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A new specimen of *Valdosaurus canaliculatus* (Ornithopoda: Dryosauridae) from the Lower Cretaceous of the Isle of Wight, England

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Abstract

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The anatomy of *Valdosaurus canaliculatus* is incompletely known and until recently was based exclusively upon the holotype femora. Additional discoveries from the Wessex Formation (Barremian) of the Isle of Wight during the past decade have considerably expanded the amount of material available and offered insights into the morphology of the vertebral column and pelvis. However, all of these specimens consist primarily of hind limb material. Here, I describe a newly discovered individual of this taxon, the most complete yet found, which was found in articulation and includes a partial dorsal series, an almost complete tail, pelvic material, and both hind limbs. Although the specimen is partially crushed it offers new information on the anatomy of *Valdosaurus*, facilitating comparisons with other dryosaurid taxa.

Keywords Wealden, Dinosauria, Wessex Formation, Barremian

Introduction

The Wessex Formation of the Isle of Wight (UK) has yielded a rich Early Cretaceous (Barremian) dinosaur fauna (Martill and Naish, 2001) that includes four well-established ornithopod taxa: the non-iguanodontian *Hypsilophodon foxii* (Huxley, 1869), the dryosaurid *Valdosaurus canaliculatus* (Galton, 1975) and the ankylopollexians *Mantellisaurus atherfieldensis* (Hooley, 1925) and *Iguanodon bernissartensis* Boulenger in Beneden, 1881. It is possible that other taxa, represented by isolated but potentially distinctive material, were also present (Galton, 2009) and other names have been proposed for Wessex Formation iguanodontian taxa (e.g. Hulke, 1879, 1882; Lydekker, 1888; Paul, 2008; Carpenter and Ishida, 2010), but these are currently regarded either as nomina dubia or as junior synonyms of the aforementioned taxa (Norman, 2004, 2012; McDonald, 2012).

Hypsilophodon, *Mantellisaurus* and *Iguanodon* are known on the basis of complete or near-complete specimens from the Isle of Wight and other Early Cretaceous strata in the UK and elsewhere in western Europe: each has been the focus of numerous studies, including comprehensive monographs (e.g. Hulke, 1882; Hooley, 1925; Galton, 1974; Norman, 1980, 1986). By contrast, *Valdosaurus* is relatively poorly known. This taxon was established on the basis of an associated pair of small femora (Galton, 1975), but the collection of new specimens and reinterpretation of historical collections has expanded both the amount and quality of material available (Galton, 2009; Barrett et al., 2011) to comprise four previously reported partial skeletons. Other dryosaurid material is also known from the Wessex Formation of the Isle of Wight and the Tunbridge Wells Sands Formation (Valanginian) and Weald Clay Subgroup (Barremian) of southern England, some of which may be referable to *Valdosaurus* (Blows, 1998; Naish and Martill, 2001; Galton, 2009; Barrett et al., 2011; pers. obs.). Unusually, all previously described specimens consist almost exclusively of hind limb elements, with sporadic preservation of material from the axial column and pelvic girdle (Barrett et al., 2011: BELUM K17051; IWCMS 2007.4; MIWG.6438, MIWG.6879; NHMUK PV R184, R185). Here, I describe a new specimen of *Valdosaurus* from the Wessex Formation of the Isle of Wight, the most complete yet found, and discuss its implications.

Institutional abbreviations

BELUM, Ulster Museum (National Museums of Northern Ireland), Belfast, UK; BMB, Booth Museum, Brighton, UK; IWCMS (formerly MIWG, note that both sets of abbreviations still in use), Dinosaur Isle, Sandown, UK; MUCPv, Universidad Nacional del Comahue, Paleovertebrate Collection, Lago Barreales, Argentina; NHMUK, Natural History Museum, London, UK; NMV, Museum Victoria, Melbourne, Australia.

Material

The specimen (IWCMS 2013.175) was discovered by Mr Nick Chase in October 2012, in a plant debris bed (sensu Sweetman and Insole, 2010) cropping out from a cliff on a National Trust owned property in Compton Bay, on the southwest coast of the Isle of Wight. As other dinosaur material was discovered nearby, the exact locality details are withheld to prevent theft from the site, but are held on file at IWCMS. The skeleton was excavated from the Wessex Formation (Lower Cretaceous: Barremian; Allen and Wimbledon, 1991; Rawson, 2006), a sequence of terrestrial mudstones and sandstones deposited by rivers and lakes on a seasonally arid floodplain that was subject to seasonal wildfires (Martill and Naish, 2001).

IWCMS 2013.175 comprises a partial postcranial skeleton representing the hindquarters of a single individual. The specimen was found in situ within the plant debris bed and in articulation (fig. 1). It consists of six middle-posterior dorsal vertebrae (the only part of the specimen found weathered out at the surface), the sacrum, an articulated series of 45 caudal vertebrae (including chevrons in the anterior part of the tail), both pelvic girdles, and both hind limbs (lacking many of the pedal phalanges, but otherwise complete). Ossified tendons are also present in the sacral and caudal regions. Although surface collected, the proximity and characteristics of the dorsal vertebrae clearly demonstrate that they pertain to the same individual. Most parts of the skeleton have been fully prepared, but matrix has been retained around the sacroiliac block, obscuring many details of the sacrum and the medial surfaces of the ilia. In addition, as the pelvic girdles and proximal parts of the femora are articulated, these elements often overlie each other preventing full description.

As the hind limb anatomy of *Valdosaurus* has already been described in detail on the basis of several other specimens (Galton, 1975, 2009; Barrett et al., 2011: BELUM K17051; IWCMS 2007.4; MIWG.6438, MIWG.6879; NHMUK PV R184, R185), and as those of IWCMS 2013.175 are rather poorly preserved in spite of their completeness, the following description focuses on those areas of the anatomy that were previously unknown or poorly documented for *Valdosaurus*, primarily the axial column and pelvic girdle.

The specimen can be referred to *Valdosaurus canaliculatus* on the basis of the following femoral characters, which are currently regarded as either autapomorphic or part of a unique character combination for the taxon (Barrett et al., 2011): the anterior trochanter extends dorsally to almost the same level as the greater trochanter; and the left femur possesses an anterior intercondylar groove that is broad, parallel-sided and ‘U’-shaped (although crushing has partially closed the groove). Moreover, the combined presence of a proximally placed fourth trochanter and of a deep anterior intercondylar groove is unique for *Valdosaurus* among the ornithopods currently known from the Wealden Group of the UK (Galton, 1975, 2009; Barrett et al., 2011).

All measurements for IWCMS 2013.175 can be found in Tables 1–5.

Description

Dorsal Vertebrae. A series of six middle-posterior dorsal (D) vertebrae is present, all of which are completely prepared and visible in all views. With the exception of two conjoined vertebrae, they were not found in articulation, but can be arranged into a series on the basis of size that suggests they did originally form a natural sequence. The following numbering scheme labels each of the vertebrae from 1 (anterior-most) to 6 (posterior-most), as arranged in the exhibition mount. There are no indications of any tendons along the dorsal series, but this observation is tentative due to the fragmentary nature of the neural arches and the exposure of the vertebrae at the surface prior to collection.

None of the vertebrae are complete, although each centrum is present (see table 1 for measurements). All six dorsals have been sheared and somewhat distorted, with the neural arch (where present) rotated relative to the centrum. The left-hand sides of all six centra are damaged: those of D1 and 2 bear indentations on their left lateral surfaces, whereas in D3–6 this entire surface is either crushed inward or poorly preserved. Some parts of the centra in D4–6 are missing. All of the dorsals preserve small parts of the neural arch. The position of the neurocentral junction can be seen in several of the vertebrae, but it is unclear whether it was open or partially fused. As D1 is the best preserved of the series most of the following description is derived from this vertebra, but this has been augmented with details from the other dorsals where possible (fig. 2).

D1 consists of a complete centrum, with a partial neural arch that is lacking all of the processes (fig. 2A–F). The arch has been rotated relative to the centrum, so that it is displaced to the right. The course of the neurocentral suture is clearly visible on the right-hand side though it is not clear if it is still open or partially fused. In anterior view, the articular surface has a subcircular outline, with a straight dorsal margin and rounded lateral and ventral margins that meet along a continuous smooth curve. The articular surface is shallowly concave and bordered by a raised rim on all sides. In lateral view, the centrum is elongate, approximately 1.9 times as long as it is high and has a ventral margin that is gently concave dorsally. The lateral surface of the centrum is anteroposteriorly concave and dorsoventrally convex and is pierced by a small

Table 1. Measurements (in mm) of the dorsal (D) vertebrae of *Valdosaurus canaliculatus* (IWCMS 2013.175). Abbreviations: ACH, anterior centrum height ACW, anterior centrum width; CL, centrum length; PCH, posterior centrum height; PCW, posterior centrum width. ‘*’ indicates that the measurement as been affected by deformation.

