



# HISTOLOGICAL STUDY OF SAUROPOD DINOSAUR BONES FROM THE HISTORIC UPPER JURASSIC HOWE QUARRY (WYOMING, USA): DETERMINATION OF AN AGE RANGE FOR EVERY SPECIMEN

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## BULLET-POINTS ABSTRACT

### KEYWORDS:

*Howe Quarry;  
sauropods;  
bone histology;  
age range;  
ontogenetic stage.*

- Morphological and Histological study on sauropod bones from the Howe Quarry with the determination of an age range and ontogenetic stage for every specimen.
- Eight specimens studied, one fibula and seven ribs: three skeletally mature, three sexually mature, one juvenile and one undetermined.
- Useful and generally applicable method without a taxonomical assignment.

## INTRODUCTION

The Howe Quarry, in the vicinity of Shell (Wyoming, USA), is one of the richest occurrences of sauropod bones in the Upper Jurassic Morrison Formation (Foster, 2007). Excavations in 1934 by the American Museum of Natural History (AMNH, New York, USA) (Brown, 1935; Bird, 1985) and in 1990 and 1991 by the Sauriermuseum Aathal (Switzerland) (Ayer, 2000) produced approximately 3000-4000 bones. The majority of the recovered specimens are sauropod dinosaurs, most of them belonging to the clade Diplodocidae. The aim of this study was to analyze sauropod bones collected from the Howe Quarry, both morphologically and histologically.

## MATERIALS AND METHODS

It was decided to focus on long bones and ribs, as these are the most useful bones to identify histological features. Long bones, developing an isometric growth pattern, can be analyzed to determine the size and mass of the specimens, whereas ribs, which do not have an isometric growth pattern, make it easier to identify histological features (Tschopp & Mateus, 2013). The fossils were firstly measured and scanned to obtain a digital database. After that, they were sectioned and then studied under the optical microscope to identify histological characteristics such as LAGs (Lines of Arrested Growth), EFS (External Fundamental System)

and osteons. LAGs are growth lines representing the former surface of the bone. The EFS is a structure visible under the surface of the bone, made of very closely spaced LAGs, which indicates the skeletal maturity of the specimen (Fig. 1).

The eight specimens analyzed by this study correspond to seven ribs (AMNH FARB 30786, AMNH FARB 30791, AMNH FARB 30901, AMNH FARB 33141, AMNH FARB 33144, AMNH FARB 33145, AMNH FARB 33147) and one fibula (AMNH FARB 30785). Following two previous studies on the same subject, histological data were gathered from the ribs counting LAGs, generations of secondary osteons and searching for the presence of an EFS.

## RESULTS AND DISCUSSIONS

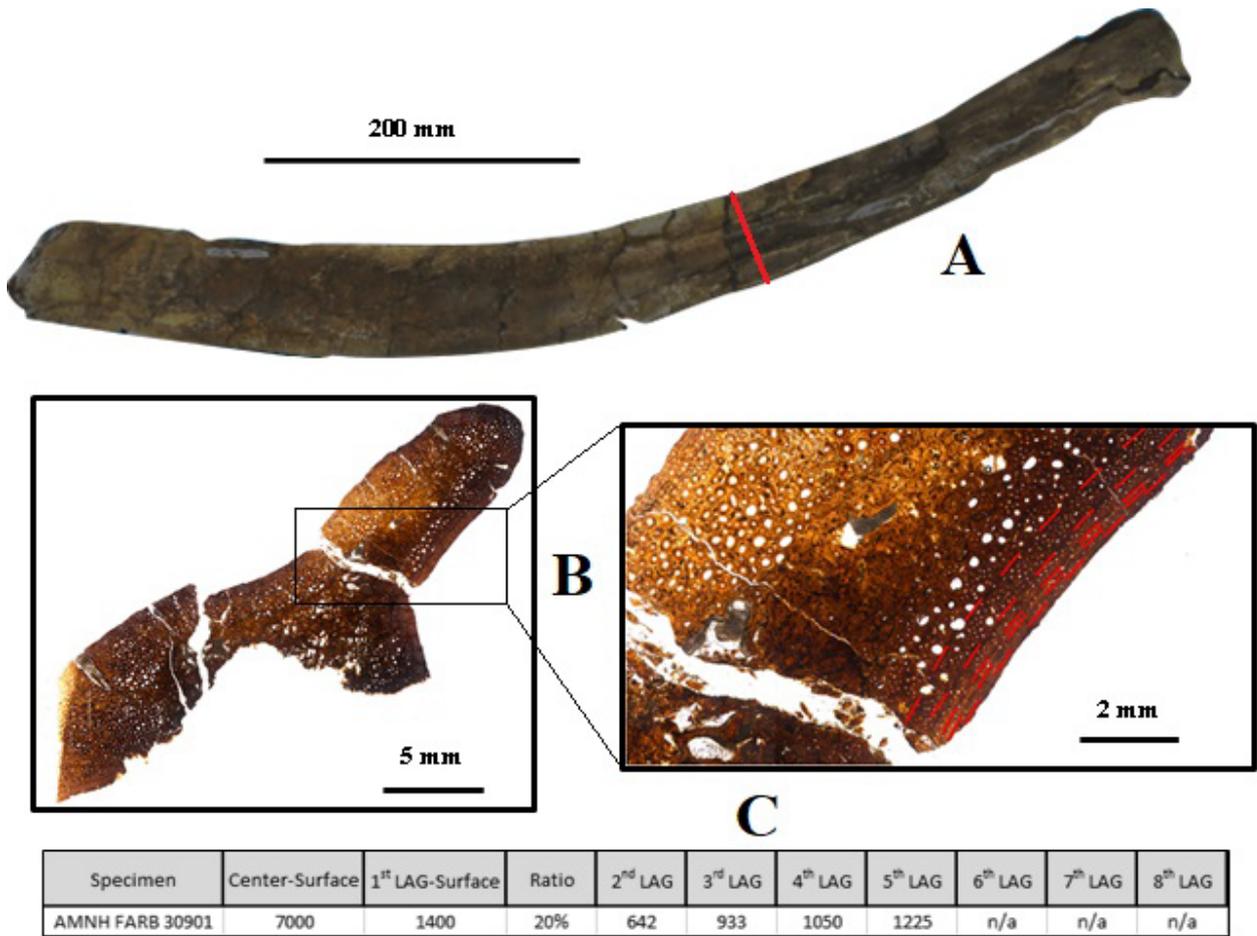
At least three different ontogenetic stages could be identified among the sampled specimens: 1) early juveniles; 2) sexually but not skeletally mature adults; and 3) skeletally mature adults. Curves showing the development of LAGs, depending on their distance from each other and their distance from the center of the bone, were produced and compared showing, in some cases, a perfect overlap of the data, resulting in curves from different specimens following an identical trend. The results witness a diversified fossil assemblage characterized by the presence of individuals with different ages and ontogenetic development (Figs. 2-3).

