al., 2013), *Hungarosaurus* (Ősi, 2005) and *Struthiosaurus languedocensis* (UM2 OLV-D50 A-G CV), the presacral rod is composed of at least five dorsosacral whose ribs extend laterally to fuse to the preacetabular process of the ilium, while *Silvisaurus* (Carpenter & Kirkland, 1998) had as many as six fused dorsosacral; however, most ankylosaurs possess fewer vertebrae in the presacral rod. There are three in *Pinacosaurus mephistocephalus* and *Talarurus* (Godefroit et al., 1999; Maryńska, 1977), and four in *Euoplocephalus*, *Gastonia lorriemcwhinneyae* and *Nodosaurus* (Arbour & Currie, 2013a; Kinneer et al., 2016; Raven et al., 2020). The centra are transversely compressed, probably accentuated by postmortem deformation.

In lateral view (Fig. 8C, D) the anterior-most centrum is upwardly concave ventrally. It is longer anteroposteriorly than wide transversely. The anterior articular facet is sub-square and slightly concave (Fig. 8E); the edge of the articular facet is abraded. The lateral surfaces of the

centrum are smooth, and gently saddle-shaped (Fig. 8C, D). The neural canal is a semi-ellipse, taller dorsoventrally than wide transversely, with a flat ventral margin. The neural arch arises level with the anterior articular facet but is broken and fractured dorsal to and either side of the neural canal. Prezygapophyses, parapophyses and the neural spine are not preserved. A partial transverse process is preserved on the left side and projects laterally, in contrast to those of the free dorsals, which project dorsolaterally. Prominent anterior and posterior centrodiapophyseal laminae extend from the ventral surface of the transverse process to the anterior and posterior articular facets of the centrum respectively (Fig. 8C, D, acdl, pcdl). Postzygapophyses are indistinguishably fused to the prezygapophyses of the second vertebra in the rod (and prezygapophyses and postzygapophyses are fused indistinguishably for the remainder of the rod).

The second centrum preserved in the rod is anteroposteriorly shorter than the first. The centrum is otherwise similar in morphology to the first. Partial transverse processes are present on both sides of the neural arch and are hourglass-shaped in cross-section. A prominent anterior centrodiapophyseal lamina (ACDL) arises on the anterior part of the neurocentral suture and extends posteriorly under the transverse process forming the anteroventral corner of the hourglass; a shallow fossa is present on the anterior surface of the transverse process (Fig. 8C, fo) and a second lamina, less well-developed than the ACDL, extends anteriorly a short distance towards the fused prezygapophyses (the prezygodiapophyseal lamina; PRDL, Fig. 8C) and forms the antero-dorsal margin of the hourglass. A similar morphology is seen on the posterior surface of the transverse process, although the lamina that extends from the diapophysis towards the postzygapophysis (the postzygodiapophyseal lamina, PODL, Fig. 8C, D) is more prominent than the PRDL and the fossa is much deeper. The posterior centrodiapophyseal lamina (PCDL) extends from the posterior neurocentral suture to form the posteroventral base of the hourglass, and a shallow fossa is present between the ACDL and the PCDL on the lateral surface of the neural arch (Fig. 8C, D, pcdl). No parapophysis is evident. The neural spine is fused indistinguishably to the neural spines posterior to it (Fig. 8C, D, ns). Its anterior surface is broken, perhaps indicating that it was fused to the neural spine of the anterior-most vertebra of the rod. The spine table is slightly transversely expanded and flat on top (Fig. 8A). An ossified tendon extends posteriorly along the neural spines on the right side just below the top.

The third centrum is cracked in the centre but appears to be a similar morphology to the preceding two. Transverse processes are partially preserved on both

sides. They are similar in morphology to those of the second vertebra but the fossa on the anterior surface of the transverse process is deeper and the laminae are correspondingly sharper.

The fourth centrum is similar in morphology to the preceding vertebrae except the ventral margin is straight in the lateral view (Fig. 8C, D). The transverse process on the left side is partially preserved. The fossa on the anterior surface of the transverse process appears shallower than in the third, but the vertebra is damaged in this area. The fossa on the posterior surface is slightly deeper than on the preceding vertebrae. The transverse process itself extends dorsolaterally, although this may be a consequence of postmortem deformation. The neural spine is low, thickened transversely and flat on top; there is a gradual reduction in height and broadening of the dorsal surface transversely from the second to the fourth neural spines.

The fifth vertebra is incomplete, having been sheared approximately in half transversely. A base of a transverse process is present on the right side; it is directed posterolaterally and is dorsoventrally deeper than those of the preceding vertebrae.

Dorsal ribs. Fragments of several dorsal ribs are preserved. The ribs are ‘T’-shaped in cross-section, a common feature in eurypodan thyreophorans (Raven *et al.*, 2020 and references therein). The shafts of the ribs are flattened on one side and convex on the other. They are broadly straight with little curvature.

Sacral vertebrae (Fig. 9). Four and a half vertebrae are fused together to form the sacrum; the anterior-most is broken in half and it does not fit with the presacral rod (Fig. 9E); it is unclear whether another vertebra lay between the two or if the halves are part of the same vertebra. The vertebral centra are fused to each other. The vertebrae are broadly equidimensional, except for the last one which is shorter than the others and shorter anteroposteriorly than it is wide transversely. The difference in morphology of the last sacral, and the fact that its rib articulated with the postacetabular process of the ilium (see ilium, below) rather than the medial surface of the acetabulum, suggests it is a sacrocaudal (Fig. 9, sc), and *Vectipelta* possessed three true sacrals, similar to some other ankylosaurs such as *Dyoplosaurus*, *Scolosaurus* and *Euoplocephalus* (Arbour *et al.*, 2009; AMNH 5409). Some ankylosaurs, such as *Dyoplosaurus* and *Scolosaurus* (Arbour *et al.*, 2009), possessed more than one sacrocaudal vertebrae which were fused to the sacral rod, but these are not present in *Vectipelta*. Ventrally, a longitudinal groove (Fig. 9B, longr) extends from the first fused sacral posteriorly. It is deepest in the third sacral vertebra, and terminates gradually on the

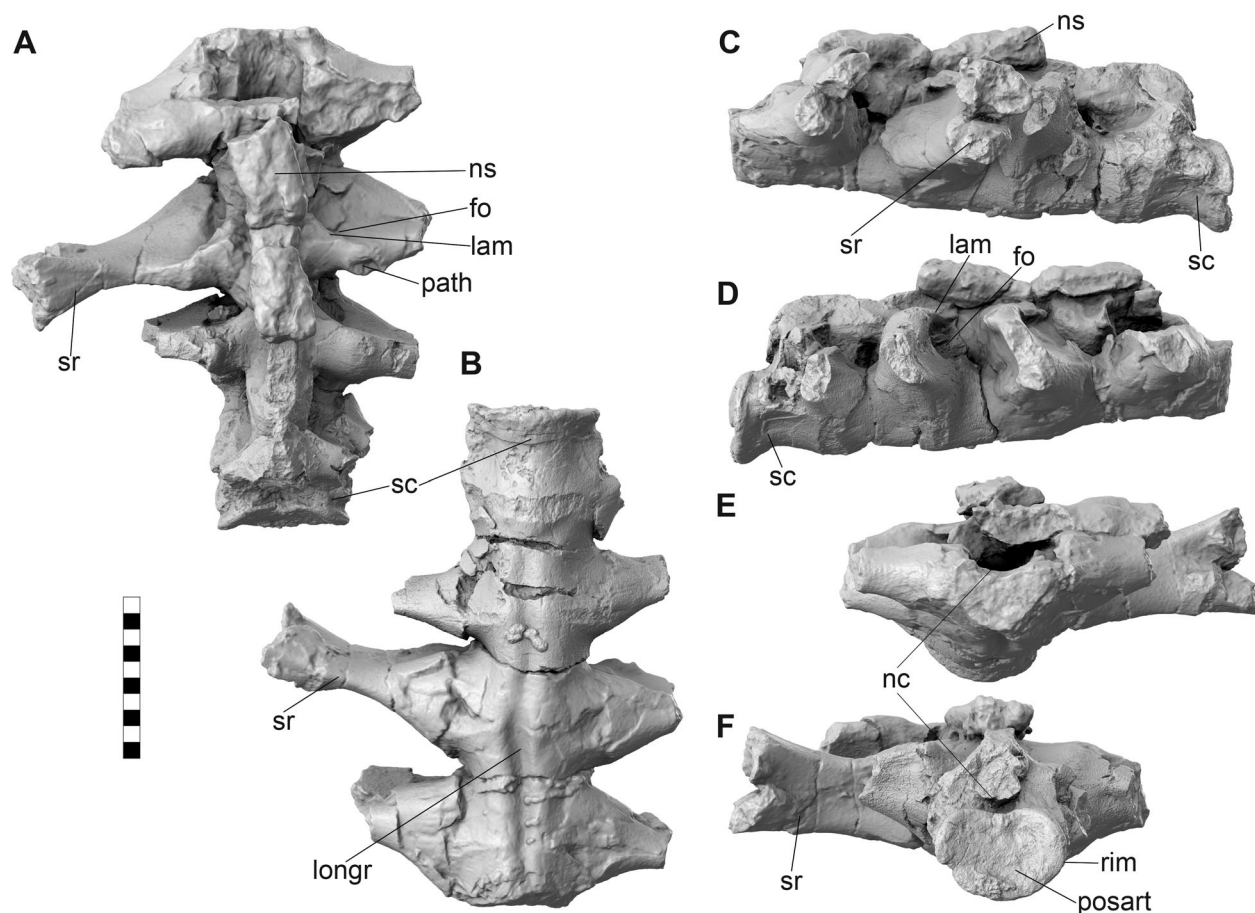


Figure 9. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. Sacrum in **A**, dorsal; **B**, ventral; **C**, left lateral; **D**, right lateral; **E**, anterior; and **F**, posterior views. **Abbreviations:** fo, fossa; lam, lamina; longr, longitudinal groove; nc, neural canal; ns, neural spine; path, pathology; posart, posterior articular facet; sc, sacrocaudal vertebra, sr, sacral rib. Scale bar = 10 cm.

fourth, disappearing at the intercentral suture and is not present on the fifth. A similar groove is known in *Edmontonia*, *Peloroplites*, *Cedarpelta*, *Niobrariasaurus*, *Polacanthus* and *Nodosaurus* but is absent in *Silvisaurus* and *Dongyangopelta* (Burns et al., 2015; Carpenter & Kirkland, 1998; Chen et al., 2013; Raven et al., 2020). The cross section of the broken centrum of the first sacral vertebra is dorsoventrally compressed and heart-shaped, with a neural canal that excavates shallowly into the top of the centrum (Fig. 9E). The neural canal is transversely wide; almost the same width as the centrum. Posteriorly, the posterior articular facet of the caudosacral is heart-shaped, shallowly concave, and wider transversely than it is tall dorsoventrally, with a prominent rim (Fig. 9F). The neural canal is much smaller than it is on the first sacral, and roughly equidimensional.

Three sets of partial sacral ribs are preserved, and they are fused across the intercentral sutures. They are broken distally. The ribs are dorsoventrally taller than

they are wide anteroposteriorly, narrowing anteroposteriorly dorsally and laterally. They are inclined postero-dorsally (Fig. 9D). The ribs obscure the lateral surfaces of the centra and neural arches. On the second and third set of ribs there is a shallow fossa on the anterior surface at the dorsal corner of the rib where it fuses to the neural arch (Fig. 9A, fo); the fossa is bordered dorsally by a lamina which is more developed on more posterior sacral ribs (Fig. 9A, lam). The second sacral rib on the right side has a dorsally located shallow excavation proximal to the vertebra that causes the dorsal margin of the rib to expand anteroposteriorly and has a rugose texture internally, and appears to be a pathology (Fig. 9A, path). The neural spines are extremely dorsoventrally compressed, being no more than a transversely expanded ridge extending posteriorly along the top of the sacrum (Fig. 9A, C). The dorsal surface is flat and an ossified tendon extends along the right side. The neural spines of the posterior two vertebrae (third sacral and caudosacral) are broken.

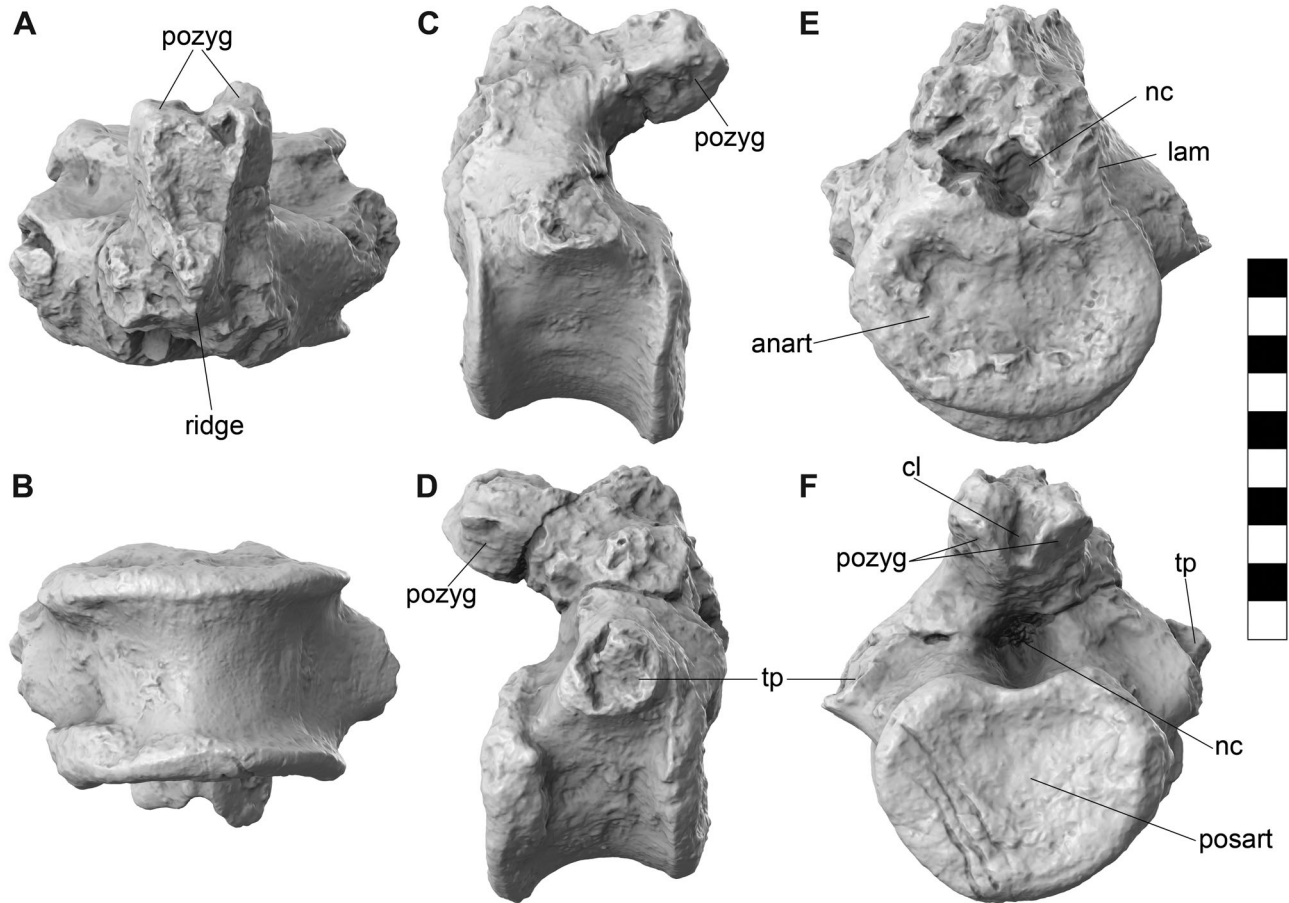


Figure 10. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. Caudal 1 in **A**, dorsal; **B**, ventral; **C**, left lateral; **D**, right lateral; **E**, anterior; **F**, posterior views. **Abbreviations:** **anart**, anterior articular facet; **cl**, clef; **nc**, neural canal; **posart**, posterior articular facet; **pozyg**, postzygapophyses; **tp** transverse process. Scale bar = 10 cm.