	ACW	ACH	CL	PCW	PCH
D1	35	31	58	32	32
D2	39	34	58	39	39
D3	41	37	60	38*	42
D4	38*	41*	64	41*	47*
D5	47*	42*	59	46	50
D6	44*	44*	58*	49*	56*

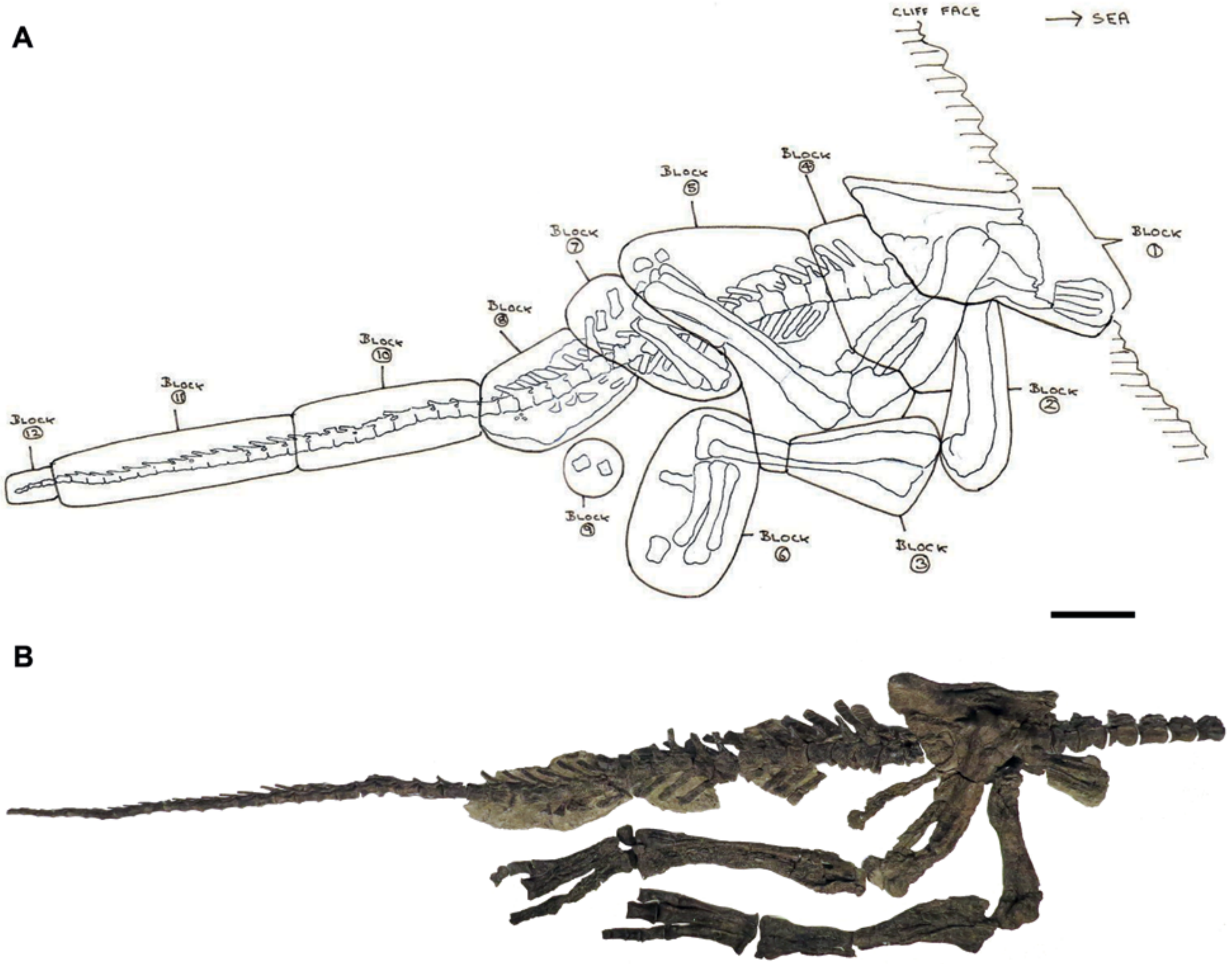

Figure 1. New specimen of *Valdosaurus canaliculatus* (IWCMS 2013.175). A, field map of the discovery showing the position of the skeleton in situ and the blocks in which the elements were originally excavated. Drawn by N. Chase, original on file at IWCMS. B, skeleton following preparation, as displayed in Dinosaur Isle, in left lateral view. Scale bars = 200 mm.

elliptical nutrient foramen at midlength. The lateral surfaces merge smoothly with the ventral surface and there is no distinct break of slope or ridge to separate them. In ventral view, the centrum is hourglass-shaped: there is some suggestion of a ventral keel, but this has probably been accentuated by mild crushing. Prominent longitudinally oriented striations extend along the lateral and ventral surfaces of the centrum from their junctions with the anterior and posterior surfaces. The posterior articular surface is also subcircular in outline, though the articular surface is flat, rather than concave.

The neural arch extends for almost the full length of the centrum. Crushing and breakage obscure much of the morphology of the processes and of the neural canal outline. However, it can be determined that a thin lamina extended posteriorly from the lateral margin of the prezygapophysis towards the diapophysis (prezygodiapophyseal lamina: PRDL; lamina terminology follows Wilson, 1999). The PRDL and anterior centrodiapophyseal lamina (ACDL) together frame a deep, anterolaterally facing prezygopophyseal centrodiapophyseal fossa (prcdf; fossa terminology follows Wilson et al., 2011) with a subelliptical outline in lateral view. There is no sign of a parapophysis on the centrum or on the ACDL, so this structure must have merged with the (missing) diapophysis. A thick, buttress-like posterior centrodiapophyseal lamina (PCDL) is also present, which with the ACDL frames a shallow, laterally facing and extensive centrodiapophyseal fossa (cdf). The PCDL merges with the base of the diapophysis to give the latter a triangular cross-section, whose apex points ventrally. A very small, elliptical spinoprezygapophyseal fossa (sprf) is present at the base of the anterior surface of the neural spine. The broken base of the neural spine indicates that it was mediolaterally compressed and plate-like. A postzygodiapophyseal lamina

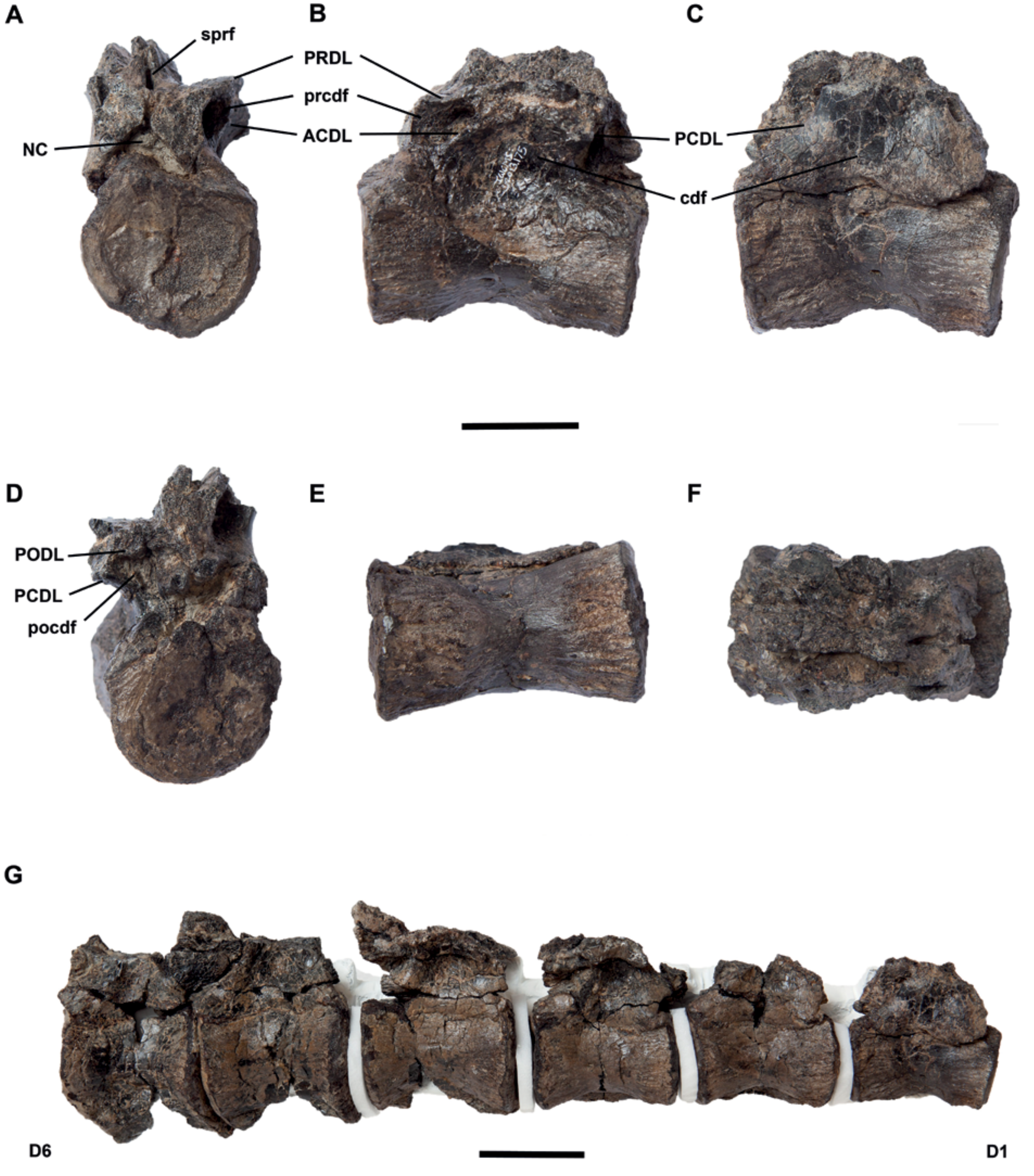

Figure 2. Dorsal vertebrae of *Valdosaurus canaliculatus* (IWCMS 2013.175). A–F, dorsal 1 in A, anterior, B, left lateral, C, right lateral, D, posterior, E, ventral, and F, dorsal views. G, dorsals 1–6 in articulation in left lateral view. Abbreviations: ACDL, anterior centrodiapophyseal lamina; cdf, centrodiapophyseal fossa; NC, neural canal; PCDL, posterior centrodiapophyseal lamina; pocdf, postzygopophyseal centrodiapophyseal fossa; PODL, postzygodiapophyseal lamina; prcdf, prezygopophyseal centrodiapophyseal fossa; PRDL, prezygodiapophyseal lamina; sprf, spinoprezygapophyseal fossa. Scale bars = 25 mm (A–F) and 50 mm (G).