Resulting histological data were then compared with Waskow & Sander (2014) to obtain more information

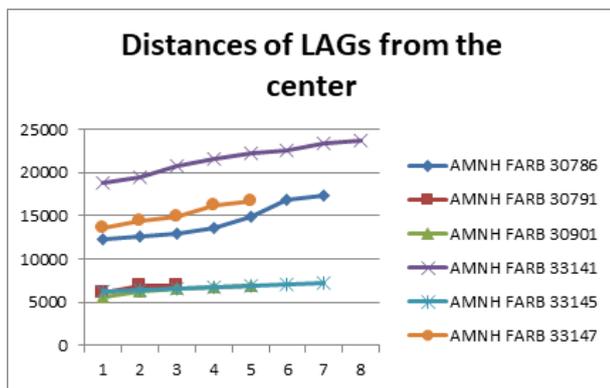
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How to cite: Moretti et al. (2018). Histological study of sauropod dinosaur bones from the historic Upper Jurassic Howe Quarry (Wyoming, USA): determination of an age range for every specimen. *Fossilia*, Volume 2018: 23-25. <https://doi.org/10.32774/FosRepPal.20.1810.092325>

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**Fig. 1.** Resume of images and data of AMNH FARB 30901. **A**, 3D scan of the dorsal rib (the red line indicates sectioning of following frames). **B**, thin section (and detail on the right) illustrating LAGs (in red), the EFS is only visible under optical microscope, white holes represent osteons. **C**, data gathered from this specimen.

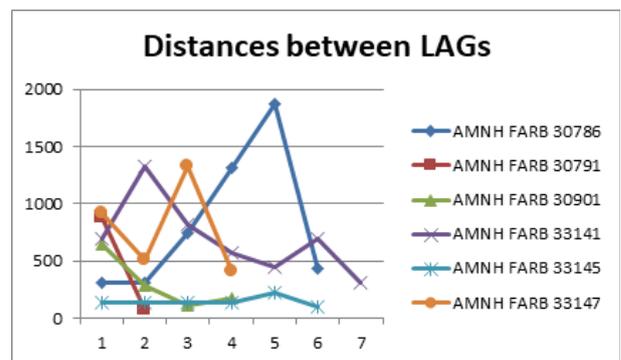


**Fig. 2.** General graphic representing the distances of LAGs from the center of the rib in all the studied specimens.

on the degree of skeletal maturity of every specimen.

The only specimen which could be associated with a very juvenile stage is AMNH FARB 33144. It does not present any LAG or secondary osteons. These histological characteristics are in accordance with the maximum diameter of the rib, which is the smallest among the studied specimens.

Three specimens, AMNH FARB 30786, AMNH FARB 30791 and AMNH FARB 33145, were in-



**Fig. 3.** General graphic representing the distances between LAGs in all the studied specimens.

terpreted as sexually mature, an intermediate stage between juveniles and skeletally mature individuals. They all have LAGs and osteons but do not show any sign of an EFS.

The last three specimens, AMNH FARB 30901, AMNH FARB 33141 and AMNH FARB 33147, were identified as skeletally mature for the presence of an EFS.

The fibula AMNH FARB 30785 did not give any hi-

stological information, therefore it was not possible to classify it in terms of ontogenetic stage.

## CONCLUSIONS

In the end, it was possible to divide all the studied specimens in three age ranges and determine the ontogenetic stage for each one of them. It is also possible to say that there are no evidences of dwarf specimens in this association, because the smallest specimen is also the most juvenile. One of the most interesting characteristics of this method is that it was applied without considering the taxonomy of the animal, which is usually difficult to determine from a single bone specimen.

## ACKNOWLEDGEMENTS

Amy Davidson, Verne Lee, Mick Ellison, Carl Mehling, Judy Galkin (all of the American Museum of Natural History) and Cary Woodruff (University of Toronto). Daniel Barta is supported by a Richard Gilder Graduate School Fellowship. E. Tschopp is supported by a Theodore Roosevelt Memorial Fund and Division of Paleontology Postdoctoral

Fellowship. Massimo Delfino (University of Turin) and Annalisa Ferretti (University of Modena and Reggio Emilia).

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Manuscript received 14 July 2018

Received after revision 21 September 2018

Accepted 2 October 2018