Chapter 2
Paleogeographic Background

The paleogeography of South America is a result of the action of a set of major geological forces such as tectonic, variations in the sea level, sea temperatures, and glaciations (Fig. 2.1), which drove the landscape and climatic evolution of this area (Ortiz Jaureguizar and Cladera 2006). Undoubtedly, these changes go hand in hand with the evolution of the biota. The purpose of this section is to integrate the roles played by these episodes, in shaping the geography and physiognomy of South America. We have focused our attention on the events involved in the formation of deposits with birds that are mentioned in this work.

The most complete Cenozoic South American land-bird fossil record is very largely restricted to Southern South America (SSA—the south of the 15° S area sensu Ortiz Jaureguizar and Cladera 2006), and not just to the earliest Cenozoic but to the latest Paleocene. Deposits with bird remains are distributed geographically across Argentina, Uruguay, Chile, Perú, and Brazil with comparatively few Tertiary land-bird bearing localities outside these countries, e.g., Colombia (Rassmusen and Kay 1992).

The Andes, the longest mountain range in the world, is the outstanding geological feature of South America. It consists of 7,000 km of massive continental rocks all crossing from the north to the south Pacific margin of the continent, which has had deep effects on plant and animal dispersion and evolution in South America. In essence, the Andes represents the tectonic upthrust of rock when the South American plate collides with the Pacific plate. The Southern Andes is the oldest, with significant uplift already prior to the Oligocene. The Central Andes has had most of the uplift in the Miocene or later, whereas the Northern Andes is younger, with its major elevations during the Plio-Pleistocene.

The absence of topographic barriers during Late Cretaceous–Cenozoic times, allowed the Atlantic waters to flood wide areas of the extra-Andean regions (Figs. 2.2 and 2.3). These transgressions occur during the Maastrichtian–Danian,

C. P. Tambussi and F. J. Degrange, *South American and Antarctic Continental Cenozoic Birds*, SpringerBriefs in Earth System Sciences, DOI: 10.1007/978-94-007-5467-6_2,

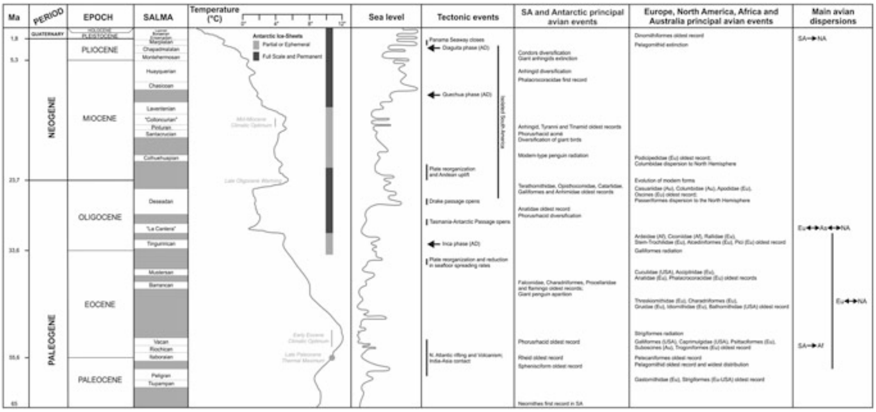

Fig. 2.1 Standard Cenozoic Epochs and some climatic and environmental indicators. Temperature after Zachos et al. (2001), Sea level after Haq et al. (1987), Tectonic events after Pascual et al. (2002) and Zachos et al. (2001), Main avian dispersion after Mayr (2009). *AD* Andean diastrophism; *Af* África; *As* Asia; *Eu* Europe; *NA* North America; *SA* South America

