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Preliminary paleomagnetic results of a terminal pleistocene/holocene record from northeastern Buenos Aires province (Argentina).

Hugo G. Nami[1,2]

[1] CONICET-Instituto de Geofísica »Daniel A. Valencio«, Departamento de Ciencias Geológicas, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad de Buenos Aires, Ciudad Universitaria (Pabellón II), Buenos Aires, República Argentina.

[2] Department of Anthropology, National Museum of Natural History, Smithsonian Institution, Washington, D. C., U.S.A.

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Paleomagnetic data from the Lomas del Mirador (34° 39.29' S, 58° 32.17' W) sedimentary section in northeastern Buenos Aires province (Argentina) comprises 149 oriented samples that record a significant but gentle gradual change in the geomagnetic field at the terminal Pleistocene and Holocene. Based on rock magnetic and detrital remanence experiments, the deposit seems to be a good recorder of the past geomagnetic field behavior. The characteristic remanent magnetization (ChRM), determined by progressive AF demagnetization, shows that the sections registered normal and intermediate polarities during the terminal Pleistocene/Holocene. The PSV is characterized by a large variation with ~ 80° difference in inclination in both sections and a significant but gentle westward shift in the declination in the upper part. A similar trend was observed in the paleomagnetic record registered in other sections from northeastern Argentina. This remarkably large PSV, especially the inclination record, became a reliable chronostratigraphical marker for latest Pleistocene/Holocene sedimentary deposits in northeastern Buenos Aires. VGPs resemble those registered during terminal Pleistocene and Holocene in the southern cone of South America. Palaeomagnetic poles for the sections other contemporaneous sites from northeastern Argentina fall some ~ 5–15° away from the Earth's rotation's axis.

Keywords: Paleomagnetism, paleosecular variation, terminal Pleistocene, Holocene, South America, Argentina.

1. Introduction

Paleomagnetic investigations of paleosecular variations (PSV) on latest Pleistocene and Holocene deposits in Argentina have been researched since the early eighties (*e.g.* Creer et al., 1983; Valencio et al., 1985; Sylwan, 1989;

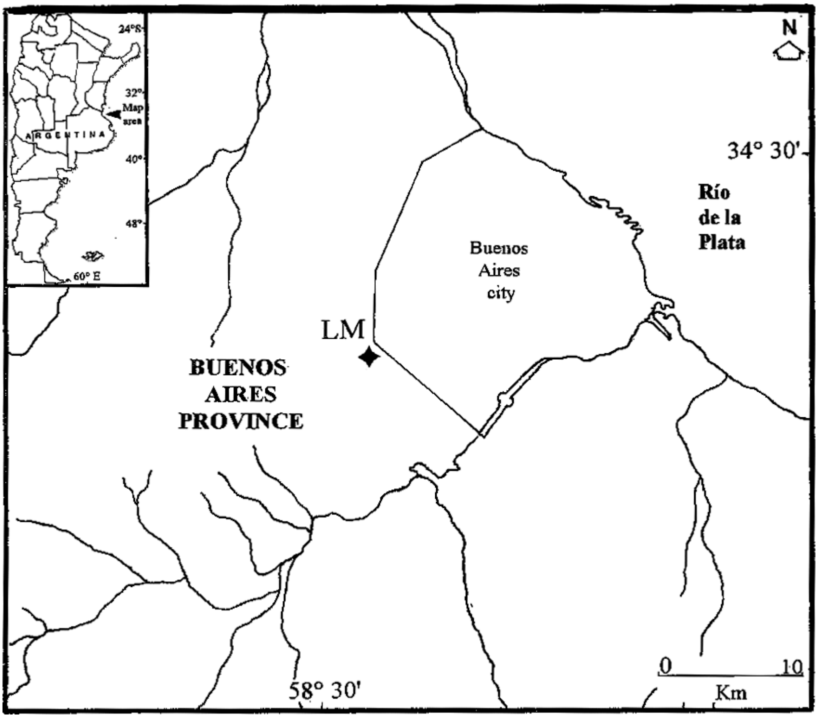


Figure 1. The Lomas del Mirador (LM) deposit in Northeastern Buenos Aires province.

Nami and Sinito, 1991; Sinito and Nuñez, 1997; Gogorza et al., 1998; 2000; etc.). Some of these studies yielded anomalous geomagnetic field (GMF) directions during very recent times; Reverse and intermediate VGPs were identified in eleven paleontological and archeological deposits (Nami, 1995; 1999a; Sinito et al., 1997). Due to the possibility of the existence of this kind of ephemeral PSV feature (Thouveny and Creer, 1992) and, the likelihood to be used as a dating tool, these investigations have important geomagnetic and stratigraphic implications (Tarling, 1983; Merrill et al., 1998; Westaway, 2003). To assess this topic, a variety of sections of recent sediments were sampled. As part of this long-term research program, this paper reports a paleomagnetic study in the terminal Pleistocene/Holocene deposit from northeastern Buenos province.

2. Sampling site and chronological considerations

The Lomas del Mirador (34° 39.29' S, 58° 32.17' W) site (LM) is in the outskirts of Buenos Aires City (Fig. 1). Currently, there is no evidence of fluvial activity in this locale; however, the sediments are characteristic floodplain

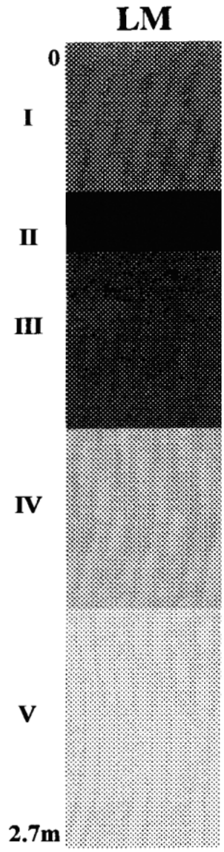


Figure 2. Schematic stratigraphic LM profile showing levels I to V.

deposits. During the terminal Pleistocene/Holocene, LM was in an active fluvial environment and also affected by pedogenesis. There is a fully developed soil that suggests a period of non-deposition and landscape stability (Holliday, 1985; Kraus and Brown, 1986). According to Favier Duvois (pers. comm., 2000), the LM deposit is similar to the Guerrero member of the Luján formation, which is a useful horizon marker for late Pleistocene and early Holocene sediments (Cione and Tonni, 1995; Tonni et al., 1999; 2003).

A 1 m^2, 2.7 m deep, trial pit in the sediment shows five stratigraphic levels named »I« to »V« (Fig. 2). »I« is an artificial landfill, »II« is very dark brown (2/2, 10YR Munsel color chart) highly compacted silt sediments, »III« is a dark brown (2.5/3, 7.5YR) silty clay level, »IV« is a pale brown (6/3, 10 YR) silty sand sediment, and »V« is a light yellowish brown (6/4, 10YR) silty clay deposit with calcareous inclusions. Levels II to V belong to the same soil formation horizon (Favier Duvois, pers. comm. 2000; Morrás, pers. comm. 2003).

In the ancient fluvial system of the Buenos Aires, LM is located in the Maldonado creek basin, the main watercourse that existed in the area. The Maldonado creek and the Riachuelo-Matanzas river were two significant water courses in the Río de la Plata (Castellanos, 1975); a great mass of water that has been shown important changes in its geomorphologic configuration since the Late Pleistocene. These changes have produced significant variations in the distribution of the submerged and emerged land (Cavalotto et al., 1995). Here it is relevant that a more dynamic drainage system existed near LM (Di Micco, 1990) and environmental magnetic research suggested that several flooding events probably occurred during these times (Vásquez and Nami, 2006).

