# A Late Triassic dinosaur bone, offshore Norway

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A section of bone is described from a well core retrieved from a depth of 2615 m MD (measured depth RKB; 2590 m mean sea level) in the Lunde Formation of the Snorre Oil Field, Norwegian North Sea. The specimen is interpreted to be the metaphyseal region of a limb bone showing radial fibro-lamellar tissue of a type described for *Plateosaurus* from the Late Triassic of Germany. Associated palynomorphs suggest the Norwegian specimen to be from the Early Rhaetian (ca. 202-203 Ma).

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## Introduction

Mesozoic reptiles are known from several localities on Svalbard and from one locality on the Norwegian mainland (Heintz 1964). The former are of Triassic and Jurassic age and include ichthyosaurs and Jurassic plesiosaurs. These are described in the early works by Hulke (1873) and Wiman (1914), but also from more recently work by Persson (1962) and Worsley & Heintz (1977) (for a historical review see Heintz 1964 and Nakrem et al. 2004). Dinosaur tracks are known from several Early Cretaceous localities on Spitsbergen (Lapparent 1960, 1962; Edwards et al. 1978). On the mainland one partially complete ichthyosaur has been described from the Late Jurassic of Andøya (Ørvig 1953; Dalland 1980; Nordborg et al. 1997). As a result of offshore drilling, several bone fragments of plesiosaurs and ichthyosaurs have been found in cores. However, these finds have only been summarily described (Heintz & Sæther 1999).

In 1997 a bone fragment was identified by M. Bergan and J.P. Nystuen in a core from the Snorre Field well 34/4-9S, in the Late Triassic Lunde Formation. The Snorre Field is located in the northern part of the Norwegian North Sea (offshore blocks 34/4 and 34/7; see Fig. 1).

Study of this bone fragment (PMO 207.207, PMO-Paleontological Museum, Oslo) forms the subject of this paper.

## Geological framework

The Lunde Formation occurs in the northern part of a Late Triassic continental basin that covered most of the present North Sea area. Several thousands of meters of fluvial sediments were deposited in this basin during a thermal subsidence phase following Late Permian to Early Triassic rifting (Badley et al. 1988; Nystuen et al. 1989; Steel 1993; Nystuen & Fält 1995). With an approximate width of 400 kms between present mainland Norway and the Shetland Platform, the continental post-rift basin contains the Teist, Lomvi and Lunde formations, and lasted throughout the Triassic until the final depositional stages of the overlying latest Triassic – Early Jurassic Statfjord Formation, when the whole area was flooded during a marine transgression from the north and south in Late Sinemurian - Early Pliensbachian time (Nystuen & Fält 1995). The climate during deposition of the Lunde Formation was semi-arid and highly seasonal, typical for the contemporary palaeogeographic position at 40-50 degrees North latitude (Müller et al. 2004).

The basin was linked to a marine borealic seaway, probably located some 10's to 100's km to the north (Nystuen & Fält 1995) and to sediment source areas composed of Archaean gneisses, Caledonian metamorphic rocks and Devonian sandstones (Mearns et al. 1989; Nystuen & Fält 1995; Knudsen 2001). These sources located on the Shetland Platform and in the SW part of Norway and shed out into a vast alluvial plain in the Triassic North Sea. The Snorre oil field is described in Jorde & Diesen (1992) and Bergan & Diesen (2002).

