



ELSEVIER

Available online at www.sciencedirect.com

SCIENCE @ DIRECT®

Annales de Paléontologie 91 (2005) 329–335

ANNALES
DE

PALÉONTOLOGIE

<http://france.elsevier.com/direct/ANNPAL/>

Article original

The implications of the numerical dating of the Messel fossil deposit (Eocene, Germany) for mammalian biochronology

Conséquences de la datation de l'âge numérique du gisement de Messel (Eocène, Allemagne) pour la biochronologie des mammifères

Jens Lorenz Franzen ^{a,b,c,*}

^a Jakobistrasse 10, 79822 Titisee-Neustadt, Germany

^b Forschungsinstitut Senckenberg Frankfurt am Main, Frankfurt am Main, Germany

^c Naturhistorisches Museum Basel, Basel, Switzerland

Received 17 January 2005; accepted 25 April 2005

Available online 10 October 2005

Abstract

Radiometric dating of volcaniclastic material from a borehole below the Middle Eocene Messel Formation leads to a revised numerical age of the Messel fossil deposit. Accordingly, the Grauvian/Geiseltalian boundary moves up from about 49 to 47.5 ma. The consequences of this change as well as the necessity of the Geiseltalian European Land Mammal Mega-Zone (ELMMZ)¹ for mammalian biochronology are discussed.

© 2005 Elsevier SAS. All rights reserved.

Résumé

La datation radiométrique du matériel volcanoclastique provenant d'un sondage sous la Formation de Messel a permis la révision de l'âge numérique du gisement de Messel. De cette façon la limite

* Tel.: +49 7651 933 773.

E-mail address: jlfrazen@t-online.de (J.L. Franzen).

Grauvien/Geiseltalien est ramenée d'environ 49 à 47,5 millions d'années. Les conséquences de ce changement et la nécessité du terme « Geiseltalien » pour la biochronologie des mammifères sont discutées.

© 2005 Elsevier SAS. All rights reserved.

Zusammenfassung

Die radiometrische Datierung von vulkaniklastischem Material, das unterhalb der mitteleozänen Messel-Formation erbohrt wurde, führt zu einer revidierten Schätzung des numerischen Alters der Fossillagerstätte Messel. Entsprechend verschiebt sich die Grauvium/Geiseltalium-Grenze von ca. 49 auf 47,5 MJ. Die Konsequenzen dieser Verschiebung sowie die Notwendigkeit des Begriffes Geiseltalium für die Säugetier-Biochronologie werden diskutiert.

© 2005 Elsevier SAS. All rights reserved.

Keywords: Mammalian biochronology; Eocene; Europe; Messel; Numerical dating

Mots clés : Biochronologie mammaliene ; Éocène ; Europe ; Messel ; Datation numérique

Schlüsselworte: Säugetierchronologie; Eozän; Europa; Messel; Numerische Datierung

1. Introduction

In recent decades the former opencast mine Grube Messel has become one of the most renowned fossil localities of the world. Besides a rich flora, and many invertebrate and vertebrate fossils, it has produced about 45 mammal species up to now. [Franzen and Haubold \(1985, 1986\)](#) have chosen Messel as reference locality for the Eocene mammal level MP 11 (MP = Mammalia Paleogene) situated just above the lower boundary of the European Geiseltalian Land Mammal Megazone. A drilling program undertaken in 2001 jointly by the “Forschungsinstitut Senckenberg”, the “Institut für Geowissenschaftliche Gemeinschaftsaufgaben” and the “Hessisches Landesamt für Umwelt und Geologie” recognized the Eocene Lake Messel as the result of a maar explosion ([Harms, 2002; Harms et al., 2003](#)). Volcaniclastic material from a borecore offered the opportunity for radiometric dating. Here, the consequences of this dating for mammalian biochronology are discussed.

