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# Quaternary International

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## Introduction

### The Ensenadan Stage-Age of southern South America: Its stratigraphic, biostratigraphic and chronological implications in present research

When Florentino Ameghino consolidated his stratigraphic scheme for the Pampean Region (Ameghino, 1889), he used such terms as “formación” (formation) and “piso” (stage, used also as “horizonte” -horizon, bed, layer- or “subformación” -“subformation”-). Nowadays, these terms are used to define units for lithostratigraphic and chronostratigraphic classification, respectively. However, for the geologists and paleontologists of the last part of the 19th century and early 20th century, the actual meanings of these terms were different. A “formation” was the name given to a time unit inferred from the fossiliferous content of a bed or other geological unit. A “stage” was a sub-division of the “formation”, using the faunal content as the basis for the definition. Ameghino’s “stages” are conceptually similar to modern biostratigraphic units, such as biozones.

As happened with the unit names used by the European stratigraphers of the time, the names introduced by Ameghino have still full validity in the stratigraphical schemes presently in use in South America (see Cione and Tonni, 2005, and the literature cited therein), although they have been re-defined.

In the 1950s, Frenguelli proposed his own stratigraphic scheme (Frenguelli, 1950, 1957). He applied the terminology first used by Ameghino but gave to it a different meaning, because he recognized “series” as main units, and a set of “pisos” (“stages”) at a subordinate position, that is, units belonging to the chronostratigraphic classification, which had been defined at the beginning of the 1940s (Schenk and Muller, 1941; see below).

Likewise, Jorge L. Kraglievich (1952) established a stratigraphic scheme for southeastern Buenos Aires province, based upon lithostratigraphic units (“Formaciones”, formations). Kraglievich took some of Ameghino’s classical names and re-defined them. Thus, the “horizonte chapalmalense” (“Chapalmalal horizon”) or “piso chapalmalense” (“Chapalmalal stage”) became the “Formación de Chapalmalal” (“Chapalmalal Formation”). In spite of the fact that the lithological characteristics of the units were described, the separation of the units was basically supported by the paleontological content.

In the 1960s, Rosendo Pascual and his collaborators generated a scheme based upon the so-called “Edades-mamífero” (“Land-Mammal Ages”). This scheme was later extended over most of the South American continent (Pascual et al., 1965). As Cione and Tonni (1995a,b) have indicated, the scheme is based mainly upon the ideas of Savage (1962) who had as a fundamental of his work the parataxonomy proposed for the stratigraphy of the North American Land Cenozoic by Wood et al. (1941). This parataxonomic

proposal was (curiously enough) published in the same volume where Schenk and Muller (1941) sustained the differentiation -presently universally accepted- of the lithostratigraphic, chronostratigraphic (“time-stratigraphic” of Schenk and Muller, 1941) and geochronological (“chronologic” as in Schenk and Muller, 1941) units.

The development of a classification that was not recognized in codes or guidelines consequently derived on conceptual isolation of the paleomastozoologists, which became evident in the use and special meaning given to terms such as “unidades biocronológicas” (“biochronological units”), “biocronología” (“biochronology”) and other related ones (Cione and Tonni, 1995a,b). As a practical result of this isolation, a marked lack of interest in biostratigraphical studies emerged, because the definition of the “biochronological” classification units (also known as “geobiotics” in the sense of Simpson, 1971) -the so-called “Mammal Ages”- is based upon the “grade” or “evolutionary level” (Pascual et al., 1965).

The theoretical aspects under which the “Mammal Ages” paradigm was developed were examined by Cione and Tonni in several papers (Cione and Tonni, 1995a,b, 1996, 1999, 2005). In summary, Cione and Tonni (2005) considered that the “Mammal Ages” are not formal units (based upon “stages”) although they recognized that there is no essential distinction between them and the formal ages. The “Mammal Ages” would thus be formal ages defined in a much less precise way than those ages based on stages based upon marine sequences. The South American “Mammal Ages” are in fact supported on poorly defined stages, according to the present requirements of the various existing stratigraphic codes.