Table 2. Measurements (in mm) of the caudal (Cd) vertebrae of *Valdosaurus canaliculatus* (IWCMS 2013.175). Abbreviations: ACH, anterior centrum height ACW, anterior centrum width; CL, centrum length; PCH, posterior centrum height; PCW, posterior centrum width. '*' indicates that the measurement as been affected by deformation. Many measurements are missing as obscured by articulation or matrix or too deformed to be useful (all measurements in the cases of Cd13–14 and Cd18).

	ACW	**ACH**	**CL**	**PCW**	**PCH**
Cd1	40*	45*	60	48*	49*
Cd2	-	-	54*	-	-
Cd3	49*	53*	50*	52*	50*
Cd4	49*	51*	54*	34	45
Cd5	36*	-	46*	-	57
Cd6	-	44	52	-	44
Cd7	-	39	60*	32*	42*
Cd8	-	-	56	-	-
Cd9	-	-	54	-	-
Cd10	-	-	50	-	-
Cd11	-	-	47	-	-
Cd12	-	-	48	-	-
Cd13	-	-	-	-	-
Cd14	-	-	-	-	-
Cd15	-	27	45	-	-
Cd16	-	30	53	-	-
Cd17	-	32	52	-	-
Cd18	-	-	-	-	-
Cd19	-	-	47	-	-
Cd20	-	27	49	-	-
Cd21	33	30	52	31	31
Cd22	32	30	52	35	32
Cd23	32	29	52	32	29
Cd24	32	27	50	33	27
Cd25	32	26	49	37*	33*
Cd26	35	28	52	34	27
Cd27	32	24	50	32	26
Cd28	29	24	49	31	25
Cd29	30	24	48	30	25
Cd30	30	25	48	29	24
Cd31	30	23	45	29	23
Cd32	31	21	45	29	22
Cd33	21	20	43	22	21
Cd34	27	20	43	25	21
Cd35	27	18	41	25	19
Cd36	23	20	42	24	19
Cd37	22	17	43	21	17
Cd38	22	16	40	21	18
Cd39	21	16	40	20	16
Cd40	19	14	38	17	14
Cd41	17	14	39	16	14
Cd42	15	15	36	16	13
Cd43	12	12	36	13	11
Cd44	14	13	34	13	13
Cd45	14	13	34	12	13

(PODL) also appears to have been present, framing a posterolaterally opening postzygopophyseal centrodiapophyseal fossa (pocdf) with the PCDL. Although broken, the posterior part of the arch dorsal to the neural canal bears a small inverted 'Y'-shaped process that extends ventral to the broken bases of the postzygapophyses.

D2 consists of the centrum and a poorly preserved, incomplete neural arch that lacks any indications of processes or laminae other than the right PCDL (fig. 2G). As far as can be determined, D2 is identical to D1 in almost every respect, although the anterior articular surface is flat rather than concave. D3 consists of a complete centrum and partial neural arch. Deformation of the centrum is severe and the entire left-hand side is crushed inward, which has created a pseudo-keel along the ventral surface. As far as can be determined, the centrum and neural arch is identical to that of D1 and 2. As in D1, the ACDL and PCDL are present and frame a shallow cdf. There is some evidence for a PODL that frames a posteriorly opening and deep pocdf with the PCDL. The bases of both diapophyses are present, which are angled dorsolaterally with respect to the centrum, but the angle between them has been exaggerated by deformation. D4 is almost identical to D3 in terms of the parts preserved and the features that can be assessed.

D5 and 6 each consists of a centrum and partial neural arch (fig. 2G). The vertebrae are larger than the preceding ones and are less elongate (length to height ratio of ~1.3). The longitudinal striations on the lateral surfaces of the centra are less prominent than in the earlier dorsals. In all other respects, however, the centra are similar to those of the other dorsals (with flat articular surfaces, no keel, an hourglass-shaped outline in ventral view, no distinct separation between the lateral and ventral surfaces, single small nutrient foramen, etc.). D5 and 6 possess a buttress-like ACDL that is less distinct that those of earlier dorsals, whereas the PCDL remains a clear and distinct lamina in all preserved dorsals. Their prominent PCDL forms the posterior margin of a deep subtriangular cdf and the anterior margin of a smaller, but deep pocdf posteriorly. The dorsal margin of the pocdf is provided by a prominent PODL. The postzygapophyses of D5 are partially preserved but are largely obscured by the overlapping prezygapophyses of D6. They appear to be very steeply inclined forming an angle of almost 80° with the horizontal plane in anterior view. The prezygapophyses of D6 only overlap the postzygapophyses of D5 for a short distance and have narrow triangular transverse cross-sections.

Sacrum. Although the sacrum is present and likely complete, it is largely obscured by matrix and the adjacent ilia. In ventral view, a dorsosacral is exposed on the anterior part of the pelvic block and the posterior margin of a posterior sacral and the anterior part of the caudosacral (and associated sacral rib) can be seen posterior to the ischia. The posterior part of the caudosacral is articulated with the first caudal vertebra and is thus preserved separately from the pelvic block. The number of sacral vertebrae cannot be determined, but on the basis of the lengths of those that are visible it seems likely that at least five and potentially six were present (including those vertebrae identified as the dorso- and caudosacrals). As each vertebra is only partially visible in ventral view, the amount of anatomical information is limited. All three vertebrae have transversely convex ventral surfaces that lack keels and longitudinal grooves. The dorsosacral is identified as such as it bears a short, anteroposteriorly narrow diapophysis that differs from the expanded morphology that would be expected in 'true' sacral ribs. This diapophysis extends laterally to contact the medial surface of the preacetabular process of the ilium. By contrast, a large, fan-shaped sacral rib is borne by the posterolateral corner of the exposed posterior sacral and the anterolateral corner of the caudosacral. The medial part of the rib is anteroposteriorly narrow, but flares within a short distance to form a broad, subtriangular and dorsally convex sheet whose scalloped lateral margin articulates with the ilium along almost the full length of the brevis shelf.

Caudal vertebrae. Forty-five caudal (Cd) vertebrae are present and it seems likely that almost the whole tail was preserved, with the loss of only a few (if any) very small distal-most vertebrae (see table 2 for measurements). Some of the vertebrae have been fully prepared (Cd1–4), while others are partially embedded in blocks of matrix and exposed in one view only. The proximal caudals (Cd1–4) have suffered the most deformation, mainly mild crushing and mediolateral shearing, and have crazed bone surfaces. Nevertheless, they are largely complete and the middle and posterior caudals are very well preserved. Many of the vertebrae are still in articulation: consequently, some individual details are obscured by the presence of other vertebrae in the series.

Cd1 and 2 are in the same block as the posterior part of the caudosacral (fig. 3A, B). As a result the posterior surface of the caudosacral and the anterior and posterior articular surfaces of Cd1 and the anterior surface of Cd2 are obscured. The right-hand sides of the vertebrae are obscured by the overlying posterior process of the left ilium, which is adhered to this block and separated from the rest of the left ilium.

The centra have ventrally concave margins in lateral view and the lateral surfaces are anteroposteriorly concave and dorsoventrally convex. The longitudinal striations present on the lateral surfaces of the dorsal vertebrae are absent, but the crazed bone surface prevents determination of the presence/absence of nutrient foramina. The lateral surfaces are distinctly separated from the ventral surfaces by a break in slope and there is some indication of a ventral groove on both Cd1 and 2. The visible parts of the articular surfaces suggest that they were very shallowly convex. Poor preservation prevents identification of the neurocentral sutures. There is no evidence for a chevron facet on Cd1, but a posterior facet is present on Cd2. This chevron facet is a flat, subtrapezoidal surface, which is indented on the ventral midline.

The neural arches are reasonably complete, but some details are obscured by matrix, deformation and the apposition of the ilium and caudosacral. The prezygapophyses of Cd2 (missing in Cd1) are short, stout triangular processes that only extend a short distance beyond the anterior margin of the centrum. In both Cd1 and 2, the caudal ribs are broken, with only the remnants of the bases present. The neural spines are inclined posteriorly and dorsally, so that their posterior margins form an angle of approximately 45° with the horizontal. They are mediolaterally compressed, maintain the same mediolateral thickness along their entire length, are anteroposteriorly short, and are taller (as measured from the level of postzygapophyses to the tip of the spine) than their respective centra are long. They are slightly constricted in lateral view just above the level of the postzygapophyses and expand again slightly anteroposteriorly above this point. In lateral view, the neural spine of Cd1 extends to terminate posterior to the anterior margin of Cd3: the overlap between the neural spine and the next two vertebrae in the series continues throughout the proximal and middle sections of the tail. The spine of Cd1 is more expanded anteroposteriorly in its distal part than that of Cd2. The neural spine summits are gently rounded in lateral view. In contrast to the dorsal series, neural arch laminae are absent. Postzygapophyses are present in Cd1 (missing from Cd2) and are short, robust and have squat subtriangular transverse cross-sections.

Cd3 and 4 are in articulation, but their neural arches are slightly detached from their respective centra (fig. 3C). Deformation makes it difficult to assess the morphology, but there is some evidence that the lateral surfaces met along a grooved midline keel and there is no evidence for a distinct ventral surface. Both vertebrae possess a large posterior chevron facet (and the chevrons associated with Cd3 and 4 are preserved on the next block in the sequence). No obvious anterior chevron facets are present due to damage. In all other respects, the centra of Cd3 and 4 are identical to those of Cd1 and 2.

The neural arches are also identical to those of Cd1 and 2, but are better preserved. In lateral view, the neural spines expand slightly anteroposteriorly towards their apices and are more strongly posteriorly inclined than in Cd1 and 2 (at around 30° from the horizontal), but this orientation may have been accentuated by crushing. Both the pre- and postzygapophyses are small, subtriangular in cross-section, almost vertically inclined, and short so that neither extends far beyond the margins of the centrum. The caudal ribs are preserved but deformed: they appear to have been inclined laterally, dorsally and slightly posteriorly. All are incomplete distally, but the caudal ribs were dorsoventrally flattened plates that were anteroposteriorly short and tapered slightly as they extended laterally. The anterior margin of the caudal rib is thickened relative to its posterior margin. At the base of the caudal rib this thickening is more marked and helps to define a shallow excavation on its proximoventral surface. This thickened leading edge could be regarded as an ACDL as it is continuous with the centrum.

