Atlasaurus imelakei n.g., n.sp., a brachiosaurid-like sauropod from the Middle Jurassic of Morocco

Atlasaurus imelakei *n.g., n.sp., un sauropode à allure de brachiosauridé du Jurassique moyen du Maroc*

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Abstract — The nearly complete skeleton of a large sauropod discovered at Wawmda (High Central Atlas of Morocco) in strata of Bathonian-Callovian age represents a new taxon: *Atlasaurus imelakei* n.g., n.sp. The sauropod appears to be closer to *Brachiosaurus* than any other known sauropod, but possesses (relative to the length of the dorsal vertebral column) a larger skull, shorter neck, longer tail and more elongated limbs. The presence of large sauropods of Middle Jurassic age is very important in understanding the history and the evolution of these Mesozoïc giants. (© 1999 Académie des sciences / Éditions scientifiques et médicales Elsevier SAS.)

Bathonian / Callovian / Morocco / Vertebrata / Dinosaur / Sauropoda

Résumé — Le squelette presque complet d'un grand sauropode découvert à Wawmda (Haut Atlas central, Maroc), dans un niveau d'âge Bathonien–Callovien, est celui d'un nouveau taxon : *Atlasaurus imelakei* n.g., n.sp. Ce sauropode semble plus proche de *Brachiosaurus* que de tout autre genre de sauropode, mais se distingue de ce genre (par rapport à la longueur de la portion dorsale de la colonne vertébrale) par un crâne plus grand, un cou plus court, une queue plus longue et des membres plus allongés. La présence d'un grand sauropode dès le Jurassique moyen est très importante pour comprendre l'histoire et l'évolution de ces géants du Mésozoïque. (© 1999 Académie des sciences / Éditions scientifiques et médicales Elsevier SAS.)

Bathonien / Callovien / Maroc / Vertebrata / Dinosaure / Sauropoda

Version abrégée (voir p. 524)

1. Introduction

The skeleton of a large sauropod dinosaur was collected from strata of Middle Jurassic (Bathonian–Callovian) age in the central High Atlas of Morocco (Monbaron and Taquet, 1981; Monbaron, 1983). Comparably complete sauropod skeletons are not common, and those with an associated skull are particularly rare (McIntosh, 1990; Wilson and Sereno, 1998). Furthermore, the specimen is among the oldest relatively complete skeletons known,

Note communicated by Philippe Taquet.

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predating the classic American and Tanzanian Late Jurassic sauropod assemblages by about 15 million years. The purpose of this note is to name, briefly characterize and comment on the evolutionary and biogeographic significance of this unusual sauropod. The specimen will be described more fully elsewhere.

2. Geological and stratigraphical context

In the calcareous central High Atlas Mountains, flat-bottomed, wide synclinal structures lie near narrow anticlines in which exposures of basic magmatic rocks often occur. These large structures are generally oriented SW–NE to west–east. The intrusions date principally from the Middle Jurassic (Monbaron, 1982a); some intrusions appear to be as old as Early Jurassic (Piqué, 1994). On the flanks of the synclines, platform carbonates are succeeded by continental facies deposited in progressive discordance, clearly indicating tilting movements associated with the intrusions. The terminal filling phase of the synclines is characterized by detritic rubefied sediments designated under the name of 'Couches rouges'.

The age of the 'Couches rouges' has long been discussed. Based on a multitude of criteria from tectonic, stratigraphic, palaeontological and radiochronological evidence, they are believed to be of Middle Jurassic age (Bathonian–Callovian, cf. Jenny et al., 1981, Souhel and Canérot, 1989), at least with regard to their lower levels which contain the dinosaur remains studied here. Note that continental sedimentation seems to have continued, with numerous lacuna and discordances, into the Early Cretaceous, constituting a thick Jurassico-Cretaceous series covering wide areas of the Atlas region (Monbaron et al., 1990); the first remains of African Cretaceous mammals were discovered toward the top of this series (Sigogneau-Russell et al., 1988).