Remains of *Heleobia sp.* And *Mactra isabelleana* micro-paleontological mollusks were found in levels II and III. Diatoms identified as *Pinnularia borealis*, *Hantzschia amphioxys* and *Navicula mutica* (Maidana, 1998) and finally, isolated dogs' teeth (*Canis familiaris*) were also found in level II. The bone remains were incorporated into the sediment before 1952 when the artificial landfill was made.

The age of the deposit was determined using different dating methods. Two ^{14}C dates were made on shell samples using mass accelerator spectrometry (AMS). A small piece of unidentified mollusk from level II contains more ^{14}C than the 1950 atmosphere and therefore its date is $\leq$ 1950 AD, compatible with the age of the artificial landfill. The second date, obtained from one specimen of micro faunal mollusk (*Mactra isabelleana*) belonging to the lower part of level III, was 4900 ± 110 yr BP (OS–24330). This is contemporaneous with the radiocarbon dates obtained from *Mactra isabelleana* collected from other sites in the region (Tonni et al., 1999). This micromollusc is also a typical fossil found in Holocene deposits from Buenos Aires (Aguirre, 1988; 1993). Additionally, the mean residence time (MRT) of the soil was determined (Scharpenseel, 1971) employing the oxidizable carbon ratio (OCR) method (Frink, 1992; 1994; 1995). The MRT is the mixing of the young organic carbon with organic carbon from earlier stages of pedogenesis (Stein, 1992). Twelve OCR dates were obtained from levels II to V ranging between 115 and 7556 yr BP (0.11–7.55 ky, Table 1). Taking into account the radiometric date, these dates must be considered as relative minimum ages. Although there are notable differences between ^{14}C and OCR dates according to depth, the latter confirm that the soil surface was open to organic input during a long period (*e.g.* Scharpenseel, 1971; Stein, 1992). Therefore, here, the MRT indicates that the deposit was open to organic material deposition during the last ~ 8 ky; through much of the Holocene, suggest a terminal Pleistocene/Holocene age for the deposit. In fact, its boundary with the Pleistocene was conventionally established at 10 ky bp (Dawson, 1992). Based on geological and chronological studies it is possible to propose that the directions reported here belong to the terminal Pleistocene-Holocene.

Table 1. Dates from LM deposit. Depths are given in meters below the surface.

Material dated	Depth	Method	Absolute date (years BP)	Relative minimum date (years BP)	Identification number
Mollusk	0.60/0.70	14C – AMS	Modern	—	CURL–5502
Mollusk	1.20 – 1.25	14C – AMS	4900 ± 110	—	OS–24330
Sediment	0. 55	OCR	—	115	Act # 2943
Sediment	1.22	OCR	—	789	Act # 2944
Sediment	1.55	OCR	—	1374	Act # 2945
Sediment	1.88	OCR	—	3110	Act # 2946
Sediment	2.05	OCR	—	4546	Act # 2947
Sediment	2.30	OCR	—	5525	Act # 3230
Sediment	2.30	OCR	—	6065	Act # 3360
Sediment	2.39	OCR	—	6139	Act # 3228
Sediment	2.39	OCR	—	6609	Act # 3362
Sediment	2.39	OCR	—	6836	Act # 3234
Sediment	2.63	OCR	—	7165	Act # 3363
Sediment	2.63	OCR	—	7556	Act # 3229

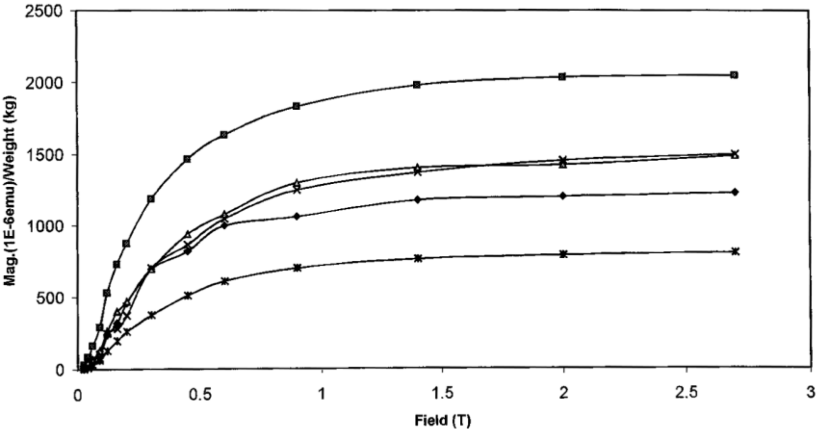
3. Paleomagnetic study: methods and results

3.1. Sampling procedure

Two vertical paleomagnetic sampling sites, LM1 (n = 79) and LM2 (n = 70), were obtained in the northern and southern profiles of the trial pit respectively. The LM samples were taken from level II (samples LM1 1 to 9 and LM2 1 to 12), level III (LM1 10 to 52 and LM2 13 to 47), level IV (LM1 53 to 72 and LM2 48 to 70) and level V (LM1 72 to 79). Samples were 2.5 cm long and 2 cm diameter cylindrical plastic containers carefully pushed into the sediments and overlapping the each other by about 50%. Their orientation was measured using a Brunton compass and they were then consolidated with sodium silicate after removal and then numbered from the top to the bottom.

3.2. Rock magnetic analysis

Stepwise acquisition of isothermal remanent magnetization (IRM) up to 2.7 T (SIRM) was with a pulse magnetizer and subsequent remanent measurements using a Digico spinner magnetometer (Fig. 3a–b). All acquisition curves have a very similar shape, showing a saturation of remanent magnetization over 1.5 T. The curves suggest that the same ferromagnetic carrier is present in different proportions in all the samples. The high saturation values suggest a)



b)

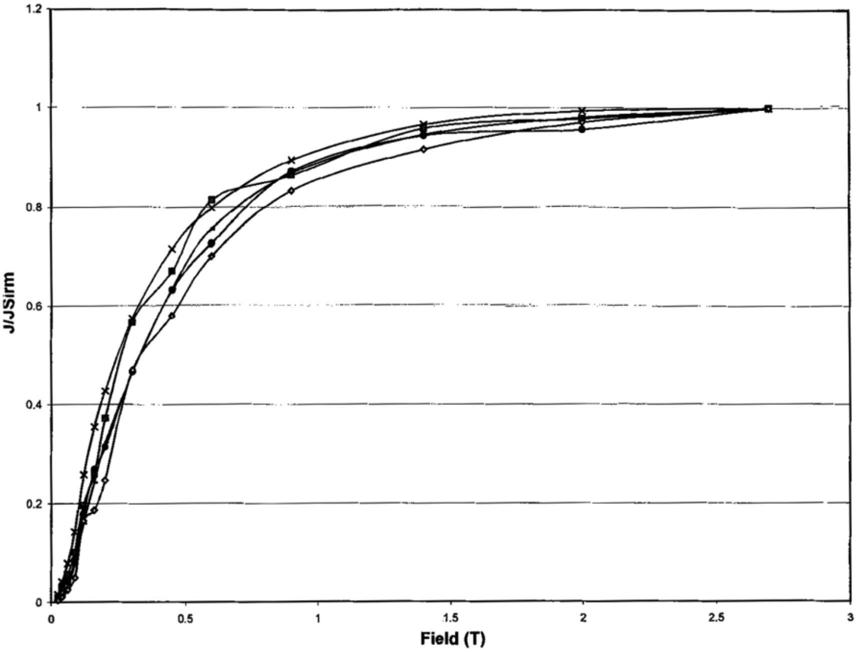


Figure 3. a) Curves of IRM acquisition until 2.7 T from levels II to V. The shape of all the curves are very similar and is charateristic of hematite. Level II (diamond), III (triangle and square), IV (cross) and V (asterisk). The values on the vertical axis must be elevated at 10^3. b) Curves of IRM acquisition normalized according the highest value of each sample.