Cd5–7 are visible in left lateral view only as they are embedded in a block, although the anterior and posterior surfaces of Cd5 and Cd7, respectively, are exposed (fig. 3C). The same block also includes the chevrons for Cd3–6. As in Cd1–4, the caudals are deformed due to mediolateral shear and torsion and their surfaces are crazed, but the shearing is less marked than in Cd1–4, so more details are visible. The centra are essentially identical to those in the preceding vertebrae, but are better preserved and only minor differences are noted here. The visible articular surfaces of the centra are subelliptical (but deformed) and shallowly concave. In contrast to earlier caudals, the neurocentral sutures are visible and appear to be open. A small anterior and large posterior chevron facet is present in Cd6 and 7. The very narrow ventral surface is separated from the lateral surfaces by a distinct break in slope and bears a marked

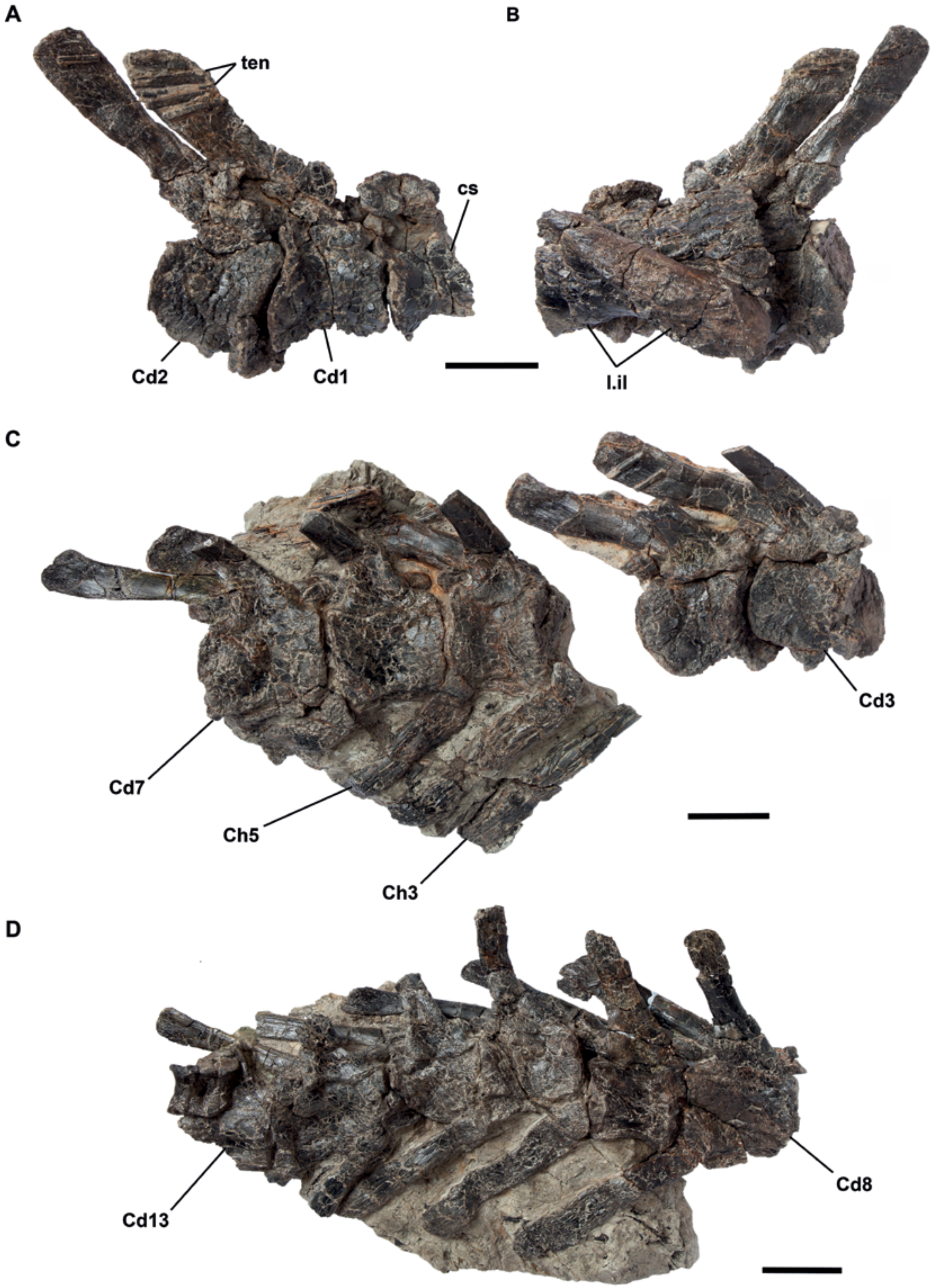

Figure 3. Proximal caudal vertebrae of *Valdosaurus canaliculatus* (IWCMS 2013.175). A–B, caudosacral plus caudals 1 and 2 in right (A) and left (B) lateral views. Note that the postacetabular process of the left ilium is attached to caudals 1 and 2. C, caudal vertebrae 3–7 in right lateral view. D, caudal vertebrae 8–13 in right lateral view. Abbreviations: Cd, caudal vertebra; Ch, chevron; Cs, caudosacral vertebra; l.il, left ilium; ten, ossified tendons. Scale bars = 50 mm.

Figure 4. Middle caudal vertebrae of *Valdosaurus canaliculatus* (IWCMS 2013.175). A, caudal vertebrae 14–20 in right lateral view. B–G, caudal vertebra 21 in right lateral (B), left lateral (C), anterior (D), posterior (E), ventral (F) and dorsal (G) views. Abbreviations: Cd, caudal vertebra; Ch, chevron. Scale bars = 50 mm (A) and 25 mm (B–G).

longitudinal groove. There are no significant differences in the morphology of the neural arches between Cd1–4 and Cd5–7 that cannot be accounted for by deformation or damage.

The next block in the caudal sequence contains Cd8–13 (though only the anterior part of Cd13, which is poorly preserved, with the remainder of this vertebra in the next block in the caudal sequence) (fig. 3D). In terms of overall morphology, these vertebrae are smaller versions of Cd5–7 and only differences from the latter are noted here. Cd8–13 are mainly visible in left lateral view and have suffered crushing so that the caudal ribs have been rotated upwards to extend parallel to the neural spines. The left caudal ribs of Cd8 and Cd10 are complete, demonstrating that they terminate in bluntly squared-off distal tips. The fossae present on the proximoventral surfaces of the caudal ribs of Cd1–8 become less prominent from Cd9 onwards and are absent from Cd12 and all subsequent caudal vertebrae. Ventral grooves on the centra are present in Cd8–10, but their presence/absence in Cd11–13 is not determinable due to the orientation in which these vertebrae are preserved.

A clear break in morphology occurs between Cd12/13 and Cd14/15 and the Cd13/14 boundary is regarded here as the transition point from the proximal to the middle caudal series. Cd14–20 are preserved in sequence in lateral view within a single block of matrix (with the posterior part of Cd13 at its anterior end), although Cd14 is not well preserved and Cd18 is slightly disarticulated from the other vertebrae, with its anterior end extending into the block (fig. 4A). Cd15–20 are much better preserved than any of the preceding caudals. An isolated phalanx from the right pes is also present in this block, overlying the chevron associated with Cd14.

Figure 5. Middle caudal vertebrae of *Valdosaurus canaliculatus* (IWCMS 2013.175). A–C, caudal vertebrae 22–25 in right lateral (A), ventral (B) and dorsal (C) views (caudal 22 is to the right in each case). D–F, caudal vertebrae 26–29 in right lateral (D), ventral (E) and dorsal (F) views (caudal 26 is to the right in each case). G, detail of caudal vertebrae 27 and 28 in left lateral view showing bundles of ossified tendons. Abbreviation: Cd, caudal vertebra. Scale bars = 50 mm.