Situated at an altitude of about 1 800 m, the fossiliferous site of Wawmda (Azilal Province) is located at the northern border of the vast synclinal basin of Tilougguit, which is filled by the 'Couches rouges' (Monbaron, 1985). The locality is at the base of a rubefied, detritic sequence in the 'Couches rouges' termed the Guettioua Formation. The latter discordantly overlies Aaleno-Bajocian carbonates, which in turn overlie the Jbel La'bbadine anticline, an active tectonic zone during medial Jurassic sedimentation (Monbaron, 1982b). The environment suggested by the Guettioua formation is that of a vast plain close to sea level traversed by powerful rivers with anastomosing channels. The clastic load (principally pelites and sand, with occasional stringers of pebbles) accumulated in the form of cross-bedded channel deposits. The sauropod skeleton was extracted from a beige to brown sandstone-pelitic lens very rich in vegetal debris (fossilised trunks and limbs, and occasionally carbonised leaf debris). The relative completeness of the skeleton suggests that the animal was borne away and drowned in a flood, then caught on an oxbow or meander and rapidly covered by fluvial sediments mixed with vegetation. The specimen was thus partially protected from dismemberment and scattering (Monbaron and Taquet, 1981, for a quarry diagram, see Monbaron, 1983, figure 5). Theropod teeth were found in association with the skeleton.

3. Systematics

Sauropoda Marsh, 1878

Eusauropoda Upchurch, 1995

***Atlasaurus*, n.g.**

Etymology

Atlas: the mountain chain from Morocco and also, Atlas, the giant.

Sauros: (Greek) lizard.

Type species: *Atlasaurus imelakei*, new species.

Diagnosis: the same as that of the type species.

Atlasaurus imelakei*, *n. sp.

Etymology

Imelake: (arabic) giant.

Type locality: Wawmda,Tilougguit Formation, Bathonian–Callovian, Azilal province, High Atlas of Morocco (Monbaron and Taquet, 1981).

Type specimen: Musée des sciences de la Terre de Rabat, Morocco; nearly complete skeleton (Monbaron and Taquet, 1981; Monbaron, 1983).

Diagnosis

Autapomorphies include: supratemporal fenestra twice as wide as long (140 by 70 mm) not visible in lateral perspective; combined width of paroccipital processes 48 % of estimated length of mandible; paroccipital processes extend horizontally at nearly right angles to long axis of skull; mandibular symphysis and dentary very shallow (symphyseal depth 116 % minimum depth of dentary, probably reversal from primitive state in sauropods); length of humerus 65 % of estimated length of dorsal series; length of ulna exceeds length of tibia by about 115 %.

In other known sauropods the supratemporal fenestra is more dilated anteroposteriorly, and the dorsal margins of the fenestra slope laterally so that it is visible in lateral perspective; the paroccipital process is markedly inclined ventrodistally, posteroventrally or both; the combined width of the processes is less than 48 % of the length of the mandible (*table I*); the ratio between the symphyseal depth and the minimum depth of the dentary is at least 150 % (Wilson and Sereno, 1998); the humerus is shorter relative to the estimated length of the dorsal series; and the ulna does not surpass the tibia so greatly in length (McIntosh, 1990, p. 377). Features in the skeletal anatomy of *Atlasaurus imelakei* (see below) distinguish it from all other Jurassic sauropods (for brief descriptions and references to other Jurassic sauropod taxa, see McIntosh, 1990).

Table I. Cranial proportions expressed as percentage of length of mandible. 1. *Shunosaurus* (Zheng, 1996; figures 6, 8, 11; length mandible 442 mm), 2. *Atlasaurus* (estimated 690 mm), 3. *Brachiosaurus* (Janensch, 1935–1936; figures 56–60; 593 mm), 4. *Camarasaurus* (McIntosh et al., 1996b; from cast 1.675 mm).

Proportions crâniennes exprimées en pourcentage par rapport à la longueur de la mandibule. **1.** *Shunosaurus* (Zheng, 1996 ; figures 6, 8, 11 ; longueur de la mandibule 442 mm). **2.** *Atlasaurus* (estimé à 690 mm). **3.** *Brachiosaurus* (Janensch, 1935–1936 ; figures 56–60 ; 593 mm). **4.** *Camarasaurus* (McIntosh et al., 1996b ; from cast 1,675 mm).