Caudal vertebrae (Figs 10–12, Supplemental material Figs S11–S24). Thirteen caudal vertebrae and an additional four partial centra represent an articulating series from the most anterior caudal. Caudals one (Fig. 10) and two (Supplemental material Fig. S11) have centra that are wider transversely than they are long anteroposteriorly or tall dorsoventrally, and the articular facets are heart-shaped, wider than tall, and flat to shallowly concave with prominent rims (Fig. 10E, F). In lateral view, the posterior articular facet extends further ventrally than the anterior articular facet (Fig. 10C, D), as in *Sauropelta* (YPM 5079) and *Hungarosaurus* (Ösi, 2005). The lateral surfaces of the centra are dorsoventrally convex and anteroposteriorly concave. There are no chevron facets (Fig. 10B). Extending along the series, from caudal three the centra become equidimensional (Figs 11, 12, S12–24), and the last preserved centrum is longer anteroposteriorly than it is wide transversely (Fig. S20). A posterior chevron facet arises on caudal three, and thereafter all centra possess ‘W’-

shaped anterior and posterior chevron facets, which are joined by a ventral sulcus extending anteroposteriorly (Figs 11B, 12B; sul), similar to the condition in *Gastonia burgei* (BYU 15526) and *Zhejiangosaurus* (Lü et al., 2007). Posterior chevron facets are larger than anterior ones from caudal six posteriorly (Fig. 12B). Rims around the articular facets are less marked from caudal three posteriorly, and the articular facets are no longer offset. From about caudal six, the articular facets become increasingly less heart-shaped and more hexagonal. From caudal three, the lateral surfaces of the centra are shallowly concave dorsoventrally ventral to the transverse processes.

Transverse processes are incomplete on all vertebrae. On caudal one, the transverse processes are broken at their base, are located on the neurocentral suture, and are rounded in cross-section (Fig. 10, tp). They maintain this morphology until caudal six, when they become dorsoventrally compressed, and move slightly ventrally onto the centrum (Fig. 12C, D). In vertebrae in which

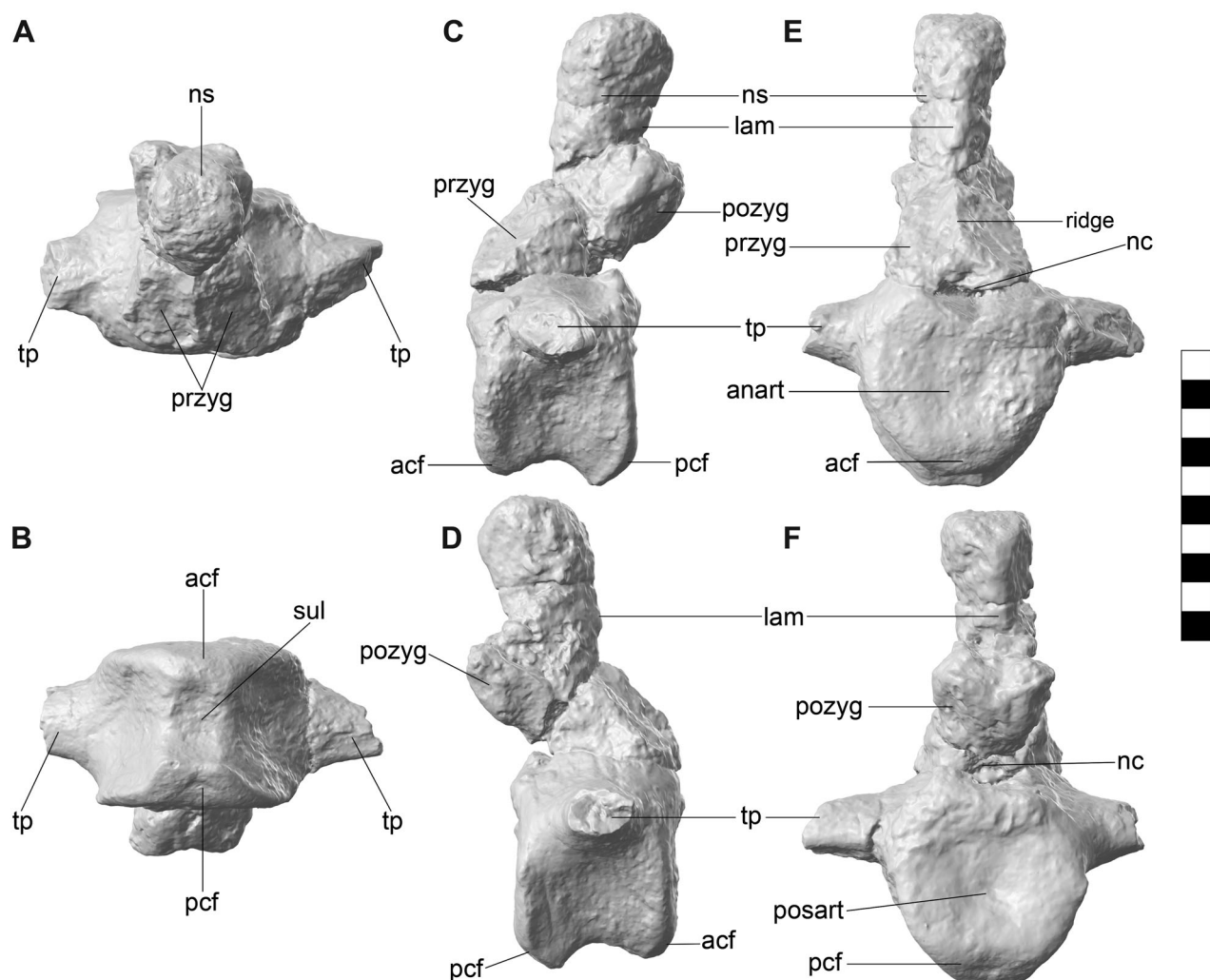


Figure 11. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. Caudal 4 in **A**, dorsal; **B**, ventral; **C**, left lateral; **D**, right lateral; **E**, anterior; **F**, posterior views. **Abbreviations:** acf, anterior chevron facet; anart, anterior articular facet; lam, lamina; nc, neural canal; ns, neural spine; pcf, posterior chevron facet; posart, posterior articular facet; pozyg, postzygapophyses; przyg, prezygapophyses; tp, transverse process; sul, sulcus. Scale bar = 10 cm.

they are preserved, the transverse processes project laterally, similar to *Ankylosaurus* (Brown, 1908), *Polacanthus* (Raven et al., 2020) and *Sauropelta* (YPM 5079) but differing from the condition in *Dyoplosaurus*, *Talarurus*, *Zhejiangosaurus* and *Pinacosaurus grangeri*, in which they project anterolaterally (Arbour et al., 2009; Lü et al., 2007), and differing from *Europelta* and *Hungarosaurus* (Ösi, 2005) in which they project ventrally in their proximal-most portions, and then laterally (Kirkland et al., 2013). In caudal twelve, a ridge extends posteriorly from the transverse process, and in the last caudal preserved in the series, which may have been caudal fourteen or fifteen, the transverse process is absent but there is a very prominent ridge extending horizontally anteroposteriorly along the side of the

centrum at about mid-height, as in *Hungarosaurus* (Ösi, 2005).

The neural canal is small and ellipsoid with the long axis dorsoventral in all caudals (Figs 10E, F, 11E, F, 12E, F); it decreases in size posteriorly. Prezygapophyses are only preserved on caudals one, three and six (that of caudal one is broken and therefore not shown in Fig. 10). The articular facets are rectangular with the long axis anteroposterior and are angled dorsomedially. They project anterior to the anterior articular facet and are separated at their bases by the dorsal extent of the neural canal, similar to *Gastonia burgei* (BYU 15526). Dorsal to the neural canal, on the midline between the prezygapophyses, a ridge arises to extend to the anterior surface of the neural spine (Fig. 11E), similar to the condition in

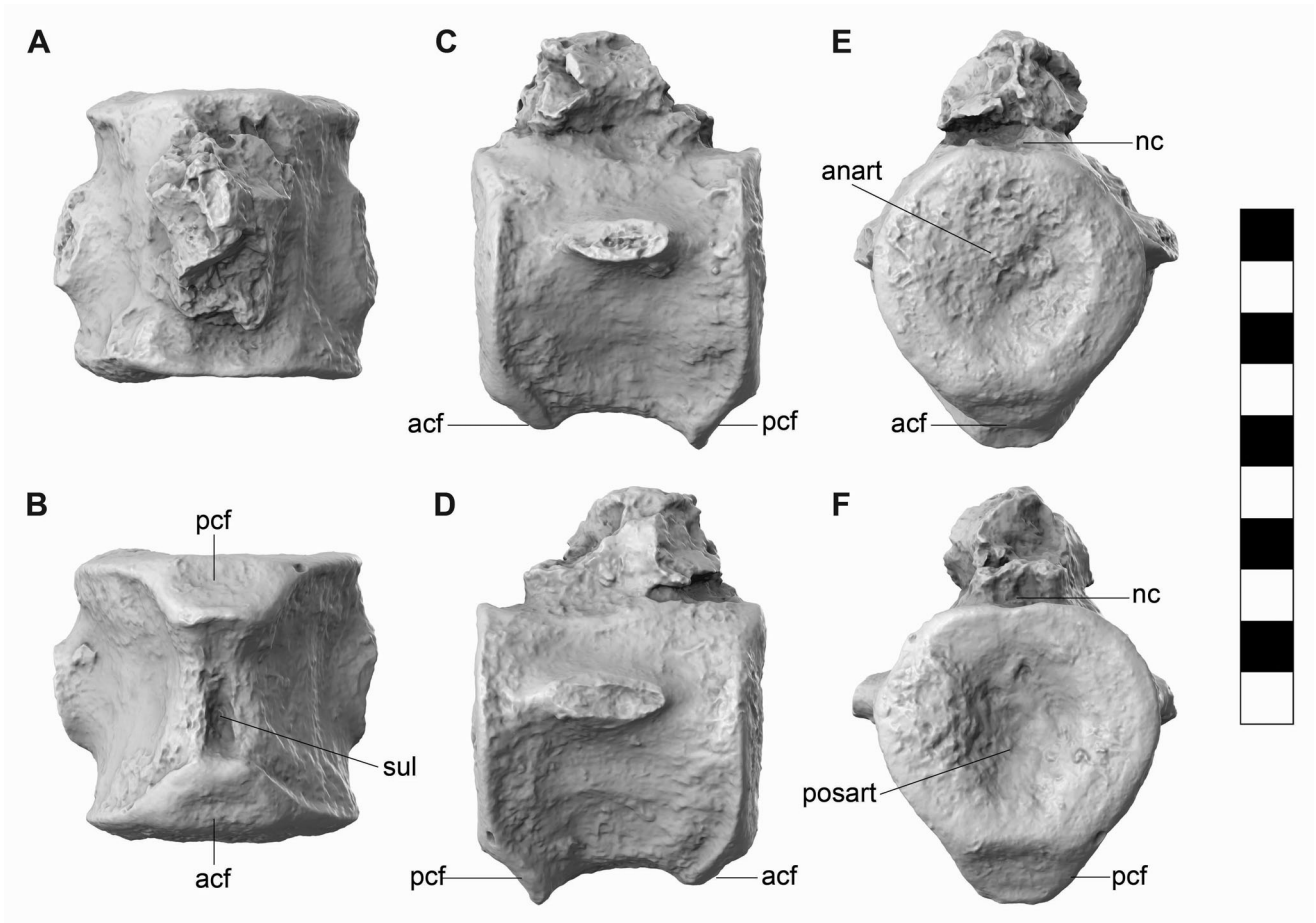


Figure 12. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. Caudal 10 in **A**, dorsal; **B**, ventral; **C**, left lateral; **D**, right lateral; **E**, anterior; **F**, posterior views. **Abbreviations:** acf, anterior chevron facet; anart, anterior articular facet; nc, neural canal; pcf, posterior chevron facet; posart, posterior articular facet; sul, sulcus. Scale bar = 10 cm.

Polacanthus (Raven *et al.*, 2020). The postzygapophyses of caudal one are elongate anteroposteriorly (Fig. 10C, D, pozyg), extending slightly beyond the posterior articular facet. Their articular surfaces are ventrolaterally inclined, and they are separated ventrally by a cleft (Fig. 10F, cl). A subtle lamina extends from the dorsal surface of the articular facet anteriorly horizontally towards the base of the prezygapophyses. The postzygapophyses maintain a similar morphology until caudal five, when they reduce in size and become increasingly separated at their bases, as in *Ankylosaurus* (Brown, 1908); postzygapophyses are unpreserved posterior to caudal seven. The lamina extending from postzygapophyses to prezygapophyses is not visible posterior to caudal one. Complete neural spines are only preserved on caudals four (Fig. 11, ns) and six. The neural spines are ellipsoidal in cross section with sharp anterior and posterior laminae (Fig. 11, lam). Such laminae do not appear to be present in *Sauropelta* (YPM 5079). Dorsally, they are transversely expanded so that they are approximately as wide transversely as they are

anteroposteriorly, as in *Sauropelta* (YPM 5079) and *Polacanthus* (Raven *et al.*, 2020). In contrast, the tops of the neural spines of *Europelta* are expanded laterally but are also elongate anteroposteriorly (Kirkland *et al.*, 2013), while those of *Dyoplosaurus* are transversely compressed, anteroposteriorly elongate, and not expanded to such a degree at the top (Arbour *et al.*, 2009), and those of *Hungarosaurus* are not expanded in any orientation (Ősi, 2005). The neural spine of caudal four projects dorsally (Fig. 11), while that of caudal six is angled posterodorsally.

There is no evidence that the distal caudal vertebrae of the series were becoming modified into handle vertebrae to support a tail club, as is observed in ankylosaurines (e.g. Arbour & Evans, 2017). *Dyoplosaurus* had eleven free caudals before the handle vertebrae (Arbour *et al.*, 2009), suggesting that *Vectipelta*, with at least thirteen unmodified vertebrae, did not possess a tail club.

Scapula (Fig. 13). The proximal part of the left scapula is preserved, although it is highly incomplete, and

difficult to interpret due to poor preservation (Fig. 13A–F). In lateral view, the acromial process (Fig. 13, acp) is an anteroventrally extending ridge, but is incomplete. It appears similar in morphology to that of *Sauropelta* (YPM 5179), *Hylaeosaurus* (Raven et al., 2020), *Hungarosaurus* (Ösi, 2005) and *Gastonia burgei* (BYU 14584), but contrasts with *Euoplocephalus* (AMNH 5337) in which the acromial process is a laterally folded dorsal margin of the scapula. In medial view, there is no medial buttress *sensu* Arbour and Currie (2013a) or scapulocoracoid buttress *sensu* Carpenter et al. (2011).

A distal end of a scapula is preserved although it is not clear if it is the right or the left (Fig. 13G–L). It is not distally expanded, with sub-parallel straight dorsal and ventral edges in lateral view, and the distal end appears to be square, similar to *Sauropelta* (AMNH 5833), *Gastonia burgei* (BYU 14584) and *Euoplocephalus* (AMNH 5337), but in contrast to *Pinacosaurus*, where the distal end is slightly flared (Burns et al., 2015), and *Ankylosaurus*, where the distal end is rounded (Brown, 1908). The transverse width is consistently 2 cm across the blade, but this tapers at the dorsal and ventral edges.

Humerus (Fig. 14). The proximal and distal ends of the left humerus are preserved separately, and the shaft is not preserved. The proximal end of the humerus is gently concave on its anterior surface (Fig. 14A). The proximal surface is rugose and overhangs the anterior surface in a distinct rim, as in *Sauropelta* (AMNH 3035). Medially, the surface of the medial tuberosity is highly rugose, with the rugosity extending onto the anterior and posterior surfaces (Fig. 14A, B, D, mt). It is incomplete proximally, but it appears that it was separated from the head by a notch in anterior or posterior view (Fig. 14B, not). In posterior view the humeral head projects posteriorly and is rounded, and below it is a convex ridge that extends ventrally. Lateral to the head the deltopectoral crest is broken.