an antiferrimagnetic mineral, probably hematite or goethite (Dankers, 1978; Dunlop and Özdemir, 1997). This was not unexpected, since the samples came from a soil profile. Acquisition of IRM suggests that hematite is the carrier of

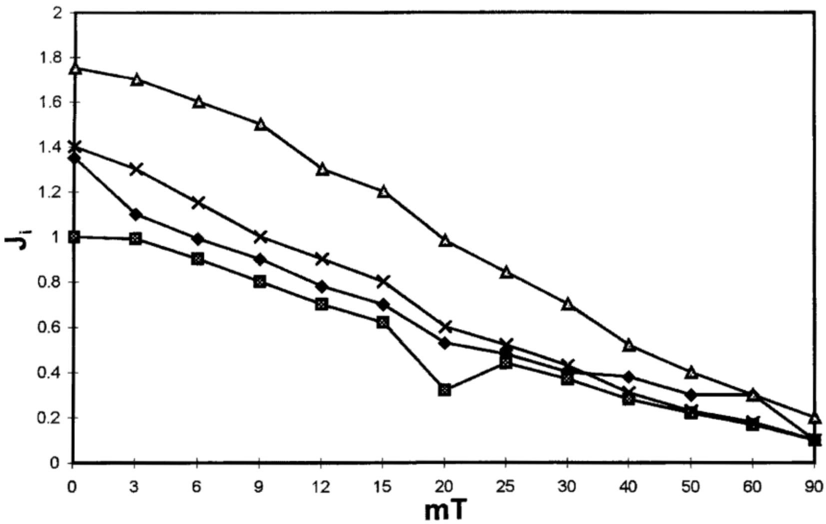


Figure 4. AF demagnetization from samples taken at levels II (triangle), III (square), IV (diamond) and V (cross).

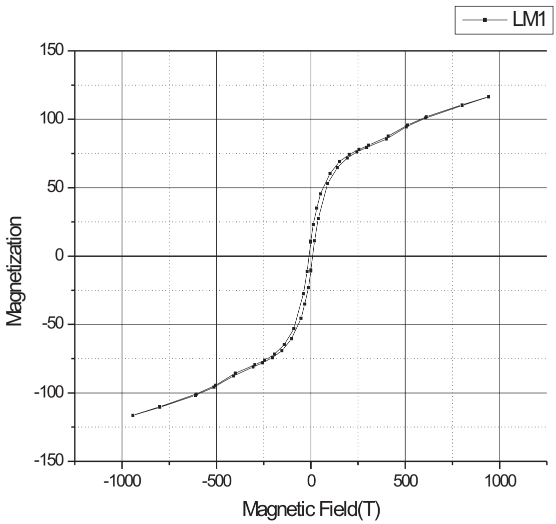


Figure 5. Typical hysteresis cycle curve from the LM deposit.

the remanence; however the AF demagnetization of SIRM, in progressive steps up to 90 mT of four samples from level II to V, shows similar behavior (Fig. 4) with a quick decrease suggesting a complex ferromagnetic mineralogy. In fact, detailed hysteresis cycle analysis was carried out (Vásquez and Nami,

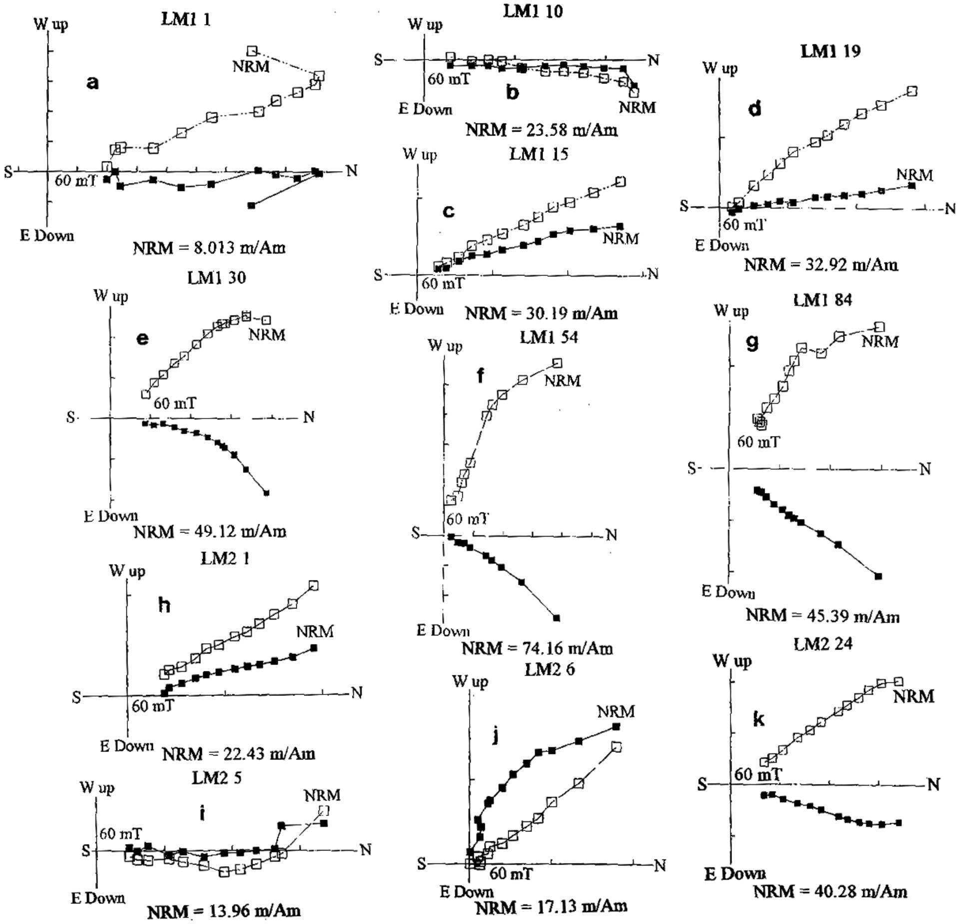


Figure 6. Typical Zijderveld diagrams from the LM1 and LM2 sections. Solid symbols correspond to the projection onto the horizontal plane, while open symbols are projection onto the vertical plane.

2006). Figure 5 shows that the LM samples also have a magnetic fraction of magnetite-titano-magnetite (Kruiver et al., 2001).

Before the demagnetization process, the mass magnetic susceptibility (k) of all samples from LM2 was measured using a Bartington MS2 model susceptometer. The values range between 1.5 to 3 $\times 10^{-7}$ m^3/kg with an apparent increase of k with increasing depth at level III. There are low k values in level II and the upper part of level III, with higher values at the lower part in levels III and IV, starting in sample # 17. This situation suggests a change in the quantity in the magnetic minerals from the middle part of level III (Vásquez and Nami, 2006).

