

The first giant dinosaurs: a large sauropod from the Late Triassic of Thailand

Eric Buffetaut^{a,*}, Varavudh Suteethorn^b, Jean Le Loeuff^c, Gilles Cuny^{d,e}, Haiyan Tong^a, Sasidhorn Khansubha^b

^a CNRS, 16, cour du Liégar, 75013 Paris, France

^b Geological Survey Division, Department of Mineral Resources, Rama VI Road, Bangkok 10400, Thailand

^c Musée des Dinosauriens, 11260 Espéraza, France

^d Geological Museum, University of Copenhagen, Øster Voldgade 5-7, 1350 Copenhagen K, Denmark

^e Faculty of Science, Mahasarakham University, Mahasarakham 44150, Thailand

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Abstract – Newly discovered sauropod material from the Upper Triassic of northeastern Thailand reveals that some of the earliest sauropods had already reached a very large size. A 1 m long humerus is within the size range of large Jurassic sauropods such as *Camarasaurus* and suggests an animal reaching a length of 12 to 15 m. It took sauropodomorph dinosaurs some 20 million years to produce giant forms, a rapid size increase when compared with that observed in the evolution of other dinosaurs, such as ornithischians. **To cite this article:** E. Buffetaut et al., C. R. Palevol 1 (2002) 103–109. © 2002 Académie des sciences / Éditions scientifiques et médicales Elsevier SAS

Thailand / Upper Triassic / Dinosauria / Sauropoda / gigantism

Résumé – Les premiers dinosaures géants : un grand sauropode du Trias de Thaïlande. De nouveaux restes de sauropodes du Trias supérieur du Nord-Est de la Thaïlande révèlent que certains de ces très anciens sauropodes atteignaient déjà une très grande taille. Un humérus long de 1 m est comparable par la taille aux grands sauropodes du Jurassique, tels que *Camarasaurus*, et suggère un animal atteignant 12 à 15 m de longueur. Il fallut aux sauropodomorphes quelque 20 Ma pour produire des formes géantes, ce qui indique un accroissement de taille rapide par rapport à ce que l'on observe dans d'autres groupes de dinosaures, comme les ornithischiens. **Pour citer cet article :** E. Buffetaut et al., C. R. Palevol 1 (2002) 103–109. © 2002 Académie des sciences / Éditions scientifiques et médicales Elsevier SAS

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Version abrégée

Les plus grands des dinosaures étaient les sauropodes, avec des poids estimés atteignant 90 t [18] et des longueurs dépassant en général 10 m. Jusqu'à une date récente, les plus anciens sauropodes connus remontaient au Jurassique inférieur, mais des sauropodes du Trias ont maintenant été découverts en Thaïlande [3]. Le spécimen décrit ci-dessous montre que certaines de ces formes triasiques atteignaient déjà une taille gigantesque. La comparaison avec d'autres groupes de dinosaures suggère que l'évolution vers une taille gigantesque fut relativement rapide chez les sauropodomorphes.

Le plus ancien sauropode actuellement connu a récemment été signalé dans la Formation Nam Phong (Trias supérieur de Thaïlande) [3], sur la base d'un squelette incomplet, décrit sous le nom d'*Isanosaurus attavipachi*, qui appartient apparemment à un individu n'ayant pas atteint le stade adulte. La longueur du type d'*Isanosaurus attavipachi* a été estimée à environ 6,50 m, ce qui est peu pour un sauropode.

Un deuxième spécimen de sauropode a été découvert récemment dans un site proche de celui qui a livré le premier squelette, près du village de Ban Non Thaworn (Province de Chaiyaphum, Nord-Est de la Thaïlande). Ce nouveau gisement, appelé Khok Hin Poeng, se trouve, lui

* Correspondence and reprints.

E-mail address: Eric.Buffetaut@wanadoo.fr (E. Buffetaut).

aussi, dans les grès rouges continentaux de la formation Nam Phong, qui est rapportée au Norien supérieur ou au Rhétien sur des arguments palynologiques [20]. Les ossements trouvés à Khok Hin Poeng sont plus ou moins érodés et appartiennent, semble-t-il, à un seul individu. Il s'agit d'un humérus droit assez bien conservé, de fragments de l'humérus gauche, d'un possible fragment de tête de fémur, d'un possible fragment de l'extrémité proximale d'un tibia, d'un centrum de vertèbre caudale du milieu de la queue et d'un centrum caudal distal.