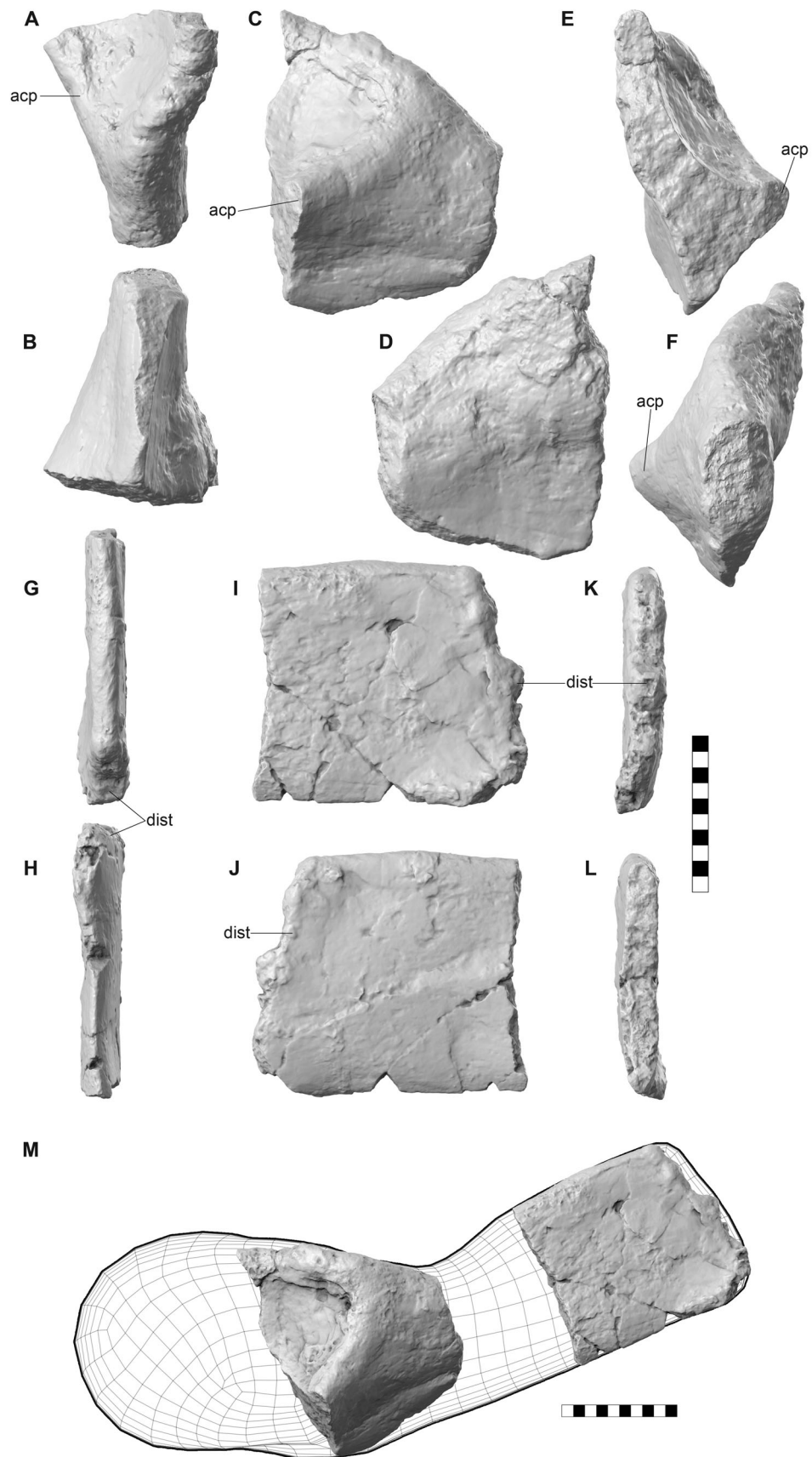
In anterior and distal view, the distal end of the humerus comprises two condyles which are roughly equidimensional (Fig. 14G, L). In distal (ventral) view, the humerus is hourglass-shaped with a convex rugose surface, which extends onto the anterior surface (Fig. 14L). Laterally, there is a very distinct supinator ridge (Fig. 14G, supr), as in *Sauropelta* (AMNH 3032) but in contrast to *Ankylosaurus* (AMNH 5214) and *Hungarosaurus* (Ösi & Makádi, 2009), in which the supinator ridge is not as distinct. The supinator ridge of *Vectipelta* has probably been accentuated by crushing to produce a sharply bounded fossa on the anterolateral surface (Fig. 14G, supn). The supinator ridge extends distally as a rugose lateral extension of the lateral condyle in distal view. On the anterior surface dorsal to the

condyles there is a shallow fossa. The posterior surface of the humerus is gently concave (Fig. 14H) but this may have been accentuated by the collapse of the medullary cavity, so that the cross-section of the shaft is now strongly anteroposteriorly compressed.

?Ulna (Fig. 15). A rugose fragment may be the olecranon process of the ulna. It has been sectioned prior to this study and the whereabouts of any sections made are unknown. The element is extremely convex and rugose, covered in ossified cartilage. In anterior view (Fig. 15C), the outline of the element is a semi-ellipse and the anterior surface is strongly convex proximally, while distally there is a groove (Fig. 15C, gro). On one side of the groove the bone narrows transversely, while the other it is strongly convex and projects anteriorly. In proximal view (Fig. 15A) the element is triangular with the apex pointing posteriorly. In posterior view, two ridges extend distally (Fig. 15D) and the element is flat between them.

Iliac (Fig. 16, Supplemental material Fig. S25). The iliosacral block is preserved in multiple pieces. Parts of both the left and right ilia are preserved, although the right is the most complete (Fig. 16A, B). Sacral ribs are fused to the medial surfaces of the ilia (Fig. 16A, B, rib), and parts of the ribs of the vertebrae in the presacral rod are also preserved (Fig. 16A, B, rib), extending laterally towards the ilia and associated with broad, flat, bony sheets that represent ossified connective tissues that roofed the area between the preacetabular processes and the spinal column (the sacral shield), as in *Polacanthus* (NHMUK PV R175).

The preacetabular process is incomplete anteriorly and medially on both sides, but is complete laterally on the left, and is longest on the right (Fig. 16A, B, pre). It projects anteriorly, slightly laterally, and horizontally with no ventral inflection along its anteroposterior length. This differs from some other ankylosaurs such as *Euoplocephalus* (Arbour et al., 2009), *Gastonia burgei* (Kirkland, 1998), *Zhejiangosaurus* (Lü et al., 2007) and *Stegouros* (Soto-Acuña et al., 2021) in which the preacetabular processes project strongly anterolaterally, and *Mymooropelta* (Kirkland & Carpenter, 1994) and *Dongyangopelta* (Chen et al., 2013) where it projects strongly ventrally, but is similar to the condition in *Polacanthus* (NHMUK PV R175), *Struthiosaurus languedocensis* (UM2 OLV-D50 A-G CV) and *Hungarosaurus* (Ösi & Makádi, 2009). Because of the incomplete medial margins of the preacetabular processes, which may be a consequence of their confluence with ossified connective tissues roofing the area between them, it is not possible to establish whether the preacetabular processes narrowed transversely towards their

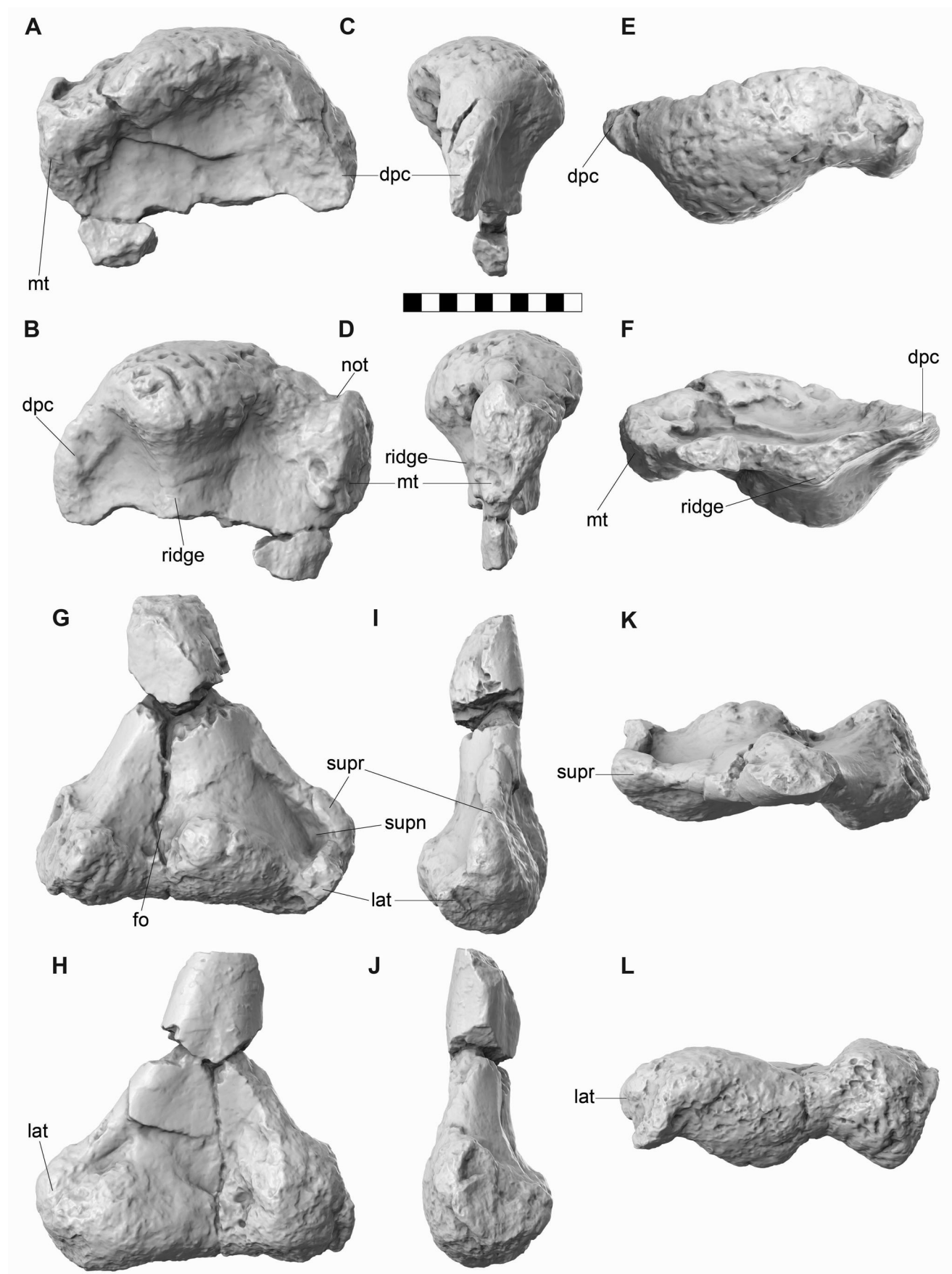


anterior ends, as appears to be the case in *Polacanthus* (NHMUK PV R175), *Gastonia burgei* (Kirkland, 1998), *Zhejiangosaurus* (Lü et al., 2007) and *Dyoplosaurus* (Arbour et al., 2009), but not in *Euoplocephalus* (Arbour et al., 2009), *Hungarosaurus* (Ösi & Makádi, 2009) or *Struthiosaurus languedocensis* (UM2 OLV-D50 A-G CV) where the preacetabular processes are parallel-sided. Dorsally, the preacetabular processes are convex, bending gently ventrally along their lateral surfaces (Fig. 16A). Ventrally, they are concave (Fig. 16B). Parts of two ribs are fused to the ventral surface of the right preacetabular process at its anterior end (Fig. 16B, rib); these are anteroposteriorly narrow, taper and extend to the point where the lateral margin starts to curve ventrally. Unlike in *Polacanthus* (NHMUK PV R175) and *Euoplocephalus* (AMNH 5409), where the ribs of the presacral rod are angled strictly laterally, the ribs in *Vectipelta* are angled anterolaterally. At the anterior end of the preacetabular process there is a dorsoventrally thickened ridge extending parallel to the ribs, and a similar feature is observed on the left preacetabular process; this may have been where another rib articulated. A large fragment comprising three presacral rod ribs, sacral shield, and some crushed osteoderms is also associated with the right side of the iliosacral block. More proximal portions of the ribs are preserved in this segment, and they are transversely compressed and gently curved anterolaterally. On the right preacetabular process, just anterior to the acetabular part of the ilium, part of the sacral shield is preserved in attachment. Between the ilium and the sacral shield is a c. 1 cm thick dark brown to black layer with no clear structure in cross-section (Fig. 17A). The sacral shield is also preserved in association with this part of the ilium in the holotype of *Polacanthus* (NHMUK PV R175) and the sacral shield is also separated from the ilium by a dark coloured layer, although it is much thinner, just 1–2 mm thick. This area of the ilium of *Vectipelta* was sectioned for palaeohistological analysis to investigate tissue type, and the results can be found below in the section ‘sacral shield’.

Extending posteriorly from the preacetabular process, in dorsal view, the lateral margin of the ilium is slightly sinuous such that it is slightly medially inflected level with the pubic peduncle of the acetabulum, and then flares slightly laterally to form the supraacetabular process level with the ischiadic peduncle, before turning medially to form the postacetabular process (Fig. 16A,

B; supra, pap). This sinuosity of the lateral margin contrasts with the condition in *Polacanthus* (NHMUK PV R175), *Gastonia burgei* (Kirkland, 1998), *Struthiosaurus languedocensis* (UM2 OLV-D50 A-G CV), *Zhejiangosaurus* (Lü et al., 2007), *Euoplocephalus* (AMNH 5409) and *Pinacosaurus* (Burns et al., 2015) in which there is no distinct supraacetabular process and the lateral margin of the ilium is straight. In contrast, a small supraacetabular process is present in *Mymooropelta* (Kirkland & Carpenter, 1994) and *Hungarosaurus* (Ösi & Makádi, 2009) and much larger one is present in *Stegouros* (Soto-Acuña et al., 2021). The ilium is slightly dorsoventrally thickened in the region of the supraacetabular process relative to the pre- and postacetabular processes. The dorsal surface of the acetabular region of the ilium and the postacetabular process is flat and smooth. Ventrally, the acetabulum is not a distinctly defined cup and possesses no clear margins (Fig. 16B), in contrast to that of *Polacanthus* (NHMUK PV R175), *Gastonia burgei* (Kirkland, 1998), *Europelta* (Kirkland et al., 2013), *Zhejiangosaurus* (Lü et al., 2007) and *Pinacosaurus* (Burns et al., 2015). It is relatively transversely broad, being more than half the width of the ilium at that point. The ischiadic peduncle is a raised rugosity angled anteromedially (Fig. 16B, ip). The medial surface of the acetabulum was formed by the lateral ends of three fused sacral ribs, which are highly rugose and confluent with each other; presumably the ischium articulated with these as well, although the elements do not fit closely together, suggesting a substantial amount of connective tissue around the joint capsule. The anterior part of the acetabulum is an oval process that curves ventrally to form a gently concave projection which is separated from the preacetabular process (Fig. 16B, pp); this is not as well developed as it is in *Pinacosaurus* (Burns et al., 2015). The pubis articulates with and was fused to the anteromedial surface of this projection (Fig. 16B, pub), and it bears a triangular facet for the ischium posteromedially. The presence of a fused but distinctly recognizable pubis on the acetabular margin in *Vectipelta* contrasts with the condition in *Polacanthus* (NHMUK PV R175), *Zhejiangosaurus* (Lü et al., 2007) and *Europelta* (Kirkland et al., 2013), in which the pubis is much more significantly reduced and cannot be recognized as a separate element (although it is not well preserved in this region), but is similar to that of *Struthiosaurus languedocensis* (Garcia & Pereda Suberbiola, 2003).

Figure 13. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. A–F, proximal left scapula in A, dorsal; B, ventral; C, lateral; D, medial; E, anterior; F, posterior views. G–L, distal scapula in G, dorsal; H, ventral; I, ?lateral; J, ?medial; K, anterior; L, posterior views. M, interpretive drawing showing the outline of the scapulocoracoid and where the parts illustrated above fit. **Abbreviations:** **acp**, acromial process; **dist**, distal end. Scale bar = 10 cm.



In ventral view, posterior to the acetabulum, the post-acetabular process bears a posteriorly extending, prominent, rounded ridge (Fig. 16B, pac). This differs from the condition in *Polacanthus* (NHMUK PV R175), *Gastonia lorriemcwhynneyae* (Kinneer et al., 2016) and *Struthiosaurus languedocensis* (UM2 OLV D50 DVC) where a ridge on the ventral surface of the postacetabular process is not present, and also to the condition in ankylosaurids such as *Euoplocephalus* (Arbour et al., 2009) and *Pinacosaurus* (Burns et al., 2015), which do not have a distinct postacetabular process. A ridge does appear to be present, however, in *Mymooropelta* (Kirkland & Carpenter, 1994) and *Gastonia burgei* (Kirkland, 1998). Lateral to the ridge, the ventral surface of the postacetabular process is shallowly concave. The medial surface of the ridge forms the medial surface of the postacetabular process, and a caudosacral rib is fused to it. The postacetabular process does not taper but ends in a smooth curve.