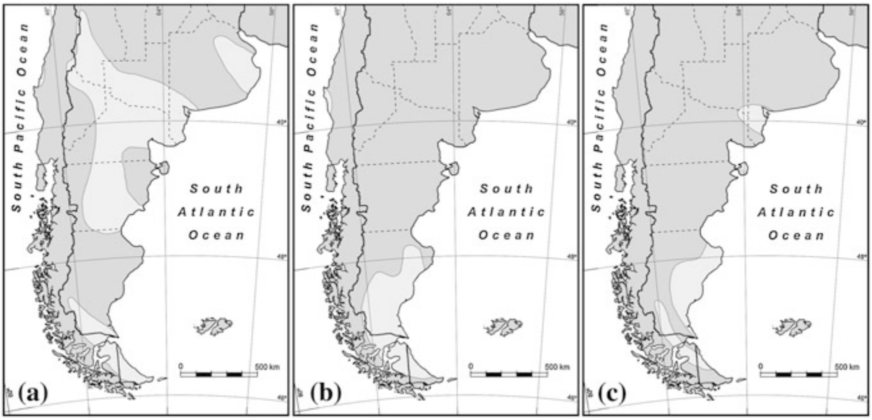

Fig. 2.2 Tentative paleogeography of the marine transgressions in Patagonia between circa 72 and 28 million years ago. **a** Maastrichtian transgression **b** Late Middle Eocene transgression **c** Late Oligocene transgression. Modified from Malumián and Náñez (2011)

Late Middle Eocene, Late Oligocene–Early Miocene, and the Middle Miocene (Malumian and Náñez 2011).

The first transgressive event (Salamancan sea) affected the entire southwest Atlantic basin (Guerstein et al. 2010) that divided southern South America (SSA) into two regions (Fig. 2.2a): the northeastern and the southeastern, respectively (Ortiz Jaureguizar and Cladera 2006). A bridge that linked West Antarctica with SSA still persists revealed by the relationships (sedimentological and faunal) among some Antarctic units (La Meseta, Fossil Hill, and Cross Valley of the James Ross Basin) and the Patagonian units (e.g. Sarmiento, Río Turbio, Cullen, Las

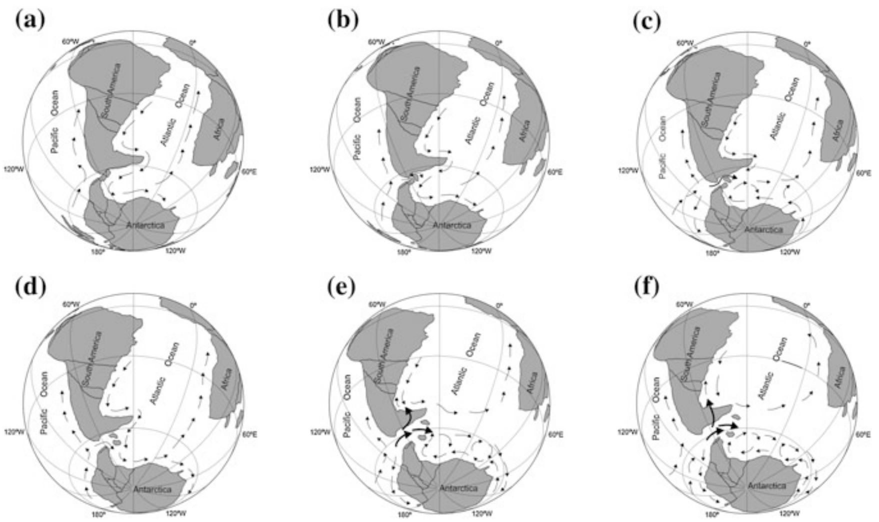

Fig. 2.3 Paleogeographic reconstruction of the major southern landmasses studied in this work, showing the Drake Passage and Atlantic Ocean evolution. **a** 65 Ma, Late Cretaceous–Early Paleocene **b** 51 Ma, Early Eocene Thermal Maximum **c** 34 Ma, Eocene–Oligocene Transition **d** 25 Ma, Late Oligocene **e** 7 Ma, Late Miocene **f** 1.8 Ma, Early Pleistocene. Gray areas indicate landmasses, *black arrows* represents oceanic circulation. Based on Plate Tectonic Reconstructions Online Paleogeographic Mapper (http://www.serg.unicam.it/) and Nullo and Combina (2011)

Flores Formations) (Reguero et al. 2002). During this marine ingression, magmatic and tectonic activity was very low and the epicontinental sea remained in most part of Patagonia until the Danian (Malumian and Náñez 2011).