La vertèbre caudale de la région moyenne de la queue est amphicoele, avec des faces articulaires ovales. L'arc neural, cassé, s'insérait sur la partie antérieure du centrum. Les processus transverses étaient aussi en position assez antérieure. Il existe ventralement une arête médiane et des facettes articulaires bien marquées pour les chevrons. Longueur totale du centrum : 110 mm. Hauteur de la face articulaire antérieure : 120 mm.

L'humérus (CH5-1), presque complet mais érodé dans la région distale, est de grande taille et clairement de type sauropode. Il montre une expansion proximale marquée. La diaphyse, relativement étroite, est aplatie craniocaudalement et de section ovale. Il existe une forte crête deltopectorale, qui débute sur le bord latéral, à peu près à mi-longueur de l'os, et a son apex dans la moitié proximale. Le contour proximal de l'os paraît avoir été régulièrement arrondi. L'expansion distale est dans le même plan que l'expansion proximale.

Cet humérus montre tous les caractères des sauropodes. Il diffère des humérus de prosauropodes par le fait que ses expansions proximale et distale sont dans le même plan, de sorte que l'os apparaît droit, alors qu'il est tordu chez les prosauropodes, chez lesquels les expansions sont dans des plans différents faisant un angle d'environ 45° [7] – caractère présent aussi chez le sauropode *Diplodocus* [8]. La crête deltopectorale du spécimen thaïlandais est moins proéminente que celle des prosauropodes et se trouve en position plus proximale ; chez les prosauropodes, elle forme une crête très saillante et anguleuse en forme d'aile, avec l'apex à mi-longueur de l'os [7]. Le seul caractère du spécimen de Khok Hin Poeng rappelant les prosauropodes est une dépression plus ou moins circulaire bien marquée sur la face craniale de l'expansion distale. Une telle dépression, pour l'insertion du *m. brachialis* [5], est peu fréquente chez les sauropodes, mais présente chez les prosauropodes.

Sa présence chez la forme de Thaïlande peut être considérée comme un caractère plésiomorphe. Dans l'ensemble, cependant, l'humérus de Khok Hin Poeng est nettement différent des humérus de prosauropodes et confirme la présence de sauropodes dans le Trias supérieur de Thaïlande. Malheureusement, le matériel de Khok Hin Poeng ne permet pas de comparaisons significatives avec le type d'*Isanosaurus attavipachi*, chez lequel, notamment, l'humérus n'est pas connu. Il n'est donc pas possible d'établir si le nouveau sauropode triasique de grande taille appartient ou non à *Isanosaurus attavipachi*. Comme le type de ce dernier est un squelette incomplet d'un individu non adulte

[3], la différence de taille entre les deux spécimens n'exclut pas l'appartenance à un même taxon, mais aucune conclusion définitive n'est possible actuellement.

Des comparaisons peuvent être faites avec les humérus de divers sauropodes [15, 16]. L'os de Khok Hin Poeng diffère à la fois des humérus très longs et grêles des Brachiosauridae, et de ceux très courts et robustes d'*Apatosaurus* et *Opisthocoelicaudia*. Les comparaisons avec les sauropodes les plus anciens ne sont pas très significatives. Chez *Vulcanodon karibaensis*, du Jurassique inférieur du Zimbabwe [5], l'humérus est incomplètement connu, et ne paraît pas aussi élargi proximale que chez le spécimen de Thaïlande. Chez *Shunosaurus lii*, du Jurassique moyen de Chine [26], les proportions de l'humérus ne sont pas très différentes de celles de la forme thaïlandaise, bien que les expansions proximale et distale apparaissent un peu plus vastes, mais la diaphyse semble être moins aplatie craniocaudalement. *Kotasaurus yamanpalliensis*, de la formation Kota (Jurassique inférieur ?) de l'Inde, rappelle la forme de Thaïlande par la présence apparente d'une dépression sur la face craniale de l'expansion distale [24].

Dimensions de l'humérus de Khok Hin Poeng

Longueur : 1040 mm.

Largeur (estimée) de l'expansion proximale : 360 mm (34% de la longueur).

Largeur minimale : 180 mm (17% de la longueur).

Largeur de l'expansion distale : 310 mm (29% de la longueur).