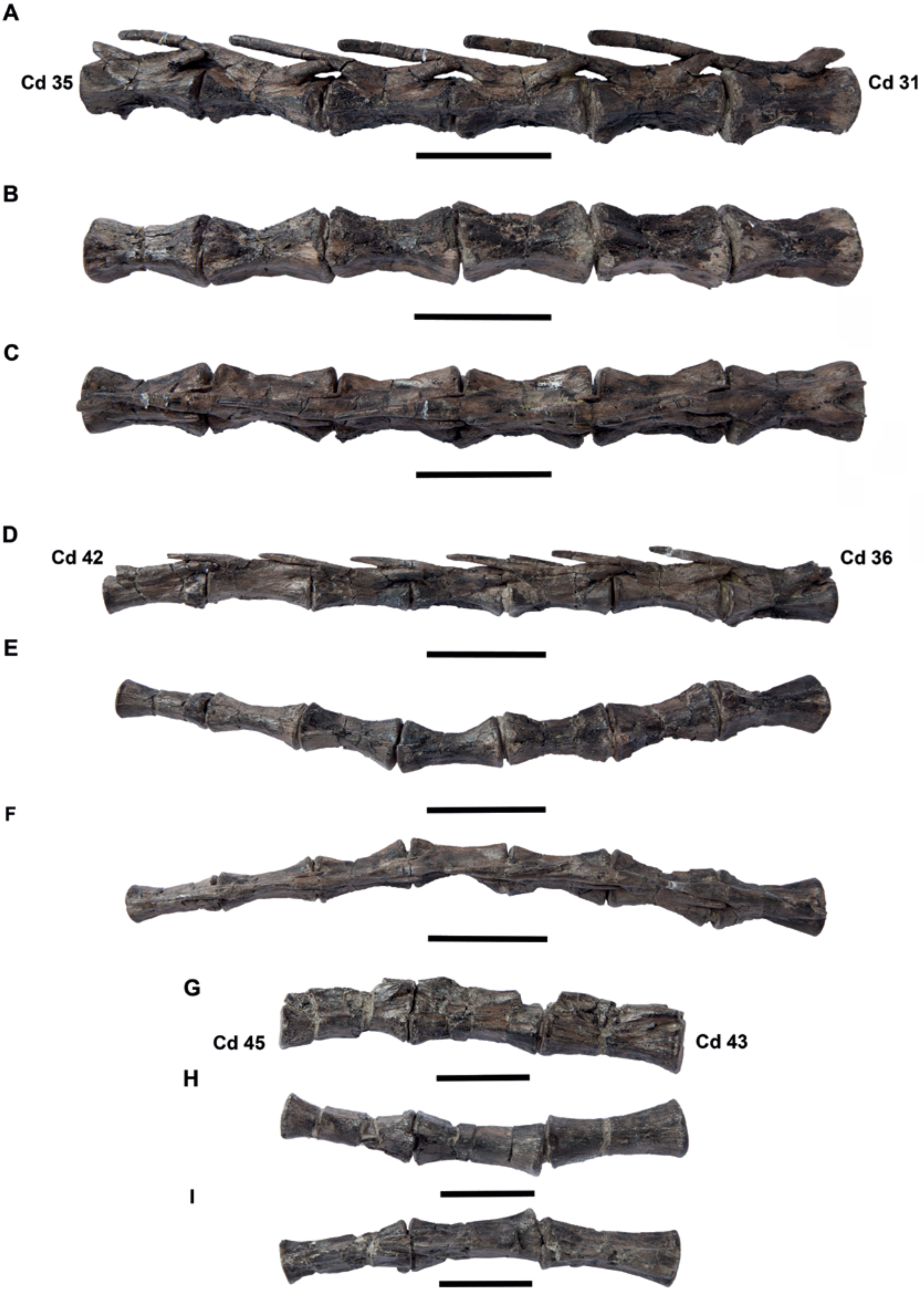

Figure 6. Distal caudal vertebrae of *Valdosaurus canaliculatus* (IWCMS 2013.175). A–C, caudal vertebrae 30–35 in right lateral (A), ventral (B) and dorsal (C) views (caudal 30 is to the right in each case). D–F, caudal vertebrae 36–42 in right lateral (D), ventral (E) and dorsal (F) views (caudal 36 is to the right in each case). G–I, caudal vertebrae 43–45 in right lateral (G), ventral (H) and dorsal (I) views (caudal 43 is to the right in each case). Abbreviation: Cd, caudal vertebra. Scale bars = 25 mm.

The centra of Cd14–20 are more elongate and spool-like than those of the preceding caudals (ratio of centrum length to height >1.6 in middle caudals whereas in proximal caudals this ratio is <1.6 and often closer to 1.0). The lateral surfaces are longitudinally concave and dorsoventrally convex, but the ventral, anterior and posterior surfaces are generally obscured and many details are not visible. Well-defined, but small, posterior chevron facets are present, but the anterior chevron facets are harder to distinguish. Cd19–20 exhibit an incipient longitudinal ridge, which extends along the full length of the centrum lateral surface, at centrum midheight.

The neural arches of the middle caudals differ from those of proximal caudals in several respects. For example, caudal ribs appear to be completely absent from Cd14 onwards. Also, the prezygapophyses of Cd14–20 are reduced in length and no longer extend beyond the anterior margins of the centrum. The postzygapophyses are no longer separate processes, but have become small facets that are positioned on the base of the neural spine. In contrast to the preceding vertebrae, the neural spines become almost parallel-sided in lateral view (whereas there is some anteroposterior expansion in the distal part of the spine in proximal caudals), and curve dorsally along their length. Together with the short prezygapophyses the neural spines form a unified, curved and scimitar-shaped structure in lateral view.

Cd21 is fully prepared out and separated from the rest of the caudals (fig. 4B–G); Cd22–25 and Cd26–29 are also fully prepared, but as two articulated series (fig. 5). Cd21–29 are well preserved and are either complete or missing only small parts of the neural spine summit. All of these vertebrae share most of the features seen in Cd14–20, but exhibit new anatomical details and/or reveal morphological trends along the tail. The centra of Cd27–29 are more elongate than those preceding, with centrum length/height ratios of >2.0. Where exposed, anterior and posterior articular surfaces of Cd21–25 are shield-shaped, shallowly concave and subequal in their mediolateral and dorsoventral dimensions. However, in Cd26–29 the anterior and posterior articular surfaces have a more hexagonal outline. This change is due to stronger development of the longitudinally extending ridges on the lateral surfaces of the centra in the latter vertebrae. These lateral ridges, which were incipiently present in Cd19–20, exhibit a progressive increase in prominence from Cd21–29. They divide the lateral surfaces of Cd21–29 into separate dorsal and ventral excavations. In Cd21 the lateral ridge is at centrum midheight, but the position of the ridge moves dorsally in Cd22–29 to a position around one-third of the distance from the dorsal margin of the centrum. A small, elliptical nutrient foramen is variably present on the lateral surfaces of the centra in Cd21–29. In addition, all of these vertebrae also bear faint longitudinal striations that extend for short distances along the lateral surfaces from their junctions with the anterior and posterior articular surfaces. In ventral view, the centra are spool-like and constricted at midlength. A distinct groove is present along the ventral midline, bounded by low, sharp ridges. A remnant of the anterior chevron facet is present in Cd21, represented by a small bevelled surface, but is absent from Cd22 onward. A distinct posterior facet is present in Cd21–29, but reduces in size through the series. The posterior chevron facet is bifurcated ventrally by the ventral midline groove giving it a ‘W’-shaped outline.

The neural arches of Cd21–29 are almost identical to those of Cd14–20 and the neural spines remain very elongate, although from Cd23 onwards the orientation of the spine changes, to form an angle of only ~15° with the horizontal (in contrast to ~30° in the preceding caudals). From Cd22 onward, the postzygapophyses are reduced to indistinct facets on the neural spine.

Cd30–45 represent the distal caudals (fig. 6). They are all fully prepared and generally well preserved (although Cd43–45 lack neural spines) and are grouped into several articulated series (Cd30–35, Cd36–42 and Cd43–45). Although similar to the middle caudals in many respects, they can be distinguished from them on the basis of several features. For example, the trend toward vertebral elongation continues, with centrum length/height ratios of ~2.7–3.0 in the posterior-most vertebrae (e.g. Cd42–45). The ventral groove present on the centra of the middle caudals is present in Cd30–35, but is reduced to a short notch that bifurcates the ventral margin of the posterior chevron facet from Cd36–40. Posterior chevron facets and ventral grooves are both absent from Cd41 onward. Cd36–40 retain the hexagonal transverse cross-section and particular surface outlines present in the middle caudal vertebrae, but the lateral ridge extending along the centrum reduces in prominence and disappears from Cd41 onward. As a result, the centra of Cd41–45 possess a simplified, spool-like morphology in which the lateral and ventral surfaces are smoothly excavated and continuous with each other.

Perhaps the most obvious difference between the middle and distal caudal vertebrae is a progressive reduction in the length and prominence of the neural spine: from Cd30 onward, the neural spine extends no further posteriorly than the posterior margin of the successive vertebra (rather than extending beyond this point, as in the more anterior caudals: see above). In Cd36–42 this trend continues, with the neural spine terminating at a point only halfway along the next caudal in the series. As the prezygapophyses and neural spines are present as distinct processes in Cd43–45, it is likely that several more distal vertebrae would have been present in vivo, as in other dinosaurs with complete tails the terminal vertebra lacks neural arch structures and tapers to a blunt point lacking an articular surface (Hone, 2012).

Chevrons. With the exceptions of those associated with Cd4 and Cd8 (which are visible in anterior view), the chevrons articulated with the proximal caudals (Cd3–13) are visible in lateral view only (fig. 3D). The chevron for Cd14 is too poorly preserved to offer any useful information. Measurements of selected chevrons are provided in table 3. In anterior view, the chevrons have a ‘Y’-

Table 3. Measurements (in mm) of selected chevrons (Ch) of *Valdosaurus canaliculatus* (IWCMS 2013.175). ‘*’ indicates that the measurement as been affected by breakage.