The areas that were covered by the Salamancan Sea were transformed into flood plains and large lake basins. During the Late Paleocene in Central and Northern Patagonia, large loess plains of pyroclastic sediment developed, while the southernmost tip of Patagonia was covered by water. The Early Paleocene floras were tropical and subtropical forest with mangroves, swampy forest, montagne rain forest, and savanna-sclerophyllous forest, and *Nothophagus* was present but rare (Ortiz Jaureguizar and Cladera 2006; Iglesias et al. 2011). It seems clear that there lived a mix of subtropical with sub-Antarctic elements (Mixed paleoflora, Romero 1986). Toward the end of the Paleocene, there are no records of mangroves.

Deposits of Las Flores (Late Paleocene–Early Eocene) or Salamanca Formations (Early Paleocene) in Patagonia for example, were deposited in these environmental contexts. Almost coeval were deposited farther north, the Itaboraian sediments (Late Paleocene).

The Late Middle Eocene transgression is widely documented in the southern hemisphere but is only recorded in the Austral Basin and offshore of the Colorado Basin in Patagonia. During this time, eustatic sea level was high and seawaters were warm (Zachos et al. 2001), and the occurrence of typical Antarctic foraminifera reveals that temperatures started to fall (Malumián and Náñez 2011). During the Late Eocene, the "Inca Phase" of the Andean orogeny produced a pronounced tectonic deformation both in the Andean basin of Perú and Bolivia, and in southern Chile and Argentina (Tambussi 1989, Ortiz Jaureguizar and Cladera 2006).

To mention one example, the sediments of Laguna del Hunco (Late Paleocene–Middle Eocene) in the northwestern Chubut Province in Argentina were deposited in these environmental contexts, with evidence of high maritime influence on the climate (Wilf et al. 2005).

In Antarctica, during the Early Eocene (50–40 Ma) the separation with Patagonia begins, and the generation of the pre-opening of the Drake Passage that eventually result in physical disconnection between both areas (Scher and Martin 2006). The Drake Passage opened definitively approximately between 32 and 10 Ma (Oligocene–Late Miocene), the Antarctic Circumpolar Current (ACC) began to operate, and concomitantly the Atlantic Ocean temperatures decreased (Figs. 2.1 and 2.3). It has long been recognized that the ACC acts as a barrier, and interrupts the watermass exchange between north to south in the southern oceans (Barnes et al. 2006).

The Late Oligocene and Early Miocene transgressions in Patagonia (Figs. 2.2c and 2.4) produced shallow epicontinental oceans ("Patagonian Sea") with limited extensions, and reveal the existence of cool water current. An updated and detailed description of these transgressions can be found in Bellosi (2010). The Middle Miocene transgression ("Paranean sea") spread to the north of Argentina, covering most of the Chaco-Paraná Basin depression and eastern Patagonia (Hernández et al. 2005) (Fig. 2.4). At Entre Ríos Province (eastern Argentina), the ingressions are represented by the Paraná Formation interpreted as brackish littoral deposits with variable salinity (Aceñolaza and Aceñolaza 2000). At Peninsula Valdes (Chubut Province, Argentina), deposits corresponding to this transgression constitute the Puerto Madryn Formation (Dozo et al. 2010 and the literature cited therein) that consist of cross-bedded sandstones with shells and bioturbated mudstones (Scasso et al. 2001). In the western sectors of SSA, limits of the Miocene transgressions are problematic. For example, the Anta, Río Sali, and San José Formations in northwestern Argentina and Chinches Formation at San Juan Province are unquestionably marine but the relationship between them is much discussed (Hernandez et al. 2005). No bird remains have been recorded so far from the western areas. The continental areas were thus reduced during each transgression, and continental and marine environments coexisted.