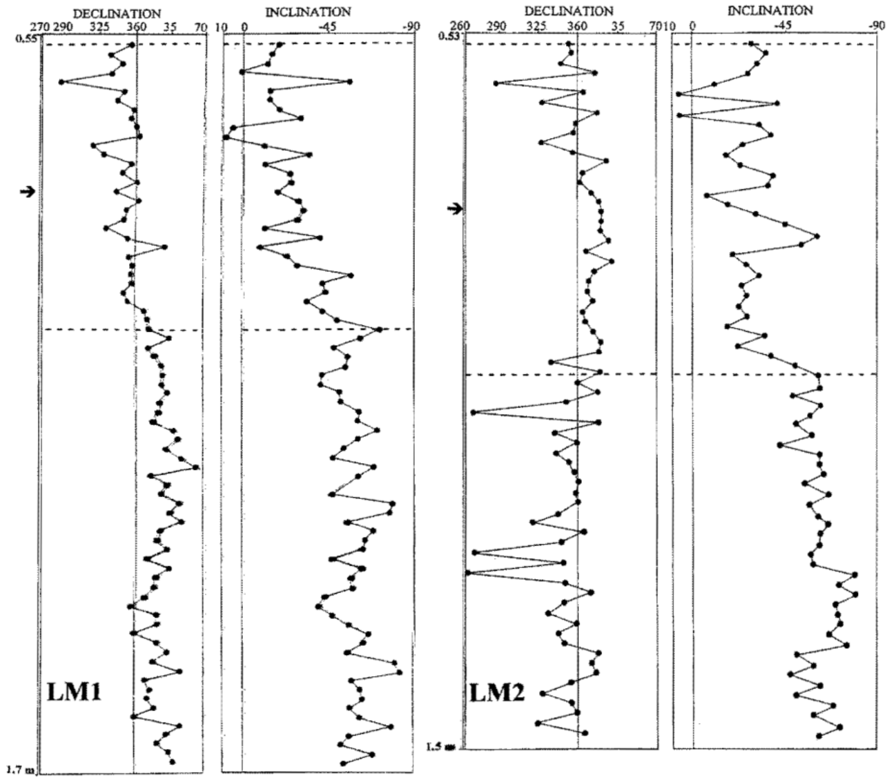


Figure 7. Stratigraphic presentation of the Declination and Inclination profiles from LM1 and LM2. The more conspicuous long directions departures are depicted between dashed lines.

3.3. Remanence directions analysis

All samples were subjected to progressive AF demagnetization in steps of 3, 6, 9, 12, 15, 20, 25, 30, 40 and 60 mT in a 3-axis static degausser, attached to a 2G cryogenic magnetometer and subsequently measured with the magnetometer. Additional steps of 80 and 100 mT were used in some samples. In most LM1 and LM2 cores, less than 30% of the NRM remained at fields of 60 mT (*e.g.* Fig. 6a, b, e, g). Characteristic remanent magnetization (ChRM) was calculated using principal components' analysis (Kirschvink, 1980). The samples shown in figure 6 were highly reliable, displaying similar patterns going to the origin in the Zijderveld diagrams (*e.g.* LM1 10, LM1 19, LM1 54, LM2 6, LM2 24, Fig. 6b, d, f, j, k). The maximum angular deviations were generally within low values, ranging between 0° to 5° (LM1 = 78.9% and LM2 = 77.1%) and between 5.1° to 10° (LM1 = 22.1% and LM2 = 22.9%). Some samples had univectorial behavior (*e.g.* LM1 15, LM1 19 and LM2 1, Fig. 6c, d, h). Others had two magnetic components; some of them had an overprint of the present GMF, which was removed around 3 to 6 mT (*e.g.* LM1 1 and LM2 5, Fig. 6a, i), while some showed two components, one of which was removed by 30–40 mT (*e.g.* LM1 30 and LM2 24, Fig. 6e, k). The ChRM shows either high (*e.g.* LM1 54, LM1 79 and LM2 24, Fig. 6f, g, k) or low negative inclinations (*e.g.* LM1 10 and LM2 5, Fig 6b, i). A few showed a northwesterly direction (*e.g.* LM2 1 and LM2 6, Fig 6h, j). The number and intervals of demagnetization steps used to isolate the ChRM are given in table 2. The stratigraphic presentation of the Declination and Inclination profiles from LM1 and LM2 is illustrated in Fig-

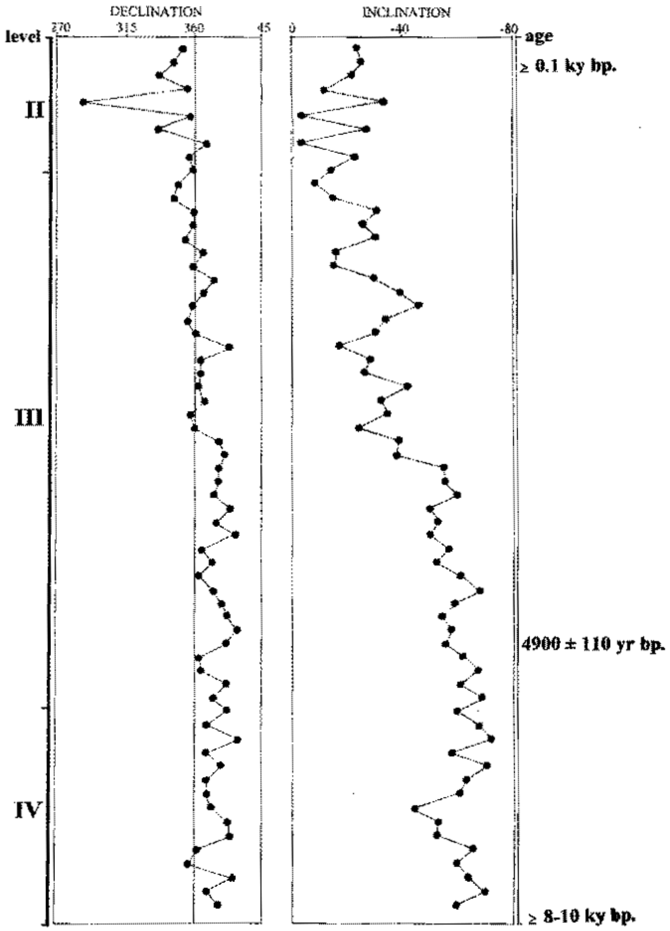


Figure 8. Mean Declination and Inclination profiles from LM1 and LM2 related with the stratigraphical section and relative and absolute ages. Samples with more than 45° difference were not averaged.

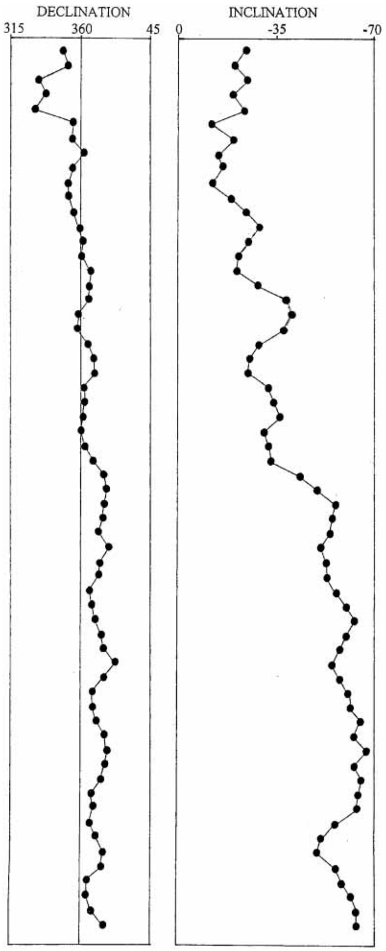


Figure 9. Stratigraphic presentation of the curves obtained with a three-pass window calculated from the mean Declination and Inclination from LM1 and LM2 sections.