Ces proportions sont généralement comparables à celles des humérus de plusieurs espèces de *Camarasaurus* fournies par McIntosh et al. [17], dont les longueurs varient de 435 à 1130 mm. Avec une longueur d'un peu plus de 1 m, cet humérus appartient clairement à un sauropode de grande taille. Pour comparaison, le Tableau 1 présente la longueur de l'humérus chez divers prosauropodes et sauropodes. Le spécimen thaïlandais est beaucoup plus long que les humérus des plus grands des prosauropodes mélanorosauridés. Parmi les sauropodes, les Brachiosauridae, qui ont des membres antérieurs particulièrement longs, ont des humérus nettement plus longs, jusqu'à deux fois la longueur du spécimen de Thaïlande.

Il n'est pas facile d'estimer la longueur totale d'un sauropode à partir de la longueur de l'humérus, car les proportions des membres varient notablement au sein de ce groupe. Comme on l'a vu, les proportions de l'humérus de Khok Hin Poeng rappellent celles de *Camarasaurus*. En supposant que le sauropode de Thaïlande ait eu les mêmes proportions que le spécimen de *Camarasaurus grandis* GMNH 101 décrit par McIntosh et al. [17], qui est long de 13,70 m, sa longueur totale serait d'environ 12,60 m. Cette estimation est évidemment hypothétique, car les proportions du sauropode thaïlandais peuvent avoir été différentes de celles de *Camarasaurus*. Des estimations fondées sur d'autres types de sauropodes, aux membres antérieurs relativement plus courts, comme *Diplodocus* [8] ou *Apatosaurus* [9], donnent une longueur d'une vingtaine de mètres.

Cependant, à en juger par ce que l'on sait d'*Isanosaurus attavipachi* [3], il est peu probable que les sauropodes du Trias supérieur aient eu des proportions semblables à celles de *Diplodocus* ou *Apatosaurus*, qui possèdent des cous et des queues particulièrement longs. Le sauropode primitif *Shunosaurus lii*, du Jurassique moyen de Chine, qui a des vertèbres cervicales relativement courtes et un humérus rappelant celui de Khok Hin Poeng, peut aussi servir de point de départ à une estimation de la longueur. D'après Zhang [26], le spécimen T5402 indique un animal de 11 m de longueur, dont l'humérus mesure 740 mm. Si l'on prête les mêmes proportions au spécimen thaïlandais, sa longueur totale dépasserait 15 m. Une estimation de longueur plus fiable devra attendre la découverte de squelettes plus complets dans le Trias de Thaïlande, mais il semble bien que ces très anciens sauropodes aient pu atteindre une longueur considérable, dépassant nettement 10 m. Ils étaient donc plus longs que les plus grands des prosauropodes (les Melanorosauridae), qui ne dépassaient pas 10 m de longueur. Cette grande taille est relativement inattendue chez des sauropodes aussi anciens. *Vulcanodon karibaensis*, de l'Hettangien du Zimbabwe, qui était le sauropode le plus ancien et le plus primitif jusqu'à la découverte des sauropodes du Trias de Thaïlande, était relativement petit pour un sauropode : la longueur estimée de son humérus [5] représente environ les deux tiers de celle de l'humérus de Khok Hin Poeng, tandis que sa longueur totale n'excédait sans doute pas 9 m. Le spécimen thaïlandais montre que l'acquisition d'une très grande taille s'est produite plus tôt dans l'histoire des sauropodes que ne le suggérait *Vulcanodon*. Bien que la découverte d'*Isanosaurus attavipachi* suggère qu'au Norien/Rhétien les sauropodes aient déjà

connu une longue histoire évolutive [3], la date d'apparition du groupe est incertaine. Les plus anciens sauropodes connus étant ceux de la formation Nam Phong, on ne peut pas dire grand chose sur l'accroissement de la taille chez les sauropodes avant le Norien supérieur ou le Rhétien. Toutefois, il semble que les premiers sauropodomorphes aient été de petits animaux, qu'il s'agisse des prosauropodes du Carnien inférieur (voire Ladinien) de Madagascar [6], qui sont les plus anciens sauropodomorphes connus (longueur totale estimée : environ 1 m), ou de *Saturnalia tunipiquim*, du Carnien du Brésil [14] (longueur environ 1,50 m). Dès le Norien supérieur ou le Rhétien, soit environ 20 Ma plus tard, certains sauropodes avaient atteint une taille gigantesque. L'accroissement de taille chez les sauropodomorphes du Trias semble donc s'être effectué assez rapidement. Il fallut beaucoup plus longtemps aux ornithischiens, l'autre groupe de dinosaures herbivores, pour atteindre des dimensions approchant celles des sauropodes. Les plus grands ornithischiens connus sont des hadrosaures, comme *Shantungosaurus* [12], long de 14 m ; de telles formes gigantesques n'apparaissent qu'au Crétacé supérieur.