Basaltic volcanism in Patagonia began during the Maastrichtian, continued during the Cenozoic, and affected wide areas of Patagonia. The highest volcanic activity occurs from the Paleocene to the Eocene (Panza and Franchi 2002), followed by a Late Oligocene basaltic lava event (29–25 Ma), and a Late Miocene to Early Pliocene one (16–5 Ma) that affected central to southern Patagonia. The lava produced from this volcanic activity added to pyroclastic materials were deposited as part of the continental sequences (Nullo and Combina 2011) that characterized most of the Patagonian paleontological sites. For example, Chichinales and Collun

Fig. 2.4 Tentative paleogeography of the marine Middle–Late Miocene Paranense transgression between 15 and 13 Ma. Modified from Donato et al. (2003)

Curá Formations (Northern Patagonia), Sarmiento, Pinturas, and Santa Cruz Formation (central and southern Patagonia) are continental deposits from the Miocene to Pliocene with high frequency of volcanic elements.

Across all central–southern Patagonia, various continental sequences from Eocene to Early Miocene (35–19 Ma) are visible. The characteristic mammal remains from these sequences ("Toba mammals") are important to understand the evolution of the entire South American continent (Flynn and Swisher 1995; Pascual et al. 2002). In Patagonia, the "Musters Formation", Early Oligocene in age and the coetaneous Abanico Formation in Chile (containing the Tinguiririca fauna) had wide continental distribution with grasslands. The Colhue Huapi Formation (Chubut, Argentina) is another important sedimentary sequence of the same age.

Basaltic lava produced during the strong volcanic activity of the Miocene, covered wide areas of SSA. This episode is associated with the collision of the Chile ridge with the continent. During the Miocene in the area of Santa Cruz and Tierra del Fuego (Argentina) the pyroclastic deposits constitute the Santa Cruz Formation (Nullo and Combina 2002) composed of claystones and tuffs typical of continental environments.

In the Early Miocene, the Panamanian land bridge connected both Americas as a result of the diastrophism as we know as "Diaguita Phase" (Ortiz Jaureguizar and Cladera 2006). In fact, the isthmus consisted as a continuous chain above sea level from Late Eocene until at least Late Miocene times (Montes et al. 2012).

During the fauna interchange, known as Great American Biotic Interchange (GABI), the movement of the fauna from the north to the south was dominant (Woodburne 2010).

During the Late Miocene and associated with the "Quechua Phase" of the Andean orogeny, the areas covered by the "Paranean sea" were succeeded by plains reaching Patagonia, central and northern Argentina, Uruguay, Bolivia, southern Perú, Venezuela and the upper Amazon basin. This marks the beginning of the episode known as the "Age of the southern plains" (Pascual and Bondesio 1982) characterized by high frequency of open environments. In the Pliocene this was the heyday of this event. The Andean cordillera progressively acts as a barrier of the moisture-laden Pacific winds (Ortiz Jaureguizar and Cladera 2006) and the differentiation between Subantarctic and Patagonian biogeographic subregions began.

From the Early Paleocene to the Pleistocene the SSA environments showed a climate change from warm, wet, and nonseasonal (Paleocene to Eocene) to cold and dry (Middle Eocene to Early Oligocene) to seasonal climate (Middle–Late Miocene) (Ortiz Jaureguizar and Cladera 2006; Barreda and Bellosi 2003; Barreda and Palazzesi 2007) (Fig. 2.1).

In a sequence that includes subtropical forest, savanna woodland, park-savanna, and savanna grassland, the Paleocene tropical forests were replaced by the steppes that now strongly characterize the extra-Andean Patagonia (Barreda and Palazzesi 2007) (Fig. 2.5). Iglesias et al. (2007) estimate the annual mean temperatures between 12 and 15 °C and palaeoprecipitations of 1,100 mm during the Paleogene. A continuous global warming is observed during the Paleogene with two pinnacles: the Late Paleocene (LPTM ~56 Ma) and the Early Eocene (EECO ~52 Ma) optima (Fig. 2.1). The global average palaeotemperatures were 10 °C higher than those currently recorded for South America (Zachos et al. 2001) with a smaller difference in temperature from the equator to the poles. The increase in the global temperatures ended in the Eocene in relation to the early opening of the Drake and Tasmania Passages between Antarctica/South America and Antarctica/Australia respectively, which allow the circum-Antarctic circulation, causing global temperature decreases that strongly affected SSA (Figs. 2.1 and 2.3).