ure 7. The mean D and I from the correlative samples from both samplings were used to construct a smooth curve (Fig. 8). Samples 38, 52, 54, 58 and 69 were not considered in this analysis as their directions have more than 45° difference. They clearly show a similar GMF magnetic behavior with a conspicuous change in declination and inclination depicted between dashed lines and indicated with arrows. An important swing in declination, which reaches values of approximately 100° to the West, occurs between samples 1 to 32 in LM1 and 1 to 34 in LM2. The record of inclination also presents a generally decreasing trend from ~ 80° at the lower part to 10° at the upper part. The declination log has a generally decreasing trend between 30° E at the bottom and 45° W at the top. The resulting data, despite the loss of resolution, were filtered to eliminate the noise and a three-point window was used to define the high-frequency directional changes of the GMF (Fig. 9). The results are shown in a log according to depth and as a polar projection (Fig. 10). They clearly show a pronounced inclination change of ~ 60° in the central part of the sections. This remarkably large PSV, especially the inclination record, became a reliable chronostratigraphical marker for terminal Pleistocene/Holocene sedimentary deposits in northeastern Buenos Aires.

3.4. Detrital remanence acquisition experiment

In the laboratory, the quality of the sediments as magnetic recorders was investigated. A paste was made from water and sediments obtained at –1.80/1.90 below the surface. These were split into three plastic boxes, and dried at ambient temperature (between 15° and 25°C). They were oriented with a Brunton compass and the inclination of the magnetic field was measured (I = –35°, Int. = 0.194 oe) with an APS460 Axial Fluxgate magnetometer. After two days, the same plastic tubes used for the paleomagnetic sampling were inserted in the slightly consolidated paste. Once dried, the samples (n = 8) were taken from the boxes and remanence analysis was performed by stepwise AF demagnetization using the same steps as previously. They showed a univectorial decay of the magnetic remanence trending toward the origin in the Zijderveld diagrams with maximum angular deviations lower than 5° (Fig. 11a–b). The mean direc-

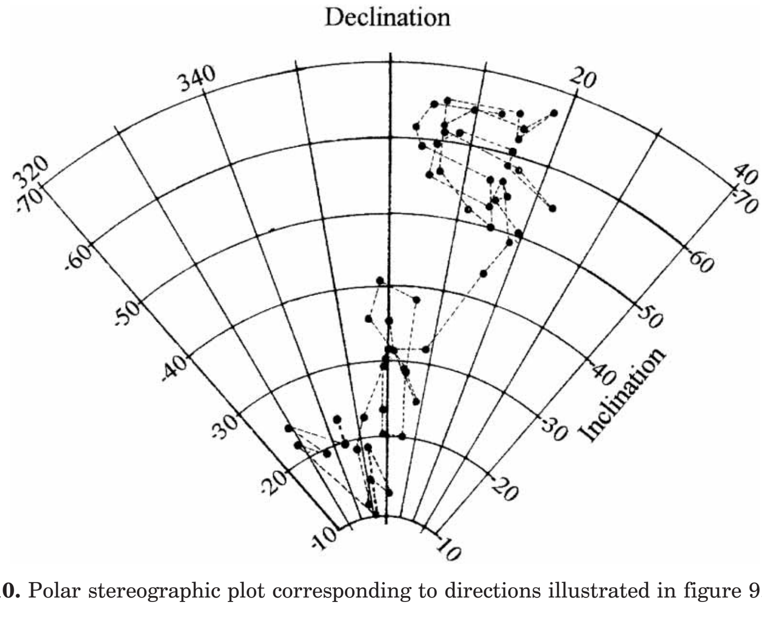


Figure 10. Polar stereographic plot corresponding to directions illustrated in figure 9.

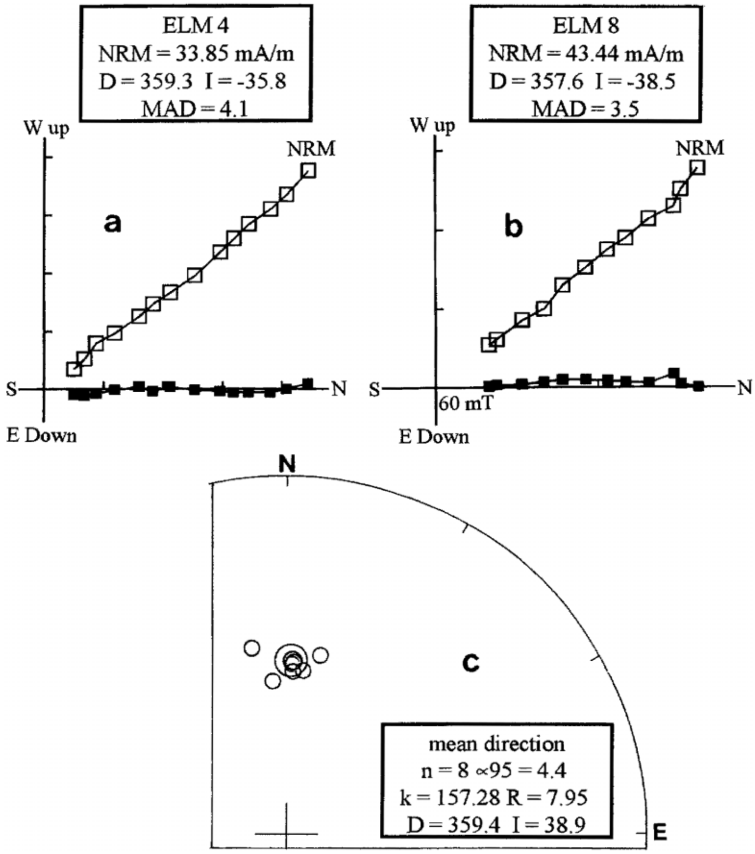


Figure 11. a–b) Zijderveld diagrams from two DRM experimental samples from LM. c) Stereographic projection of the ChRM of each experimental sample and the mean direction with the calculated interval of confidence.

tion was calculated with Fisherian statistic (Fisher, 1953). The resulting direction (D = 359.4, I = –38.9, Fig. 11c) shows a remarkably good agreement with the direction in the experimental site. The sediments acquired a magnetic remanence due to their alignment with the Earth's magnetic field between 10 and 14 days of setting and consolidation. This was a period necessary for magnetic particles to become locked parallel to the GMF. Similar behavior, with a stable linear remanence toward the origin, was observed in most paleomagnetic samples (Fig. 6). The results of this experiment show that the LM sediments recorded the magnetic field direction very rapidly and accurately, indicating that they are good paleomagnetic recorders. This phenomenon suggests that the low magnetic inclination recorded in the top half of the profiles is not an artifact of the recording process.

Table 2. Characteristic remanent magnetization, virtual geomagnetic pole positions and intervals of each sample. Negatives values show negative inclination or VGP located in the Southern Hemisphere. Intervals of selected ChRM are given in mT. References: D: Declination, I: Inclination, Long.: Longitude, Lat.: Latitude, IChRM: Intervals of selected ChRM, Or.: Origin in the Zijderveld diagram.