2. The determination of the $^{40}\text{Ar}/^{39}\text{Ar}$ age

The $^{40}\text{Ar}/^{39}\text{Ar}$ age of 47.8 ± 0.2 ma for the Messel phreatomagmatic origin derives from a basalt fragment out of the volcanic chimney below the deposits of Eocene Lake Messel ([Mertz et al., 2004](#)). It was recovered from the borecore of the research drilling at Messel in 2001 at a depth of 267.8 m. The dating was carried out at the Berkeley Geochronology

¹ In order to avoid any confusion with the term age as a basic unit of geochronology, and to express its real biochronologic meaning, [Steininger \(1999\)](#) has proposed to replace the term European Land Mammal Age (ELMA) by ELMMZ.

Center after treating the sample with fast neutrons at the TRIGA reactor of the Oregon State University. The sample consisted of several grains of groundmass enriched in nepheline and plagioclase. These grains were tempered using a CO₂ laser. Then the argon was separated from the evaporated gas fractions. Its isotopic composition was determined by a mass spectrometer of the type Mass Analyzer Products 215-50. The age of the sample was calculated on the basis of the ⁴⁰Ar/³⁹Ar relation. Any bias due to excess argon is excluded. The plateau age (Fleck et al., 1977) of 47.8 ± 0.2 ma is ca. 1.5% younger than the integral age of the basalt of 48.5 ± 0.2 ma.

3. Discussion

The Geiseltalian was introduced by Franzen and Haubold (1985, 1986) as a European Land Mammal Age. It was officially accepted by a meeting of European mammalian paleontologists held in 1987 at Mainz (Schmidt-Kittler, 1987). Biochronologically its beginning was defined by the first appearance of the equid *Propalaeotherium*, the artiodactyl *Messelobunodon* and the primate *Europolemur*, while its upper boundary was marked by the first appearance of the artiodactyls *Haplomeryx* and *Pseudamphimeryx*, and of the primates *Microadapis*, *Adapis* and *Anchomomys* (Franzen and Haubold, 1986). This definition is now revised due to new discoveries. The equid *Lophiotherium* is added as a newcomer at the beginning of the Geiseltalian (Franzen, 1999) while the primate *Caenopithecus* appears at the beginning of the Robiacian. *Leptadapis* is substituted for *Adapis* while *Anchomomys* occurs already within the Geiseltalian (Godinot, 1998).

The Geiseltalian refers to the former lignite mine Geiseltal near Halle a. d. Saale (Germany). It comprises the MP levels 11–13 (Franzen, 1987)². Escarguel et al. (1997) have chosen the Geiseltal UK (UK = “Unterkohle” = lower coal seam) as reference locality of MP 11. Here, we return to Messel as original reference locality (Franzen and Haubold, 1985; 1986) because it is not known if the Geiseltal UK is exactly as old as Messel. Escarguel et al. (1997: 447–448, 450) calculated for the Geiseltal UK a numerical age of 46.28 ± 0.341 ma, versus 47.14 ± 0.18 ma for Messel.

Franzen and Haubold created the Geiseltalian for three reasons. One was to have a term for the hitherto unnamed time interval between the European Land Mammal Mega-Zones (ELMMZs) Robiacian above (Savage and Russell, 1983: 100–104, 126), and Grauvian below (Savage in Savage and Russell, 1977). The second reason was that the “Lutétien” of the Paris Basin sensu De Lapparent (1883), i.e. the Calcaire Grossier, is in its lower part marine. It transgresses in an eastern and south-eastern direction over the fluviolacustrine sediments of the Grauvian (“Cuisien”). Therefore, a hiatus exists at the base of the “Luté-

² The term “mammal level” is synonymous with “Säugetierstratigraphisches Niveau” (Franzen, 1968: 160) or “niveau repère” (Hartenberger, 1969: 57). It should not be confused with “mammal zone” sensu Mein (1975, 1989). While a mammal zone refers to first or last appearances of mammal taxa (FADs or LADs) a level of mammalian chronology refers to the fauna of a certain reference locality whose stage of evolutionary development is regarded typical for a certain time. This way, the boundary problem is avoided and levels may be intercalated as well as deleted as knowledge increases. Such a method corresponds with that of physicists subdividing the continuum of time. Contrary to the numerals of a clock, however, in mammalian biochronology the distances between the different levels are variable (see Fig. 1).