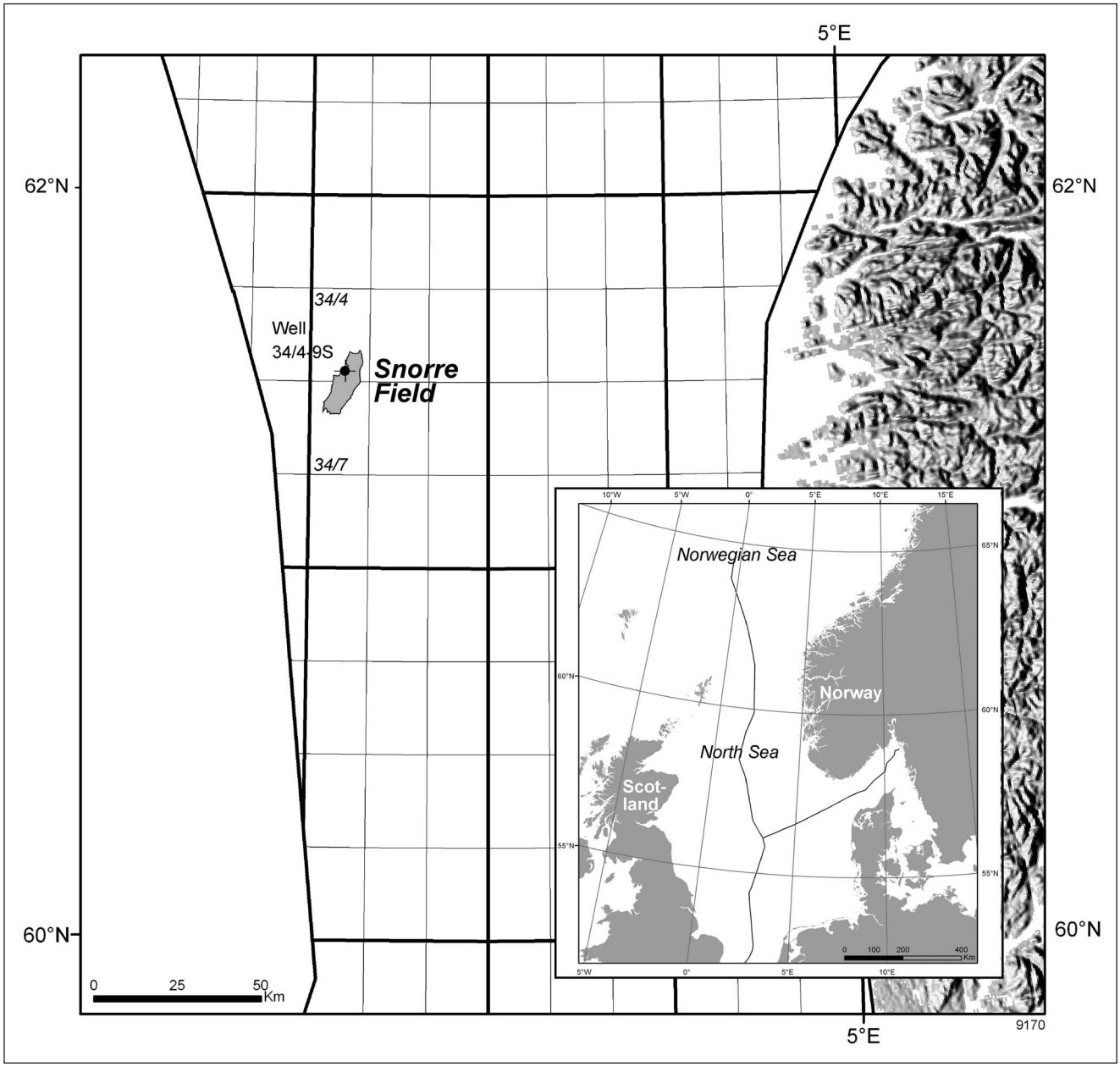


*Fig. 1. Map of the area with Snorre well 34/4-9S location.*

## Location, depositional environment and age

The bone slice was discovered during the description of a core retrieved in February 1997 from well 34/4-9S in the north-western part of the Snorre Field (61°30'45"N and 2°10'18"E). It occurs in a reddish-brown, mudstone interval referred to as the upper member of the Lunde Formation ( reservoir zone L03 ; cf. Diesen et al. 1995) (Fig. 2). The mudstone is composed of dominantly compound and cumulative paleosols that formed in distal to fluvial channels in a flood-plain forming the uppermost part of the upper member of the Lunde Formation (Müller 2003). The paleosols are characterized by carbonate nodules, pedogenic mud aggregates and slickensides, mottling, root traces and mud cracks. The paleosol type is similar to modern vertisols forming in semi-arid areas with seasonal precipitation, commonly with dry periods lasting 4-8 months (Dudal & Eswaran 1988; Driese & Mora 1993; Müller et al. 2004). The presence of root traces suggests that the flood-plain was covered with small trees and bushes, vegetation suitable for herbivorous animals living on the alluvial plain.

Beds containing the bone specimen belong to the younger of two palynomorph assemblages containing the spore *Kreuselisporites reissingeri* thought to indicate an early Rhaetian rather than a Norian age (Eide 1989), corresponding approximately to an age of 202-203Ma according to the time scale of Gradstein et al. (2005).