	1	2	3	4
Length maxillary tooth row	39	44	46	35
Length dentary tooth row	53	44	43	47
Length supratemp. fenestra	15	10	11	7
Width parocc. processes	29	48	44	42
Length quadrate	38	38	49	35
Length lower jaw	100	100	100	100

Abridged description (*figure*)

Atlasaurus imelakei is a moderately large, adult sauropod (the sutures between the neural arches and centra, and between the centra of the sacral vertebrae are closed) with unusually long forelimbs and moderately long hindlimbs (*table II*, see references listed in the tables for morphological details cited in the following paragraphs). Minimum midshaft circumferences of the humerus (565 mm) and femur (690 mm) indicate a weight of 22.5 metric tonnes (Anderson et al., 1985). Relative to the estimated length of the dorsal column in *Brachiosaurus* the skull is large, the neck is short, the tail is long and the limbs are very long. Other sauropods may have relatively larger heads (*Shunosaurus*), longer necks (*Omeisaurus*) or longer tails (*Apatosaurus*).

In the skull, the postorbital process is broader transversely than anteroposteriorly, and the quadratic fossa is much shallower than in *Camarasaurus* (Wilson and Sereno, 1998, characters 75.90). The basipterygoid processes are longer than in *Brachiosaurus* and *Camarasaurus*. The anterior end of the dentary is straight, not curved toward the symphysis. As preserved, the dental formula is pmx?, mx 14–15? dent at least 14; some teeth bear marginal tooth denticles.

At least 13 cervical vertebrae are present. The shafts of the cervical ribs are slender and project beneath the centra of the following vertebra. Dorsal ribs suggest the presence of 12 dorsal vertebrae, or an additional vertebra anterior to the dorsosacral relative to conditions in *Plateosaurus* (Huene, 1926). The shallower curvature of their shafts implies that the chest was not as broad as it is in *Brachiosaurus* and *Camarasaurus* (Janensch, 1950b; McIntosh et al., 1996b). Intercentral facets of posterior dorsals are less opisthocoelous and less transversely elongated than in *Brachiosaurus*. The five sacral vertebrae support a sacricostal yoke, but the sacrum does not narrow posteriorly as it does in *Brachiosaurus*. The orientation of intercentral facets and slope of the neural arches indicate that the tail was arched dorsally at its base. Proximal chevrons are unbridged. Except as noted above, the vertebral column of *Atlasaurus imelakei* closely resembles that of *Brachiosaurus*. In the manus, a large, block-like carpal overlaps metacarpals I–II, and a tiny, irregularly spherical ossicle without facets is associated with the proximal end of metacarpal III. Manus phalanx II-1 bears a small, imperfect facet, suggesting an articulation with a more distal phalanx.

Comparisons

Atlasaurus imelakei contains several plesiomorphous features. The neck is short (*table II*). The cervical vertebrae are relatively uniform in length, as indicated by the ratio between the lengths of cervical centra 2 and 7: 0.64 in *Plateosaurus* (Huene 1926), 0.61 in *Atlasaurus*, 0.59 in *Shunosaurus*, 0.46–0.42 in *Camarasaurus* and 0.34 in *Brachiosaurus* and by the relatively small discrepancy between the ratios of the length of the longest cervical centrum and the average length of the dorsal vertebrae: 1.55 in *Shunosaurus*, 1.86 in *Atlasaurus* and 3.26 in *Mamenchisaurus* (Yang and Zhao, 1972). Although the animal was mature, functional capitular facets occur throughout the cervical series. In *Camarasaurus* the ribs are fused to the centrum beginning on cervical 3; in *Brachiosaurus* ribs become fused on cervicals 5 or 6. The spines were undivided in the cervical and preserved anterior dorsal vertebrae. The spine of cervical 13 bears lateral tuberosities with a shallow groove separating them on the midline, as in cervical 5 in *Camarasaurus* (McIntosh et al., 1996a, b). In *Atlasaurus* metacarpals I–III face anteriorly as in *Omeisaurus* (He et al., 1988), but metacarpals IV–V are sharply rotated posteriorly and medially around the lateral edge of the forefoot. Thus the metacarpus is only incipiently columnar.

As noted earlier (Monbaron and Taquet 1981), these primitive features place *Atlasaurus* among primitive sauropods formerly known as cetiosaurs. However, the type specimen of the generotypic species of *Cetiosaurus* is generically indeterminate, and the Cetiosauridae have disappeared from recent phylogenies (Upchurch, 1995; Wilson and Sereno, 1998). Noting differences between the present specimen (as informally described in Monbaron 1983) and the type of *'Cetiosaurus' oxoniensis* (Phillips, 1871; McIntosh, 1990, p. 378) casts doubt on a close relationship between the two forms. His inference is supported by differences in the relative lengths of limb elements (for example, in the British specimen the humerus: femur ratio is 0.80 and the ulna:tibia ratio is 1.00 whereas in the Moroccan specimen the ratios are respectively 0.99 and 1.15. In a specimen referred to *'C.' oxoniensis* (Jones, 1970), a posterior cervical centrum is much longer relative to that of a mid-dorsal (by a ratio of 2.54) than in *Atlasaurus*.