Pubes (Fig. 18). Both pubes are fused to the anteromedial margins of the acetabula, as in *Struthiosaurus languedocensis* (Garcia & Pereda Suberbiola, 2003). Both are well preserved, missing only the distal ends of the postpubes (Fig. 18, pop). In anterior or posterior view, the pubis is oval in outline with the long axis trending transversely (Fig. 18). It is thickened anteroposteriorly, and does not form a transversely compressed plate ventral to the iliac peduncle. The posterior surface of the pubis is highly rugose and it formed the anteromedial margin of the acetabulum. Medially, a second, rugose facet was presumably for articulation of the ischium (Fig. 18A, C; if). The anterior surface is strongly convex, and the shaft of the postpubis arises from its centre. The postpubis projects anteriorly and then curves medially to contact the medial edge of ischial facet of the pubis, forming an oval obturator foramen (Fig. 18, obt).

Ischia (Fig. 19, Supplemental material Figs S26, S27). The left ischium is more-or-less complete, missing only a small part of the shaft (Fig. 19, Supplemental material Fig. S26), while only the proximal part of the right is preserved (Supplemental material Fig. S27). The ischium is described with its long axis held vertically, as it would have articulated under the ilium. In lateral view the ischium comprises a triangular proximal portion, and an elongate, gently curved shaft with a slight

distal expansion (Fig. 19A). The shaft curves gently anteriorly at approximately midlength; in anterior view the shaft is straight (Fig. 19C). This contrasts to *Polacanthus* (NHMUK PV R175) where the shaft curves medially and is bowed at a much sharper angle, *Sauropelta* (AMNH 3032) and *Europelta* (Kirkland et al., 2013), where the shaft possesses a distinct angle, rather than the smooth curve observed in *Vectipelta*, and *Ankylosaurus* (AMNH 5214), *Euoplocephalus* (AMNH 5266) and *Hungarosaurus* (Ösi, 2005), where the shaft is straight in lateral view. In *Gastonia burgei* (BYU 10786), the shaft also curves gently, but the proximal end of the ischium is much deeper anteroposteriorly. In *Struthiosaurus languedocensis* the shaft of the ischium is much shorter and only slightly curved (Garcia & Pereda Suberbiola, 2003). Proximally, the proximal margin of the ischium of *Vectipelta* is straight in lateral view (Fig. 19A), as in *Sauropelta* (AMNH 3032) and *Europelta* (Kirkland et al., 2013) but in contrast to *Ankylosaurus* (AMNH 5214) and *Euoplocephalus* (AMNH 5266) where the proximal margin is convex in lateral view. The pubic peduncle of the ischium is triangular in proximal view with the apex pointing posteriorly and it is gently convex dorsally. Posteriorly, the apex of the triangle continues as a transversely compressed flange of bone and extends posteriorly to meet the iliac peduncle. The iliac peduncle is rounded and bulbous in proximal view, transversely thickened relative to the rest of the proximal end, and slopes ventrolaterally. Distal to the iliac peduncle, the medial surface bears a rugose boss (Fig. 19B, medb). In *Cedarpelta* a similar boss is present on the medial surface near the pubic peduncle (this is an autapomorphy of the latter according to Carpenter & Kirkland, 1998). Ventral to the boss, a ridge extends down the shaft and forms the posteromedial margin. Anterior to this ridge on the medial surface the shaft is flat. In lateral view, the proximal end of the ischium is slightly concave. Extending distally from the pubic peduncle, a ridge extends a short distance and continues distally to form the anterior edge of the shaft. About one third of the way down the shaft in lateral view, a ridge arises which divides the shaft into two surfaces, one facing laterally and one facing anteriorly (Fig. 19A, lar). The ridge continues to the distal end so that towards the distal end the shaft is sub-triangular in cross-section with the apex pointing posteriorly. The distal end of the shaft is

Figure 14. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. **A–F**, proximal left humerus in **A**, anterior; **B**, posterior; **C**, lateral; **D**, medial; **E**, dorsal (proximal); and **F**, ventral (distal) views. **G–L**, distal left humerus in **G**, anterior; **H**, posterior; **I**, lateral; **J**, medial; **K**, dorsal; and **L**, ventral views. **Abbreviations:** **dpc**, deltopectoral crest; **fo**, fossa; **lat**, lateral condyle; **mt**, medial tuberosity; **not**, notch; **supn**, supinator notch; **supr**, supinator ridge. Scale bar = 10 cm.

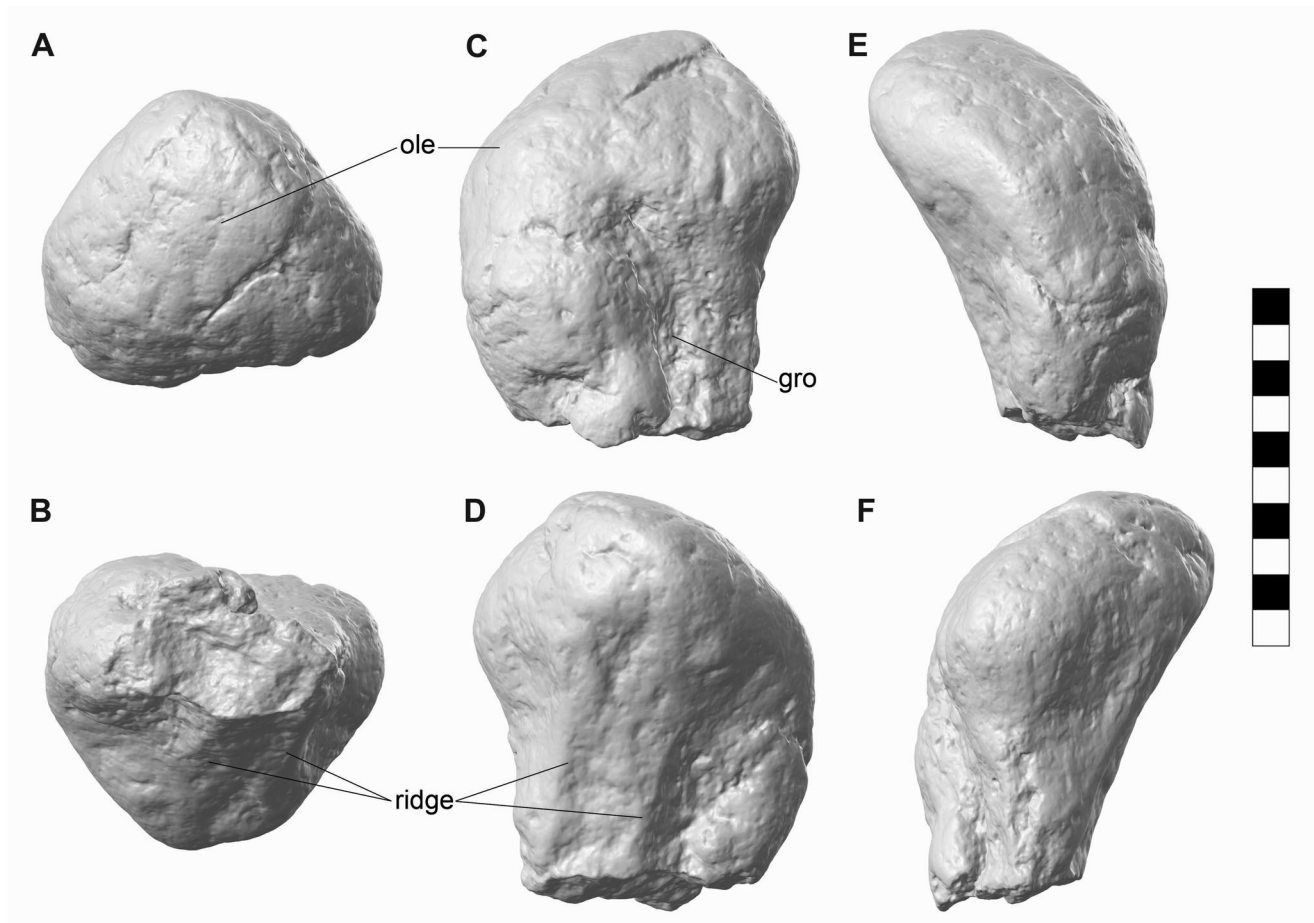


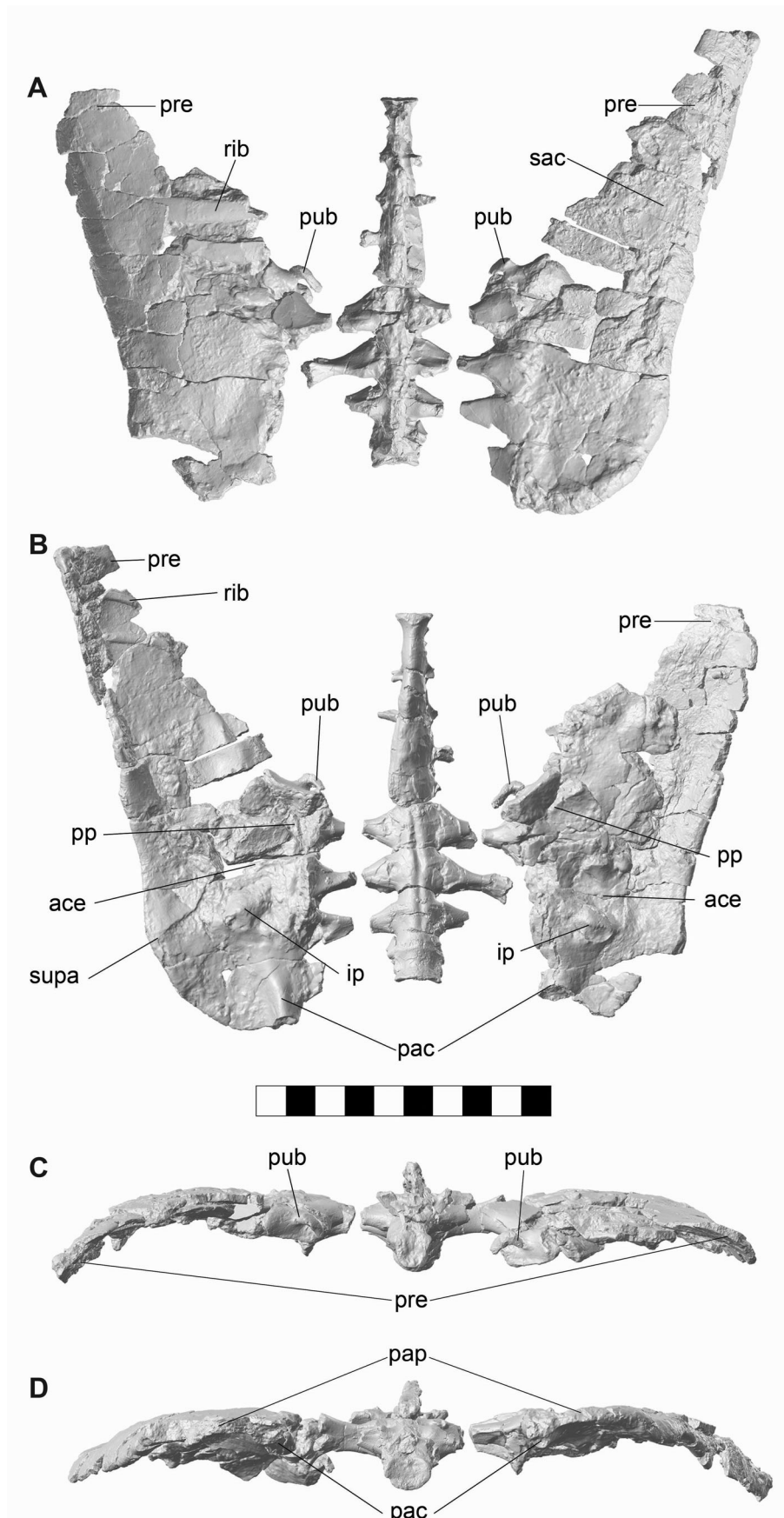
Figure 15. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. ?Proximal ulna in **A**, dorsal; **B**, ventral; **C**, anterior; **D**, posterior; **E**, ?lateral; and **F**, ?medial views. **Abbreviations:** **gro**, groove; **ole**, olecranon process. Scale bar = 10 cm.

bulbous, slightly transversely expanded evenly medially and laterally, and is rugose with a small lateral boss (Fig. 19A, latb).

?Fibula (Supplemental material Fig. S28). Some partial fragments may be part of a fibula. The bone comprises a section of shaft and a distal end. The shaft is parallel-sided for the length of what is preserved. It is teardrop-shaped in cross-section. One side, presumably the medial surface, is flattened, while the lateral surface is strongly convex. The distal end is slightly expanded and rugose; there are no clear facets for the tibia.

Metatarsal II (Fig. 20). A single metatarsal is preserved, which appears to be right metatarsal II based on comparison with the complete pes of *Euoplocephalus* (AMNH 5266) and *Pinacosaurus* (Currie et al., 2011). In proximal view, the proximal end is roughly crescent-shaped, with convex anterior, medial and posterior margins and a concave lateral margin (Fig. 20A), as in

Euoplocephalus (AMNH 5266). The posterior part of the lateral margin extends further laterally than the anterior part of the lateral margin. In anterior and lateral views, the shaft of the metatarsal is straight. The posterior surface is gently concave. The lateral surface bears a concavity proximally for articulation with metatarsal III (Fig. 20E, conc). At midshaft, there is a laterally projecting boss, which is flat on its lateral surface and slightly anteroposteriorly expanded relative to the rest of the shaft. The anterior surface of the metatarsal is smooth and gently concave proximodistally. In distal view, the distal surface is parallelogram-shaped such that the anterior and posterior surfaces are angled transversely, while the medial and lateral surfaces are angled antero-laterally. Although the shape of the proximal end of the metatarsal is highly similar to *Euoplocephalus* (AMNH 5266), the metatarsal of *Vectipelta* is much longer and more slender, with less expanded proximal and distal ends in anterior and lateral view than that of *Euoplocephalus*.



Dermal armour

Sacral shield (Fig. 21).

Macroscopic observations. The sacral shield is *c.* 1 cm thick (Fig. 17A, B). The dorsal surface (Fig. 21) is gently undulating, with circular, depressed areas that form part of the very low-relief ornamentation visible on some areas of the sacral shield (Fig. 21B). This ornamentation is not as clearly defined as in other ankylosaur sacral shields (Arbour *et al.*, 2011) and is unlike the sacral shields of *Polacanthus* and *Gastonia* (Kinneer *et al.*, 2016), where the arrangements of osteoderms are well defined. These low-relief structures (Fig. 21B) may indicate where keratinous scales were embedded in the skin directly above the shield. Ventrally, a distinctive cross-hatched pattern of structural fibres can clearly be seen. In cross-section, the shield comprises a series of light and dark horizontal layers, each *c.* 1 mm in thickness (Fig. 17B). Cross-sections of the sacral shield of *Polacanthus* (NHMUK PV R175) and an indeterminate ankylosaur from the Isle of Wight (NHMUK PV R9293) also reveal the light and dark layering observed in *Vectipelta*, but the shield is somewhat thinner in NHMUK PV R9293, and in *Polacanthus* it is variable in thickness, approaching the thickness seen in *Vectipelta* in the region of the preacetabular processes, but decreasing in thickness above the acetabular region of the iliosacral block.

Palaeohistological observations. The pelvic shield is composed of fibrolamellar bone with a woven bone matrix and a complex, organized arrangement of structural fibre bundles (Fig. 17C; *sensu* Scheyer & Sander, 2004). The centre of the pelvic shield is dominated by large resorption cavities, simple vascular canals, primary osteons, and reticular and plexiform vascular canals which reduce in size towards the dorsal surface, occasionally opening to the upper surface (Fig. 17A). In the ventral third there are small resorption cavities and a few simple vascular canals. Osteocyte lacunae are visible in the lamellar infill of the resorption cavities within the pelvic shield and are oval with long canaliculi, whereas the osteocytes in the woven fibrolamellar bone matrix are more rounded and have shorter or almost no canaliculi. The vascular canals intersect the fibre bundles in most instances, as do the concentric lamellations of the primary osteons, indicating that the fibre bundles were laid down as part of the primary bone tissue and subsequently resorbed.