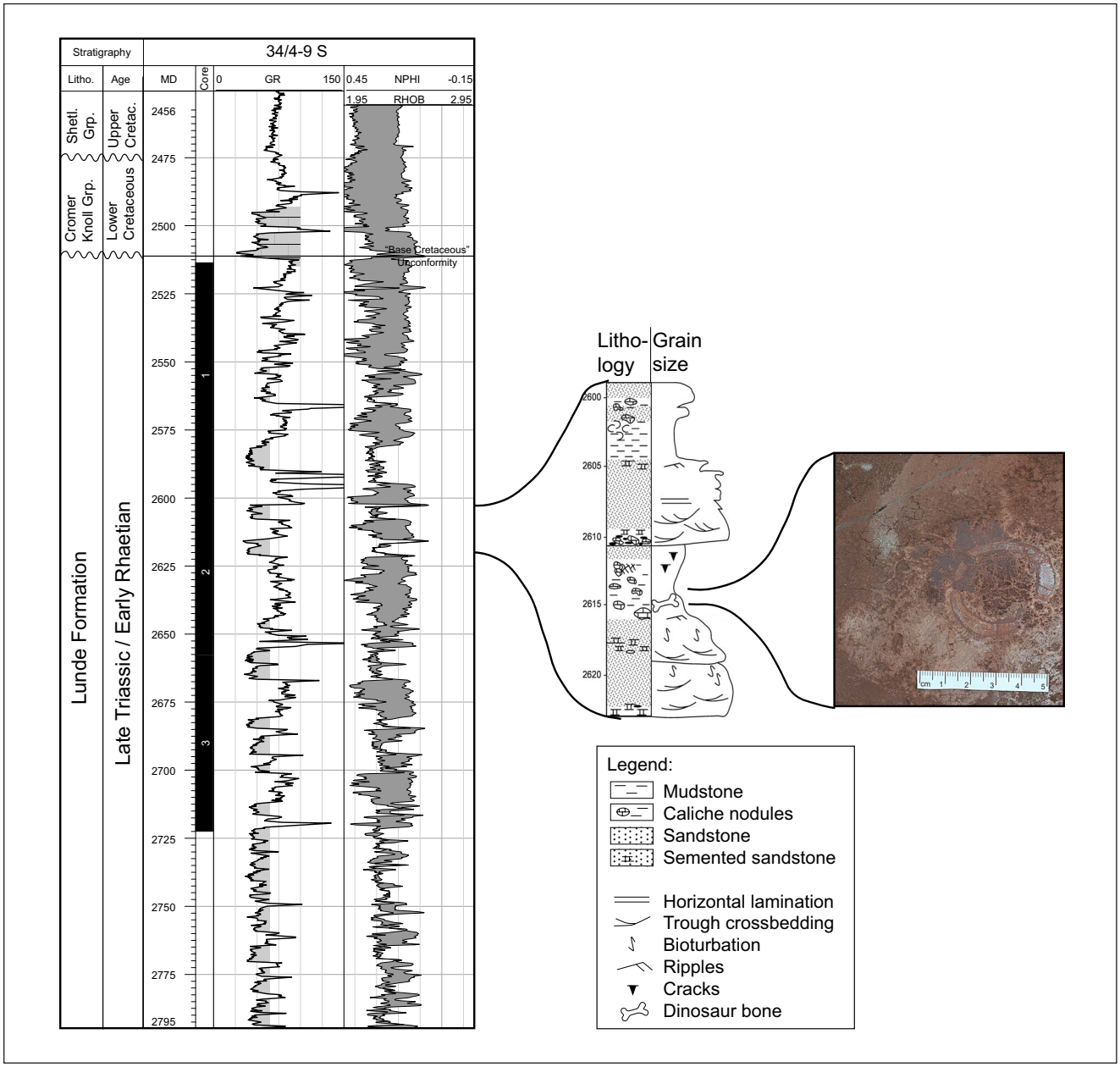


*Fig. 2. Section of the sedimentological log from well 34/4-9S in the Snorre Field with the position of the bone shown in detail.*

## Histological description

The described specimen (PMO 207.207) has been slightly crushed but is clearly a cross section of a long bone. The bone is about 40 mm in diameter, well preserved and whitish to light grey in color. The medullary cavity lined with cancellous bone, and the cortical compacta or cortex, are both identifiable. The compact bone exhibits two different histological compositions, an inner dense tissue or fibro-lamellar bone and an outer more vascular part (Fig. 3). The fibro-lamellar bone is present in almost all dinosaurs and is a characteristic feature of fast growing animals. In thin sections it shows two lines of arrested growth (LAGs) in its outer part. The bone shows a relatively high vascular density and therefore represents fast growing bone tissue (Klein 2004). The osteons in the tissue are mostly rounded and primary. There are only a few known examples of remodeling with secondary osteons.

The outer zone of the bone is extremely vascular and is identical to what Klein (2004) called the radial fibro-lamellar bone tissue (RFB). This she describes as *"The bone tissue is still the fibro-lamellar complex, but the kind of vascularization is different. It consists of parallel radial vascular canals with a very high density. Although this bone type shows such a high vascularization, which indicates a very rapid growth rate, the tissue is deposited cyclically and delimited by normal lines of arrested growth. It occurs always in the outer cortex areas. Due to*