Atlasaurus can be distinguished from each of the three incomplete skeletons from the Middle Atlas of Morocco considered by Lapparent (1955) as the cotypes of

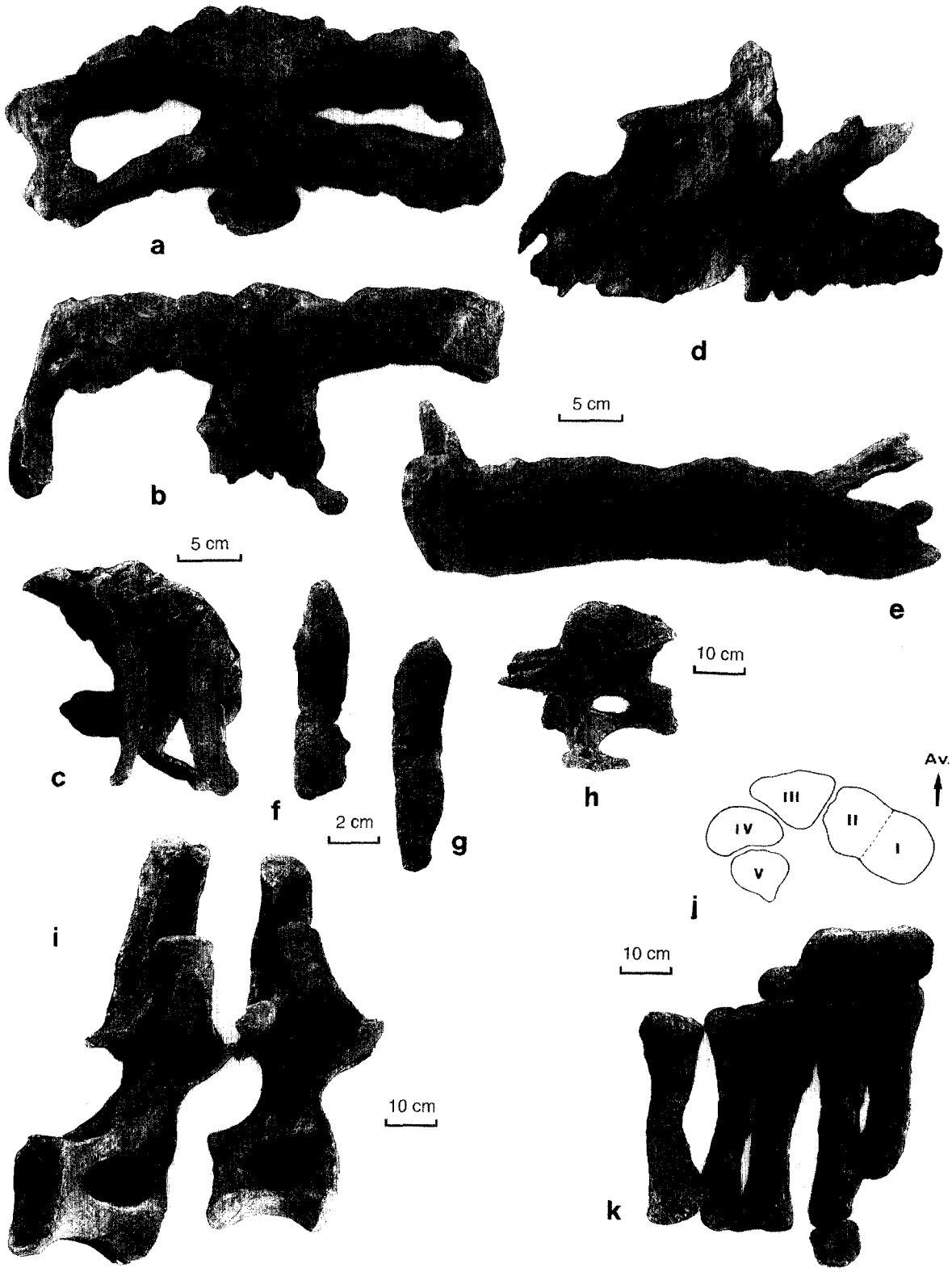

Figure. ***Atlasaurus imelakei*** **nov. gen., nov. sp. a. Braincase, dorsal view. b. Braincase, posterior view. c. Braincase, left lateral view. d. Left maxilla, lateral view. e. Left dentary, lateral view. f–g. Teeth, lateral view. h. Cervical, left lateral view. i. Two dorsal vertebrae, left lateral view. j. Proximal articular relationships of the metacarpals. k. Carpals and metacarpals of the left hand view from behind; metacarpal V is upside-down.**