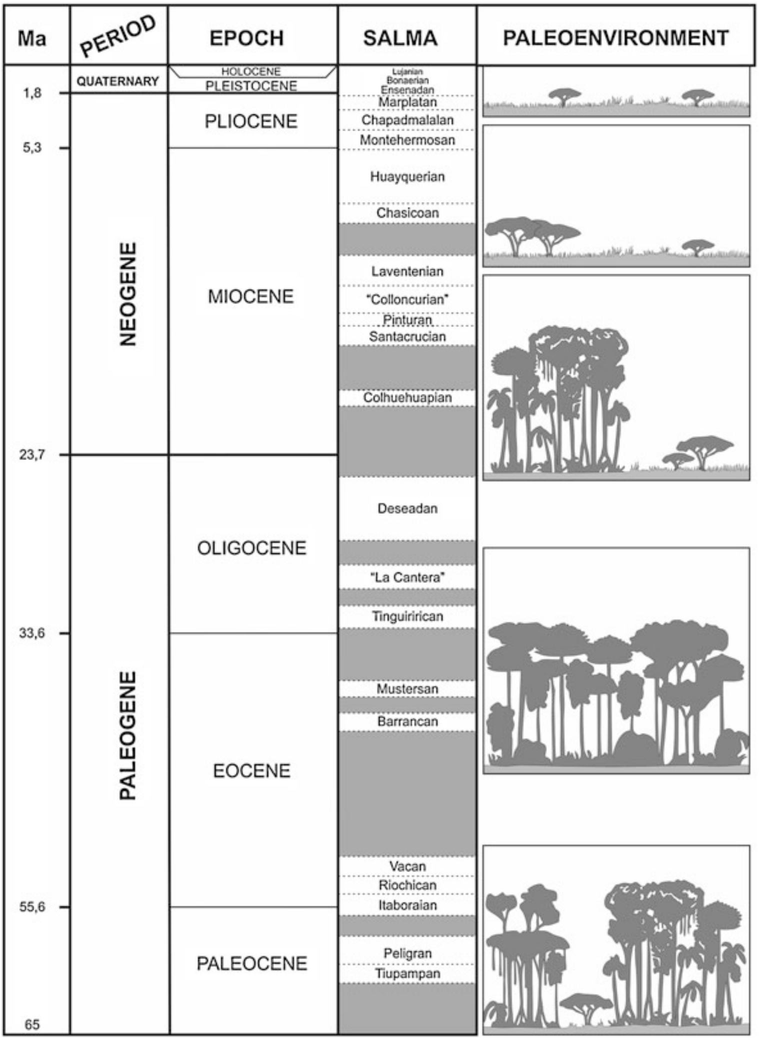

Fig. 2.5 Palaeocene to recent timescale following Gradstein et al. (2004) including timescale for Cenozoic mammalian faunas of South America (SALMA) showing vegetation-type physiognomies under increasingly drier and/or more markedly seasonal climates. Paleoenvironments were taken from Barreda and Palazzesi (2007)

A third event of temperature increase takes place toward the end of Oligocene (Zachos et al. 2001); it is called Late Oligocene warming (LOW, Fig. 2.1).

Since the Oligocene, all biogeographical regions previously recognized migrated to lower latitudes (Iglesias et al. 2011). For the Miocene, the first expansion of herbaceous shrub is noticed and began the development of extreme aridity and seasonality in eastern Patagonia (Fig. 2.5).

For a long time, from the Cretaceous to the Neogene, West Antarctica and SA (Magallanic Region) remained attached forming an independent continent isolated by oceans to the north and east (Nullo and Combina 2011). This isolation in turn, gave a particular footprint to the fauna and flora (Olivero et al. 1990, Marenssi et al. 1994, Shen 1995, Reguero et al. 1998, 2002). From the EECO to the Eocene–Oligocene transition ($\sim$34 Ma) temperature was a descent into an icehouse climate. During this decrease ice began to reappear at the poles, and Antarctic ice sheet began to rapidly expand (Fig. 2.1).