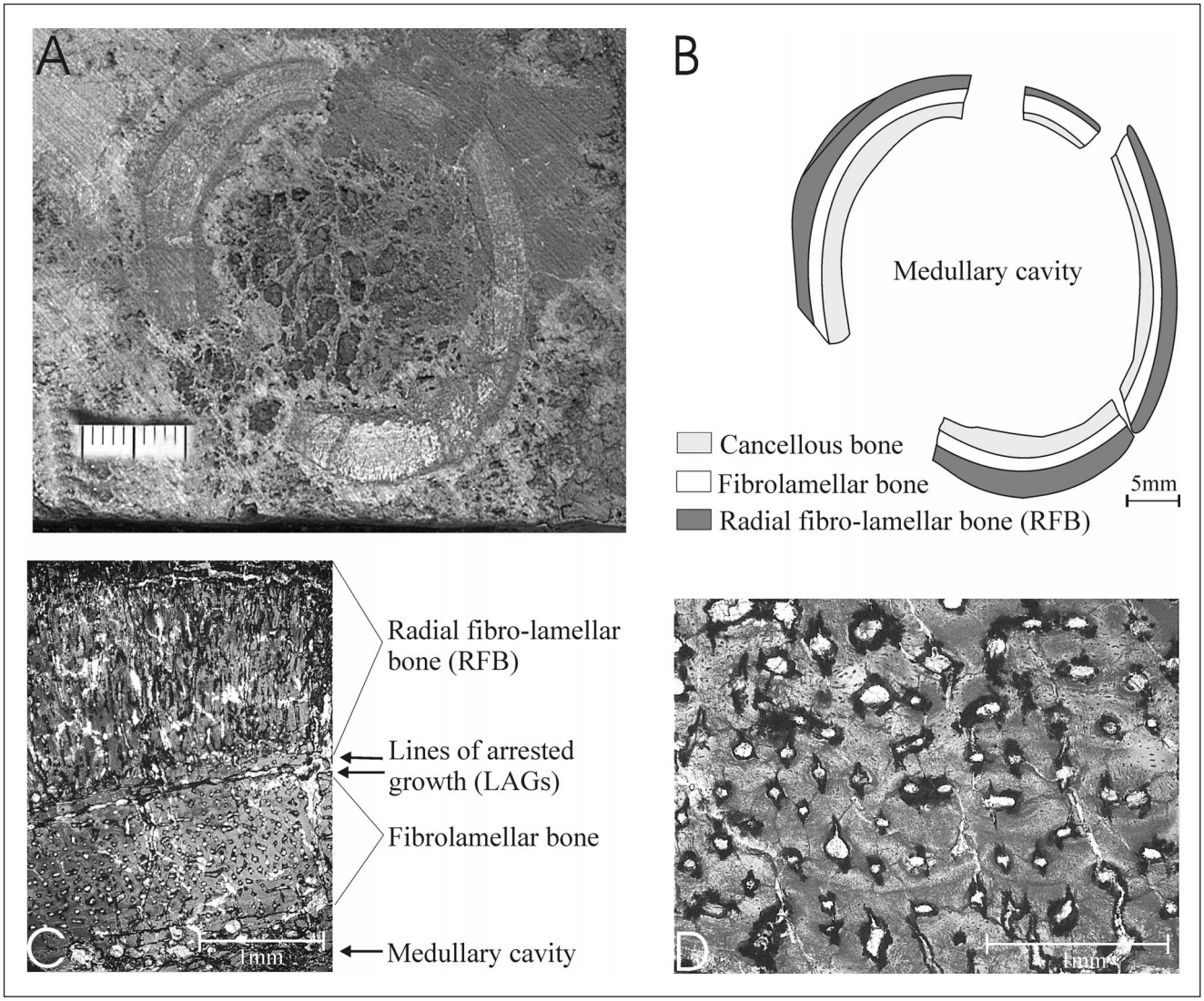


*Fig. 3. Detail of bone found at 2615 meter in well 34/4-9S. B. Schematic drawing of section. C. Thin section of bone showing three different histologies. D. Detail of the fibro-lamellar bone, showing few secondary osteons.*

*the predominance of radial vascular canals in this tissue, it is called in the following radial fibro-lamellar bone tissue (RFB)"* Klein (2004:53). The radial fibro-lamellar bone tissue forms from a third to more than a half of the thickness of the Snorre Field bone in PMO 207.207. The very thin cortex suggests that the section is from the metaphyseal region of the bone, not the middle of the shaft.

## Discussion

Histological studies of Triassic terrestrial tetrapods began with the work of Seitz (1907) and Gross (1934), whilst later dinosaur histology includes that on the prosauropods by Ricqlès (1968), Reid (1990), Chinsamy (1993a), and Klein (2004), the theropods by Chinsamy (1993b) and Starck & Chinsamy (2002) and the mammal-like reptiles by Ricqlès (1969) and Ray & Chinsamy (2004).