Les raisons de la taille gigantesque des sauropodes (protection contre les prédateurs, régulation thermique ?) sont encore discutées [4, 19]. Quels que soient les facteurs en cause, il semble clair cependant qu'une rapide augmentation de taille fut un trait notable des débuts de l'histoire du groupe et qu'à cet égard, leur évolution fut plus rapide que celle d'autres groupes de dinosaures. Non seulement les sauropodes devinrent les plus grands des dinosaures, mais ils atteignirent cette grande taille plus vite que tout autre groupe.

1. Introduction

The largest of all dinosaurs were the sauropods, with estimated weights reaching up to 90 t [18], and lengths usually in excess of 10 m, with the longest forms possibly reaching 40 m. Until recently, the earliest known sauropods were Early Jurassic in age. Triassic sauropods have now been found in Thailand [3], and the specimen described below indicates that some of these early forms had already reached a gigantic size, comparable to that of some of the large and massive Late Jurassic forms. Comparisons can thus be made between rates of size increase in sauropodomorphs and other dinosaurs, suggesting a comparatively rapid evolution towards giant size in the former.

2. Geological setting

The earliest currently known sauropod dinosaur was recently reported from the Late Triassic Nam

Phong Formation of Thailand [3]. This first report of a Triassic sauropod was based on a fragmentary skeleton, described as *Isanosaurus attavipachi*, apparently belonging to an individual that was not fully grown, to judge from the unfused neurocentral sutures of some of the vertebrae. The length of the type specimen of *Isanosaurus attavipachi* was estimated to have been about 6.5 m, which is small for a sauropod.

A second Triassic sauropod specimen was recently discovered at a locality about 1 km distant from the first, near the village of Ban Non Thaworn, Chaiyaphum Province, northeastern Thailand. Like the first site, this new locality, called Khok Hin Poeng, is in the continental red sandstones of the Nam Phong Formation. The age of the Nam Phong Formation is well constrained by palynological data, showing that it is older than Jurassic and not earlier than Norian, indicating a Late Norian or Rhaetian age [20]. The material found at Khok Hin Poeng consists of more or less badly weathered bones, which appear to belong to a single individual (there is no indication of non-sauropod material, no duplication of skeletal

elements, and no size discrepancy). The bones include a fairly well preserved right humerus, fragments of the left humerus, a possible fragment of a femoral head, a possible fragment of the proximal end of a tibia, a caudal centrum from the middle part of the tail, and a distal caudal centrum.

3. Description and comparisons

The only skeletal elements from Khok Hin Poeng worth describing are the centrum of a mid-caudal vertebra, and a fairly complete right humerus (Fig. 1).

The caudal vertebra is amphicoelous, with oval articular faces. The neural arch, which is broken, arose from the anterior part of the centrum. The transverse processes were also located in a rather anterior position. Ventrally, there is a median ridge and well-marked articular facets for the chevron bones. The total length of the centrum is 110 mm, the height of the anterior articular face is 120 mm. The length of the centrum is comparable to that of mid-caudal centra in the *Camarasaurus* skeleton (GMNH 101) described by McIntosh et al. [17].

The humerus (palaeontological collection, Department of Mineral Resources, n° CH5-1) is remarkable for both its typically sauropod-like appearance and its large size. It is nearly complete, except for the missing lateral corner of the proximal expansion. Its distal end has been subjected to rather severe weathering. The bone shows a marked proximal expansion, so that it is noticeably wider proximally than distally. The relatively narrow shaft is craniocaudally flattened and oval in cross-section. The cranial surface of the proximal expansion is concave because of the presence of a strong deltopectoral crest, which arises on the lateral edge near mid-length of the bone and has its apex in the proximal half. The proximal outline of the bone seems to have been smoothly rounded. The distal expansion is in the same plane as the proximal one. The distal condyles have been destroyed by weathering. This humerus shows all the characteristics of the Sauropoda. In particular, it differs from the humeri of the Prosauropoda in having its proximal and distal expansions in the same plane, so that the bone appears straight, whereas it is twisted in prosauropods, in which the proximal and distal expansions are in different planes making a well-marked angle (about 45°) relative to each other [7] – a feature also present in the sauropod *Diplodocus* [8]. The deltopectoral crest of the Thai specimen differs from that of the prosauropods in being less sharply prominent and in having its apex in a relatively proximal position, whereas in prosauropods it forms a very prominent, wing-shaped and sharply angled crest, with its apex usually at about mid-length of the bone [7]. The