The abstraction level increases when the biostratigraphic, chronostratigraphic and geochronological units are taken into consideration. All these units are not “real entities”, that is, they are not true individuals in Nature. However, the biostratigraphic units have certain characteristics (such as the spatial distribution of certain taxa) which may be observed in the field, although there is a large amount of interpretation in their identification. The chronostratigraphic units are based upon a non-observable characteristic (the time of deposition). For this reason, the recognition of such characteristic relies upon the distinction of other units (zones, in an ample sense; CAE, 1992): biozones, magnetozone or absolute datings obtained by radiometric techniques. The geochronologic zones are not stratigraphic units, and they are scientific abstractions that represent the geologic time that cannot be directly observed or measured since, as Simpson (1971: 288) stated, “... only the present is observable”. The “Mammal Ages” are actually relatively

informal ages (see Simpson, 1971; for a different point of view, Walsh, 1998, and Woodburne, 2004). Presently there are certain opinions about the convenience of establishing a single, unique chronological scale, overlooking the differences between the chronostratigraphic and geochronological scales, using the “stage” level and rejecting the “age” category (Odin et al., 2004).

The North American fossil mammals that penetrated into South America during the Late Cenozoic are very valuable elements for the study of this problem. The absence of a careful biostratigraphic scheme had consequences upon the understanding of fundamental processes in the evolution of the South American faunas, such as the extraordinary biogeographic phenomenon that was named the “Great American Biotic Interchange” (GABI; see Cione and Tonni, 2001; Woodburne et al., 2006).

Due to the fact that the old and new stratotypes of the Pliocene and Pleistocene continental units are adequate for biostratigraphic studies (Cione and Tonni, 1995b, 1999; Tonni et al., 1999), it has been proposed to return to the chronostratigraphic/geochronological classification with a stratigraphic base. As a result of this, a new chronological scheme was summarized by Cione and Tonni (2005), which is the one used in the present volume, though with some minor modifications.

In chronological terms, the Ensenadan Stage-Age is, according to the most recent investigations, the period that extends between the Olduvai geomagnetic sub-chron, ca. 1.8 Ma and the base of the Bonarian Stage-Age in Argentina, that is, around 0.5–0.4 Ma, as presented in Soibelzon et al. (2006). Thus, the Ensenadan Stage-Age covers the Middle–Late Early Pleistocene (following the definition of the base of the Quaternary at 2.6 Ma as proposed in the last INQUA Congress, Cairns, Australia, 2007) and the earlier portion of the Middle Pleistocene, accepting that the boundary between the Early and the Middle Pleistocene is located at the Matuyama–Brunhes geomagnetic transition, ca. 0.78 Ma.