Fibro-lamellar bone tissue is very common in dinosaurs, birds and mammals but the radial fibro-lamellar bone tissue (RFB) seen in the thin sections is so far only described in two dinosaur genera. Klein (2004) described RFB in the tibia, femur, vertebra and ischium of the prosauropod *Plateosaurus engelhardti*, and it is associated with very rapid growth and high rates of bone deposition. Similar tissue (referred to as "highly porous radially vascularized bone") is also known from the Cretaceous ornithischian dinosaur *Psittacosaurus mongoliensis* (Erickson & Tumanova 2000). The terminology of Klein (2004) is followed here since the present bone histology can be directly compared with that figured by her (Klein 2004, figs. 3D,H).

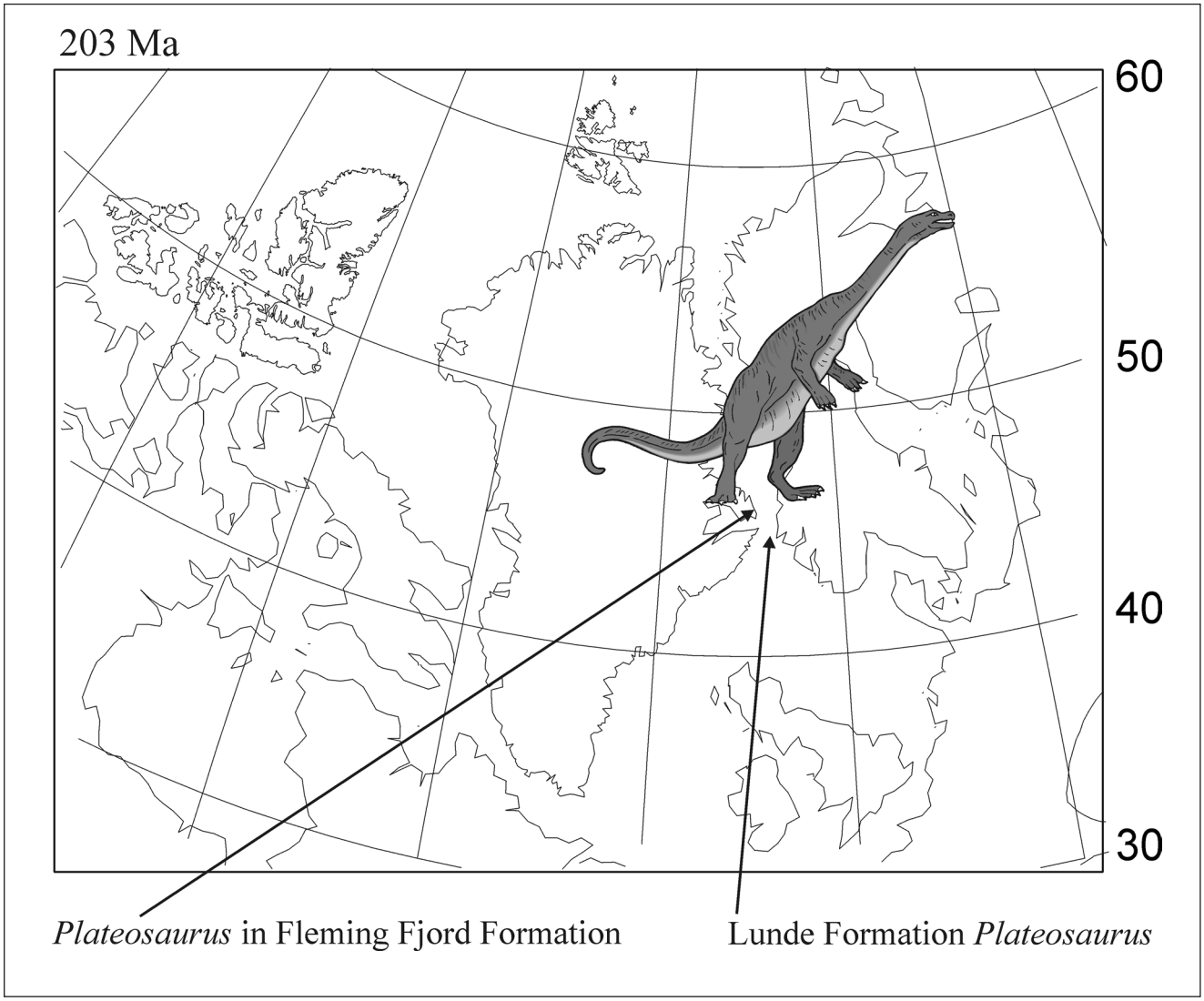


*Fig. 4. Paleogeographic reconstruction showing the position of the Snorre Field and the East Greenland localities.*

The size of the bone fragment and general appearance causes us to interpret this as a prosauropod limb bone. Prosauropods are the most common dinosaurs of the Norian (Late Triassic) and are also important in the Early Jurassic. *Plateosaurus* is a fairly large and well known prosauropod dinosaur (adults about 6-10 m long). It was first described by von Meyer (1837) and has since become one of the best known early dinosaurs following excavations between 1911-1932 at Trossingen, near Tübingen, Germany (Sander 1992). These excavations uncovered a huge accumulation of articulated, partial to complete skeletons of this late Norian prosauropod. It was this material that Klein (2004) used to describe the histology of *Plateosaurus engelhardti*. Interestingly, the prosauropods are the first known high-browsing terrestrial herbivores (Galton & Upchurch 2004) and could have fed up to 4 meters above the ground (Galton 1986).