MA	EPOCH	STAGE	ELMMZ	MP-ZONE	LEVEL	NALMA
34	Late Eocene	Priabonian	Headonian	20	— St. Capraise	Duchesnean
35				19	— Escamps	
36				18	— La Débruge	
37				17b	— Perrière	
38				17a	— Fons 4	
39				16	— Robiac	
40	Bartonian	Robiacian		15	— La Livinière 2	Uintan
41				14	— Egerkingen alpha + beta	
42				13	— Geiseltal oMK	
43				12	— Geiseltal uMK	
44				11	— Messel	
45	Middle Eocene	Lutetian	Geiseltalian	10b	— Prémontré	Bridgerian
46				10a	— Grauves	
47				8+9	— Avenay	
48				7	— Dormal	
49						
50						
51	Early Eocene	Ypresian	Neustrian			Wasatchian
52						
53						
54						

Fig. 1. Time table showing a correlation of numerical, marine, and terrestrial biochronologic scales of Europe and North America, including the position of the Geiseltalian (black) versus the Lutetian (gray). Except for Messel and Geiseltal oMK the numerical position of the reference localities of European mammal levels is based on Escarguel et al. (1997). Boundaries of uncertain age between some NALMAs are indicated by gray bars instead of black lines. ELMZZ = “European Land Mammal Mega-Zone” (see footnote 1), NALMA = “North American Land Mammal Age”. Draft and drawing: J.L. Franzen.

Fig. 1. Tableau chronologique montrant la corrélation des échelles numériques ainsi que biochronologiques marines et terrestres de l’Europe et de l’Amérique du Nord. La position du Geiseltalian (en noir) est opposée au Lutétien (en gris). Les datations numériques des gisements repères de l’Europe sont basées sur Escarguel et al. (1997). Les limites incertaines entre quelques NALMAs sont indiquées par des barres grises au lieu des lignes noires. ELMZZ = « European Land Mammal Mega-Zone », NALMA = « North American Land Mammal Age » (voir note de bas de page 1). Conception et réalisation : J.L. Franzen.

tien” (Franzen and Haubold, 1986; Duprat, 1997: 318, Fig. 1). Steurbaut (1988) estimated its duration at about 4 ma. The third reason for creating the Geiseltalian was the fact that the sedimentary sequence of the Geiseltal covers the whole time interval between the Grauvian below and the Robiacian above.

However, there are more reasons to avoid the term “Lutétien” in the terrestrial realm and to replace it by the Geiseltalian. At first, the Lutetian became a global standard for the time interval between the Bartonian above and the Ypresian below (Jenkins and Luterbacher, 1992). The stratotype is no longer the Calcaire Grossier. It is now situated about 50 km north of Paris in a continuous marine section (Blondeau, 1981). Numerically, this time interval ranges from about 49.0 ma (Ypresian/Lutetian boundary) to 41.2 ma (Lutetian/Bartonian boundary; Berggren et al., 1995).

The $^{40}\text{Ar}/^{39}\text{Ar}$ age of 47.8 ± 0.2 ma for the Messel phreatomagmatic origin derives from a basalt fragment out of the volcanic chimney below the deposits of Eocene Lake Messel. Thus it represents an age older than the Messel Formation and its fossils. The fossiliferous layers investigated up to now are situated at about 2/3 height of the lake sediments. Taking the sedimentation rate of the lake of ca. 0.15 m/ka (Goth, 1990: 71) as well as its maximum

thickness of ca. 225 m into account (Harms et al., 2003: 142), the age of the fossiliferous layers must be some hundreds of thousands of years younger, hence ca. 47 ma³. With this age on the one hand, and the numerical dating of the Eckfeld locality at 44.3 ± 0.4 ma on the other (Mertz et al., 2000), it becomes possible to estimate the Geiseltalian Land Mammal Mega-Zone numerically. Messel is situated slightly above its lower boundary, while Eckfeld is correlated with Bouxwiller and Geiseltal oMK, hence closely below the upper boundary (Franzen, 1993, 1994). Consequently, the Geiseltalian ranges from about 47.5 to 43.5 ma (Fig. 1).