The structural fibre bundles (Fig. 17C, SF), seen as dark lines in bundles approximately 0.2–0.4 mm thick under plane polarized light, are arranged as a ‘primary’ network which extends parallel to the dorsal surface within the bone matrix, forming a plywood-like structure (Weiss & Ferris, 1954), each ply being oriented at approximately 90° to the adjacent layers. A more intricate, less dense ‘secondary’ network of fibre bundles weaves through the primary network, at approximately 30° to 45° from perpendicular to the dorsal surface in three planes of orientation.

Fine-grained sediment has infilled the space between the pelvic shield and ilium, within which is a cluster of rectilinear cells, each approximately 15 µm × 20 µm, becoming lengthened and more irregular towards the ilium (Fig. 17A).

Osteoderms. A large number of osteoderms are preserved, ranging from small ossicles to large spines and flattened plate-like structures. Most of these are incomplete and although they are morphologically disparate, their life position is unknown and so we do not assign any osteoderm to a specific anatomical position. The osteoderms can be grouped into five broad morphotypes, and the most complete and best-preserved are described herein. The orientation of osteoderms adopted here is for descriptive purposes only; this might not reflect orientation in life. Unless otherwise stated, osteoderms are described using the usual terms anterior/posterior/-proximal/distal, with any spine or ridge present assumed to point posteriorly. The base is considered proximal and the tips of the spine distal. Left and right are used when describing osteoderms with spines or ridges, with the sagittal plane presumed to extend through the centre of the osteoderm roughly aligned to the apex of the spine or ridge.

Recurved spines (Fig. 22). Recurved spines have expanded bases that are gently upwardly concave, and transversely compressed spines that curve posteriorly along their length. Three examples are described and figured here.

A large, transversely compressed, flat-based spine, the distal section of which is missing (Fig. 22A, D, G, J, M, P). The spine blade is angled posterodorsally, with a sharp ridge extending along its anterior margin and a more rounded ridge on the posterior margin, so that it is tear drop-shaped in cross-section. In left lateral view, the anterior edge of the spine is straight

Figure 16. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. Iliosacral block in **A**, dorsal; **B**, ventral; **C**, anterior, and **D**, posterior views. **Abbreviations:** ace, acetabulum; ip, ischiadic peduncle; pre, preacetabular process; pac, postacetabular crest; pap, postacetabular process; pub, pubes; pp, pubic peduncle; sac, sacral shield; supa, supraacetabular process. Scale bar = 50 cm.

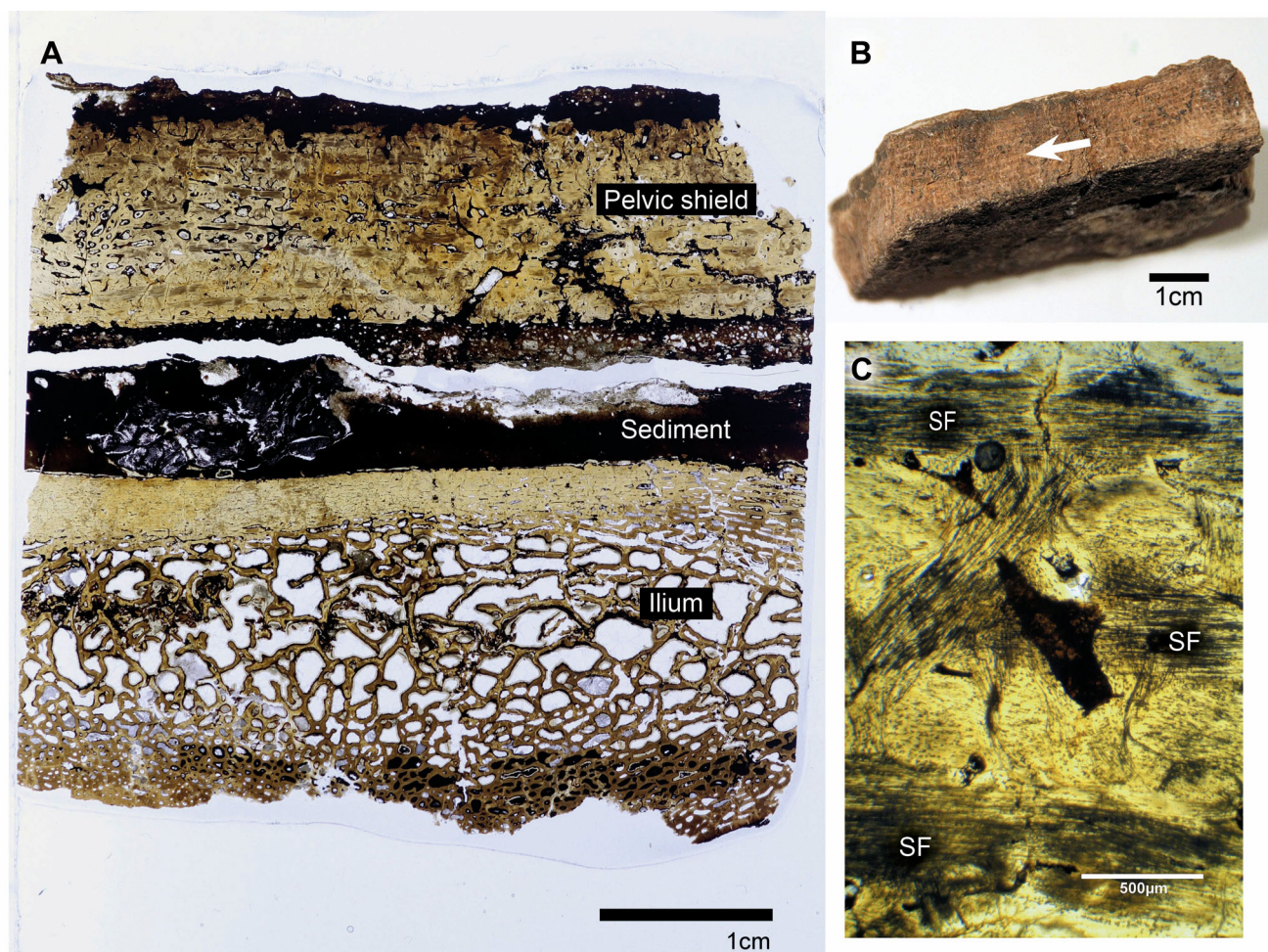


Figure 17. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. Sacral shield. **A**, thin section showing a cross-section through part of the ilium and sacral shield showing sacral shield (top), sediment and cell cluster, and ilium (bottom). **B**, fragment of sacral shield viewed in cross-section. White arrow indicates one of the 11 lighter coloured alternating bands. **C**, thin section in plane polarized light showing dense structural fibre bundles. **Abbreviation:** SF, primary network of fibre bundles.

while the posterior edge curves gently posteriorly as it extends from the base. The ventral surface of the base is gently upwardly concave (Fig. 22A). In ventral view, the base is teardrop-shaped, with the apex of the teardrop directed posteriorly. In lateral view the base flexes posterodorsally just over halfway along its length, trending away from the anterior section of the base at an angle of approximately 25° . The margins of the base are rounded, with mildly rugose ventral edges. A section of the left lateral margin of the base is missing, and there is a distinct swelling, perhaps a pathology, along its posterolateral margin. In *Borealopelta* (Brown et al., 2017), the third band of cervical osteoderms are broadly similar in morphology to this spine, consisting of shorter spines with shorter base length and less width than those of the first and second bands, and these represent the transition to thoracic osteoderms.

In a smaller recurved spine, with the distal tip missing (Fig. 22B, E, H, K, N, Q), the blade of the spine is very gently recurved and transversally compressed along its entire length, with a sharp ridge extending along the anterior surface, and the posterior edge being rounded. The spine tapers towards the tip, narrowing to a laterally compressed point, although the distal-most tip of the spine is missing. The blade is angled at approximately 7° relative to its base which, assuming the base lay flat to the contour of the body in the living animal, suggests that the spine would have been orientated at a low angle to sagittal plane. The margins of the base are damaged on three sides with only the rounded right anterior section intact. Viewed ventrally the base is gently concave. This spine has some similarities to an ankylosaur osteoderm (NHMUK PV OR28681) reported by Mantell (1843), with the transversally compressed spine rising from a sub-circular base at a similar angle,

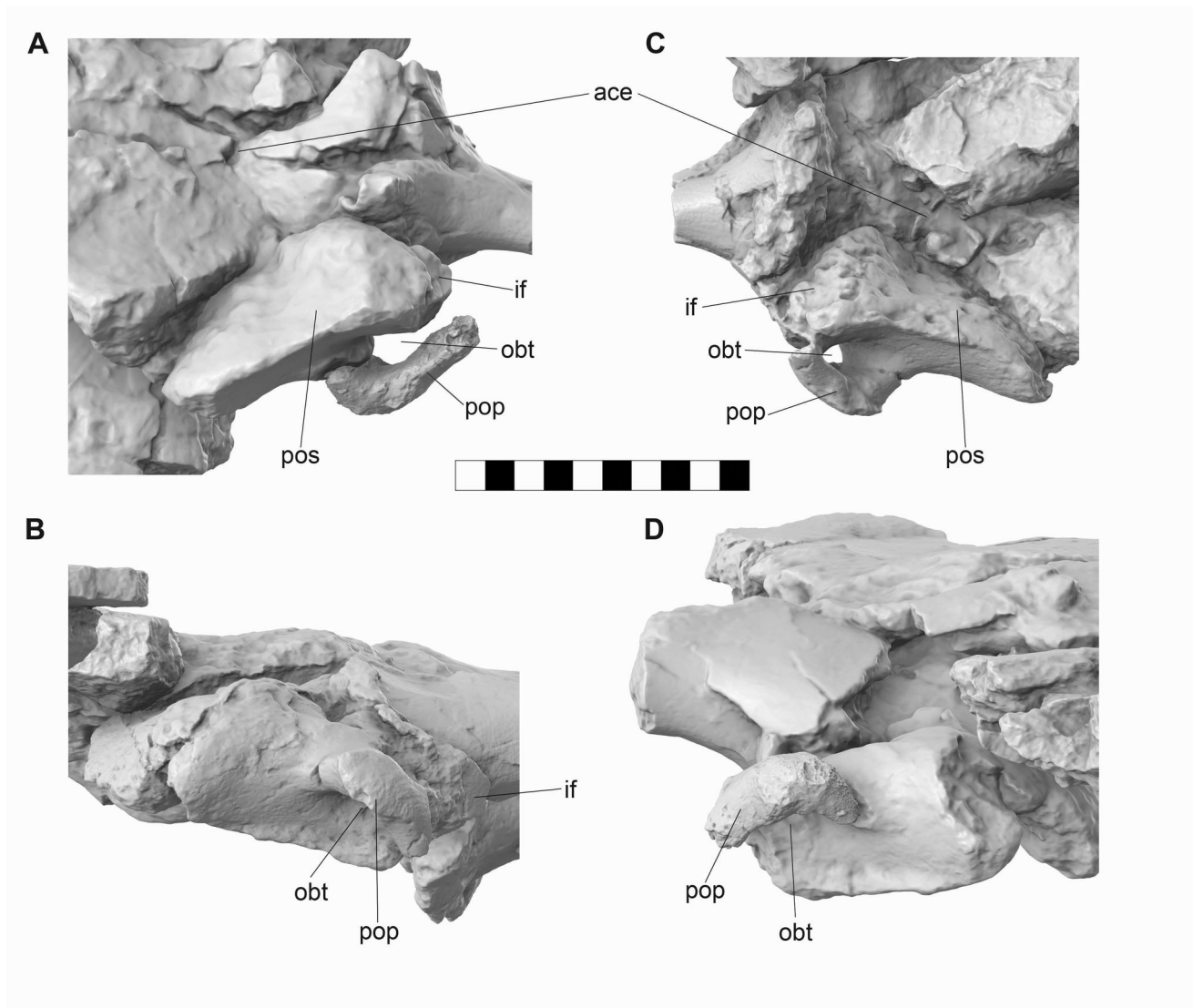


Figure 18. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. Pubes. **A, B**, left pubis in **A**, posterior and **B**, anterior views. **C, D**, right pubis in **C**, posterior, and **D**, anterior views. **Abbreviations:** **ace**, acetabulum, **if**, ischial facet, **obt**, obturator foramen, **pos**, posterior surface; **pop**, postpubis. Scale = 10 cm.

although the leading edge of NHMUK PV OR 28681 is straighter and the rear margin is missing. Brown *et al.* (2017) described a recurved parascapular spine preserved in life position with the distal tip orientated posteriorly in *Borealopelta*, and *Hylaeosaurus* (NHMUK PV OR3775) also has three recurved spines preserved in life position in the pectoral region (Raven *et al.*, 2020) that also angled posteriorly, the anterior-most of which resembles this spine from *Vectipelta*.

A large, transversely compressed recurved spine (Fig. 22C, F, I, L, O, R). The spine is nearly complete with only the distal-most tip missing. The anterior margin of the spine is a sharp ridge that curves posterodorsally; the posterior margin is incomplete, but is shorter than the anterior margin. In dorsal view the spine is offset

from the centre so that the spine arises on the left side. The base is sub-circular and shallowly concave in ventral view. In anterior view the base margin curves ventrally, roughly along the axis of the spine, with the left lateral margin of the base dipping ventrally. This spine is very similar to the parascapular spine of *Borealopelta* (Brown *et al.*, 2017) that is preserved in life position, and a large osteoderm found with the holotype of *Sauropelta* (Ostrom, 1970) that was interpreted by Carpenter (1984) as a shoulder spine.

Recurved spines are found in many species of ankylosaur including *Europelta* (Kirkland *et al.*, 2013), *Gastonia* (Kinneer *et al.*, 2016), *Struthiosaurus* (Ösi & Pereda Suberbiola, 2017), *Hungarosaurus* (Ösi, 2005) and *Hylaeosaurus* (Mantell, 1843). However, robust,

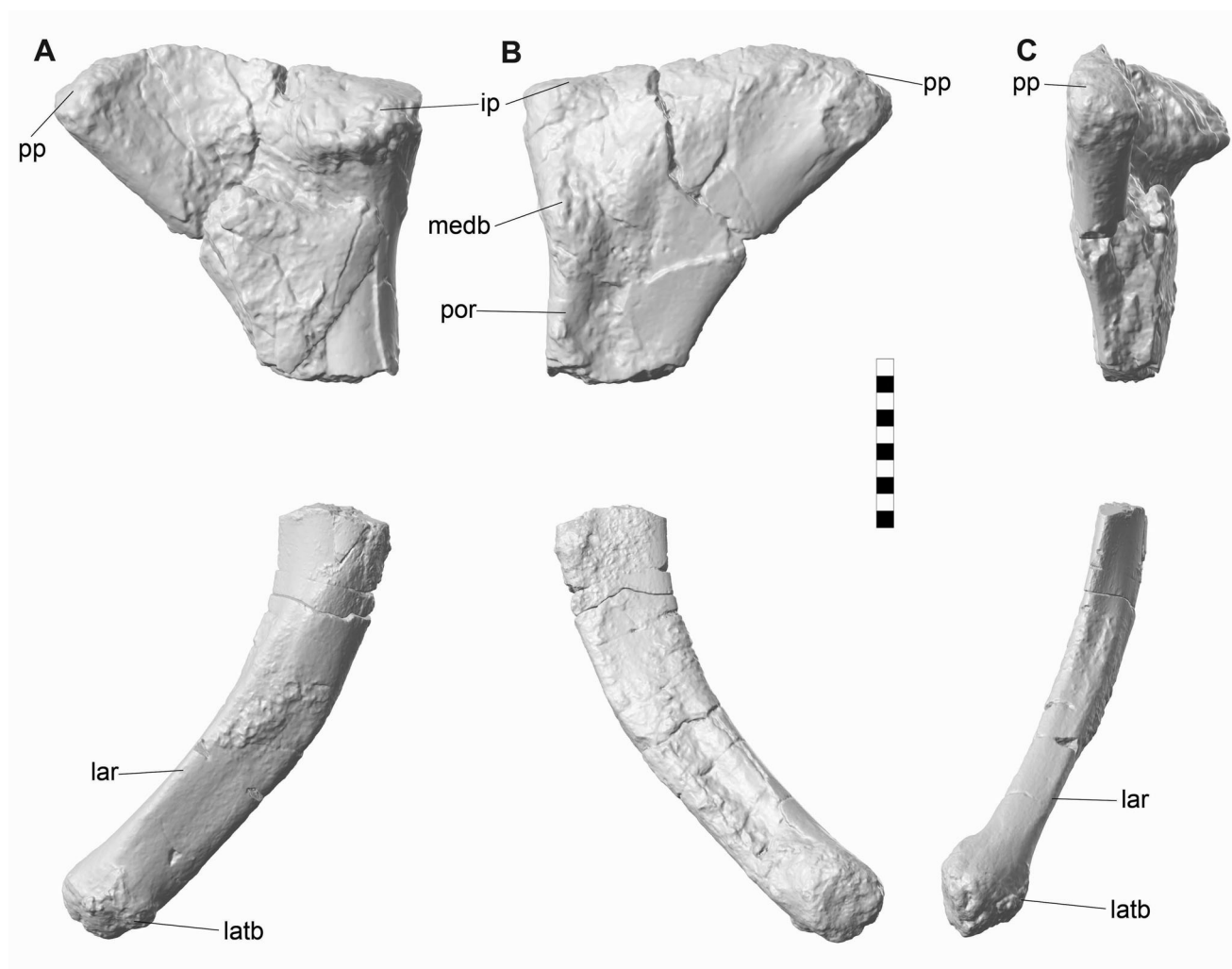


Figure 19. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. Left ischium in **A**, lateral; **B**, medial; and **C**, anterior views. **Abbreviations:** **ip**, iliac peduncle; **lar**, lateral ridge; **latb**, lateral boss; **medb**, medial boss; **por**, posteromedial ridge; **pp**, pubic peduncle. Scale bar = 10 cm.