LM1											
Sample	D°	I°	Long. E	Lat.	Int. ChRM	Sample	D°	I°	Long. E	Lat.	Int. ChRM
1	358	–19	297	65	6–60	40	25	–51	31	69	20–Or.
2	335	–15	257	55	3–60	41	24	–60	58	70	9–Or.
3	350	–12	281	60	3–50	42	19	–58	53	74	12–60
4	336	3	266	48	3–60	43	41	–70	79	55	20–Or.
5	289	–56	187	34	3–Or.	44	42	–59	53	56	5–60
6	346	–13	274	60	3–40	45	37	–52	39	59	12–Or.
7	342	–13	267	58	3–60	46	47	–45	34	49	3–Or.
8	360	–13	302	62	3–Or.	47	61	–67	70	44	15–Or.
9	351	–31	273	71	3–Or.	48	18	–60	62	74	12–Or.
10	1	7	303	52	3–Or.	49	33	–59	53	63	9–Or.
11	6	8	311	51	3–Or.	50	30	–46	25	63	9–Or.
12	319	–11	239	42	3–Or.	51	46	–69	75	53	20–Or.
13	333	–36	236	62	3–Or.	52	41	–67	71	56	9–Or.
14	355	–12	291	61	3–Or.	53	49	–53	45	50	12–Or.
15	346	–24	268	65	0–Or.	54	27	–67	78	65	9–Or.
16	4	–25	312	68	3–Or.	55	22	–62	66	71	9–Or.
17	341	–14	264	58	3–Or.	56	35	–63	73	61	25–Or.
18	5	–28	316	70	3–Or.	57	17	–45	8	73	3–Or.
19	353	–33	279	73	0–Or.	58	38	–63	62	59	0–Or.
20	345	–29	262	67	15–Or.	59	27	–68	80	64	20–Or.
21	330	–12	250	50	3–60	60	22	–57	48	72	12–Or.
22	352	–42	265	78	0–Or.	61	14	–44	360	75	9–Or.
23	31	–8	352	48	3–Or.	62	359	–39	297	78	9–Or.
24	350	–24	277	66	3–12	63	24	–47	21	69	25–Or.
25	357	–28	293	70	3–Or.	64	24	–56	45	70	3–Or.
26	356	–57	166	85	3–Or.	65	4	–66	111	76	3–Or.
27	359	–41	297	79	3–Or.	66	25	–62	64	69	12–Or.
28	350	–43	256	77	2–Or.	67	38	–55	45	59	3–Or.
29	353	–33	279	72	3–Or.	68	19	–80	112	52	6–Or.
30	12	–41	348	75	12–Or.	69	49	–83	108	43	3–Or.
31	13	–52	26	79	7–Or.	70	16	–56	46	77	0–Or.
32	17	–72	99	65	3–Or.	71	18	–62	69	73	6–Or.
33	40	–62	60	58	3–Or.	72	16	–63	76	74	0–Or.
34	16	–50	21	76	25–Or.	73	22	–56	45	72	3–Or.
35	20	–56	45	74	3–Or.	74	2	–62	112	81	6–Or.
36	24	–52	33	70	12–30	75	44	–78	97	49	0–30
37	27	–41	14	64	20–Or.	76	29	–56	45	66	6–60
38	25	–40	10	65	12–Or.	77	25	–52	34	69	9–Or.
39	32	–50	33	63	20–Or.	78	35	–69	79	59	12–Or.
						79	37	–53	41	59	9–Or.

Table 2. cont.

LM2											
Sample	D°	I°	Long. E	Lat.	Int. ChRM	Sample	D°	I°	Long. E	Lat.	Int. ChRM
1	346	–28	265	67	0–Or.	36	19	–48	19	73	3–30
2	350	–35	269	72	3–Or.	37	346	–62	168	76	3–Or.
3	343	–31	257	67	2–Or.	38	268	–57	179	19	3–Or.
4	15	–26	339	65	3–Or.	39	18	–51	27	75	0–Or.
5	287	–10	217	17	30–Or.	40	338	–58	192	72	3–Or.
6	4	7	308	52	20–Or.	41	360	–42	302	80	6–Or.
7	327	–40	225	59	0–Or.	42	339	–61	180	72	6–Or.
8	17	7	328	49	9–Or.	43	349	–61	167	78	3–Or.
9	359	–32	298	73	0–Or.	44	353	–63	148	79	6–Or.
10	355	–36	283	75	12–60	45	3	–54	36	88	6–Or.
11	324	–23	237	50	0–9	46	359	–65	125	77	3–Or.
12	365	–15	291	63	6–Or.	47	360	–56	122	88	12–Or.
13	22	–22	348	60	8–Or.	48	340	–60	183	73	3–Or.
14	3	–38	314	77	0–Or.	49	320	–66	174	57	12–Or.
15	360	–37	302	76	0–Or.	50	5	–63	102	79	3–Or.
16	9	–7	319	58	25–60	51	342	–62	174	73	6–Or.
17	15	–16	333	60	3–60	52	269	–57	179	19	6–Or.
18	17	–30	346	66	3–Or.	53	346	–58	187	78	3–Or.
19	20	–45	13	71	3–Or.	54	262	–79	146	29	6–Or.
20	20	–61	64	73	3–60	55	343	–71	146	66	3–Or.
21	25	–52	34	69	9–Or.	56	11	–80	116	53	6–Or.
22	6	–19	31	65	3–Or.	57	343	–70	148	67	6–Or.
23	11	–26	330	67	0–Or.	58	331	–71	156	61	0–50
24	14	–32	342	69	0–Or.	59	359	–72	123	67	9–Or.
25	7	–24	320	67	0–Or.	60	340	–67	159	69	6–Or.
26	4	–26	313	69	3–Or.	61	343	–75	138	61	6–Or.
27	10	–23	326	66	0–Or.	62	18	–50	23	74	3–Or.
28	359	–26	299	69	0–Or.	63	12	–59	65	79	6–Or.
29	2	–16	306	64	3–Or.	64	17	–47	13	74	6–Or.
30	14	–35	345	71	9–Or.	65	352	–62	154	79	6–Or.
31	20	–22	345	61	0–Or.	66	327	–50	210	62	3–Or.
32	19	–38	359	69	0–Or.	67	354	–69	133	71	6–Or.
33	334	–50	214	68	0–Or.	68	359	–59	130	85	12–Or.
34	21	–61	63	72	9–Or.	69	320	–72	159	55	6–Or.
35	360	–63	122	80	0–or.	70	6	–61	92	81	25–Or.

3.5. Site mean directions, VGPs and paleo-pole determinations

Fisher (1953) statistic was used to calculate the mean directions and the precision parameter for both sections, which are fairly well clustered. The ∝ 95, which represents the 95% cone of confidence about the mean direction, plots as a circle on the stereonet (Fig. 12). The IGRF (NASA, 1995) or International

Geomagnetic Reference Field directions for the location of LM are also shown and were compared with the resulting mean directions in LM1 and LM2. Additionally, the mean directions were calculated using the data from the upper part of the sections (named as LM1a and LM2a) and those from the lower por-

Table 3. Site mean direction and the difference with the IGRF directions. These sites are in Northeastern Argentina, where anomalous directions were observed. References: RA: relative age, n: number of samples, A95: semi-angle of cone 95% confidence, K: Fisher's precision parameter; R: resultant vector, dif: difference.