## References

- Ameghino, F., 1889. Contribución al conocimiento de los mamíferos fósiles de la República Argentina. *Actas Academia Nacional de Ciencias*, Córdoba 6, 1–1027.
- CAE, 1992. Código Argentino de Estratigrafía. Serie B de la Asociación Geológica Argentina 20, 1–64 (Buenos Aires).
- Cione, A.L., Tonni, E.P., 1995. Chronostratigraphy and “Land mammal-ages”: the Uquian problem. *Journal of Paleontology* 69, 135–159.
- Cione, A.L., Tonni, E.P., 1995. El estratipo de los pisos Montehermosense y Chapadmalalense (Plioceno) del esquema cronológico sudamericano. *Ameghiniana* 32, 369–374 (Buenos Aires).
- Cione, A.L., Tonni, E.P., 1996. Reassessment of the Pliocene–Pleistocene continental time scale of southern South America. Correlation of the Chapadmalal with Bolivian sections. *Journal of South American Earth Sciences* 9, 221–236.
- Cione, A.L., Tonni, E.P., 1999. Biostratigraphy and chronological scale of uppermost Cenozoic in the Pampean area, Argentina. In: Tonni, E.P., Cione, A.L. (Eds.), *Quaternary Vertebrate Paleontology in South America*. Quaternary of South America and Antarctic Peninsula, vol. 12. A.A. Balkema Publishers, Rotterdam, pp. 23–51.
- Cione, A.L., Tonni, E.P., 2001. Correlation of Pliocene to Holocene southern South American and European vertebrate-bearing units. In: Rook, L., Torre, D. (Eds.), *Neogene and Quaternary Continental Stratigraphy and Mammal Evolution*. *Bollettino Società Paleontologica Italiana*, vol. 40(2), pp. 167–173.
- Cione, A.L., Tonni, E.P., 2005. Bioestratigrafía basada en mamíferos del Cenozoico superior de la provincia de Buenos Aires, Argentina. In: R.E. de Barrio, R.O. Etcheverry, M.F. Caballé, E. Llambías (Eds.), *Geología y Recursos Minerales de la Provincia de Buenos Aires*. *Relatorio del XVI Congreso Geológico Argentino*, capítulo, vol. 11, pp. 183–200 (La Plata).
- Frenguelli, J., 1950. Rasgos generales de la morfología y la geología de la provincia de Buenos Aires. *Laboratorio de Ensayo de Materiales e Investigaciones Tecnológicas (LEMIT)*, serie 2 (33), 1–72 (La Plata).
- Frenguelli, J., 1957. Neozoico. *GAEA* 2, 1–115 (Buenos Aires).
- Kraglievich, J.L., 1952. El perfil geológico de Chapadmalal y Miramar, Provincia de Buenos Aires. *Revista Museo Municipal Ciencias Naturales y Tradicional Mar del Plata* 1, 8–37 (Mar del Plata).
- Odin, G.S., Gardin, S., Robszynski, F., Thierry, J., 2004. Stage boundaries, global stratigraphy, and the time scale: towards a simplification. *Carnets de Géologie/Notebooks on Geology* 2, 1–12.
- Pascual, R., Ortega Hinojosa, E.J., Gondar, D., Tonni, E.P., 1965. Las Edades del Cenozoico mamífero de la Argentina con especial atención a aquellas del territorio bonaerense. *Anales de la Comisión de Investigaciones Científicas de la Provincia de Buenos Aires* 6, 165–194 (La Plata).
- Savage, D.E., 1962. Cenozoic geochronology of the fossil mammals of the western hemisphere. *Revista Museo Argentino de Ciencias Naturales “Bernardino Rivadavia” Zoología* 8, 53–67 (Buenos Aires).
- Schenk, H.G., Muller, S., 1941. Stratigraphic terminology. *Geological Society of America Bulletin* 52, 1419–1426.
- Simpson, G.G., 1971. Clasificación, terminología y nomenclatura provinciales para el Cenozoico mamífero. *Revista Asociación Geológica Argentina* 26, 281–297 (Buenos Aires).
- Soibelzon, E., Carlini, A.A., Tonni, E.P., Soibelzon, L.H., 2006. *Chaetophractus vellerosus* (Mammalia: Dasyproctidae) in the Ensenadan (Early–Middle Pleistocene) of the southeastern Pampean region (Argentina). Paleogeographical and paleoclimatic aspects. *Neues Jahrbuch für Geologie und Paläontologie Mh* 12, 734–748.
- Tonni, E.P., Nabel, P., Cione, A.L., Etchichury, M., Tófaló, R., Scillato Yané, G., San Cristóbal, J., Carlini, A.A., Vargas, D., 1999. The Ensenada and Buenos Aires formations (Pleistocene) in a quarry near La Plata, Argentina. *Journal of South American Earth Sciences* 12, 273–291.
- Walsh, S.L., 1998. Fossil datum and paleobiological event terms, paleo-chronostratigraphy, chronostratigraphy and the definition of land mammal “age” boundaries. *Journal of Vertebrate Paleontology* 18, 150–179.
- Wood, H., Chaney, R.W., Clark, J., Colbert, E., Jepsen, G.L., Reeside, J.B., Stock, C., 1941. Nomenclature and correlation of the North America continental Tertiary. *Geological Society of America Bulletin* 52, 1–48.
- Woodburne, M.O. (Ed.), 2004. *Late Cretaceous and Cenozoic Mammals of North America*. *Biostratigraphy and Geochronology*. Columbia University Press, New York, 391 pp.
- Woodburne, M.O., Cione, A.L., Tonni, E.P., 2006. Central American provincialism and the Great American Biotic Interchange. In: Carranza Castañeda, O., Lindsay, E.H. (Eds.), *Advances in Late Tertiary Vertebrate Paleontology in Mexico*, vol. 4. Universidad Nacional Autónoma de México, Instituto de Geología y Centro de Geociencias, *Publicación Especial*, México, pp. 73–101.

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Available online 16 April 2009