	Chevron length
Ch8	116
Ch9	111
Ch15	51
Ch16	37*

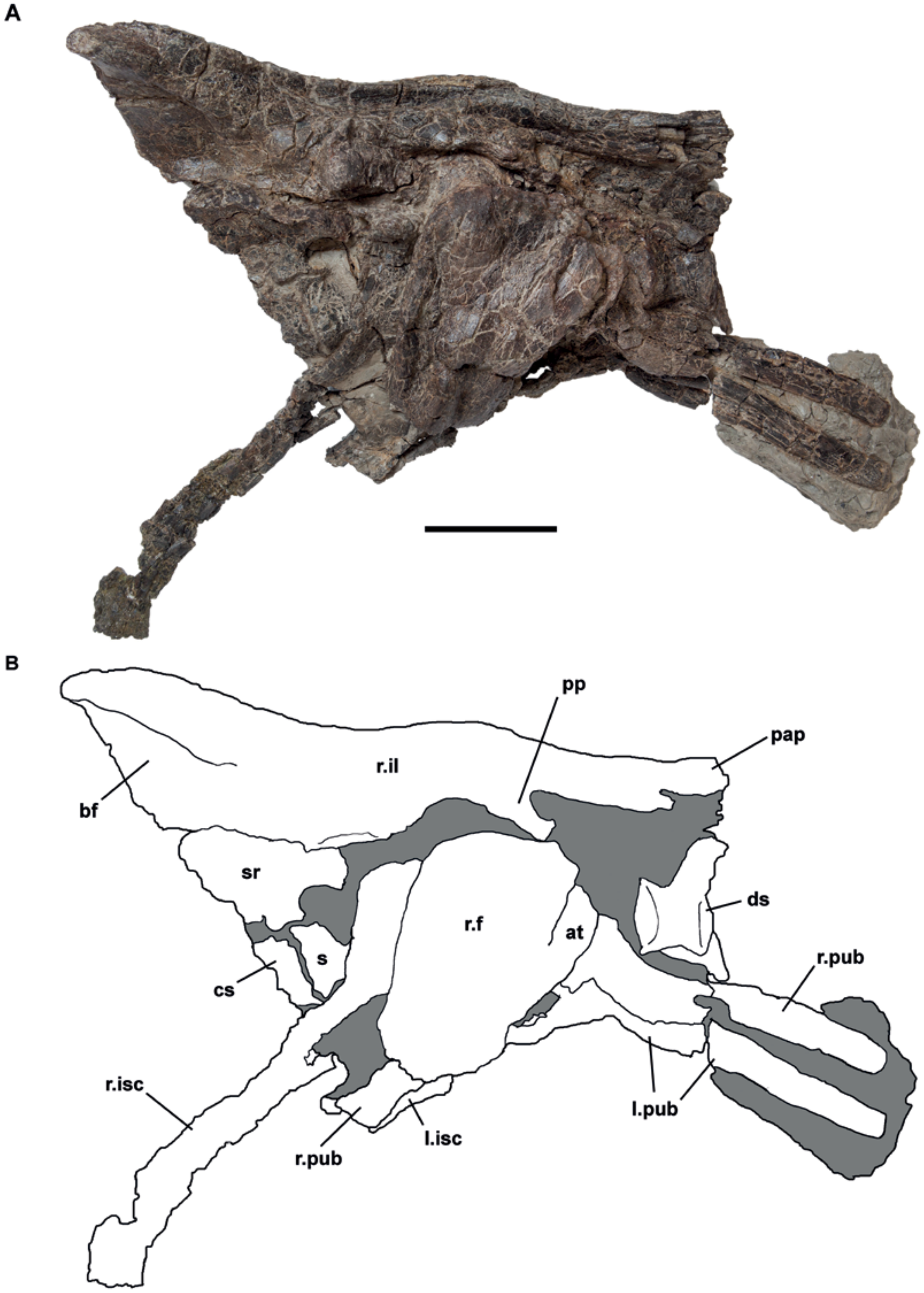

Figure 7. Partially articulated pelvic girdle of *Valdosaurus canaliculatus* (IWCMS 2013.175) in right lateral view. Note that majority of the right femur and adhered left ischium have been removed for clarity. Photograph (A) and interpretative diagram (B). Abbreviations: at, anterior trochanter; bf, brevis fossa; cs, caudosacral; ds, dorsosacral; l.isc, left ischium; l.pub, left pubis; pap, preacetabular process; pp, pubic peduncle; r.f, right femur; r.il, right ilium; r.isc, right ischium; r.pub, right pubis; s, sacral vertebra; sr, sacral rib. Scale bar = 100 mm.

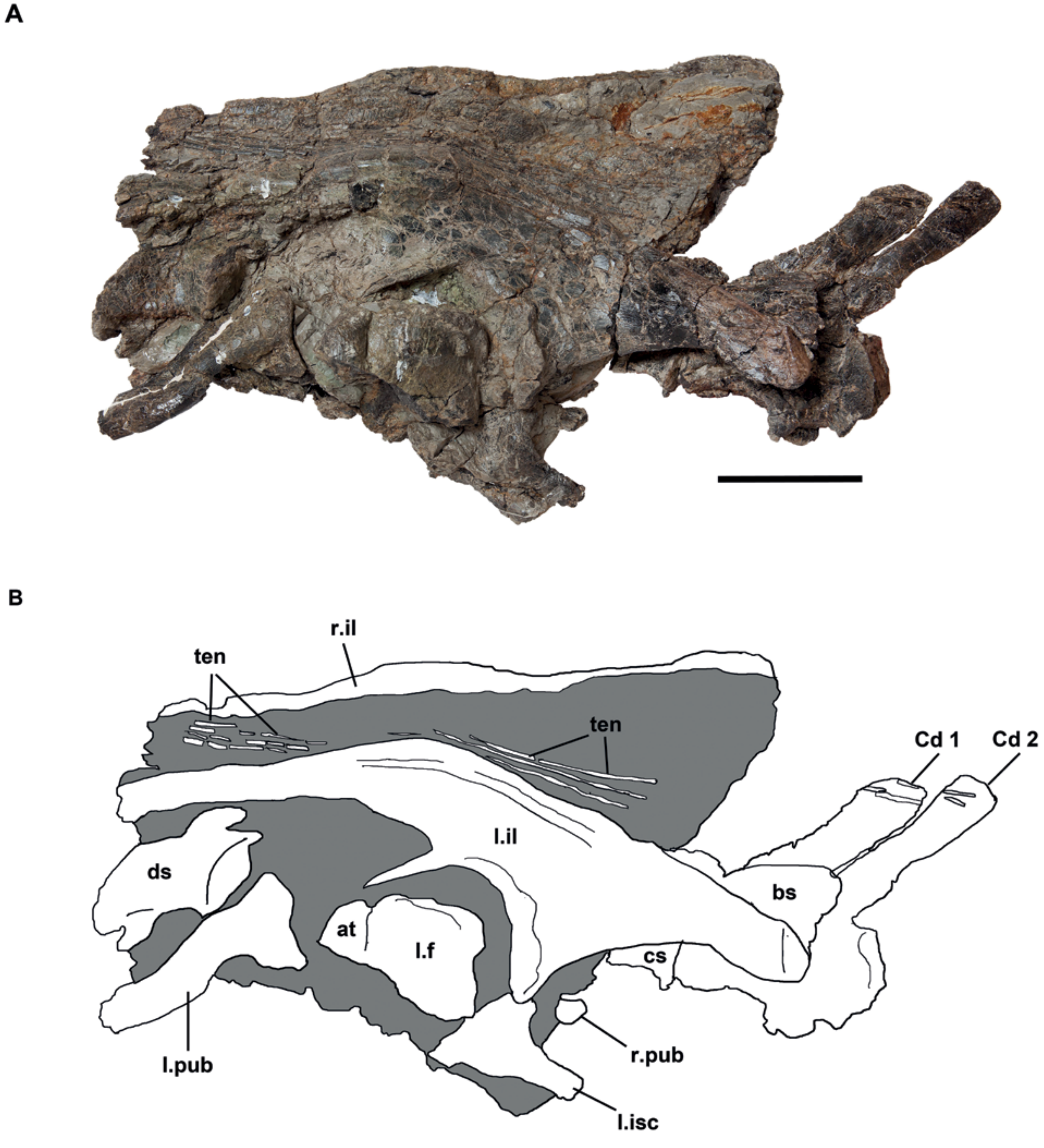

Figure 8. Left pelvic girdle and articulated proximal caudal vertebrae of *Valdosaurus canaliculatus* (IWCMS 2013.175) in left lateral view. Note that majority of the left femur has been removed for clarity. Photograph (A) and interpretative diagram (B). Abbreviations: at, anterior trochanter; bs, brevis shelf; Cd, caudal vertebra; cs, caudosacral; ds, dorsosacral; l.f, left femur; l.il, left ilium; l.isc, left ischium; l.pub, left pubis; r.il, right ilium; r.pub, right pubis; ten, ossified tendons. Scale bar = 100 mm.

shaped morphology, with the proximal branches enclosing a short, narrow and triangular haemal canal that is closed dorsally. The haemal canal is recessed within a shallow fossa that extends for approximately 30% of total chevron length. Ventral to the haemal canal the chevron shaft extends as a thin vertical strut. In dorsal view, the articular surface of the chevron has a dumbbell-shaped outline that is mediolaterally concave.

In lateral view, the chevrons associated with Cd3–11 are straight, parallel-sided rods, whose shafts possess no constrictions or expansions along their length and that terminate in bluntly rounded ventral margins. They are very elongate, reaching up to 2.0 times the length of their associated centrum where complete (e.g. those associated with Cd8–9). The chevrons articulated with Cd12–13 possess a subtly different morphology in lateral view, in which the distal-most end of the shaft becomes slightly expanded anteroposteriorly relative to the rest of the shaft.

Chevrons associated with the middle caudal series (Cd15–18: the chevron for Cd17 is missing) differ in morphology from those in the proximal part of the tail (fig. 4A). In lateral view, they are reduced in length relative to the proximal caudals and are approximately equal in length to their respective centra. The distal ends of the chevron shafts are anteroposteriorly expanded relative to their proximal portions: most of this expansion occurs posteriorly to form an asymmetrical distal flange with a subtriangular outline. Numerous fine striations are present on the ventrolateral surfaces of these expanded flanges. No chevrons are preserved posterior to Cd18, but the presence of posterior chevron facets up to Cd40 indicates they were present for most of the length of the tail.

Ossified tendons. Fragments of numerous ossified tendons are either adhered to the neural spines of the caudal vertebrae or found in the matrix adjacent to the tail along its entire length. These vary between 1.5 and 5 mm in diameter and some have a circular cross-section, while that of others is flattened (figs. 3A, 5G). Those tendons that are preserved in their natural orientations (e.g. those preserved alongside Cd26–29) extend subparallel to each other, and the overlapping trellis-like arrangement seen in ankylopollexian ornithopods (e.g. Norman, 1980, 1986) was absent.

