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Late Pleistocene and Holocene Loess Deposits of the Southeastern Buenos Aires Province, Argentina

Zarate, Marcelo, Prof. Dr., CONICET, Centro de Geologia de Costas y del Cuaternario-UNMDP, cc 722 correo central, 7600 Mar del Plata, Argentina; Adriana Blasi, Dr., CIC, Instituto de Geomorfologia y Suelos-UNLP, calle 3, 583, 1900 La Plata, Argentina

ABSTRACT: The Late Pleistocene and Holocene loess deposits of the SE Buenos Aires province are composed of four allostratigraphic units that represent four episodes of loess deposition. The first and the second episodes occurred in Late Pleistocene times. The second episode was followed by a soil forming interval (Early Holocene to Mid-Holocene times). The third episode took place at about 5000 yr BP, after the Holocene sea-level maximum when marine regression began. The fourth episode constitutes a historical event of only local significance.

Loess shows a fairly constant granulometric and mineralogical composition. The modal fraction consists of very fine sand and coarse silt (3 to 5 phi). They are classified as sandy silts or silty sands. Three grain-size subpopulations are differentiated: coarse, medium and fine. The medium-size subpopulation, which is the most important, consists of most of the very fine sand and coarse silt. It is thought to be transported by modified saltation and short-term suspension during local dust-storms.

The mineralogical composition of loess consists of a volcaniclastic assemblage derived mainly from reworked pyroclastic deposits, primary tephras and volcaniclastic sediments. The source area of these materials was located in the lower Colorado river valley about 400 km SW of the studied area. There was also a direct supply by volcanic ash falls.

Introduction

The Pampean sediments were first reported as loess in the late 1800s by Heusser and Claraz (1866) who noted their similarity with the loess deposits of the Rhine valley. Since then all workers, who agreed on the eolian origin of the material, referred to the Argentine deposits as loess. The studies were specially focused on the stratigraphy and composition of the sediments. The most significant and detailed investigations were made by Frenguelli (1928, 1955). In fact, our present knowledge on the Argentine loess is mostly based on these contributions. Later, Teruggi (1957) carried out an outstanding petrographic study of great value, even nowadays, because it provided the general clues on the origin, source areas and processes in the genesis of loess deposits. After these earlier studies no further systematic investigations continued, except for some isolated works. It was not until recent years that loess research attracted again the attention of scientists.

The primary purpose of this paper is to provide – through preliminary results on field descriptions, granulometric and mineralogical data – an up-to-date review of the last cycle of loess deposition.

Geology and Geomorphology of the Studied Area

The studied area is located in the SE part of Buenos Aires province. It is traversed by local streams that flow from the Tandilia range to the Atlantic ocean. The area is an extensive grassland which has been deeply modified by intensive agricultural activities for almost a century (Fig 1). The climate is characterized by temperate conditions with a mean annual precipitation of 800 to 900 mm and a mean annual temperature of about 15 °C.

Geologically, the studied area, where the last cycle of loess deposition is particularly well developed, includes two main domains: the Tandilia system and the so called "Llanura interserrana" (inter-range plain).

The Tandilia system is a faulted block mountain range composed of metamorphic and igneous rocks of Precambrian age overlain by a Lower Paleozoic