Evidently, the Geiseltalian and the Lutetian are not synonymous. The Lutetian does not correspond with the time gap between the Grauvian and the Robiacian. Therefore, it cannot serve at the same time as the world standard of marine stratigraphy and, with a different meaning and temporal duration, as an ELMMZ.

Two examples demonstrate how confusing such a mixing of marine and terrestrial terms can be. Hooker (1996: 170) wondered about the presence of the helaletid *Hyrachyus* aff. *stehlini* suggesting an MP 10 age (Grauvian) in the Earnley Formation E4, which is marine and early Lutetian. Hooker supposed “in this case, the MP11 faunas of Messel and the Geiseltal Unterkohle, where another species of *Hyrachyus*, *H. minimus*, occurs, might not belong to the earliest Lutetian.” Hooker was right, but only the numerical dating of Messel which elevates the Grauvian/Geiseltalian boundary from 49.0 to 47.5 ma solves the problem principally. The late Grauvian is not below the Lutetian but contemporaneous with the early Lutetian. There is a difference of about 2.5 ma between the lower boundaries of the Geiseltalian and the Lutetian. It is exactly this time interval into which *Hyrachyus* aff. *stehlini* from the Earnley Formation belongs, and which corresponds with the late Grauvian and the early Lutetian at the same time.

Another case is the mammal fauna of Prémontré. This fauna comes from the sands of the uppermost “Cuisien” which correspond in age with the late Grauvian. The fossil bearing layer is situated just below the glauconitic facies of the basal “Lutétien” (Dégremont et al., 1985: 11–13, Fig. 1; Sudre and Erfurt, 1996: 393). Its numerical age was estimated at 48.4 ma (Duprat, 1997: 325), hence younger than the former Grauvian/Geiseltalian boundary. With the lower boundary of the Geiseltalian moving up from 49 to 47.5 ma, such an age no longer contradicts a position of Prémontré within the late Grauvian. Also the alleged presence of *Europolemur* in the fauna of Prémontré (Louis, 1996: 99) does not contradict such a position because Louis mentioned that genus only with a question mark. It may be a transitional form. In any case, Prémontré is considered older than Messel because the artiodactyl *Eurodexis russelli* from that locality displays an evolutionary stage more primitive than so-called *Messelobunodon* sp. from Messel, which is transitional to *Eurodexis ceciliensis* from the upper part of the middle coal seam (oMK) of the Geiseltal (Sudre and Erfurt, 1996: 402).

4. Conclusions

The Geiseltalian is the European Land Mammal Mega-Zone filling in the gap between the ELMMZs Robiacian above and Grauvian below. With the numerical dating of the Mes-

³ Interestingly, already Escarguel et al. (1997: 447) calculated the numerical age of Messel at 47.14 ± 0.18 ma on the basis of biochronological evaluations of evolutionary chronoclines of the chewing areas.

sel phreatomagmatic origin at 47.8 ± 0.2 ma leading to an estimate of the age of the fossil deposit of ca. 47 ma, the lower boundary of the Geiseltalian moves up from about 49 to ca. 47.5 ma. Thus, it indicates a time range of the Geiseltalian from ca. 47.5 until 43.5 ma. Consequently, the Geiseltalian is contemporaneous with only part of the Lutetian, which represents the time interval from 49.0 until 41.2 ma. Moreover, the Lutetian is a stage of marine stratigraphy and the correlation of terrestrial mammal localities with the marine sequence is open to question except where marine and continental strata are directly intercalated.

Acknowledgements

Thanks go to Fritz F. Steininger (Forschungsinstitut und Naturmuseum Senckenberg, Frankfurt am), Dietrich Mertz (Mainz University), and Kenneth D. Rose (The Johns Hopkins University, Baltimore) for critical discussions. Kenneth D. Rose also improved the English.