References

Aceñolaza FG, Aceñolaza G (2000) Trazas fósiles del Terciario marino de Entre Ríos (Formación Paraná, Mioceno Medio), República Argentina. Bol Acad Nac Cienc 64:209–233

Barnes DKA, Hodgson DA, Convey P, Allen CS, Clarke A (2006) Incursion and excursion of Antarctic biota: past, present and future. Global Ecol Biogeogr 15:121–142

Barreda V, Bellosi E (2003) Ecosistemas terrestres del Mioceno temprano de la Patagonia central: primeros avances. Rev Mus Arg Cienc Nat 5:125–134

Barreda V, Palazzesi L (2007) Patagonian vegetation turnovers during the paleogene-early neogene: origin of arid adapted floras. Bot Rev 73:31–50

Bellosi E (2010) Physical stratigraphy of the Sarmiento formation (middle Eocene-lower Miocene) at Gran Barranca, central Patagonia. In: Madden RH, Carlini AA, Vucetich MG, Kay RF (eds) The paleontology of Gran Barranca: evolution and environmental change through the middle Cenozoic of Patagonia. Cambridge University Press, New York

Donato M, Posadas P, Miranda-Esquivel DR, Ortiz Jaureguizar E, Cladera G (2003) Historical biogeography of the Andean region: evidence from Listroderina (Coleoptera: Curculionidae: Rhytirrhinini) in the context of the South American geobiotic scenario. Biol J Linn Soc 80:339–352

Dozo T, Bouza P, Monti A, Palazzesi L, Barreda V, Massaferro G, Scasso R, Tambussi CP (2010) Late Miocene continental biota in northeastern Patagonia (Península Valdés, Chubut, Argentina). Palaeogeog Palaeoecol 297:100–109

Flynn J, Swisher C III (1995) Cenozoic South American land mammal ages: correlation to global geochronologies. Soc Sed Geol, Special Pub 54:317–333

Gradstein F, Ogg J, Smith A (2004) A geologic time scale. Cambridge University Press, Cambridge

Guerstein GR, Guler MV, Brinkhuis H, Warnaar J (2010) Mid Cenozoic palaeoclimatic and palaeoceanographic trends in the Southwest Atlantic basins, a dinoflagellate view. The paleontology of Gran Barranca. In: Madden RH, Carlini AA, Vucetich MG, Kay RF (eds) The paleontology of Gran Barranca: evolution and environmental change through the middle Cenozoic of Patagonia. Cambridge University Press, Cambridge

Haq BU, Hardenbol J, Vail PR (1987) Chronology of fluctuating sea levels since the triassic (250 million years ago to present). Science 235:1156–1167

Hernández RM, Jordan TE, Dalenz Farjat A, Echavarría L, Idleman BD, Reynolds JH (2005) Age, distribution, tectonics, and eustatic controls of the Paranense and Caribbean marine transgressions in southern Bolivia and Argentina. J South Am Earth Sci 19:495–512

Iglesias A, Wilf P, Johnson K, Zamuner A, Cuneo NR, Matheos S (2007) A paleocene lowland macroflora from Patagonia reveals significantly greater richness than North American analogs. Geology 35:947–950

Iglesias A, Artabe AE, Morel EM (2011) The evolution of Patagonian climate and vegetation, from the Mesozoic to the present. Biol J Linn Soc 103:409–422