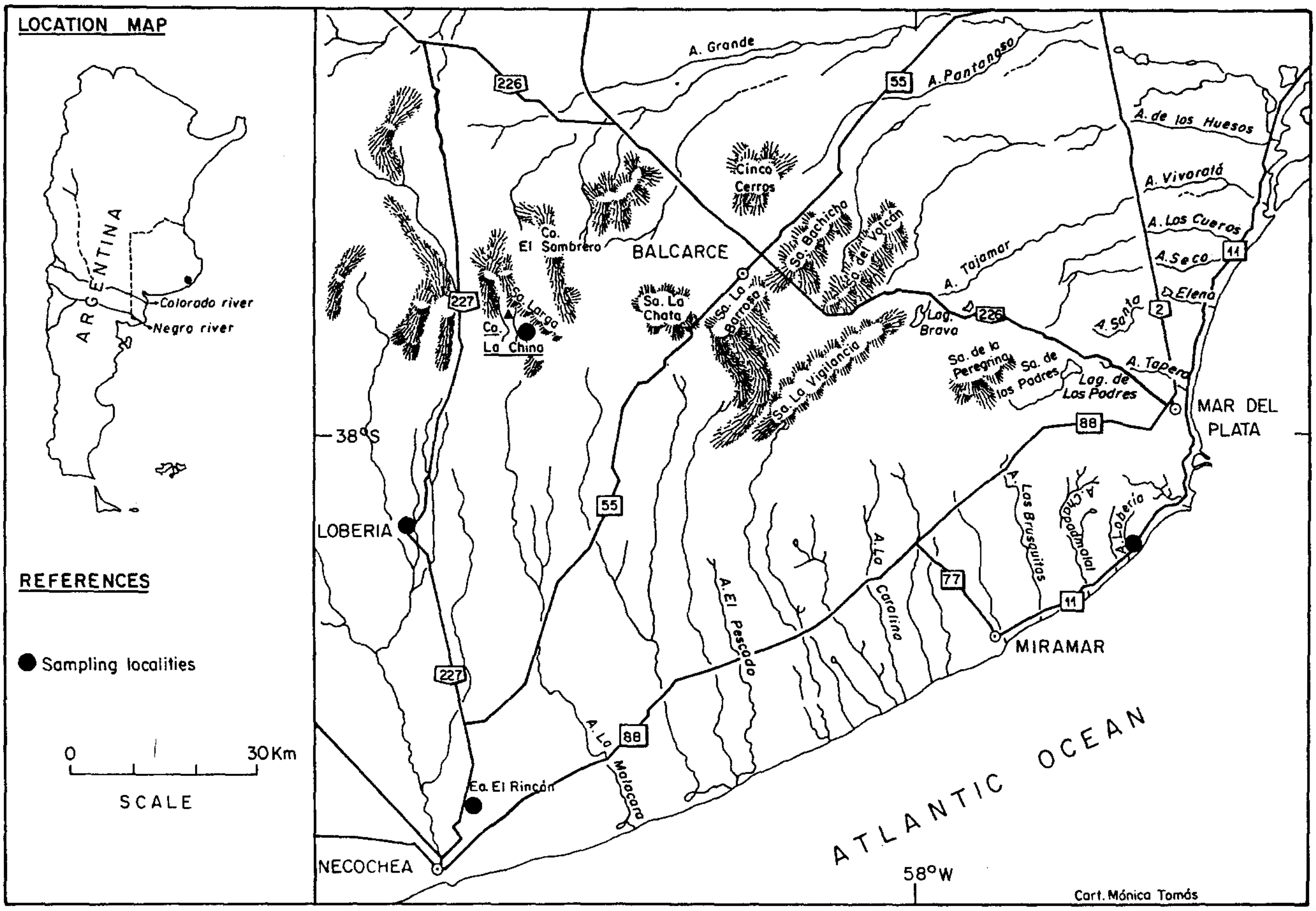

Fig 1 Location map

sedimentary cover, mostly made up of quartzite rocks. This range consists of isolated groups of relatively low and flat crested mountains (relative relief ranging from 50 to 300m) standing abruptly above the surrounding plain (Fig 2a). The faulted blocks were differentially uplifted in Late Cenozoic times (Miocene and Pliocene) giving place to the present horst and graben landscape.

The inter-range plain, which extends southwest of the Tandilia range, is made up of Upper Tertiary (Pliocene) and Lower Pleistocene deposits grouped under the collective name of *Pampean Formation.* This complex stratigraphic unit is mainly composed of reworked loess with some intervening primary loess facies. Paleosols and calcrete crusts are striking features of the Pampean Formation that is well exposed along the sea-cliffs between Mar del Plata and Miramar (Zarate and Fasano 1989). The Pampean Formation unconformably overlies the Precambrian and Paleozoic bedrock that was reached at a depth of about 100m in Necochea (Fig 1). In Miramar, where the bedrock was found at a depth of about 180m, the Late Cenozoic stratigraphic record begins with Miocene marine facies of age, unconformably overlain by 90m of the Pampean Formation.

Since Late Tertiary times the inter-range plain was a more stable tectonic area than the N region of the Salado basin, which is presently a subsident environment. As a result, the Pleistocene stratigraphic record of the studied area is more incomplete than the Quaternary sedimentary sequences described for the N Buenos Aires province.