## Correlation with other known terrestrial localities

Several famous terrestrial vertebrate localities of Norian to Rhaetian age are known around the world (Zawiskie 1986). In North America, Early - Middle Norian terrestrial faunas come from the middle Chinle Formation and Newark Supergroup, whilst in Germany they are known from the Keuper Stubensandstein and Knollenmergel. The faunas are somewhat provincial, but they have certain elements in common. The European localities contain an abundance of prosauropods (Sander 1992) and turtles, while the North American fauna is dominated by metoposaurs, phytosaurs and aetosaurs (Lucas 1998).

Late Norian to Rhaetain European faunas include a variety of sphenodontids and primitive mammals in

addition to dinosaurs, crocodilomorphs, labyrinthodonts and thecodonts. The North American faunas are characterized by a relatively high abundance of theropod dinosaurs (Lucas 1998).

The closest terrestrial vertebrate localities to the Snorre Field, when palaeogeographical reconstructions are taken into consideration (Fig. 4), are those from Upper Triassic outcrops in East Greenland, such as the Fleming Fjord Formation (Jenkins et al. 1995). Here, the depositional environment is similar to that of the Lunde Formation. However, the biostratigraphy is uncertain and both invertebrates and palynomorphs only indicate that the formation spans most of the Carnian, Norian and Rhaetian. Jenkins et al. (1995) described a predominantly European assemblage containing *Plateosaurus*, theropods, turtles, mammals, aetosaurs, pterosaurs, labyrinthodont amphibians and fishes from the Ørsted Dal and Malmros Klint members of the Fleming Fjord Formation, and assigned the Ørsted Dal Member to be of Norian age based on the tetrapods. Lucas (1998) correlated this with the Stubensandstein of Germany.

## Conclusion

The bone found in the Late Triassic upper member of the Lunde Formation in core from well 34/4-9S in the Snorre Field in the northern North Sea represents a prosauropod longbone. Although the assignment of the present material to the Early Rhaetian, based on pollen and spores is imprecise, the histology of the skeletal fragment is so like the German Norian material of the prosauropod dinosaur *Plateosaurus* that we assign it with confidence to this genus. This is the first find of any dinosaur bone from Norwegian territory.

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## References

Badley, M.E., Price, J.D., Rambech Dahl, C. & Agdestein, T. 1988: The structural evolution of the northern Viking Graben and its bearing upon extensional models of basin formation. *Journal of the Geological Society, London 145*, 455-472.

Bergan M. & Diesen G.W. 2002: Snorre Field. *In* A. Armour (ed.): *The Millennium Atlas. The Petroleum Geology of the Central and Northern North Sea*, 122-124.

Chinsamy, A. 1993a: Bone histology and growth trajectory of the prosauropod dinosaur *Massospondylus carinatus* (Owen). *Modern Geology 18*, 319-329.

Chinsamy, A. 1993b: Image analysis and the physiological implications of the vascularisation of femora in Archosaurs. *Modern Geology 19*. 101-108.

Dalland, A. 1980: Mesozoic sedimentary succession at Andøy, northern Norway, and relation to structural development of the north Atlantic area. *Canadian Society of Petroleum Geologists Memoir 7*, 563-584.

Diesen, G.W., Edvardsen, A., Nystuen, J.P., Sverdrup, E. & Tollefsrud, J.I. 19 1995: Gepophysical and geological tools and methods used for reservoir characterization and modelling of the Snorre Field - North Sea, Norway. *In* Miyazaki H. (ed.): *Reservoir Characterization: Integration of Geology, Geophysics and Reservoir Engineering*, The third JNOC-TRC International Symposium February 20-23, 1995 at the TRC, Chiba, Japan, Technology Research Center Special Publication No. 5, Japan National Oil Corporation, 69-90.

Driese, S.G. & Mora, C.I. 1993: Physico-chemical environment of pedogenic carbonate formation in Devonian vertic paleosols, central Appalachians, U.S.A. *Sedimentology 40*, 199-216.

Dudal, R. & Eswaran, H. 1988: Distribution, properties, and classification of Vertisols. *In* Wilding, L.P. & Puentes, R.. (eds.): Vertisols: *Their Distribution, Properties, Classification, and Management*. College Station, Texas, Texas A & M University Printing Center, 1-22.