Ilium. Both ilia are substantially complete and preserved in articulation with the sacrum and femoral heads, though each is only visible in lateral view (figs. 7, 8). The right ilium is lacking the anterior-most part of the preacetabular process, has been slightly crushed, and its brevis fossa has been artificially enlarged by plastic deformation (fig. 7). By contrast, the left ilium is well preserved and undeformed, but has been broken so that its postacetabular process is associated with Cd1 and 2 and is not currently attached to the sacral block (fig. 8).

The ilium is long and low, with the dorsoventral distance between the dorsal rim of the acetabulum relatively short in comparison to overall iliac length (ratio of height above acetabulum to total length of the left ilium is 0.17). The dorsal margin of the ilium is slightly sinuous in outline, due to the downturning of the preacetabular process in combination with a dorsally convex margin over the pubic peduncle, a slightly concave margin over the ischiadic peduncle, and a strongly concave dorsal margin of the postacetabular process. The preacetabular process extends almost anteriorly in the right ilium, but anteroventrally in the left ilium: as the latter is less deformed this is considered to be closer to the original morphology. The preacetabular process is strap-like in lateral view, and has parallel dorsal and ventral margins. It is incomplete anteriorly in both ilia. The ventral margin of the preacetabular process and the anterior margin of the pubic peduncle are separated by a deep, concave sulcus.

The pubic peduncle has a thin, elongate subtriangular outline in lateral view and is anteroposteriorly narrow. It has a subtriangular transverse cross-section, with the apex of this triangle pointing laterally and is considerably smaller than the ischiadic peduncle. The lateral surface of the iliac body dorsal to the acetabulum was shallowly concave both dorsoventrally and anteroposteriorly, with this concavity accentuated by deformation in the right ilium. Neither ilium possesses a distinct supraacetabular flange. In lateral view, the dorsal margin of the acetabulum describes a low, gentle curve and is not strongly arched. The ischiadic peduncle has a stout subtriangular outline and is pyramidal in shape. Both the pubic and ischiadic peduncles appear to have extended for the same distance ventrally.

The postacetabular process is elongate and bears an extensive brevis fossa, which faces ventrally in the left ilium and ventrolaterally in the deformed right ilium. The fossa is separated from the lateral surface of the postacetabular process by a robust anteroventrally extending ridge that merges with the posterior margin of the ischiadic peduncle. The fossa was not visible in lateral view in the left ilium, but has been exposed by deformation in the right ilium. In ventral view, the brevis fossa is very strongly flared laterally and expands posteriorly to form an equilateral triangle-shaped flange in ventral view. In lateral view, the dorsal margin of the iliac body is slightly thickened mediolaterally, but it is not folded to form an antitrochanter. This area bears numerous short striations indicative of muscular attachment (for the M. iliotibialis: e.g. Norman, 1986; Maidment and Barrett, 2011). A shallow groove extends parallel to the dorsal margin of the ilium along the central part of the iliac body in lateral view. It is not clear if this groove is a natural feature or due to deformation, but it is present in both ilia.

A large and well-preserved bundle of ossified tendons is present in the matrix between the ilia, which extend parallel to each other and do not form a trellis-like arrangement (fig. 8). Measurements of both ilia are presented in table 4.

Table 4. Selected measurements (in mm) of the pelvic elements of *Valdosaurus canaliculatus* (IWCMS 2013.175). Abbreviations: L, left; R, right. '*' indicates damaged or deformed.

Ilium	
Total ilium length	410 (L) 390* (R)
Height of iliac body above acetabulum	70 (L) 52* (R)
Length of postacetabular process	135 (L) 170* (R)
Maximum transverse width of postacetabular process	90 (L) 120* (R)
Pubis	
Length of prepubic process (as preserved)	195 (L) 220 (R)

Figure 9. Selected hind limb elements of *Valdosaurus canaliculatus* (IWCMS 2013.175). A, left femur in lateral view (proximal end missing as attached to pelvic block). B, articulated left tibia, fibula, astragalus and calcaneum in posterior view. C, right calcaneum in lateral view. D, right metatarsus in anterior view. E, left metatarsus in anterior view. Scale bars = 100 mm (A, B, D, E) and 25 mm (C).

Pubis. The proximal parts of each pubis are present, but it is unclear how much of the postpubic processes might extend into the matrix that encases most of the sacral block. The prepubic processes are elongate, strap-like and extended beyond the anterior margin of the preacetabular process of the ilium in lateral view (see table 4 for measurements) (figs. 7, 8). They have subparallel dorsal and ventral borders and do not expand distally, but end in a bluntly rounded terminus. The prepubic processes are mediolaterally-compressed plates, with rounded dorsal and ventral margins in transverse cross-section. Prominent depressions that extend along the lateral surface of the right prepubis and medial surface of the left prepubis are probably due to crushing. More posteriorly, the prepubes curve ventrally then dorsally as they merge into the main body of the pubis, but this may be a preservational artefact.

The pubic body is expanded relative to the plate-like prepubis, is anteroposteriorly short and block-like and bears a strongly convex surface for articulation with the ischium and ilium. The pubic contribution to the acetabulum was relatively small. An open obturator notch was present, but was partially enclosed posteriorly by a ventral projection from the posterior articular surface of the pubic body. The proximal part of the postpubic rod is cylindrical in cross-section.

Ischium. Both ischia are present, but the proximal ends are obscured by the overlying femora and by matrix and the shafts are friable and poorly preserved (figs. 7, 8). The left ischial shaft is attached to the right femur, whereas the right ischial shaft is free. The right ischium has a fan-shaped proximal plate, whose iliac articulation is visible in lateral and dorsal views. The articular surface is oval in outline and mediolaterally expanded relative to the rest of the exposed part of the proximal plate. The shaft arises from the posteroventral corner of the proximal plate. There is no indication of a groove along the dorsal margin of the proximal part of the shaft, which is smooth and rounded. The presence/absence of an obturator process cannot be determined due to breakage. In lateral view, the ischial shafts are straight, extend posteroventrally from the proximal plate and have parallel dorsal and ventral margins. There is no sign of any ventral curvature, although both ischia are incomplete distally so its absence might be artefactual. The shafts are mediolaterally compressed. It is not possible to determine the extent of any symphysis between them due to breakage and poor surface preservation.

Table 5. Selected measurements (in mm) of the hind limb elements of *Valdosaurus canaliculatus* (IWCMS 2013.175). Abbreviations: L, left; R, right. '*' indicates damaged or deformed.

Femoral length	460* (L)	499* (R)
Tibia length	562* (L)	555* (R)
Distal width of tibia	102 (L)	121* (R)
Fibula length	510* (L)	505* (R)
Length of fibula proximal end	88 (L)	– (R)
Fibula midshaft diameter	20 (L)	21 (R)
Mediolateral width of astragalus	83 (L)	90 (R)
Dorsoventral height of calcaneum	- (L)	51 (R)
Mediolateral width of calcaneum	- (L)	24 (R)
Metatarsal II length	199 (L)	200 (R)
Metatarsal II proximal width	27 (L)	26 (R)
Metatarsal II midshaft diameter	14 (L)	12 (R)
Metatarsal II distal width	29 (L)	29 (R)
Metatarsal III length	239 (L)	247 (R)
Metatarsal III proximal width	- (L)	46* (R)
Metatarsal III midshaft diameter	34 (L)	43* (R)
Metatarsal III distal width	52 (L)	52 (R)
Metatarsal IV length	195 (L)	221* (R)
Metatarsal IV proximal width	57* (L)	29 (R)
Metatarsal IV midshaft diameter	35 (L)	35 (R)
Metatarsal IV distal width	29 (L)	28 (R)

Hind limb. Although they are almost complete, the hind limbs of IWCMS 2013.175 provide no new anatomical information. Some elements, such as the femora, tibiae and fibulae are crushed, deformed and possess poor surface preservation, although the proximal tarsals, metatarsi and pedal elements are well preserved (fig. 9). As far as can be determined, all of these elements are identical to those of other recently described specimens of *Valdosaurus* (see Barrett et al., 2011). Measurements for all hind limb elements are presented in table 5.

Both femora are complete, but each is preserved in two parts, with the proximal part of the bone in articulation with each acetabulum (figs. 7, 8) and the distal part prepared separately (fig. 9A). The right femur is adhered to the left ischial shaft. *Valdosaurus* possesses several diagnostic femoral characteristics: 1) a deep cleft between the anterior and greater trochanters that is visible in both medial and anterior views; 2) a scar for the M. caudofemoralis that is placed close to the base of the fourth trochanter; 3) a 'U'-shaped anterior intercondylar groove that is deeply incised into the femur with near parallel sides; and 4) the proximal end of the anterior trochanter of the femur is level with, or only slightly ventral to, the proximal end of the greater trochanter (Barrett et al., 2011). Unfortunately, it is not possible to assess the presence or absence of characters 1) and 2) in IWCMS 2013.175 due to damage, but characters 3) and 4) are present, supporting referral to *Valdosaurus canaliculatus* (see above). It appears that the anterior intercondylar groove was partially closed by a lip of bone arising from the medial condyle, as occurs in other large individuals (Galton, 2009; Barrett et al., 2011).

The tibiae are also complete, but preserved in several sections. The left tibia is preserved in two parts (fig. 9B): a proximal part comprising the proximal expansion and two-thirds of the shaft and a distal part consisting of the rest of the shaft, which articulated with the distal part of the left fibula, the left astragalus and a fragment of the left calcaneum. The right tibia is also preserved in two sections: the small proximal section is in articulation with the proximal region of the right fibula, while the larger distal section, comprising around three-quarters of the length of the bone, is articulated with the distal fibula shaft and the right astragalus. The proximal ends of both tibiae are very poorly preserved: that of the right tibia is flattened, while that of the left tibia has experienced both crushing and strong torsion, although all three of the major proximal processes (cnemial crest, inner and outer condyles) can be identified. Torsion has caused the cnemial crest of the left tibia to extend laterally rather than anteriorly.