recurved spines with wide, sub-circular bases have not been reported in other ankylosaurs to our knowledge, although there is a large diversity of dermal armour across the clade. Such spines do not appear to have been described for *Polacanthus* (Blows, 2015), and are not represented among the holotype material (NHMUK PV R175). A large wide-based spine was recovered as part of indeterminate ankylosaur from the Isle of Wight (NHMUK PV R9293), although this is not recurved. Two wide-based, recurved spines referred to *Polacanthus* sp. and described as lateral and medial shoulder spines were reported by Pereda Suberbiola et al. (2007) from the Early Cretaceous of Soria, Spain. One is recurved but is less robust and curves strongly mediolaterally, unlike those of *Vectipelta*, while the other is more similar in form to those of *Vectipelta*, although the spine is less robust and gently recurved,

and does not flex posteriorly in the mid-section of the spine, which is also proportionately longer with a wider base than those of *Vectipelta*. Recurved spines are also known for *Struthiosaurus* (Ösi & Pereda Suberbiola, 2017; Pereda Suberbiola & Galton, 2001), but these are conical and not transversally compressed and, where preserved, the bases are boomerang-shaped.

Flattened, blade-like spines (Fig. 23, Supplemental material Figs S29, S30). Blade-like spines are more transversally compressed than the recurved spines. They are straight, rather than gently curved. They have strongly concave, pup-tent-shaped bases, although due to erosion and crushing, this is not always clear. Two examples are described below; images of others can be found in the [Supplementary material](#).

A blade-like spine with an eroded base and the distal tip of the spine is missing (Fig. 23A, C, E, F, I, K). The

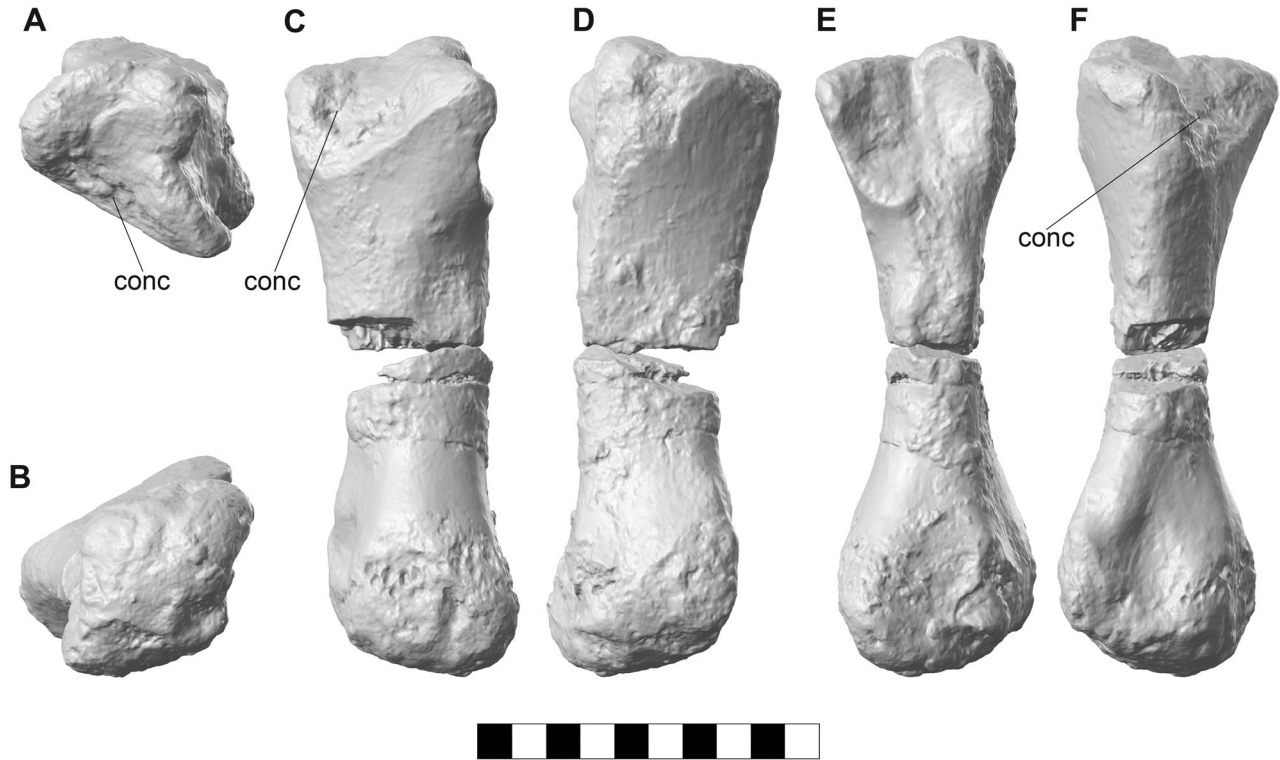


Figure 20. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. Right metatarsal II in **A**, dorsal, **B**, ventral, **C**, anterior, **D**, posterior, **E**, lateral and **F**, medial views. **Abbreviation:** conc, concavity. Scale bar = 10 cm.

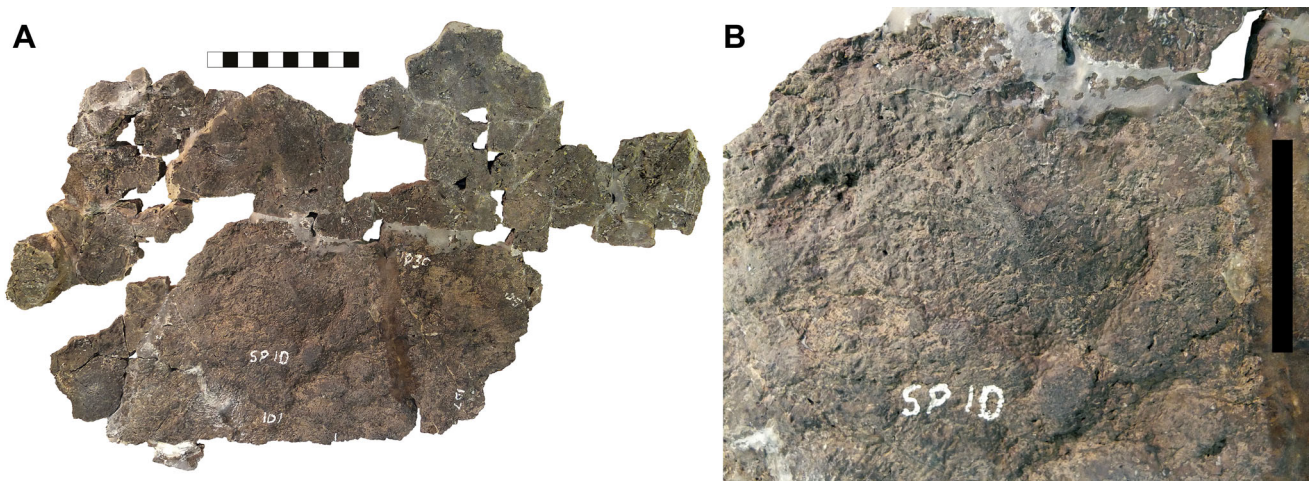


Figure 21. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. Sacral shield. **A**, the entire preserved portion of the sacral shield; **B**, a close-up of the dorsal surface showing a subtle, low relief, ovate swelling with a slight keel, which is the only ornamentation observed on the surface. Scale bar for **A** = 10 cm, and for **B** = 5 cm.

spine blade is strongly transversely compressed. The anterior edge is a transversely thin ridge, while the posterior edge is more rounded, giving a similar cross-section to an aerofoil. The base is concave in ventral view and broken and eroded on its margins, although it

preserves some original rugose edges. The lower flange of the base has two deep pits of different sizes, the larger being circular and bowl-shaped, with the smaller lying on the anterior margin of the larger and being lozenge-shaped. The spine projects from the base at a low

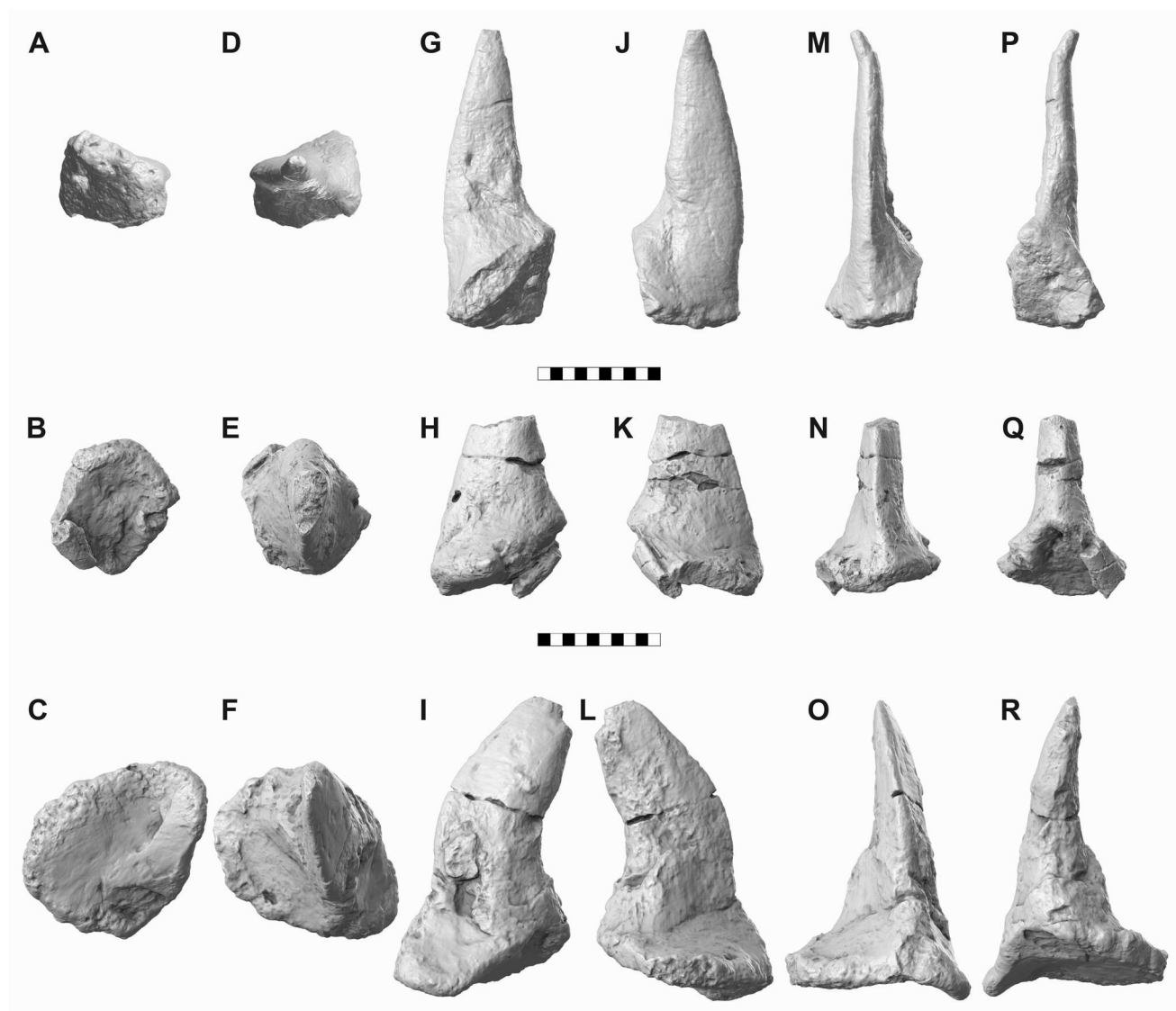


Figure 22. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. Examples of recurved spines discussed in the text. Orientation presumed: A–C, proximal; D–F, distal; G–I, left lateral; J–L, right lateral; M–O, anterior; P–R, posterior. Scale bar = 10 cm.

angle. This spine bears some similarities to two spines from the holotype of *Hylaeosaurus* (NHMUK PV OR 3775; Raven et al., 2020 and references therein).

In a large-bladed spine, with an incomplete blade (Fig. 23B, D, G, H, J, L), the blade is highly dorsoventrally compressed. Both anterior and posterior edges are equally as sharp as each other and are more-or-less straight. The base of the spine is transversely expanded and would have been pup-tent-shaped, but the two sides have been compressed together postmortem. The surface of the better-preserved side is rugose. The spine projects at a similar angle from the base as the spine described above.