Edwards, M.B., Edwards, R. & Colbert. E.H. 1978: Carnosaurian footprints in the Lower Cretaceous of eastern Spitsbergen, *Journal of Paleontology 52*, 940-941.

Eide, F. 1989: Biostratigraphic correlation within the Triassic Lunde Formation in the Snorre area. *In* Collinson, J.D. (Ed.), *Correlation in Hydrocarbon Exploration*. Norwegian Petroleum Society (NPS). Graham & Trotman, London, 291-297.

Erickson G.M. & Tumanova T.A. 2000: Growth curve of *Psittacosaurus mongoloiensis* Osborn (Ceratopsia: Psittacosauridae) inferred from long bone histology. *Zoological Journal of the Linnean Society 130*, 551-566.

Galton, P.M 1986: Herbivorous adaptions of dinosaurs. *In* Padian, K. (ed.): *The Beginning of the Age of Dinosaurs - faunal changes across the Triassic-Jurassic boundary.* Cambridge University Press, Cambridge, 203-222.

Galton, P.M. & Upchurch, P. 2004: Prosauropoda. *In* Weishampel, D. B., Dodson, P. & . Osmolska, H. (Eds.), *The Dinosauria*. University of California Press, 232-258.

Gradstein, F.M., Ogg, J.G. & Smith, A.G. (Eds.) 2005: *A Geologic Time Scale 2004*, Cambridge University Press, 610 pp.

Gross, W. 1934: Die Typen des mikroskopischen Knochenbaues bei fossilen Stegocepahlen und Reptilien. *Zeitschrift der Anatomie und Entwicklungsgeschichte 203*, 731-764.

Heintz, N. 1964: Mesozoiske øglefunn fra Norge og Svalbard. Paleontologisk Museum Oslo, 40 pp.

Heintz, N. & Sæther, T. 1999: Fiskeøgle på Haltenbanken. *Geonytt 1*, 22-23.

Hulke, I. W. 1873. Memorandum on Some Fossil Vertebrate Remains Collected By the Swedish Expeditions to Spitzbergen in 1864 & 1868. *Bihang till Kongliga Svenske Vetenskapsakademiens Handlingar (KVAH)* 1, 9, 3-11.

Jenkins F.A., Shubin, N.H., Amaral, W.A., Gatesy, S.M., Schaff, C.R., Clemmensen, L.B., Downs, W.R., Davidson, A.R., Bonde, N. & Osbæck, F. 1995: Late Triassic continental vertebrates and depositional environments of the Fleming Fjord Formation, Jameson Land, East Greenland. *Monographs on Greenland, Geoscience* 32, 25 pp.

Jorde K. & Diesen G. W. 1992: The Snorre Field: A Major Field in the Northern North Sea. *In Giant Oil and Gas Fields of the Decade 1978-1988 1992 AAPG Special Publication*, 407 - 416

Klein, N. 2004: B*one histology and growth of the prosauropod dinosaur Plateosaurus engelhardti MEYER, 1837 from the Norian bonebeds of Trossingen (Germany) and Frick (Switzerland)*. Dissertation zur

Erlangung des Doktorgrades der Mathematisch-Naturwissenschaftlichen Fakultät der Rheinischen Friedrich-Wilhelms-Universität Bonn. http://hss.ulb.uni-bonn.de/diss_online/math_nat_fak/2004/klein_nicole/0466.pdf.

Knudsen, T.L. 2001: Contrasting provenance of Triassic/Jurassic sediments in the North Sea Rift; a single zircon (SIMS), Sm-Nd and trace element study. *Chemical Geology 171*, 273-293.

Lapparent, A.F. de 1960: Decouverte de traces de pas de dinosauriens dans le Cretace de Spitsberg. *Comptes rendus de l'Académie des sciences. Paris 251*, 1399-1400

Lapparent, A.F. de. 1962: Footprints of Dinosaur in the Lower Cretaceous of Vestspitsbergen - Svalbard. *Norsk Polarinstitutts årbok 1960*, 14-21.

Lucas, S.G. 1998: Global Triassic tetrapod biostratigraphy and biochronology. *Palaeogeography, Palaeoclimatology, Palaeoecology 143*, 347-384.

Mearns, E.W., Knarud, R., Ræstad, N., Stanley, K.O., & Stockbridge, C.P. 1989: Samarium-neodymium isotope stratigraphy of the Lunde and Statfjord Formations of Snorre Oil Field, northern North Sea. *Journal of the Geological Society, London 146*, 217-228.

Meyer, H.H. von. 1837: Mitteilung an Prof. Bronn *(Plateosaurus engelhardti)*. *Neues Jahrbuch für Geologie und Paläontologie* 1837, 316.