References

- Berggren, W.A., Kent, D.V., Swisher III, C.C., Aubry, M.-P., 1995. A revised cenozoic geochronology and chronostratigraphy. In: Berggren, W.A., Kent, D.V., Aubry, M.-P., Hardenbol, J. (Eds.), *Geochronology, Time Scales, and Global Stratigraphic Correlations: A Unified Temporal Framework for an Historical Geology*. Society for Sedimentary Geology, Tulsa, Special Publication 54, pp. 129–212.
- Blondeau, A., 1981. Lutetian. *Bulletin d'Information des Géologues du Bassin de Paris* 2, 167–180.
- Dégremont, E., Duchaussois, F., Hautefeuille, F., Laurain, M., Louis, P., Tétu, R., 1985. Paléontologie : Découverte d'un gisement du Cuisien tardif à Prémontre (Aisne). *Bulletin d'Information des Géologues du Bassin de Paris* 22, 11–18.
- De Lapparent, A., 1883. *Traité de géologie*. 1. Édition F. Savy, Paris.
- Duprat, M., 1997. Les faciès à mammifères (MP 6 à MP 16) dans le Nord-Est du Bassin de Paris (France) : argumentation du modèle tectono-sédimentaire des dépôts paléogènes. In: Aguilar, J.-P., Legendre, S., Michaux, J. (Eds.), *Actes du Congrès BiochroM'97. Mémoires et Travaux de l'École Pratique des Hautes Études*. Institut de Montpellier 21, pp. 315–336.
- Escarguel, G., Marandat, B., Legendre, S., 1997. Sur l'âge numérique des faunes de mammifères du Paléogène d'Europe Occidentale, en particulier celles de l'Éocène Inférieur et Moyen. In: Aguilar, J.-P., Legendre, S., Michaux, J. (Eds.), *Actes du Congrès BiochroM'97. Mémoires et Travaux de l'École Pratique des Hautes Études*, Institut de Montpellier 21, pp. 443–460.
- Fleck, R.J., Sutter, J.F., Elliot, D.H., 1977. Interpretation of discordant $^{40}\text{Ar}/^{39}\text{Ar}$ age spectra of Mesozoic tholeiites from Antarctica. *Geochimica Cosmochimica Acta* 41, 15–32.
- Franzen, J.L., 1968. Revision der Gattung *Palaeotherium* Cuvier, 1804 (Palaeotheriidae, Perissodactyla, Mammalia). Albert-Ludwigs-Universität, Freiburg i.Br., pp. 1–181 (Dissertation, 2 volumes).
- Franzen, J.L., 1987. Mammalian reference levels MP 11–13. *Münchner Geowissenschaftliche Abhandlungen* (A) 10, 24–25.
- Franzen, J.L., 1993. Das biostratigraphische Alter der Fossil Lagerstätte Eckfelder Maar bei Manderscheid (Eifel). *Mainzer naturwissenschaftliches Archiv* 31, pp. 201–214.
- Franzen, J.L., 1994. Neue Säugerfunde aus dem Eozän des Eckfelder Maares bei Manderscheid (Eifel). *Mainzer naturwissenschaftliches Archiv* 16, pp. 189–211.
- Franzen, J.L., 1999. *Lophiotherium sondaari* n. sp. (Mammalia, Perissodactyla, Equidae) aus der oberen Unterkohle des Geiseltales bei Halle (Saale). In: Reumer, J.W.F., de Vos, J. (Eds.), *Elephants have a Snorkel! Papers in Honour of Paul Y. Sondaar*. Deinsea 7, pp. 187–194.