Section	Coordinates	RA (ky bp)	n	D°	I°	D° IGRF dif.	I ° IGRF dif.	k	R	A95
LM1	34°39'S 58°32'W	≥ 8/10 – ≥ 0.1	79	7.87	–47.20	13.73	10.58	9.77	71.02	5.4
LM2	Id.	Id.	70	357.7	–48.7	3.56	12.08	9.78	62.94	5.7
LM1a	Id.	≥ 0.1 – < 5	32	351.02	–25.03	3.12	11.59	10.8	29.12	8.1
LM2a	Id.	≥ 0.1 – < 5	32	2.69	–27.88	8.55	8.74	13.07	29.62	7.3
LM1b	Id.	> 5 – ≥ 8	47	26.63	–58.45	32.49	22.03	46.85	44.06	3.1
LM2b	Id.	> 5 – ≥ 8	38	349.68	–63.93	4.46	27.34	28.58	36.70	4.4
AY	26°S 55°21'W	~ 7 – 1	14	12	–17.84	23.34	9.89	5.58	11.67	18.5
SJ	30°S 57°44'W	~ 6 – 0.3	21	12.44	–23.09	20.53	8.51	7.35	18.3	12.6
BP	30°15'S 57°37°W	~ 6 – 0.3	34	13.29	–19.26	21.39	12.54	5.75	28	11.3

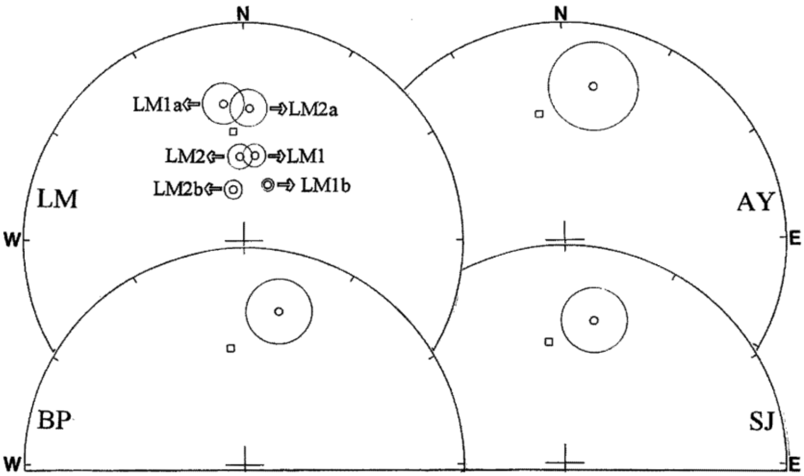


Figure 12. Sites mean magnetization directions for the different sites with normal and intermediate directions from Northeastern Argentine. The IGRF directions are indicated with squares.

tion (called LM1b and LM2b). In general, they showed a little difference with the IGRF calculated in 1998 (D = –5.86° and I = –36.62°). However, the largest differences are observed in the LM1a and LM2a (Table 3 and Fig. 12).

Using previously published data to compare with the LM results, site mean directions were also calculated for all the sites with intermediate directions from NE Argentina. Arroyo Yarará (AY) in Misiones province, San Juan (SJ) and Barraca Pelada (BP) in Corrientes province also show low inclination values and easterly directions in BP (Nami, 1999a). In general, they show similar site mean directions and also some similarities with LM1a and LM2a. However, a significant difference from the present GMF direction was observed (Fig. 12).

Virtual geomagnetic pole positions (VGP) were calculated from the declination and inclination data (Table 2). Both records show intermediate VGPs in the Northern Hemisphere between 60° and 30° latitude. Generally VGPs are located in two patches in northern North America and Greenland and

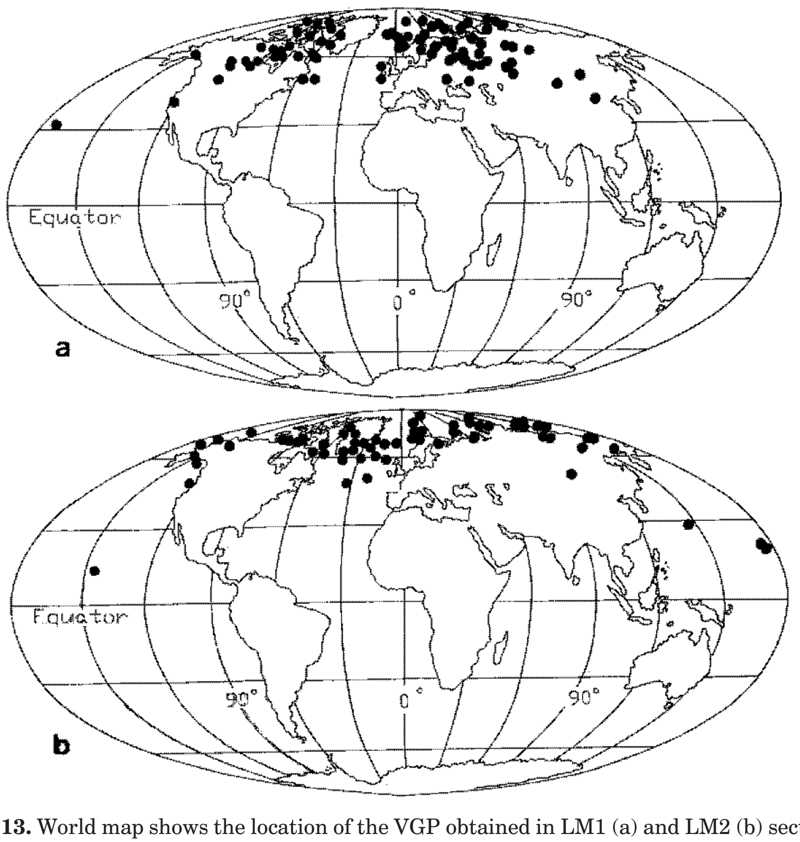


Figure 13. World map shows the location of the VGP obtained in LM1 (a) and LM2 (b) sections.

Table 4. Late Pleistocene/Holocene geomagnetic poles from Northeastern Argentina and LM. Calculated within 40° around their mean. References: n = number of samples for LM1 and LM2 and sites for EA, A95: semi-angle of cone 95% confidence, K: Fisher's precision parameter; R: resultant vector.

Section/Site	n	Long E. (°)	Lat. (°)	A95	R	K
LM1	71	20.25	78.16	4.8	65.64	13.08
LM2	65	291.79	87.12	4.9	60.39	13.89
EA	5	344.37	76.18	8.6	4.95	80.50

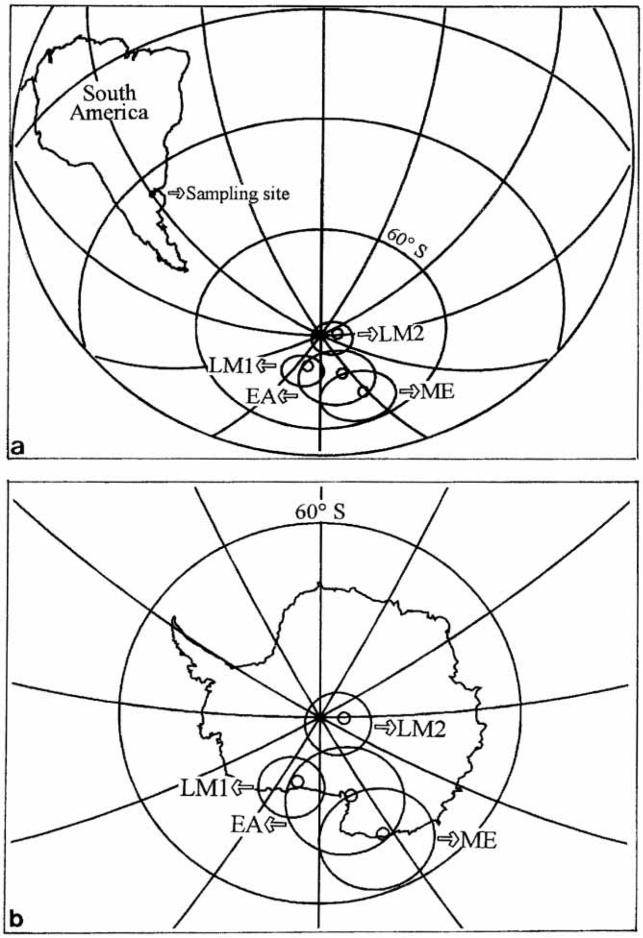


Figure 14. Projection shows the paleo-pole obtained with 40° filter and their confidence interval in relation with the paleo-pole obtained for the Holocene excursion observed in other sites from Northeastern Argentina in relation with the sampling site (a) and the Antarctic continent (b)

northern Eurasia (Fig. 13). These positions coincide with VGPs isolated for the sites where anomalous directions were observed in previous paleomagnetic studies on latest Pleistocene and Holocene sections (Nami, 1999a; 1999b; Mena and Nami, 2002).