Müller, R. 2003: *Basin infill dynamics of the Triassic of the northern North Sea and Mid-Norwegian shelf: control of autogenic and allogenic factors*. Thesis Doctor Scientarium, Department of Geology, Faculty of Mathematics and Natural Science, University of Oslo, Norway. ISSN 1501-7710, No. 301.

Müller, R., Nystuen, J.P. & Wright, V. P. 2004: Pedogenic mud aggregates and paleosol development in ancient dryland river systems: criteria for interpreting alluvial mudrock origin and floodplain dynamics. *Journal of Sedimentary Research 74*, 537-551.

Nakrem, H.A., Hurum, J.H. & Dallmann, W. 2004: Protection of articulated marine Jurassic reptiles of Svalbard. *ProGEO News 4*: 1-4

Norborg, A.K., Dalland, A., Heintz, N. & Nakrem, H.A. 19 1997: Catalogue of Jurassic/Cretaceous fossils and sedimentary rocks from Andøya, northern Norway. Collections in the Paleontological Museum, Oslo, the Bergen Museum, the Tromsø Museum, and the Swedish Museum of Natural History, Stockholm. *Contributions from the Paleontological Museum, University of Oslo 406*, 77 pp.

Nystuen, J.P. & Fält, L.-M. 1995: Upper Triassic-Lower Jurassic reservoir rocks in the Tampen Spur area, Norwegian North Sea. *In* S. Hanslien (Ed.), Petroleum: *Exploration and Exploitation in Norway.* Norwegian Petroleum Society (NPF), Special Publication 4, Elsevier, Amsterdam, 135-179.

Nystuen, J.P., Knarud, R. & Jorde, K. 1989: Correlation of Triassic to Lower Jurassic sequences, Snorre Field and adjacent areas, northern North Sea. *In* J.D. Collinson (Ed.), *Correlation in Hydrocarbon Exploration*. Norwegian Petroleum Society (NPS). Graham and Trotman, London, 273-289.

Persson, P.O. 1962: Plesiosaurians from Spitsbergen. *Norsk Polarinstitutt, Årbok 1961*, 62-68.

Ray, S., & Chinsamy, A. 2004. Diictodon feliceps (Therapsida, Dicynodontia): bone histology, growth and biomechanics. *Journal of Vertebrate Paleontology 24*, 180-194.

Reid, R.E.H. 1990: Zonal "growth rings" in dinosaurs. *Modern Geology 15*, 19-48.

Ricqlès, A. de. 1968: Recherches Palèohistologiques sur les os longs des tetrapodes. I.- Origine du tissu osseux plexiforme des dinosaurians sauropodes. *Annales de Paléontologie 54*, 133-145.

Ricqlès, A. de. 1969: Recherches Palèohistologiques sur les os longs des tetrapodes. II.- Quelques observations sur la structure des os longs des thériodontes. *Annales de Paléontologie 55*, 1-52.

Sander, P.M. 1992: The Norian Plateosaurus Bonebeds of central Europe and their taphonomy. *Palaeogeography, Palaeoclimatology, Palaeoecology 93*, 255- 299.

Seitz, A.L. 1907: Vergleichende Studien über den makroskopischen Knochenbau fossiler und rezenter Reptilien. *Nova Acta Academiae Caesareae Leopoldino-Carolinae Germanicae Naturae Curiosorum* 87: 230-370.

Starck, J.M. & Chinsamy, A. 2002: Bone microstructure and developmental plasticity in birds and other dinosaurs. *Journal of Morphology 254*, 232-246.

Steel, R. 1993: Triassic-Jurassic megasequence stratigraphy in the Northern North Sea: rift to post-rift evolution. *In* Parker, J.R. (Ed.), *Petroleum Geology of Northwest Europe*. Proceedings of the 4th Conference, 1, The Geological Society, London, 299-315.

Wiman, C. 1914: Ein Plesiosauriewirbel aus dem jüngeren Mesozoicum Spitsbergens. *Bulletin of the Geological Institution of the University of Uppsala 12*, 202-204.

Worsley, D. & Heintz, N. 1977: The stratigraphical significance of a marine vertebrate fauna of Rhaetian age, Kong Karls Land. *Norsk Polarinstitutt Årbok 1976*, 69-81.

Zawiskie, J.M. 1986: Terrestrial vertebrate faunal succession during the Triassic. *In* Kevin Padian (Ed.), *The Beginning of the Age of Dinosaurs - faunal changes across the Triassic-Jurassic boundary*, Cambridge University Press, Cambridge, 353-362.

Ørvig, T. 1953: On the Mesozoic field of Andøya 1. Notes on the Ichthyosaurian remains collected in 1952, with remarks on the age of the vertebrate bearing beds. *Acta Borealia, A. Scientia 4*, 32 pp.