Atlasaurus imelakei nov. gen., nov. sp. **a.** Boîte crânienne, vue dorsale. **b.** Boîte crânienne, vue postérieure. **c.** Boîte crânienne, vue latérale gauche. **d.** Maxillaire gauche, vue latérale. **e.** Dentaire gauche, vue latérale. **f–g.** Dents, vue latérale. **h.** Vertèbre cervicale, vue latérale gauche. **i.** Deux vertèbres dorsales, vue latérale gauche. **j.** Relations articulaires proximales des métacarpiens. **k.** Carpiens et métacarpiens de la patte antérieure gauche en vue postérieure ; le métacarpien V est à l'envers.

Table II. Skeletal proportions expressed as percentage of length of dorsal vertebral series. 1. *Plateosaurus* (Huene, 1926). 2. *Shunosaurus* (Zhang, 1998; mature individual, length of dorsal series 1.746 mm). 3. *Atlasaurus* (estimated assuming 12 dorsal vertebrae, 3.036 mm). 4. *Brachiosaurus* (Janensch, 1935–1936, 1950a, 1961, specimens SII and D, length dorsal series estimated assuming 12 dorsal vertebrae; after Wilson and Sereno, 1998; 4.140 mm). 5. *Omeisaurus* (He et al., 1988; specimens T4703 skull; T4704 skeleton, 2.420 mm). 6. *Camarasaurus* (Gilmore, 1925; immature individual, 952 mm). 7. *Apatosaurus* (Gilmore, 1936; 2.629 mm). The length of the tail is based on the combined lengths of caudal centra 1–15; the 'length of the lower jaw' in *Apatosaurus* is the length of the skull.

Proportions du squelette exprimées en pourcentage de la longueur de la série des vertèbres dorsales. **1.** *Plateosaurus* (Huene, 1926). **2.** *Shunosaurus* (Zhang, 1998 ; individu mature, 1,746 mm). **3.** *Atlasaurus* (estimé en supposant 12 vertèbres dorsales, 3,036 mm). **4.** *Brachiosaurus* (Janensch, 1935–1936, 1950a, 1961 ; spécimens SII et D, longueur de la série des dorsales estimée en supposant 12 vertèbres, d'après Wilson et Sereno (1998), 4,140 mm). **5.** *Omeisaurus* (He et al., 1988 ; spécimens T4703 crâne, T4704 squelette, 2,420 mm). **6.** *Camarasaurus* (Gilmore, 1925 ; individu immature ; 952 mm). **7.** *Apatosaurus* (Gilmore, 1936 ; 2,629 mm). La longueur de la queue est basée sur les longueurs combinées des centra des caudales 1–15 ; la « longueur de la mandibule » chez *Apatosaurus* est la longueur du crâne.

	1	2	3	4	5	6	7
Length lower jaw	30	40	23	15	25	35	25
Length neck	72	125	127	196	384	107	217
Length back	100	100	100	100	100	100	100
Length tail 1–15	87	80	86	58	108	94	112
Length humerus	28	40	65	51	43	46	44
Length ulna	19	28	41	31	35	32	32
Length radius	16	28	40	30	32	31	30
Length mcIII	6	10	15	14	10	14	11
Forelimb	50	78	120	95	85	91	85
Length femur	47	69	64	50	53	60	68
Length fibula	36	40	38	30	38	—	45
Length tibia	34	39	36	29	36	37	42
Length MtI	9	6	8	6	7	7	7
Length MtIII	17	10	10	7	9	9	9
Hindlimb	98	118	110	86	98	106	119

'Cetiosaurus' mogrebiensis: the neural arch bases and pleurocentra are situated in a mid-length position on dorsal vertebrae (El Mers n° I) whereas they are more anterior in position in *Atlasaurus*; the length of the humerus is shorter relative to that of the femur (the ratio is 0.86 in El Mers n° 3) whereas they are equal in length in *Atlasaurus*; and the lengths of the ulna and metacarpals are longer relative to the length of the humerus (the ratios are respectively 0.77 and 0.28 in El Mers n° 8) than in *Atlasaurus* where the ratios are 0.65 and 0.24. It should be noted that huge lunate manus imprints from the Bathonian of the High Atlas (*Breviparopus taghbaloutensis* Ishigaki 1989) are inconsistent with the smaller size of the manus and non-reflexed position of the first metacarpal in *Atlasaurus*. At least three different sauropods were present in the Middle Jurassic of Morocco.