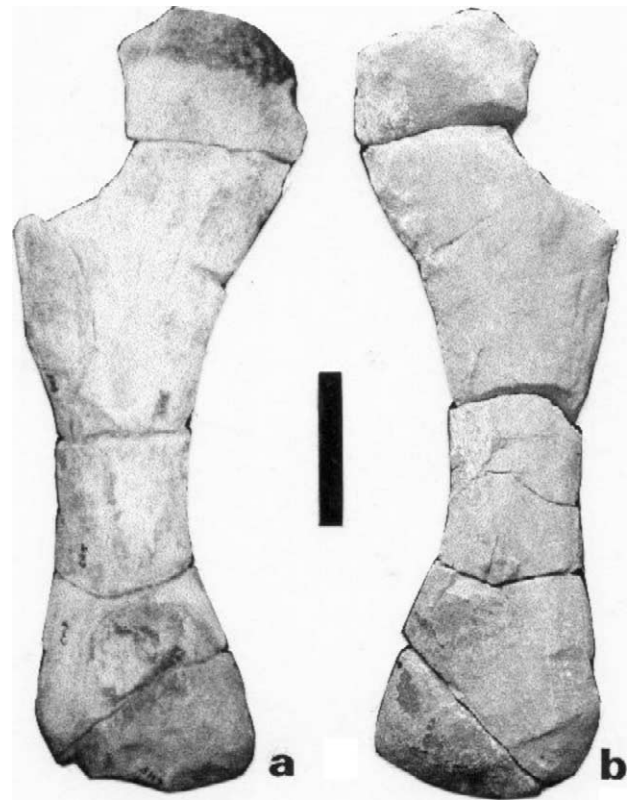


Figure 1. Right humerus of a sauropod dinosaur from the Nam Phong Formation (Late Triassic) at Khok Hin Poeng, Chaiyaphum Province, northeastern Thailand, in cranial (a) and caudal (b) views. Palaeontological collection of the Thai Department of Mineral Resources, No. CH5-1. Scale bar: 250 mm.

Figure 1. Humérus droit de dinosaure sauropode de la formation Nam Phong (Trias supérieur) de Khok Hin Poeng, province de Chaiyaphum, Nord-Est de la Thaïlande, en vues craniale (a) et caudale (b). Collection paléontologique du Department of Mineral Resources, Bangkok, n° CH5-1. Barre d'échelle : 250 mm.

only significant feature in which the Thai specimen is reminiscent of the Prosauropoda is a well-marked depression on the cranial face of the distal expansion; this more or less circular, basin-like depression is about 130 mm in diameter and its greatest depth is 30 mm. Such a depression is usually not developed in sauropods, but is present in prosauropods, where it marks the insertion of the *m. brachialis* [5]. By comparison with prosauropods, its occurrence in the Thai form can be considered as a plesiomorphic feature. On the whole, however, the humerus from Khok Hin Poeng is quite distinct from prosauropod humeri and confirms the occurrence of sauropods in the Late Triassic Nam Phong Formation of Thailand, already revealed by the discovery of *Isanosaurus atavipachi* [3]. Unfortunately, the newly discovered material from Khok Hin Poeng does not allow significant comparisons with the type of *Isanosaurus atavipachi*; the humerus, in particular, is not known

in the latter. Consequently, it is not possible to decide whether the newly found large sauropod belongs to *Isanosaurus attavipachi*. Considering that the type of the latter is an incomplete skeleton of a not fully grown individual [3], the size discrepancy between the two specimens would not preclude inclusion in the same taxon, but at the moment no definite conclusion can be reached in this respect.