- Franzen, J.L., Haubold, H., 1985. The European Middle Eocene of Mammalian Stratigraphy. *Terra cognita* 5, pp. 134.
- Franzen, J.L., Haubold, H., 1986. The Middle Eocene of European Mammalian Stratigraphy. Definition of the Geiseltalian. *Modern Geology* 10, 159–170.
- Godinot, M., 1998. A summary of adapiform systematics and phylogeny. *Folia primatologica* 69, pp. 218–249 (Suppl. 1).
- Goth, K., 1990. Der Messeler Ölschiefer—ein Algenlaminit. *Courier Forschungsanstalt Senckenberg* 131, 1–143.
- Harms, F.J., 2002. Steine erzählen Geschichte(n): Ursache für die Entstehung des Messel-Sees gefunden. *Natur und Museum* 132, 1–4.
- Harms, F.J., Nix, T., Felder, M., 2003. Neue Darstellungen zur Geologie des Ölschiefer-Vorkommens Grube Messel. *Natur und Museum* 133, 140–148.
- Hartenberger, J.-L., 1969. Les Pseudosciuridae (Mammalia, Rodentia) de l'Éocène moyen de Bouxwiller, Egerkingen et Lissieu. *Palaeovertebrata* 3, 27–61.
- Hooker, J.J., 1996. Mammals from the Early (Late Ypresian) to Middle (Lutetian) Eocene Bracklesham Group, southern England. *Tertiary Research* 16, 141–174.
- Jenkins, D.G., Luterbacher, H., 1992. Paleogene stages and their boundaries (Introductory remarks). *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen* 186, 1–5.
- Louis, P., 1996. Recherches de mammifères paléogènes dans les départements de l'Aisne et de la Marne pendant la deuxième moitié du Vingtième Siècle. *Palaeovertebrata* 25, 83–113.
- Mein, P., 1975. Résultats du Groupe de Travail des Vertébrés. In: Senes, J. (Ed.), Report on Activity of R.C.M.N.S. Working Groups. 6. Congress of the Regional Committee of Mediterranean Neogene Stratigraphy. Proceedings 1, Bratislava, pp. 78–81.
- Mein, P., 1989. Updating of MN Zones. In: Lindsay, E.H., Fahrbach, V., Mein, P. (Eds.), European Neogene Chronology, NATO ASI Series (A) 180. Plenum, New York, pp. 73–90.
- Mertz, D.F., Harms, F.-J., Gabriel, G., Felder, M., 2004. Arbeitstreffen in der Forschungsstation Grube Messel mit neuen Egebnissen aus der Messel-Forschung. *Natur und Museum* 134, 289–290.
- Mertz, D.F., Swisher, C.C., Franzen, J.L., Neuffer, O., Lutz, H., 2000. Numerical dating of the Eckfeld maar fossil site, Eifel, Germany: a calibration mark for the Eocene time scale. *Naturwissenschaften* 87, 270–274.
- Savage, D.E., Russell, D.E., 1977. Comments on mammalian paleontologic stratigraphy and geochronology: Eocene stages and mammal stages of Europe and North America. In: Hartenberger, J.L. (Ed.), Faunes de Mammifères du Paléogène d'Eurasie, Colloque international CNRS. *Geobios MS* 1, Montpellier, pp. 47–56 (1976).
- Savage, D.E., Russell, D.E., 1983. Mammalian Paleofaunas of the World. Addison-Wesley Publ. Co, London.
- Schmidt-Kittler, N. (Ed.), 1987. International Symposium on Mammalian Biostratigraphy and Palaeoecology of the European Paleogene—Mainz, February 18th–21st 1987. Münchner Geowissenschaftliche Abhandlungen (A) 10, pp. 1–312.
- Steininger, F.F., 1999. The Continental European Miocene. Chronostratigraphy and Biochronology of the Miocene “European Land Mammal Mega-Zones” (ELMZZ) and the Miocene “Mammal-Zones (MN-Zones)”. In: Rössner, G.E., Heissig, K. (Eds.), The Miocene Land Mammals of Europe. Verlag Dr. Friedrich Pfeil, München, pp. 9–24.
- Sturbaut, E., 1988. New Early and Middle Eocene calcareous nanoplankton events and correlations in middle to high latitudes of the northern hemisphere. *Newsletter on Stratigraphy* 18, 99–115.
- Sudre, J., Erfurt, J., 1996. Les artiodactyles du gisement yprésien terminal de Prémontré (Aisne, France). *Palaeovertebrata* 25, 391–414.