The landscape of the inter-range plain consists of a gently undulating surface with narrow valleys, excavated into the Pampean Formation, and wide interfluvial areas. Earlier workers believed that the present fluvial cycle was originated by a regional tectonic uplift in Late Pleistocene times. This idea was abandoned for many years although presently it is again taken into account. Instead, climate changes were postulated to explain the last major cycle of landscape reactivation.

Distribution, Stratigraphy and Age of Loess Deposits

Distribution

The loess mantle extends over all the landforms with the exception of the highest crests and slopes of the

Tandilia range. In most of the studied area it typically forms a blanket of fairly constant thickness. In general loess thickness varies between 1.5 and 2 m over the extensive interfluvial surfaces of the inter-range plain. Major thickness variations occur in the intermountain areas of Tandilia, where stratigraphic sections up to 5m thick are present (Fig 2b). In these environments loess is progressively thicker downslope varying between 1 and 3m.

Stratigraphy

The stratigraphy of Quaternary deposits has been a subject of controversy for a long time. Firstly because the subdivision was based on general lithological characteristics of difficult recognition in field observations. In addition, several authors gave different names to the same stratigraphic unit; whereas other investigators created stratigraphic schemes of local significance. As a result there has been much confusion concerning the nomenclature to be adopted. Up to the moment a regional stratigraphic scheme has not been proposed.

The stratigraphic relationships of the Late Pleistocene and Holocene loess deposits were briefly discussed, among others, by Ameghino (1908), Frenguelli (1928, 1957), Tapia (1937) and Kraglievich (1952). These authors gave different interpretations on the geological history of the deposits. Later, Tricart (1973) recognized two main episodes of eolian deposition which he named E3 and E1. More recently Fidalgo and Tonni (1981) pointed out the existence of "at least three lithostratigraphic units bounded by two buried soils" in the studied area.

Most of the stratigraphic work followed the general principles and procedures for lithostratigraphic units. However, the homogeneous lithological characteristics of Late Cenozoic deposits and the variability of depositional sedimentary environments, make the lithostratigraphic approach rather impractical. Thus, in several cases, the fossil content has been used as a fundamental basis for a stratigraphic differentiation of the deposits.

In order to clarify the stratigraphy of loess deposits an allostratigraphic approach was applied in key localities of the studied area as well as in profiles not described previously. The work consisted of the subdivision of the loess mantle by means of surfaces of discontinuity which are defined by paleosols and erosional surfaces. According to this procedure, four allostratigraphic units, numbered 1 to 4 in order of decreasing age, were differentiated.

Unit 1 forms the bulk of the loess mantle (Fig 2 b,c). It is a yellowish brown sediment with carbonate nodules and powdery carbonate in some locations such as upslope segments and over the interfluvial areas. The unit attains a thickness of up to 4m in fluvial valleys where it usually overlies diamicton facies of Late Pleistocene age; in these sites, unit 1 includes intervening layers of reworked loess. In the interfluvial areas it uncomformably overlies the Pampean Formation. On the hillslopes of the Tandilia range, unit 1 buries an erosional surface partially marked by a stone line of quartzite clasts. The surface beveled a strong developed paleosol of unknown age, which is mostly preserved on the uppermost slope segments.

Unit 2 is a 1 to 1.5m thick reddish brown deposit. Its upper part has been modified by pedogenesis into the present soil which is characterized by a moderate to well developed B horizon (Fig 2 d, e). Due to pedogenesis the unit is decalcified throughout. The contact between unit 2 and unit 1 is either an obscure erosional surface or it is marked by a very incipient soil. This boundary is not always recognized owing to the modification of primary relationships by pedogenesis. In some places unit 2 unconformably overlies the Pampean Formation.

Unit 3 is a dark brown deposit (Fig 2d, e). It shows an average thickness of 0.4m with a maximum measured of 0.85m. In most of the studied area, unit 3 makes up the A horizon of present soil profiles. This episode of loess deposition was less significant than the previous ones and cannot be differentiated in some sections. Stratigraphically the lower limit of unit 3 is an erosional surface which has truncated in variable degree the soil profile developed on top of unit 2.

Unit 4 is a dark to very dark brown deposit of very restricted distribution. It constitutes a minor episode of loess deposition which attained some relevance in certain places. Hence it is only recognized in few localities of the studied area. The best exposure is observed at Cerro la China where it attains a thickness of about 0.20m. Here it shows a sharp lower contact with unit 3. It is believed that in many other places unit 4 was mingled with unit 3 by agricultural activities.