Isolated finds of large blade-like spines have previously been reported from the Wessex Formation of the

Isle of Wight, most notably a very large spine (IWCMS 2014:89) and a similar but slightly smaller spine considered by Raven et al. (2020) as belonging to an indeterminate ankylosaur. Although of comparable size to the large-bladed spine of *Vectipelta*, both of these spines differ from those found with *Vectipelta* in that their bases are large, robust, highly rugose and solid rather than pup-tent-shaped, and their posterior surfaces have deep grooves extending along their length, a feature lacking in the spines of *Vectipelta*, where the posterior margin has a rounded edge. A blade-like spine with a pup-tent base similar to those of *Vectipelta* appears to be present in *Mymoorapelta* (Kirkland & Carpenter, 1994), and blade-like spines are also present in

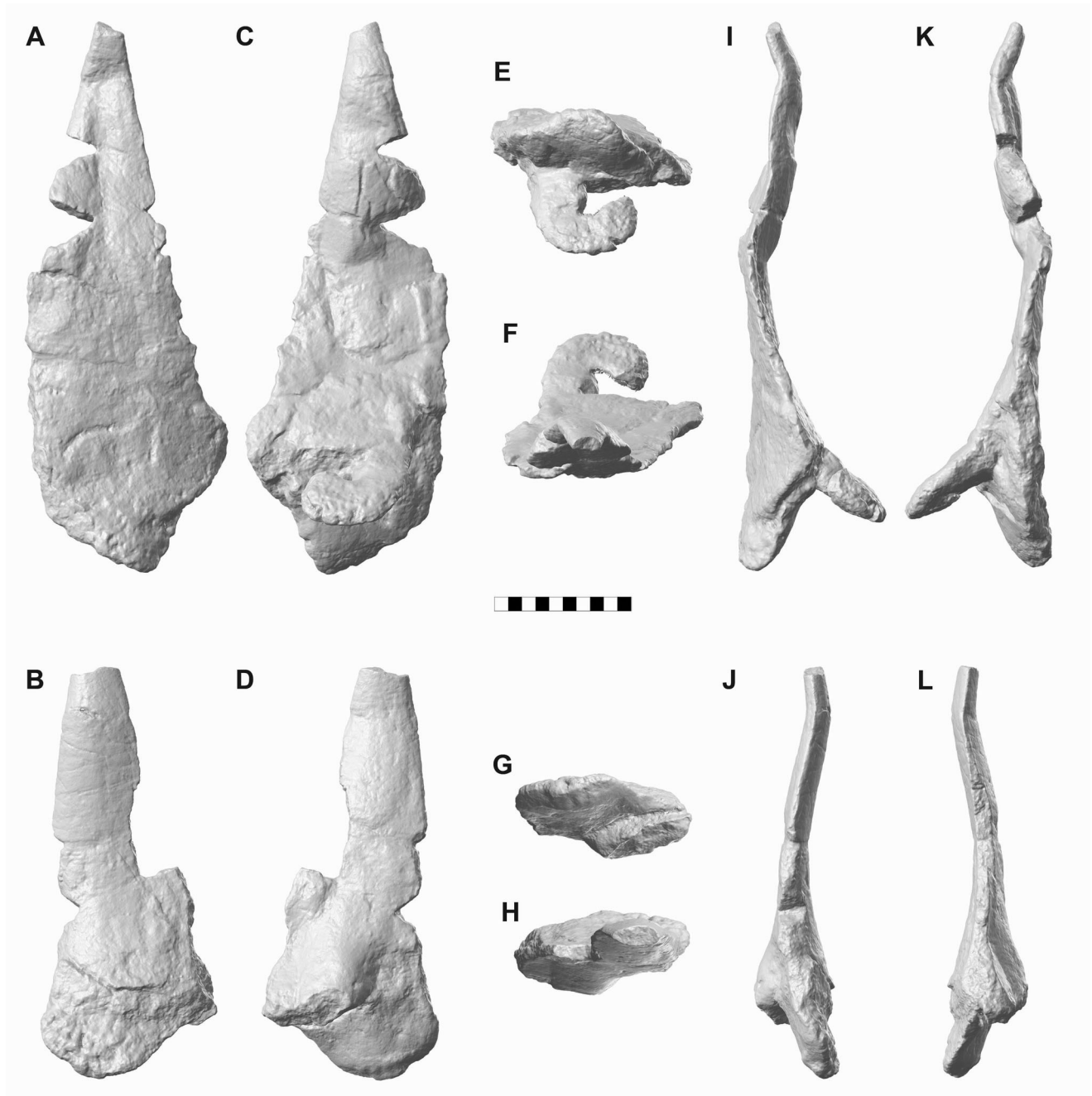


Figure 23. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. Examples of flattened, blade-like spines discussed in the text. Orientation presumed: **A, B**, left lateral; **C, D**, right lateral; **E, G**, proximal; **F, H**, distal; **I, J**, anterior; **K, L**, posterior. Scale bar = 10 cm.

Hylaeosaurus (Raven et al., 2020), although the morphology of their basal region is not clearly preserved. Elongated triangular bladed spines with hollow-bases similar to those of *Vectipelta* were recovered from the late cervical/early thoracic area of *Gargoyleosaurus* and referred to as a shoulder spine by Kilbourne and Carpenter (2005).

Plates (Fig. 24). Plates are transversely compressed both proximally and distally, with unexpanded bases. Although there are a large number of partial plates associated with the skeleton, only one is more-or-less complete, with a clear outline (Fig. 24). Although it is slightly deformed, the plate appears uniformly transversely compressed across the entire structure, except at

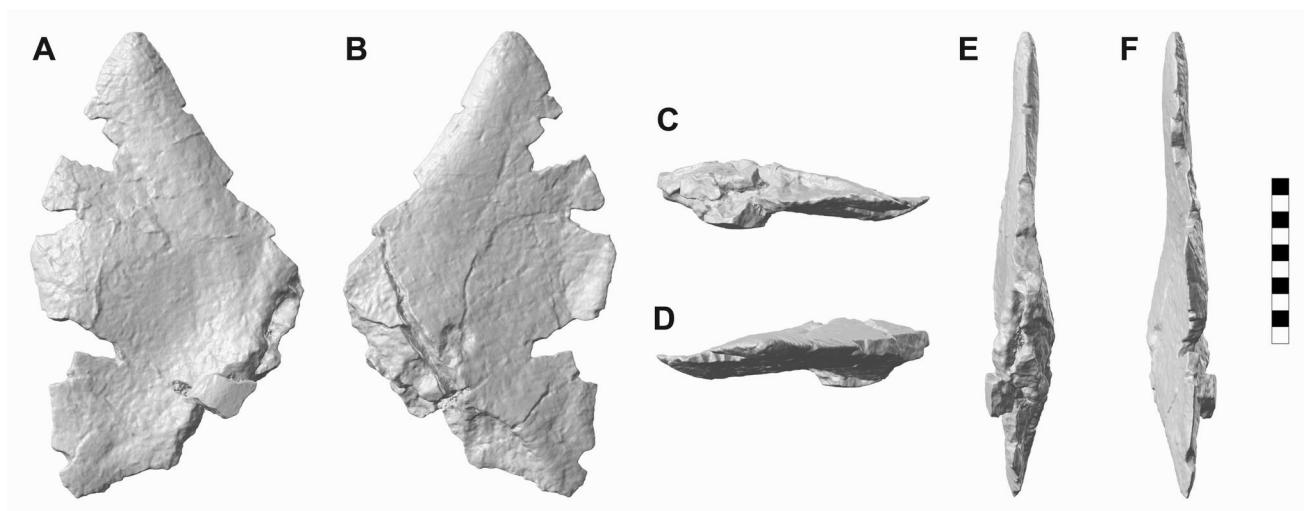


Figure 24. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. An example of a plate, as discussed in the text. Orientation presumed: **A**, left lateral; **B**, right lateral; **C**, proximal; **D**, distal; **E**, anterior; **F**, posterior. Scale bar = 10 cm.

the base where it is very slightly thicker transversely. Anterior and posterior margins are sharp ridges; the anterior margin curves as it extends distally, while the posterior margin is straight, giving the plate a posterior curvature in lateral view. The base is broken but is only slightly transversely expanded relative to the plate. An almost identical plate is preserved on a block from the pelvic region, suggesting the plates may have been paired. The plate appears to have been crushed onto the surface of the ribs of the presacral rod, which extended to articulate with the preacetabular process of the ilium. This suggests that the plate may have been located around the posterior thoracic or pelvic region in life. A number of such plates are preserved in life position along the tail of the ankylosaurid *Zuul* (Arbour & Evans, 2017) with larger, anteriorly orientated recurved plates located in the proximal region of the tail grading to smaller triangular plates distally, closer to the tail club. Many ankylosaurs, including *Polacanthus* (NHMUK PV R175), *Gastonia burgei* (Kinneer et al., 2016) and *Mymoorapelta* (Kirkland & Carpenter, 1994) also have similar flattened, recurved plates, and these are usually considered to have been positioned in the tail region in life, although plates or dorsoventrally compressed osteoderms have been found in the lateral pelvic region of several ankylosaurs including an ankylosaur from Mongolia (Arbour & Currie, 2013b), *Saichania chulsanensis* (Carpenter et al., 2011) and *Dyoplosaurus* (Arbour et al., 2009). Conversely, the ‘splates’ of ‘polacanthid’ ankylosaurs such as *Polacanthus* (NHMUK PV R175), *Hoplitosaurus* (USNM V4752), *Gastonia lorriemcwhinneyae* (DMNH 59591), and an indeterminate ankylosaur from the Isle of Wight

previously referred to *Polacanthus* (NHMUK PV R9293; Raven et al., 2020) have not been recovered with *Vectipelta*, although of course absence of evidence cannot be taken as evidence of definitive absence.

Small spines with unexpanded bases (Fig. 25, Supplemental material Fig. S31). These spines arise more-or-less directly from the base, so that the base is unexpanded relative to the lateral sides of the spine. They are smaller than the recurved spines, blade-like spines, and the plates, and have a flat base. Two examples are described here.

A low, transversally compressed, flat-based spine (Fig. 25A–F) in left lateral view shows that the anterior edge of the spine is straight while the posterior is gently recurved, and the anterior edge is the longer of the two. The distal surface is rounded rather than pointed and has a rugose texture. The maximum transverse width of the base is approximately equal to the dorsoventral height of the osteoderm. The base is shallowly convex and sub-rhomboidal in ventral view. The margins of the base are rounded, although this rounding is less prominent on the posterior margin. The right lateral margin of the base is broken. When seen in left lateral view, the ventral surface of the base flexes approximately halfway along its length, with the posteroventral part orientated posterodorsally approximately 50° from the anterior section of the base. The osteoderm described here bears some similarities with the cervical spines of *Borealopelta* (Brown et al., 2017), although these are pointed rather than rounded distally.

In a partial, asymmetrical spine (Fig. 25G–L), the spine arises from the right side of the base and is angled posteriorly. The distal end of the spine is missing, but

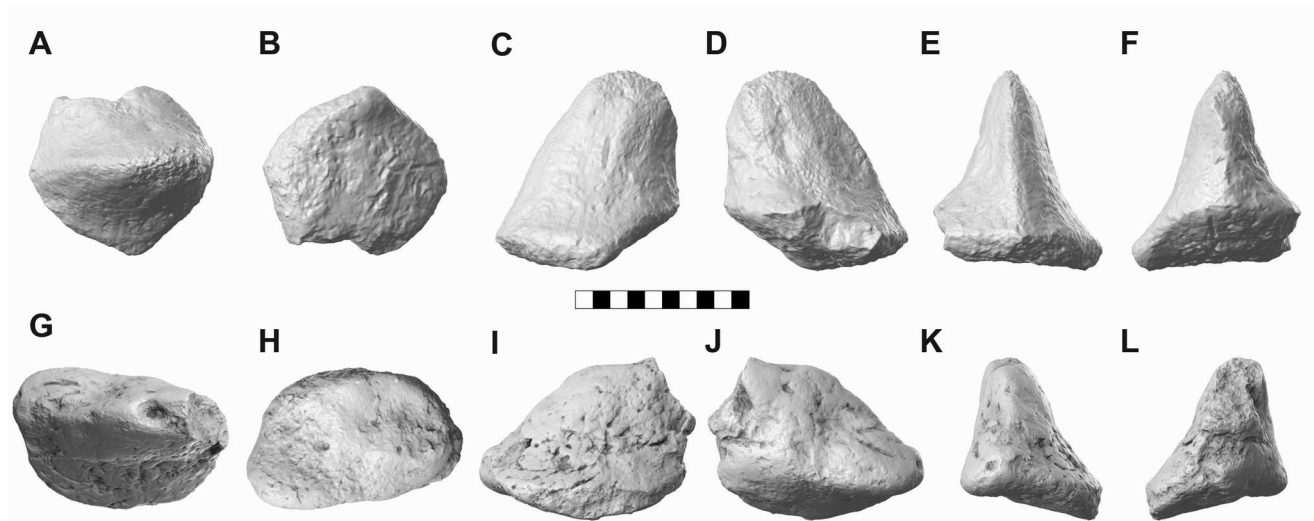


Figure 25. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. Examples of small spines with unexpanded bases discussed in the text. Orientation presumed: A, G, distal; B, H, proximal; C, I, left lateral; D, J, right lateral; E, K, anterior; F, L, posterior. Scale bar = 10 cm.

the abraded edges are rounded, indicating the osteoderm may have been beached-rolled before collection. A deep pit on the dorsal surface may be due to erosion, or could be pathologic. The ventral surface of the base is flat with all margins rounded; a small section of the left lateral margin is missing. In proximal view the base is sub-rectangular with a distinct bulge on the anterior edge where the spine rises from the base. This spine resembles the transitional spine of *Borealopelta* (Brown *et al.*, 2017), both having the spine angled posteriorly. It is also similar to a spine (NHMUK PV R15951) described by Blows (2001), which Raven *et al.* (2020) considered an indeterminate ankylosaur. Both have sub-elliptical solid bases, are longer anteroposteriorly than transversally and have transversally compressed spines.

Spines with unexpanded bases are known in several other ankylosaurs, including a spine referred to cf. *Hylaeosaurus* from the Early Cretaceous of Burgos, Spain (Sanz, 1983), *Gastonia lorriemcwhinneyae* (Kinneer *et al.*, 2016) and *Pinacosaurus*, where they are located at the base of the tail handle (Arbour & Evans, 2017). Similar spines also occur in *Gastonia burgei* (Kirkland, 1998), but these are pup-tent-shaped at the base rather than solid. A solid-based spine of this type was found with *Invictarx* that McDonald and Wolfe (2018) considered to be from the thoracic region.

Low keeled scutes (Figs 26, S32, S33). A large number of small, circular to ellipsoid osteoderms with a small peak are present. They generally have flat bases, although slightly larger ones with larger peaks are concave. The peaks arise from the lateral margins of the base, sloping gently to the peak, which is generally offset from the centre of the osteoderm. These sorts of

scutes are widely present in ankylosaurs, such as *Euoplocephalus* (AMNH 5404), *Nodosaurus* (YPM 1815) and *Ankylosaurus* (NHMUK PV R8001).

Results of the phylogenetic analysis

Acantholipan and *Mongolostegus* were removed prior to analysis because safe taxonomic reduction identified them as taxonomic equivalents of *Euoplocephalus* and *Chungkingosaurus* respectively. Analysis of the resulting character–taxon matrix resulted in three most parsimonious trees (MPTs) with lengths of 115.624 steps (CI = 0.269; RI = 0.498; RC = 0.134). A strict consensus of the three MPTs is well resolved, but does not recover the usual nodosaurid–ankylosaurid split. *Vectipelta* is recovered in a small clade as sister-taxon to a clade containing *Zhejiangosaurus* and *Dongyangopelta* (Fig. 27). The clade containing *Vectipelta*, *Dongyangopelta* and *Zhejiangosaurus* is supported by three unambiguous synapomorphies: the possession of more than four sacral rod vertebrae (character [ch] 156:5), the possession of a longitudinal ridge at mid-height of the centra of mid- and posterior caudal vertebrae (ch. 179:1), and the possession of co-ossified sacral shield (ch. 330:1).

The clade containing *Vectipelta* is itself sister taxon to a clade containing a large number of ‘ankylosaurid’ ankylosaurs, including *Shamosaurus*, *Zaraapelta*, *Euoplocephalus*, *Saichania*, *Jinyunpelta* and *Ankylosaurus*, among others. The sister-taxon relationship between the two clades is supported by seven unambiguous synapomorphies: the posterior margin of the skull has a transverse width greater than the

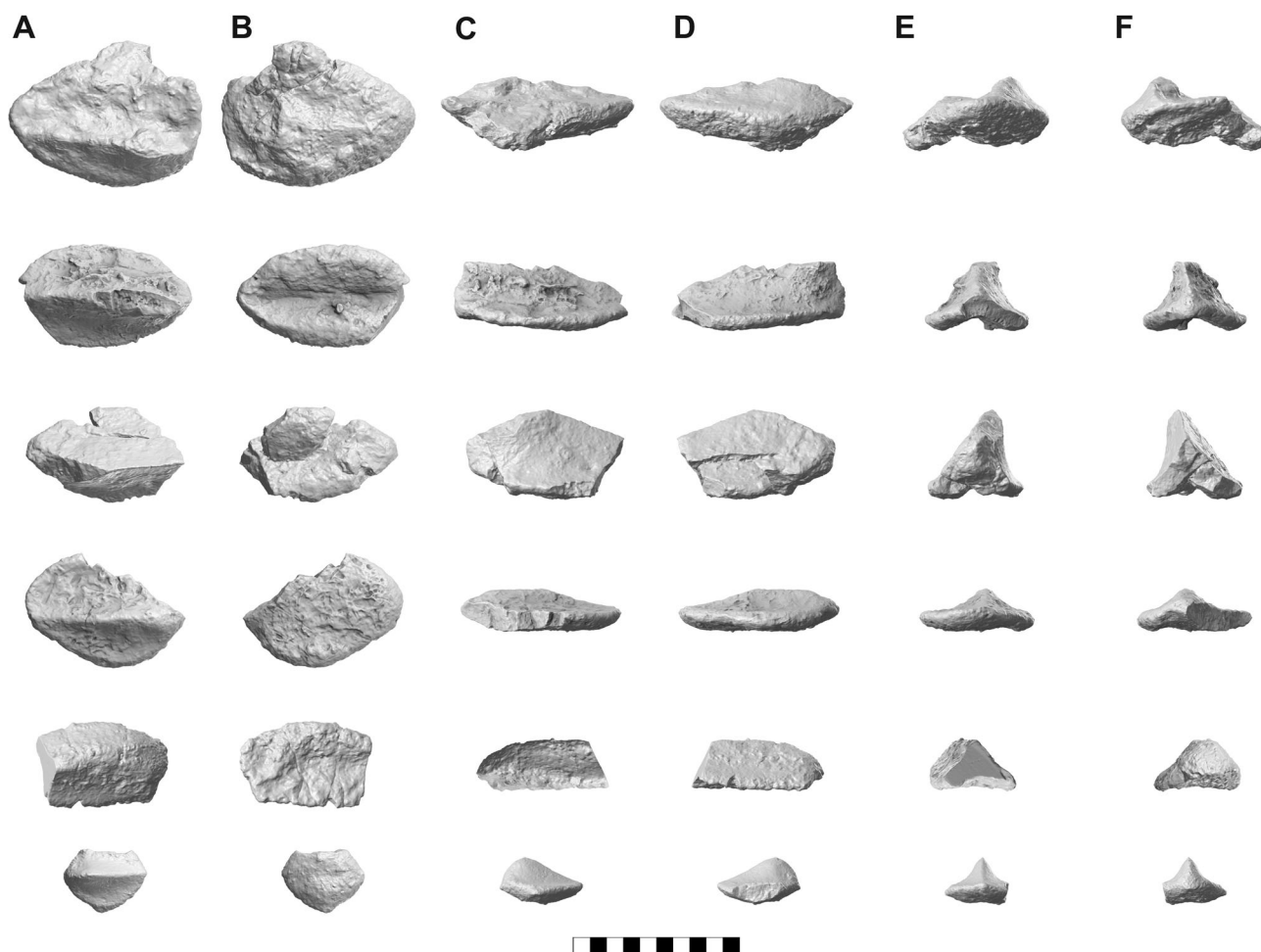


Figure 26. *Vectipelta barretti* gen. et sp. nov., IWCMS 2021.75. Examples of low keeled scutes. Orientation presumed: **A**, distal; **B**, proximal; **C**, left lateral; **D**, right lateral; **E**, anterior; **F**, posterior. Scale bar = 10 cm.