The relationships of *Atlasaurus* appear to be within camarasauromorph sauropods, including *Brachiosaurus* and *Camarasaurus*, as indicated by a quadratojugal the major rami of which embrace an angle of 90 degrees or less, relatively long metacarpals, and invaginated dorsal pleurocoels that extend to the posterior end of the presacral column (see Janensch, 1935–1936; Madsen et al., 1995; McIntosh et al., 1996b). Detailed similarities between the vertebral column and limbs suggest a closer affinity to *Brachiosaurus* than to any other known sauropod.

4. Implications

Atlasaurus from the Middle Jurassic of Morocco is approximately 15 million years older than another, larger giraffoid sauropod, *Brachiosaurus*, from Late Jurassic strata (Zils et al., 1995; Kowallis et al., 1998) in East Africa and North America, to which it is most closely related. In Middle Jurassic strata in Morocco as in China, at least three major taxa of sauropods are present — in Morocco: *Atlasaurus*, *"Cetiosaurus" mogrebiensis* and a giant sauropod indicated by a trackway (Ishigaki, 1989) and the longest sauropod femur known (2 360 mm; Charroud and Fedan 1992); in China: *Datousaurus* (Dong and Tang, 1984), *Omeisaurus* and *Shunosaurus*. The morphological diversity represented by these taxa (*table II*) suggests a major, early radiation of sauropods. This radiation coincided with a great increase in size, from a relatively small sauropod recorded in basal Jurassic strata (Raath, 1972) to the Moroccan Middle Jurassic giant. It also coincided with high, mid-Mesozoic levels of atmospheric carbon dioxide (Berner, 1997), and possibly higher levels of plant productivity. The Atlantic rift had not yet separated the southeastern North America and West African coasts (Gradstein et al. 1990), so that Moroccan sauropods, at a latitude of 25–27° N of the Middle Jurassic equator (C.S. Scotese personal communication, 1999), probably resembled those inhabiting the western side of the rift in the south-

eastern USA. The Middle Jurassic dinosaurs of China appear to be endemic to eastern Asia (Russell, 1993; Upchurch, 1995). Clearly, the Early and Middle Jurassic of Morocco potentially hold information of fundamental importance in resolving the early history of the sauropodan giants of the Mesozoic.

Version abrégée

Le squelette d'un grand dinosaure sauropode a été récolté à Wawmda, dans les couches du Jurassique moyen (Bathonien–Callovien) du Haut Atlas central au Maroc (Monbaron et Taquet, 1981 ; Monbaron, 1983). La récolte d'un tel squelette de sauropode, comprenant le crâne, est très rare (McIntosh, 1990 ; Wilson et Sereno, 1998). De plus, ce spécimen précède de 15 Ma les faunes classiques de sauropodes du Jurassique supérieur d'Amérique du Nord et de Tanzanie.

Cette note a pour objet de nommer ce nouveau taxon et d'en donner les caractéristiques ; elle aborde également la signification évolutive et biogéographique de la découverte de ce sauropode exceptionnel.

Contexte géologique et stratigraphique du gisement

Dans de larges structures synclinales du Haut Atlas central se sont déposés des sédiments continentaux, détritiques et rubéfiés, désignés sous le nom de « Couches rouges ». L'âge de ces 'Couches rouges' a été longtemps discuté. On admet qu'elles sont d'âge Jurassique : Bathonien–Callovien (Jenny et al., 1981 ; Souhel et Canérot, 1989), du moins dans leur portion inférieure, qui renferme le dinosaure décrit ici.

Le site fossilifère de Wawmda se situe à la bordure septentrionale du synclinal de Tilougguit. Le milieu de dépôt suggère un environnement de vaste plaine, proche du niveau de la mer, parcourue par de puissants fleuves aux chenaux anastomosés. Les ossements se trouvaient dans une lentille gréso-pélitique, riche en débris végétaux. Le squelette, presque complet, indique que l'animal a été emporté lors d'une crue, puis rapidement piégé dans une anse ou un méandre, avant d'être recouvert par des sédiments mêlés de branchages.