Malumián N, Nañez C (2011) The late cretaceous-cenozoic transgressions in Patagonia and the Fuegian Andes: foraminifera, paleoecology and paleogeography. Biol J Linn Soc 103:269–288
Marenssi SA, Reguero MA, Santillana SA, Vizcaíno SF (1994) Eocene land mammals from Seymour Island, Antarctic palaeobiogeographical implications. Antarctic Sci 6:3–15
Mayr G (2009) Paleogene fossil birds. Springer, Berlin
Montes C, Bayona G, Cardona A, Buchs DM, Silva CA, Morón S, Hoyos N, Ramírez DA, Jaramillo CA, Valencia V (2012) Arc-continent collision and orocline formation: closing of the Central American seaway. J Geophys Res. doi:10.1029/2011JB008959
Nullo F, Combina A (2002) Sedimentitas terciarias continentales. In: Haller MJ (ed) Geología y Recursos naturales de Santa Cruz. Buenos Aires
Nullo F, Combina A (2011) Patagonian continental deposits (Cretaceous-Tertiary). Biol J Linn Soc 103:289–304
Olivero EB, Gasparini Z, Rinaldi CA, Scasso R (1990) First record of dinosaurs in Antarctica (Upper Cretaceous, James Ross Island): palaeogeographical implications. In: Thomson MRA, Crame JA, Thomson JW (eds) Geological Evolution of Antarctica. Cambridge University Press, Cambridge.
Ortiz Jaureguizar E, Cladera GA (2006) Paleoenvironmental evolution of southern South America during the cenozoic. J Arid Environ 66:498–532
Panza JL, Franchi MR (2002) Magmatismo basáltico Cenozoico extrandino. In: Haller MJ (ed) Geología y Recursos Naturales de Santa Cruz. XV Congreso Geológico Argentino
Pascual R, Bondesio P (1982) Un roedor Cardiatheriinae (Hydrochoerydae) de la Edad Huayqueriense (Mioceno tardío) de La Pampa. Sumario de los ambientes terrestres en la Argentina durante el Mioceno. Ameginiana 29:19–35
Pascual R, Carlini AA, Bond M, goin FJ (2002) Mamíferos cenozoicos. In: Haller MJ (ed) Geologia y Recursos Naturales de Santa Cruz. Asociación Geológica Argentina, Buenos Aires
Rasmussen DT, Kay RF (1992) A Miocene anhinga from Colombia, and comments on the zoogeographic relationships of South America's Tertiary avifauna. Sci Series 36:225–230
Reguero MA, Vizcaíno SF, Goin FJ, Marenssi SA, Santillana SN (1998) Eocene high-latitude terrestrial vertebrates from Antarctica as biogeographic evidence. Asoc Pal Arg 5:185–198
Reguero MA, Marenssi SA, Santillana SN (2002) Antarctic Peninsula and Patagonia Paleogene terrestrial environments: biotic and biogeographic relationships. Palaeogeog Palaeoecol 2776:1–22
Romero E (1986) Paleogene phytogeography and climatology of South America. Ann Miss Bot Gard 73:449–461
Scasso R, McArthur JM, del Río C, Martínez S, Thirlwall MF (2001) 87Sr/86Sr Late Miocene age of fossil molluscs in the "Entrerriense" of the Valdés Peninsula (Chubut, Argentina). J South Am Earth Sci 14:319–329
Shen Y (1995) Subdivision and correlation of Cretaceous to Paleogene Volcano-sedimentary sequence from Fildes Peninsula, King George Island, Antarctica. In: Shen Y (ed) Stratigraphy and Paleontology of Fildes Peninsula, King George Island, Antarctica. State Antarctic Committee Monograph 3, Beijing Science Press.
Scher HD, Martin EE (2006) Timing and climatic consequences of the opening of Drake Passage. Science 312:428–430
Tambussi CP (1989) Las aves del Plioceno tardío-Pleistoceno temprano de la Provincia de Buenos Aires. Dissertation, Universidad Nacional de La Plata
Wilf P, Johnson KR, Cúneo NR, Smith ME, Singer BS, Gandolfo MA (2005) Eocene plant diversity at Laguna del Hunco and Río Pichileufú. Patagonia, Argentina Am Nat 165:634–650
Woodburne MO (2010) The Great American biotic interchange: dispersals, tectonics, climate, sea level and holding pens. J Mamm Evol 17:245–264
Zachos J, Shackleton NJ, Revenaugh JS, Pälike H, Flower BP (2001) Climate response to orbital forcing across the oligocene-miocene. Science 292:274–278

http://www.springer.com/978-94-007-5466-9

South American and Antarctic Continental Cenozoic Birds
Paleobiogeographic Affinities and Disparities
Tambussi, C.P.; Degrange, F.
2013, XI, 113 p. 23 illus., 7 illus. in color., Softcover
ISBN: 978-94-007-5466-9