The humerus is not an especially useful bone for systematic assignment in sauropods. Nevertheless, some comparisons can be made, using, for instance, the comparative drawings provided by McIntosh [16] and Martin et al. [15]. The bone from Khok Hin Poeng differs from both the very long and slender humeri of the brachiosaurids and from the very short and robust ones of *Apatosaurus* and, especially, *Opisthocoelicaudia*. Comparisons with early sauropods are not particularly revealing. In *Vulcanodon karibaensis*, from the basal Jurassic of Zimbabwe [5], the humerus is incompletely known, and does not seem to be as much expanded proximally as the specimen from Thailand. In *Shunosaurus lii*, from the Middle Jurassic of China [26], the proportions of the humerus are not very different from those of the Thai form, although the proximal and distal expansions appear somewhat greater, but the shaft appears to be less craniocaudally flattened. *Kotasaurus yamanpalliensis*, from the possibly Early Jurassic Kota Formation of India, resembles the Thai form in that its humerus apparently has a depression on the cranial face of the distal expansion [24].

4. Size estimates and comparisons

Although the shape of the humerus from Khok Hin Poeng does not provide much evidence as to the position of this dinosaur within the Sauropoda, its size is worth a brief discussion. Its dimensions are as follows:

Length: 1040 mm.

Width of proximal expansion (estimated): 360 mm (34% of length).

Minimum width: 180 mm (17% of length).

Width of distal expansion: 310 mm (29% of length).

The proportions of this humerus are generally similar to those of the humeri of several species of *Camarasaurus* given by McIntosh et al. [17], the lengths of which range from 435 to 1130 mm.

With a length of slightly more than 1 m, this humerus clearly belongs to a large sauropod. Table 1 shows the length of the humerus in various large prosauropods and sauropods, for comparison.

The Thai specimen thus turns out to be much longer than the humeri of even the largest melanorosaurid

Table 1. Length of the humerus in various prosauropods and sauropods. When measurements for several specimens were given by the authors listed, the greatest length was chosen.

Tableau 1. Longueur de l'humérus chez divers prosauropodes et sauropodes. Quand les mesures de plusieurs spécimens sont données par les auteurs, la plus grande a été retenue.

| Prosauropoda | |
|---|--------------|
| <i>Euskelosaurus browni</i> [23] | 453 mm |
| <i>Jingshanosaurus xinwaensis</i> [27] | 470 mm |
| <i>Melanorosaurus readi</i> [10] | 500 mm |
| <i>Riojasaurus incertus</i> [1] | 783 mm |
| Sauropoda | |
| <i>Apatosaurus louisae</i> [9] | 1150 mm |
| <i>Barosaurus africanus</i> [13] | 990 mm |
| <i>Brachiosaurus altithorax</i> [22] | 2040 mm |
| <i>Brachiosaurus brancai</i> [13] | 2130 mm |
| <i>Camarasaurus grandis</i> [17] | 1130 mm |
| <i>Diplodocus longus</i> [8] | 1010 mm |
| <i>Euhelopus zdanskyi</i> [25] | 910 mm |
| <i>Kotasaurus yamanpalliensis</i> [24] | 770 mm |
| <i>Omeisaurus tianfuensis</i> [11] | 1080 mm |
| <i>Opisthocoelicaudia skarzynskii</i> [2] | 1000 mm |
| <i>Phuwiangosaurus sirindhornae</i> [15] | 990 mm |
| <i>Shunosaurus lii</i> [26] | 720 mm |
| <i>Tehuelchesaurus benitezii</i> [21] | 1140 mm |
| <i>Vulcanodon karibaensis</i> [5] | circa 700 mm |

prosauropods. Among the sauropods, the Brachiosauridae, which had exceptionally long front limbs, have noticeably longer humeri, up to twice the length of the Thai specimen.

Estimating the total length of a sauropod on the basis of the length of the humerus is not easy, since limb proportions vary rather widely among sauropods. To judge from the shape of the bone from Khok Hin Poeng, there is no reason to use the Brachiosauridae, with their very long forelimbs and slender humeri, as a model. As mentioned above, the proportions of the Thai humerus fall within the range of *Camarasaurus*. Assuming that the Thai sauropod had the same proportions as the specimen of *Camarasaurus grandis* GMNH 101 (Gunma Museum) described by McIntosh et al. [17], which is 13.7 m long, its estimated length was about 12.6 m. This estimate is based on *Camarasaurus*, because of general morphological resemblance between the Thai specimen and humeri of *Camarasaurus*, and of course does not imply any close phylogenetic relationship. Moreover, the skeletal proportions of the Thai form may have been different from those of *Camarasaurus*, so that the total length estimate must be considered as tentative. It should also be considered as relatively conservative: estimates based on other types of sauropods with relatively shorter front limbs, such as *Diplodocus* or *Apatosaurus*, would suggest a greater