Systématique

Sauropoda Marsh, 1878

Eusauropoda Upchurch, 1995

Atlasaurus imelakei nov. gen., nov. spec.

Étymologie

Atlas : du nom de la chaîne de montagnes marocaine et du nom du géant du même nom ; Sauros : du grec, lézard ; Imelake : de l'arabe, géant.

Localité : gisement de Wawmda, formation de Tilougguit, grès de Guettioua, Bathonien–Callovien, province d'Azilal, Haut Atlas, Maroc.

Spécimen type : un squelette presque complet. Musée des sciences de la Terre, Rabat, Maroc.

Diagnose

Autapomorphies incluant : fenêtres supratemporales deux fois plus larges que longues (140 par 70 mm), invisibles en vue latérale : largeur reconstituée entre les processus paroccipitaux égale à 48 % de la longueur estimée de la mandibule ; processus paroccipitaux s'étendant horizontalement pratiquement à angle droit par rapport à l'axe d'allongement du crâne ; dentaire et symphyse mandibulaire très peu élevés (la hauteur symphysaire égale à 116 % de la hauteur minimale du dentaire, réversion probable de l'état primitif des sauropodes) ; longueur de l'humérus égale à 65 % de la longueur estimée de la série des dorsales ; longueur de l'ulna dépassant la longueur du tibia de 115 %.

Comparaisons

Atlasaurus imelakei se distingue par les caractères de son squelette de tous les autres sauropodes jurassiques déjà décrits. Par rapport aux proportions du *Brachiosaurus*, le crâne est grand, le cou est court, la queue est longue et les membres sont très allongés. Les circonférences minimales du corps de l'humérus (565 mm) et du fémur (690 mm) indiquent un poids de 22,5 t (Anderson et al. 1985). Les caractères primitifs d'*Atlasaurus* (cou court, vertèbres cervicales relativement semblables en longueur, une partie seulement du métacarpe en colonne), le rapprochaient des sauropodes connus sous le nom de Cétiosaures. Cependant, le spécimen type de *Cetiosaurus* est indéterminé et les Cétiosaures ne figurent plus dans les phylogénies récentes (Upchurch, 1995 ; Wilson et Sereno, 1998). Ce spécimen est différent d'autre part de *'Cetiosaurus' oxoniensis* (Phillips, 1871), comme l'a montré McIntosh (1990, p. 378) ; Il est également différent des spécimens décrits par Lapparent (1955) sous le nom de *'Cetiosaurus' mogrebiensis*. Enfin, des empreintes géantes de sauropode (*Breviparopus taghbaloutensis* Ishigaki 1989) du Bathonien du Haut Atlas montrent qu'il existait au Maroc au moins trois lignées différentes de sauropodes, dès le Jurassique moyen.

Les plus proches parents d'*Atlasaurus* sont les sauropodes camarasauroïdes, incluant *Brachiosaurus* et *Camarasaurus*, comme l'indiquent les caractères du quadratojugal, la relative longueur des métacarpiens, la profondeur des cavités pleurocoeles des dorsales, qui sont présentes également jusqu'à l'extrémité postérieure de la partie présacrée de la colonne vertébrale. D'autres caractères, présents sur la colonne vertébrale et sur les membres, suggèrent qu'*Atlasaurus* est plus proche de *Brachiosaurus* que de tout autre sauropode connu.

Implications

Atlasaurus, du Jurassique moyen du Maroc, est plus âgé approximativement de 15 Ma que le grand sauropode giraffoïde *Brachiosaurus* du Jurassique supérieur (Kimméridgien) de l'Est de l'Afrique et de l'Amérique du Nord (Zils et al., 1995).

La diversité morphologique des différents taxa de sauropodes du Jurassique moyen (au Maroc et en Chine) suggère une différenciation et une radiation précoce des sauropodes. Cette radiation majeure coïncide avec une grande augmentation de la taille de ces reptiles herbivores ; elle coïncide également avec une augmentation majeure de la teneur en dioxide de carbone (Berner, 1997) et probablement avec l'augmentation de la productivité des plantes.

Les couches du Jurassique inférieur et moyen du Maroc renferment donc des informations potentiellement extrêmement importantes, concernant les débuts de l'histoire des sauropodes géants du Mésozoïque.

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