Finally, mean geomagnetic poles were calculated from LM1 and LM2. They were computed from all VGP's within 40° of the mean geomagnetic pole (*cf*. McElhinny et al., 1974). An additional palaeopole –called here EA– for the sites from northeastern Argentina was also determined. It was computed using 193 VGP's from AY, BP, SJ, LM1 and LM2. This paleopole is almost coincident with the paleopole determined with the sites where the Mylodon excursion [ME = 336.7° W. Long., 68.65°S. Lat. With ($\propto$ 95) 8.2°] was observed (Nami, 1999a). The resulting paleo-poles also show ~ 3–15° difference in relation to the rotation axis of the Earth (Table 4, Fig. 14). Except LM2, in which the statistical oval of confidence at the 95 per cent level includes the present rotation pole, it is significant that they do not agree with the geographical pole. As previously stated (Nami, 1999a; Mena and Nami, 2002), this suggests that a time span of ~ 10 ky is insufficient to average out geomagnetic secular variations (Hyodo et al., 1993).

4. Summary and conclusion

The LM deposit seems to be a good recorder of the past GMF behavior. The PSV is characterized by a large variation with ~ 80° difference in inclination in both sampling and a significant but gentle westward shift in the declination in the upper part of the section. A similar trend was observed in the paleomagnetic record registered in other sections from northeastern Argentina. In fact, AY, SJ, BP sites also registered low inclination values and westerly directions in BP during the Holocene (Nami, 1999a). Susceptibility changes occur at the upper part of level III (sample # 17); while directional change, mainly in inclination, occur in the middle samples (LM1 32 and LM2 34). This suggests that these changes are not correlated. Additionally, the experiments carried out with sediments from the lower levels very fast and accurately registered the GMF. Therefore, there are good reasons to suppose that the record from the lowest levels also reflects the GMF direction. Mean directions of the first samples from LM1 and LM2 are very close to the present GMF, suggesting that sediments from level II recorded the remanence very recently. Comparative PSV records in southern Argentina, in the southwest of the Río Negro province in northwestern Patagonia, are lacustrine sediments that show stable records during the last 10 ky (Sinito and Nuñez, 1997; Gogorza et al., 1998; 2000). In general, they show a variation from ~ 70° to –30° in inclination and from ~ 30° to –30° in declination during the Middle and Late Holocene, between 6.0 to 0.5 ky. Particularly, the Moreno lake log reported by Valencio and colleagues (1985: Fig. 11) shows major variation in inclination occurred at ~ 7.5–7.0, 5.5–4.5 and 1.5–0.5 ky and, the more conspicuous declination changes, between ~ 30° to –30° at ~ 8–6.5 and 6–5.5 ky. However, recent data presented by Gogorza and colleagues (2000: Fig. 6) shows some similarities with LM, especially in decrease in inclination from about –70° to –50° at ~ 1.0 to 2.0 ky and from ~ 25° to –10° in declination between ~ 1.0 and 2.6 ky. At ~ 200 km northeast from the Patagonian lakes, another Middle and Late Holocene detailed record, obtained at Piedra del Aguila 11 site in southeastern Neuquén province, also yielded very low inclination values but a gentle eastward shift in declination at ≤ 1.9 ky bp (Nami, 1999a). In Chubut province, Campo Cerda rockshelter registered a large PSV record with low inclination values during the Late Holocene. By comparison with the magnetograms' lakes, it was suggested that dates of this record belong to the last ~ 1.5 ky (Nami and Sinito, 1991; Sinito et al., 1997). In the same region, Angostura Blanca rockshelter yielded intermediate and positive inclination values in the last 3.0 ky (Nami and Sinito, 1993; Sinito et al., 1997). In summary, the LM deposit can be interpreted as a preliminary PSV record for Southern South America during the terminal Pleistocene and Holocene that shows significant directional changes in declination and inclination with intermediate VGPs during the Middle and mainly, Late Holocene at ~ 4.9–0.1 ky. These results must be simply interpreted as chronostratigraphic tool. At this moment, experiments are in progress on sedimentary cores from Riachuelo river, Los Berros creek, Castelar, and Lezama Park located in Buenos Aires city and its suburban area in order to test the results of this investigation.

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SAŽETAK

Preliminarni paleomagnetski rezultati zapisa iz završnog pleistocena/holocena, iz sjeveroistočne provincije Buenos Aires (Argentina)

Hugo G. Nami

Paleomagnetski podaci iz sedimentnog terena Lomas del Mirador (34° 39.29' S, 58° 32.17' W) u sjeveroistočnoj provinciji Buenos Aires (Argentina) obuhvaćaju 149 orjentiranih uzoraka. Zabilježena je značajna ali postupna promjena u geomagnetskom polju u završnom pleistocenu i holocenu. Pokazalo se da su u ispitivanim naslagama dobro zabilježene povijesne geomagnetske promjene. Karakteristična remanencija magnetiziranja (ChRM), određena progresivnom AF demagnetizacijom ukazuje na normalni i prijelazni polaritet za vrijeme pleistocena/holocena. Paleosekularna varijacija (PSV) je karakterizirana velikim odstupanjem, s razlikom u inklinaciji u obje sekcije (oko 80°), te signifikantnim, iako blagim, pomakom deklinacije prema zapadu u gornjem dijelu. Sličan je trend opažen u paleomagnetskim zapisima registriranima u drugim područjima sjeveroistočne Argentine. Taj izrazito veliki PSV, osobito u zabilježenoj inklinaciji, postao je pouzdan kronostratigrafski marker za plesistocenske/holocenske sedimentne naslage u sjevereoistočnom Buenos Airesu. Virtuelni položaj geomagnetskih polova (VGP) nalikuje onima registriranima za vrijeme završnog pleistocena i holocena u južnom dijelu Južne Amerike. Paleomagnetski polovi za isto razdoblje za sekcije iz drugih područja sjeveroistočne Argentine otklonjeni su približno 5–15° od osi Zemljine rotacije.

Ključne riječi: paleomagnetizam, paleosekularne varijacije, završni pleistocen, holocen, Južna Amerika, Argentina

Author's addresses: Hugo G. Nami, (1) CONICET-Instituto de Geofísica »Daniel A. Valencio«, Departamento de Ciencias Geológicas, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad de Buenos Aires, Ciudad Universitaria (Pabellón II), (C1428EHA) Buenos Aires, República Argentina. (2) Associate Researcher, Department of Anthropology, National Museum of Natural History, Smithsonian Institution, Washington, D. C., U.S.A.
e-mail: hgnami@fulbrightweb.org