Both fibulae are almost complete and each is preserved in two sections with small sections of the shaft missing. The proximal end of the left fibula is generally well preserved, but has been crushed mediolaterally, whereas the distal part of the shaft is extensively cracked and warped. By contrast, the proximal end of the right fibula is poorly preserved and extensively crushed, but the shaft is more three-dimensional. A small contact was present between the distal fibula and the astragalus.

In general, the proximal tarsals are well preserved and undeformed. Both astragali are present and in articulation with their respective tibiae. The left calcaneum is also in articulation with the left tibia, but is broken and incomplete, whereas the complete right calcaneum has become separated from the rest of the right ankle (fig. 9C). The only differences between these elements and those previously described for *Valdosaurus* are that the medial surfaces of the calcanea, which form the articulation for the astragalus, are strongly rugose and that the articular surfaces for the distal tarsals for both the astragali and calcanea are slightly corrugated, in contrast to the smooth surfaces present in other specimens referred to this taxon (Barrett et al., 2011).

Both metatarsi, comprising metatarsals (Mt) 2–4, are preserved in articulation and each metatarsal is complete (fig. 9D, E). The left metatarsus has suffered some minor deformation, but has good surface preservation; the right is slightly crushed, but also in good condition. A distal tarsal is articulated with the proximal surface of the left metatarsus and positioned primarily over Mt3, but also partially overlaps the proximal surfaces of Mt2 and Mt4. It has an elliptical outline and concave proximal surface. Mt2 and Mt3 are closely appressed along their entire lengths, whereas Mt4 is kinked laterally at a point about halfway along its length so its distal end diverges slightly from that of Mt3 (both conditions are present in both metatarsi). There is no evidence for the presence of a first or fifth metatarsal in either foot.

Several non-ungual phalanges are preserved, though they were not found in articulation with the metatarsals. Several are very well preserved and are uncracked and undistorted: it is possible that these are associated with the similarly well-preserved left metatarsus. Conversely, the other more heavily cracked and crushed phalanges might pertain to the slightly crushed right metatarsus. Preserved phalanges (Ph) include both PhII.1 and one PhIII.1. Several other phalanges are also present, but their positions within the pes cannot be determined.

Discussion

The anatomy of dryosaurids is poorly known: all known taxa are represented by either isolated femora (*Callovosaurus*, *Elrhazosaurus*), partial skeletons (*Dryosaurus*, *Eousdryosaurus*, *Kangnasaurus*, *Valdosaurus*), or bonebed material that is disarticulated and lacks some key skeletal elements (*Dysalotosaurus*) (see Janensch, 1955; Shepherd et al., 1977; Galton, 1975, 1981, 1983, 1989, 2009; Galton and Taquet, 1982; Cooper, 1985; Blows, 1998; Ruiz-Omeñaca et al., 2007; Hübner and Rauhut, 2010; Barrett et al., 2011; Escaso et al., 2014). Thus, the new specimen reported herein not only increases the amount of anatomical information available for *Valdosaurus*, but also provides some information that might be more generally applicable for the clade as a whole.

IWCMS 2013.175 confirms the validity of a previously proposed autapomorphy for *Valdosaurus*: the presence of an open obturator notch on the pubis (Barrett et al., 2011). Other dryosaurids for which the pubis is known (*Dryosaurus*, *Dysalotosaurus*) have a closed notch (Janensch, 1955; Galton, 1981). One new feature of the tail is proposed herein as a potential autapomorphy of *Valdosaurus*: the presence of elongate neural spines in the middle of the caudal series that extend to reach over more than one subsequent vertebra (fig. 5D). This condition appears to be absent in *Kangnasaurus* (although on the basis of fragmentary material: Cooper, 1985) and is absent in non-iguanodontian ornithopods like *Hypsilophodon* (NHMUK OR28707; NHMUK PV R196), *Tenontosaurus* (Forster, 1990), rhabdodontids (Weishampel et al., 2003) and ankylopollexians (Norman, 1986). It is difficult to assess this character in *Dryosaurus* due to damage, but the orientation of the preserved bases of the neural spines suggests that they might have been more vertically inclined and thus might not have extended beyond the posterior margin of the succeeding vertebra (Galton, 1981). Unfortunately this feature cannot be assessed in *Callovosaurus*, *Dysalotosaurus*, *Elrhazosaurus* or *Eousdryosaurus* due to incomplete preservation (Janensch, 1955; Galton and Taquet, 1982; Ruiz-Omeñaca et al., 2007; Escaso et al., 2014).

IWCMS 2013.175 enables comparisons with other taxa that were not previously possible. With the exception of the potentially autapomorphic middle caudal neural spines, the preserved axial column of IWCMS 2013.175 is generally similar to that of *Dryosaurus*, *Dysalotosaurus*, *Eousdryosaurus* and *Kangnasaurus* (Janensch, 1955; Galton, 1981; Cooper, 1985; Escaso et al., 2014). The neural arches of the proximal caudal vertebrae in *Eousdryosaurus* possess small, anteriorly projecting, “thorn-like” processes that have been proposed as diagnostic for this taxon (Escaso et al., 2014: 1104): these processes are absent in *Valdosaurus*. The distal ends of the middle caudal chevrons of *Valdosaurus* are anteroposteriorly expanded in lateral view (fig. 4A): although comparative material is lacking for other dryosaurids, similar chevrons are known in *Gasparinisaura* (Coria and Salgado, 1996; MUCPv-212), *Leaellynasaura* (NMV P185992, NMV P186047) and *Tenontosaurus* (Forster, 1990). Fortuitously, IWCMS 2013.175 possesses the most complete tail of any dryosaurid specimen described to date and demonstrates that *Valdosaurus* is likely to have possessed no more than 46–50 caudal vertebrae (fig. 1B). This number is similar to that seen in many other ornithopods (Norman, 2004; Norman et al., 2004), but much lower than those recorded for the exceptionally long tails of *Leaellynasaura* (>70 caudal vertebrae; Herne, 2009) and *Tenontosaurus* (60–65 caudal vertebrae: Forster, 1990).

The overall shape of the ilium in *Valdosaurus* (IWCMS 2013.175) falls within the range of variation seen in *Dryosaurus* and *Dysalotosaurus* (Janensch, 1955; Galton, 1981). In *Eousdryosaurus* the brevis fossa is exposed in lateral view (Escaso et al., 2014), but that of *Valdosaurus* is largely obscured and faces posteroventrally (fig. 8: the right ilium of IWCMS 2013.175 has a laterally open brevis fossa, but this has resulted from plastic deformation: see above). The ilia of *Eousdryosaurus*, some *Dryosaurus* individuals and of an indeterminate dryosaurid from the Tunbridge Wells Sands Formation of Cuckfield, UK (NHMUK OR2132) possess a straight dorsal margin in lateral view (Escaso et al., 2014). By contrast, those of *Dysalotosaurus*, *Valdosaurus* and two other indeterminate dryosaurid specimens from the Tunbridge Wells Sands Formation (BMB 004274; NHMUK OR2150) are gently sinuous (Janensch, 1955; Galton, 2009; see above). In *Valdosaurus*, BMB 00472 and NHMUK OR2150 the postacetabular processes are posterodorsally inclined (BMB 004274; NHMUK OR2150; Galton, 2009), whereas in NHMUK OR2131, this process extends posteriorly.

Escaso et al. (2014) proposed that the calcaneum of *Eousdryosaurus* could be distinguished from those of other dryosaurids on the basis of the rounded (rather than more sharply triangular) 'proximal projection', which comprises the triangular process that divides the facets for the tibia and fibula in lateral view. However, this process is similarly rounded in IWCMS 2013.175 (fig. 9C) and hence, this feature cannot be regarded as a reliable autapomorphy for *Eousdryosaurus*. Moreover, Escaso et al. (2014) also proposed that the calcaneum of *Valdosaurus* differed from that of other dryosaurids in possessing a distinct offset between the facets for the tibia and fibula in lateral view (with the tibia facet positioned more ventrally), whereas in other dryosaurids the facets were at the same level. However, this is not the case: if the calcanea are figured in their 'natural' orientations (i.e. as if in articulation with the distal tibia) the fibula facets in all of these taxa (including *Eousdryosaurus*) would be positioned somewhat dorsally relative to the level of the tibia facets, reflecting the shorter length of the fibula relative to the tibia in dryosaurids (Galton, 1981; Barrett et al., 2011; Escaso et al., 2014).

Finally, IWCMS 2013.175 enables the scoring of several phylogenetic characters for *Valdosaurus* that were unknown from other specimens and scored as missing data in the analyses of McDonald et al. (2010), Barrett et al. (2011) and Escaso et al. (2014). For example, it reveals the longitudinal (rather than basket-like) arrangement of ossified tendons along the vertebral column (McDonald et al., 2010: character 95[0]). Several iliac characters can also be scored: the preacetabular process of the ilium was not twisted along its length (McDonald et al., 2010: character 110[0]); the dorsal margin of the main iliac body is only slightly sinuous, rather than displaying the extreme sinuosity seen in more derived iguanodontians (McDonald et al., 2010: character 111[0]); and the dorsal margin of the iliac body dorsal to the ischial peduncle is smooth and lacks the development of any prominent processes (McDonald et al., 2010: character 112[0]). All of these character scores are identical to those present in *Dryosaurus* and *Dysalotosaurus* (McDonald et al., 2010; Barrett et al., 2011).

Conclusions

IWCMS 2013.175 is the most complete individual of *Valdosaurus canaliculatus* yet found and offers new information on the axial skeleton and pelvis of this poorly known iguanodontian ornithopod. Its discovery highlights the fact that *Valdosaurus* was a more common component of the Wessex Formation dinosaur fauna than usually thought. Frustratingly, all known individuals are represented by their hindquarters only, limiting comparisons with other dryosaurids. Additional discoveries of specimens that include both hind limb material and elements from the presacral region are now critical to enable further integration of *Valdosaurus* into both phylogenetic and palaeoecological scenarios.

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