Age of Loess

In general the chronological control of the Quaternary stratigraphic record has been chiefly based on the paleontological content of the units. Due to the lack of a systematic control of absolute dating, much uncertainty arises when the stratigraphic sections of different localities are correlated. In this context, because of the very limited number of absolute datings available, the time of deposition assigned to the loess units is tentative.

Unit 1 is assigned to Late Pleistocene age. It bears the last specimens of the typical pampean fossil megafauna. The initiation of this eolian episode is not known. According to regional evidences, it is tentatively placed some time during or immediately after the last glacial maximum (20000–18000? ka BP). For its uppermost section a radiocarbon dating on fossil bone remains *(Glossotherium* (P) *myloides)* was obtained by Figini et al. (1987). It yielded and age of 10710 ± 90 BP.

Unit 2 encompasses an interval between Late Pleistocene and Early Holocene times. Scarce specimens of fossil megafauna were reported from the lowermost levels of the unit in Necochea (Frenquelli 1928) and Loberia (Fidalgo and Tonni 1981). Instead, remains of the

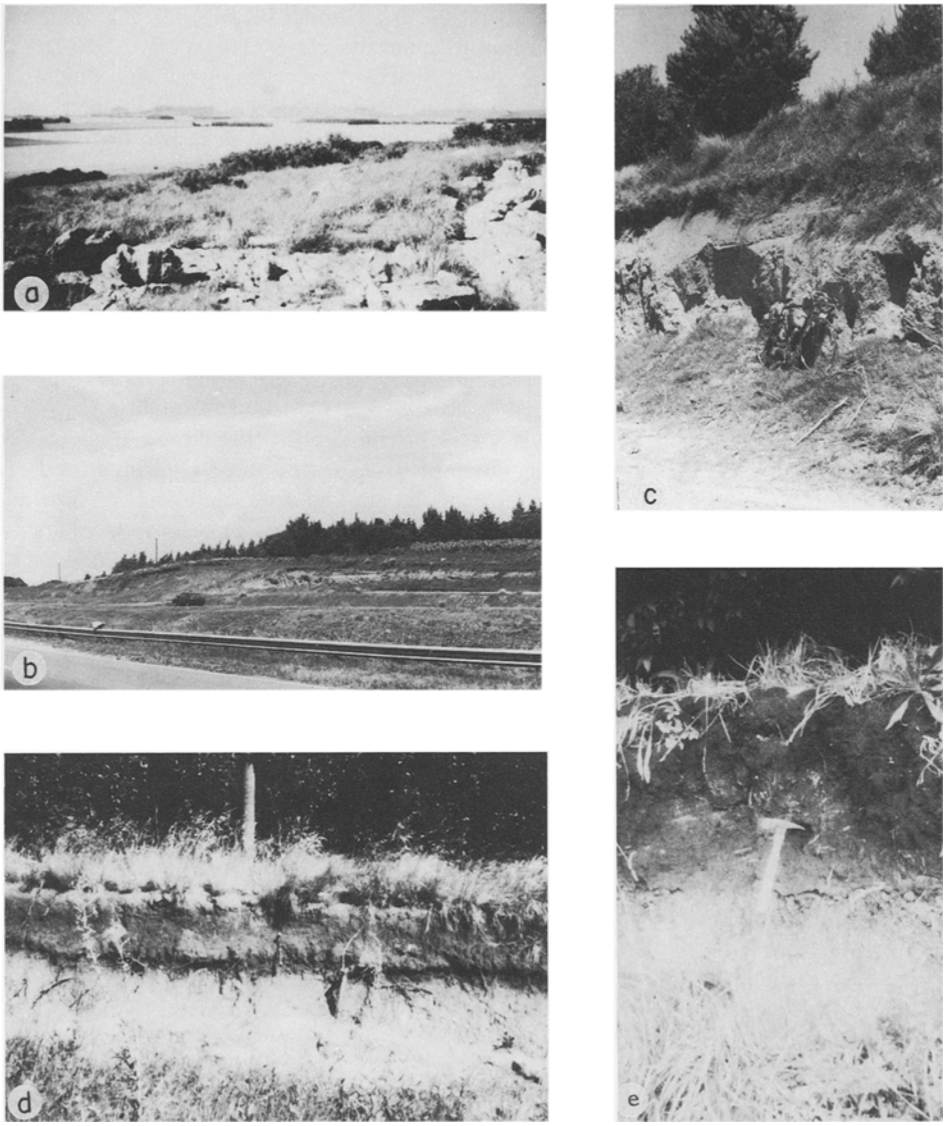

Fig 2a
General view of the Tandilia range and the surrounding plain
b) Loess hill near Mar del Plata
c) Detailes view of the loess hill mostly composed of unit 1; unit 2 at the top
d) Present soil profile developed on unit 2 and unit 3 (A horizon)
e) Unit 2 with a Bt horizon on its upper part. It is unconformably overlain by unit 3