maximum width across the orbits (ch. 70: 0), caudal vertebrae are fused to the haemal arches (ch. 165: 1), haemal arches of the posterior caudal vertebrae are inverted ‘T’-shapes in lateral view (ch. 184: 1), the acromial process of the scapula is shelf-like and extends laterally (ch. 193: 2), humeral head and the medial tubercle are continuous in anterior view (ch. 201: 0), the length of the base of the jugal horn is greater than the length of the orbit (ch. 302: 1), and the basal surface of osteoderms is deeply excavated (ch. 315: 1).

The other Wealden Group ankylosaurs, *Polacanthus* and *Hylaeosaurus*, are found in a clade of ‘polacanthid’ taxa, which forms the earliest-diverging major ankylosaur clade, and contains other taxa traditionally considered polacanthids, such as *Gastonia* and *Texasetes* (Fig. 27). Raven et al. (2023) carried out a number of constraint analyses to further explore the robustness of phylogenetic relationships recovered. In one such analysis, ‘polacanthid’ taxa were constrained as members of

the ‘ankylosaurid’ clade. In this analysis, the close relationship between *Vectipelta*, *Dongyangopelta* and *Zhejiangosaurus* broke down, and *Vectipelta* was sister-taxon to *Texasetes* and near to the ‘panoplosaurid’ taxa. These analyses demonstrate that there is not a close phylogenetic relationship between *Vectipelta* and *Polacanthus*.

Discussion

Sacral shield morphology in ankylosaurs

Sacral shields are known from a variety of ankylosaurs, and Arbour et al. (2011) established three categories of sacral shield based on osteoderm arrangements (see also Ősi & Pereda Suberbiola, 2017). In Category 1, the armour is not co-ossified; in Category 2, the sacral shields consist of co-ossified rosettes, and in Category 3, sacral shields are formed from co-ossified polygons

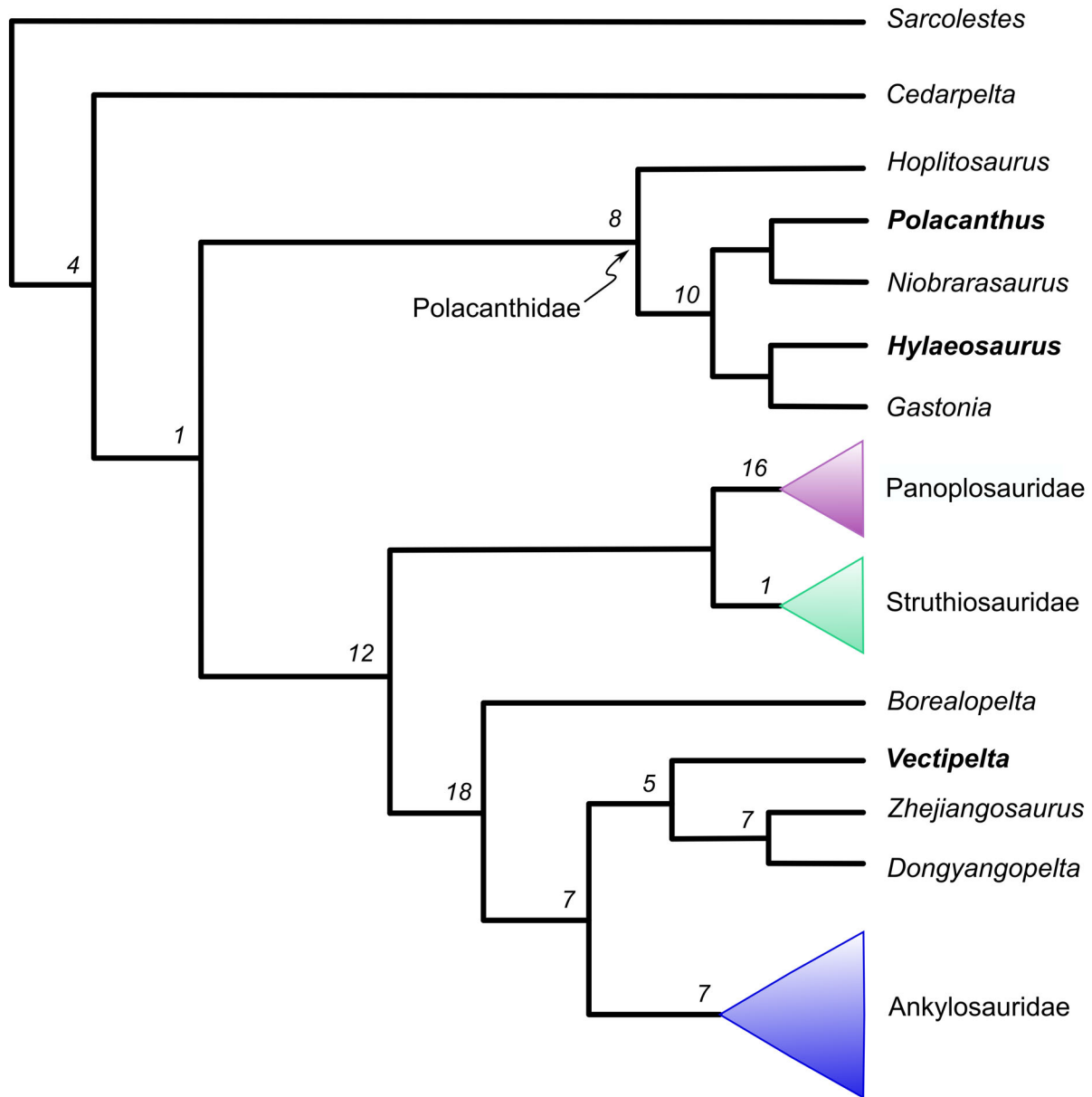


Figure 27. Summary results of the phylogenetic analysis carried out in Raven *et al.* (2023), showing the phylogenetic position of the Wealden Group ankylosaurs (in bold). Figures above the nodes are decay indices. Full phylogenetic results can be found in Raven *et al.* (2023).

that are of uniform size. ‘Polacanthid’ ankylosaurs, including *Polacanthus* (NHMUK PV R175; Blows, 2015), *Gastonia burgei* (Kirkland, 1998) and *Mymooropelta* (Kirkland & Carpenter, 1994) were considered to have Category 2 shields consisting of co-ossified rosettes ornamented with larger bosses surrounded by smaller tubercles or ossicles (Arbour *et al.*, 2011). It does not appear that the very low-relief ornamentation present on the sacral shield of *Vectipelta* represents

more prominent structures that have been eroded, as the bone surface is intact across sections of the dorsal surface. It is possible that ossicles and scutes were embedded in the skin but not fused with the shield itself, although none were found in association.

Not all ankylosaur sacral shields fall within the classification established by Arbour *et al.* (2011). The sacral shield of *Dongyangopelta* (Chen *et al.*, 2013) appears to differ from Category 1–3 sacral shields because the

central osteoderms are not surrounded completely by smaller osteoderms (Arbour & Currie, 2016), and the ornamentation of the osteoderms of the shield of *Taohelong* (Yang et al., 2013) also differs from that of other ankylosaurs, indicating greater morphological diversity in ankylosaur sacral shields than the existing system of classification allows. The unique morphology of *Vectipelta*'s more extensively preserved sacral shield possibly represents a new category of ankylosaur sacral shield, Category 4, where the shield consists of a thin sheet of undifferentiated, layered dermal bone, smooth in dorsal view with a gently undulating surface either entirely lacking or possessing very low relief ornamentation and no evidence of the co-ossification of osteoderms. The taxonomic utility of sacral shield morphology is uncertain, and further research is needed to better understand these unique structures.

The histology of the sacral shield

A complex, plywood-like arrangement of structural fibre bundles is clearly observed in the sacral shield of *Vectipelta*. A similar arrangement of structural fibres has been described in the osteoderms of numerous other ankylosaurs (Barrett et al., 2002; Burns & Currie, 2014; Maidment et al., 2021; Scheyer & Sander, 2004) and is considered a synapomorphy of Ankylosauria within Thyreophora (the armoured dinosaurs; Burns & Currie, 2014; Scheyer & Sander, 2004). The structural fibre bundles appear to be complex but ordered, unlike the random arrangement previously noted in the histology of a *Polacanthus foxii* shield (Blows, 1987).

The fibre bundles are thought to reflect the incorporation of collagen fibres from the dermis during bone formation via metaplastic ossification (Haines & Mohiuddin, 1968; Main et al., 2005; Kirby et al., 2020; Scheyer & Sander, 2004). The addition and arrangement of collagenous fibres increases toughness and hinders the spreading of microcracks in bone (Currey, 2002; Currey et al., 2009). This would increase resistance to compressive impact forces from a blow or a bite that otherwise might cause fracture, and it therefore seems likely that the sacral shield of ankylosaurs performed a predominantly defensive function (Coombs, 1978; Scheyer & Sander, 2004).

In *Vectipelta*, there is clear demarcation between the periosteal surface of ilium and the sedimentary layer above, indicating the sacral shield was not fused to and was separated from the ilium. It is presumed that a cellular layer of connective tissue (cartilage) would originally have filled the space between the sacral shield and the pelvic bones beneath. Ossified tendons were noted in the space between the sacrum and the shield in *Polacanthus foxii* (Blows, 2001), and calcified

hypertrophic cartilage has previously been recorded on the articular surface of an *Allosaurus* femur (Reid, 1996), showing similar features to the cellular structure preserved between the ilium and sacral shield in *Vectipelta*. However, the cell size is more typical of plant cells ($\approx 10\text{--}100\ \mu\text{m}$) which are generally larger than animal cells ($\approx 1\text{--}10\ \mu\text{m}$), so we do not discount the possibility that the cells could be plant debris incorporated into the skeleton postmortem.

Diversity of ankylosaurs in the Wealden Group

Three ankylosaurs are now known from the Wealden Group of southern England: *Hylaeosaurus armatus* from the Valanginian Grinstead Clay Formation of Sussex, and *Polacanthus foxii* and *Vectipelta barretti* from the Barremian Wessex Formation of the Isle of Wight. The Barremian–Aptian boundary is thought to lie within the Vectis Formation, which overlies the Wessex Formation, while the oldest Wessex deposits exposed on the Island are lower Barremian (Lockwood et al., 2021). The exact duration of the exposed Wessex Formation on the Isle of Wight is not known, but the holotype of *Polacanthus* was found at Barnes High, in some of the youngest Wessex sediments exposed, and is likely to be late Barremian in age. In contrast, *Vectipelta*, found in plant debris bed L5 of Stewart (1978) at Chilton Chine, was found close to the base of the exposed Wessex Formation on the Island, and therefore is early Barremian in age. It is likely *Vectipelta* and *Polacanthus* were separated by 6–8 million years, while *Hylaeosaurus* was older still by at least 3 million years.

The fauna of the Wealden Group is often divided into a 'lower' Wealden fauna and an 'upper' Wealden fauna (e.g. Norman, 2010), but new discoveries, including *Vectipelta* and the recently named iguanodontian *Brighstoneus* (Lockwood et al., 2021) indicate that the situation is actually far more complex. The 'upper' Wealden fauna comprises animals that may have been separated in time by as much as the period of time between the Late Miocene and today. New stratigraphical work and examination of historical specimens in museum collections will no doubt reveal a hidden diversity of dinosaurs from throughout this temporal window. Anecdotally, ankylosaurs found in the Wessex Formation are usually called *Polacanthus* without reference to autapomorphies or unique character combinations, but it is clear that this practice among collectors and within museum catalogues has meant that important variation has been overlooked, and has led to the true diversity of ankylosaurs in the Wealden being hidden.

Biogeographical implications

In the phylogenetic analysis presented here, *Vectipelta* is recovered as sister-taxon to a clade containing two Chinese taxa: *Zhejiangosaurus* and *Dongyangopelta*, both from the Albian–Aptian Chaochuan Formation. The taxonomic identity of these two taxa is the subject of debate (Arbour & Currie, 2016; Chen *et al.*, 2013; Lü *et al.*, 2007), but the results suggest a close relationship between *Vectipelta* and the Chaochuan ankylosaurs. This is perhaps surprising, given the minimum 16-million-year stratigraphical, and significant geographical, separation between *Vectipelta* and the Chaochuan taxa. A close faunal similarity between Europe and North America in the Early Cretaceous has previously been hypothesized, with the ankylosaurs of the Wealden Group (Raven *et al.*, 2020) and the North American taxa *Gastonia burgei* and *Hoplitosaurus*, among others, being considered closely related (Carpenter *et al.*, 2008; Kinneer *et al.*, 2016). These faunal similarities between North America and Europe in the Late Jurassic to Early Cretaceous are also supported by palaeogeography; a potential episodic corridor between Newfoundland and Iberia in the Late Jurassic (Escaso *et al.*, 2007) and Early Cretaceous (Torsvik *et al.*, 2002) is thought to have been present. A close faunal relationship between Europe and Asia is less well documented, however, but the presence of a land bridge across the Turgai Sea between Europe and Asia, which started in the early Berriasian (Xu *et al.*, 2018), could have contributed to the dispersal of ankylosaurs from Europe to Asia. It is also possible, however, that the close relationship between *Vectipelta* and *Dongyangopelta* and *Zhejiangosaurus* recovered here could be due to the relatively few synapomorphies they share having an overwhelming effect on their topological placement. Indeed, given the taxonomic debate surrounding the two Chinese taxa (Arbour & Currie, 2016; Chen *et al.*, 2013; Xu *et al.*, 2007), more work is clearly needed in understanding the anatomy and systematic position of both *Dongyangopelta* and *Zhejiangosaurus*.

Conclusions

Vectipelta barretti is a new genus and species of ankylosaur from the lower Barremian part of the Wessex Formation of the Isle of Wight. Based on currently available data, the taxon is not closely related to *Polacanthus foxii*, the other ankylosaur from the Island, but is instead more closely related to some Chinese ankylosaurs, suggesting a complex picture of dispersal and vicariance from both Asia and North America into Europe in the Early Cretaceous. *Vectipelta* is around 6–

8 million years older than *Polacanthus*, and indicates that the ‘upper Wealden fauna’ was not homogeneous over the time period represented by the Wessex Formation. Historical practises of considering all ankylosaur material from the Isle of Wight to be *Polacanthus* have hidden a greater diversity of ankylosaurs than was hitherto realized and should cease in favour of autapomorphy-based appraisals of newly-found material.

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Supplemental material

Supplemental material for this article can be accessed here: <https://doi.org/10.1080/14772019.2023.2210577>

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