overall length; estimates based on the measurements of the *Diplodocus longus* skeleton in the US National Museum [8], or on those of the *Apatosaurus louisae* skeleton in the Carnegie Museum [9], thus give a length of about 20 m. However, it is unlikely that Late Triassic sauropods had proportions reminiscent of *Diplodocus* or *Apatosaurus*, which had especially long necks and tails. What is known of *Isanosaurus attavipachi* [3] indicates that this early and primitive sauropod had relatively short cervical vertebrae. The primitive sauropod *Shunosaurus lii*, from the Middle Jurassic of China, which has relatively short cervical vertebrae and a humerus not unlike the Thai one, can also be used as a basis for a length estimate. According to Zhang [26], the well-preserved specimen T5402 indicates an animal 11 m long, with a humerus 740 mm long. Assuming similar proportions in the Thai specimen, its total length would have been more than 15 m. A more reliable length estimate for the Triassic sauropods of Thailand will have to wait for the discovery of more complete skeletons, but both the estimates based on *Camarasaurus* and those based on *Shunosaurus* indicate that they could reach quite a considerable length, well in excess of 10 m.

5. Conclusions: Size increase in sauropodomorph evolution

The large humerus from Khok Hin Poeng indicates that Late Triassic sauropods had already reached considerable sizes, approaching that of some of the large and robust forms of the Late Jurassic, such as *Camarasaurus*. They appear to have been larger than the largest Late Triassic prosauropods (the Melanorosauridae), which barely reached 10 m in length. This large size is relatively unexpected in such early sauropods. *Vulcanodon karibaensis*, from the Hettangian of Zimbabwe, which was the earliest and most primitive known sauropod prior to the discovery of the Triassic sauropods from Thailand, was a fairly small form by sauropod standards. The estimated length of its humerus [5] is about two thirds that of the humerus from Khok Hin Poeng, and its overall length was probably under 9 m. The Thai specimen shows that the acquisition of very large body size took place earlier in sauropod evolution than was suggested by *Vulcanodon*. Although the dis-

covery of *Isanosaurus attavipachi* suggests that by the Late Norian/Rhaetian the sauropods already had gone through a fairly long evolutionary history [3], the date of appearance of the first sauropods is uncertain. The earliest currently known sauropods being those from the Nam Phong Formation of Thailand, little can be said about size increase in sauropods prior to the Late Norian or the Rhaetian. However, it appears that early sauropodomorphs were small animals: the possibly Early Carnian, or even Ladinian, prosauropods from Madagascar described by Flynn et al. [6], which are the earliest currently known sauropodomorphs, are small animals, with tooth rows about 5 cm in length, suggesting an overall length of about 1 m. *Saturnalia tupiniquim*, from the Carnian of Brazil, was about 1.5 m in length [14]. By Late Norian or Rhaetian times, i.e., some 20 Myr later, some sauropods had reached giant size, as exemplified by the specimen from Khok Hin Poeng. Size increase in Triassic sauropodomorphs thus appears to have proceeded at a comparatively fast pace. It took the other group of herbivorous dinosaurs, the ornithischians, much longer to reach giant, sauropod-like dimensions. The largest known ornithischians were giant hadrosaurs such as the 14 m long *Shantungosaurus* [12], and such gigantic forms did not appear until the Late Cretaceous. Among carnivorous dinosaurs (Theropoda), very large forms appeared in the Late Jurassic, and even larger ones in the Cretaceous, but theropods never became as bulky as large sauropods. The reasons for the giant size of sauropods are still a matter of discussion [4, 19]. A possible advantage of extremely large size may have been the relative protection it afforded against predators, in animals that had no protective ‘weapons’ such as horns or (except in the case of some titanosaurids) armour. The ability to maintain a relatively stable body temperature thanks to a low surface to volume ratio has also been considered as an advantage of very large size. Whatever the exact physiological and/or ecological factors involved, it seems clear that rapid size increase was a notable feature of the early history of sauropods, and that in this respect their evolution was more rapid than that of other groups of dinosaurs. Although many groups of dinosaurs tended toward large size in the course of their evolutionary history, sauropods not only reached the largest size, but also attained it faster than any other group.

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