autochtonous pampean fauna of Holocene age were exhumed from the middle and upper levels of the unit. In relation to the chronological control of unit 2, three radiocarbon datings on charcoal were obtained from the lower section of the unit at Cerro La China. They yielded an age of 10730 ± 150 ka BP, 10790 ± 120 ka BP and 10610 ± 180 ka BP. (Flegenheimer and Zárate, 1989). The deposition of unit 2 would have ceased around 8500–9000 ka BP on the basis of regional correlation with marine sequences. It was followed by a soil forming interval which continued until Mid-Holocene times.

Unit 3 is assigned to Mid-to Late Holocene times. It bears remains of present pampean fauna; archaeological remains are also common. The deposition of unit 3 started after the Holocene sea-level maximum when marine regression began. This idea is in agreement with a TL dating of 4540 ± 550 ka BP obtained from its lowermost section at Cerro La China (Flegenheimer and Zarate, in press).

Unit 4 is a recent episode of loess deposition that post-dates the Spanish arrival in the 15th century. It contains European fauna remains. Further southwest of the studied area, Rabassa et al. (1985) reported a stratigraphic unit with similar characteristics that was considered to be synchronous with the "Little Ice Age" in the N Patagonian Andes.

Granulometry and Mineralogical Composition of Loess Deposits

The granulometric and mineralogical composition of loess has been analysed in a general way considering that the number of samples studied is scarce to draw definitive trends among the stratigraphic units identified.

Granulometry

Granulometric analyses were performed following standard methodological procedures. The results obtained are summarized in table 1. Taken as a whole, loess deposits are of a fairly uniform material. Major textural variations are showed by those loess levels deeply modified by pedogenesis, which has altered the original texture of the sediments. The granulometric differences observed in unmodified loess are much less significant.

The dominant grain size is composed of very fine sand and coarse silt (3 to 5 phi). These granulometric classes form the bulk of loess; they comprise 60 to 80% of the deposits. The sand fraction is usually greater than 20%; it ranges from 19 to 56% with only scanty amounts of medium sand (1–2 phi) and fine sand (2–3 phi) (Fig 3 b,c). At Cerro La China locality these grain-sizes were found to be more significant due to local supply of quartzite rocks (Fig 3 d). On the other hand, the clay content is normally less than 13% except where the deposits have been modified by pedogenesis (uppermost section of unit 2, unit 3). Following the sedimentological classification of Folk and Ward (1957) the loess studied is a sandy silt or a silty sand Whereas it corresponds to a sandy mud when it is altered by pedogenesis. On the basis of the sand fraction content, most of the loess samples are classified as sandy loess.

Grain size histograms (Fig 3) show strong unimodality in either the 3–4 or 4–5 phi classes. On the contrary loess modified by pedogenesis exhibits a general tendency to bimodality (Fig 3 e). In these cases, histograms do not really depict the bimodal trend because the grain size distribution of the clay fraction was not identified.

Statistical coefficients were calculated following the method of Folk (1954). The data are summarized in Table 1. The coefficients were sensitive to differentiate textural modification by pedogenesis (Table 1)

Loess not modified by pedogenesis is relatively coarse (average size of 4.7 phi), mainly poorly sorted, very positively to symmetric skewed and leptokurtic to extremely leptokurtic. Loess modified by pedogenesis is finer, very poorly sorted, very positively skewed and mesokurtic.

In this study, log-probability plots were used to represent grain size cumulative distributions. This method of plotting, not commonly applied for fine eolian sediments, was chosen in preference to the cumulative frequency curves in arithmetic scale, because it is more useful to interpret the dynamics of sedimentary processes. As a result the frequency-plots of the loess studied consist of three straight – line segments. According to Visher (1969) the number, slope and breaks between segments are thought to vary systematically with sedimentary processes; each of the segments represents grain-size subpopulations moved by different modes of transport.

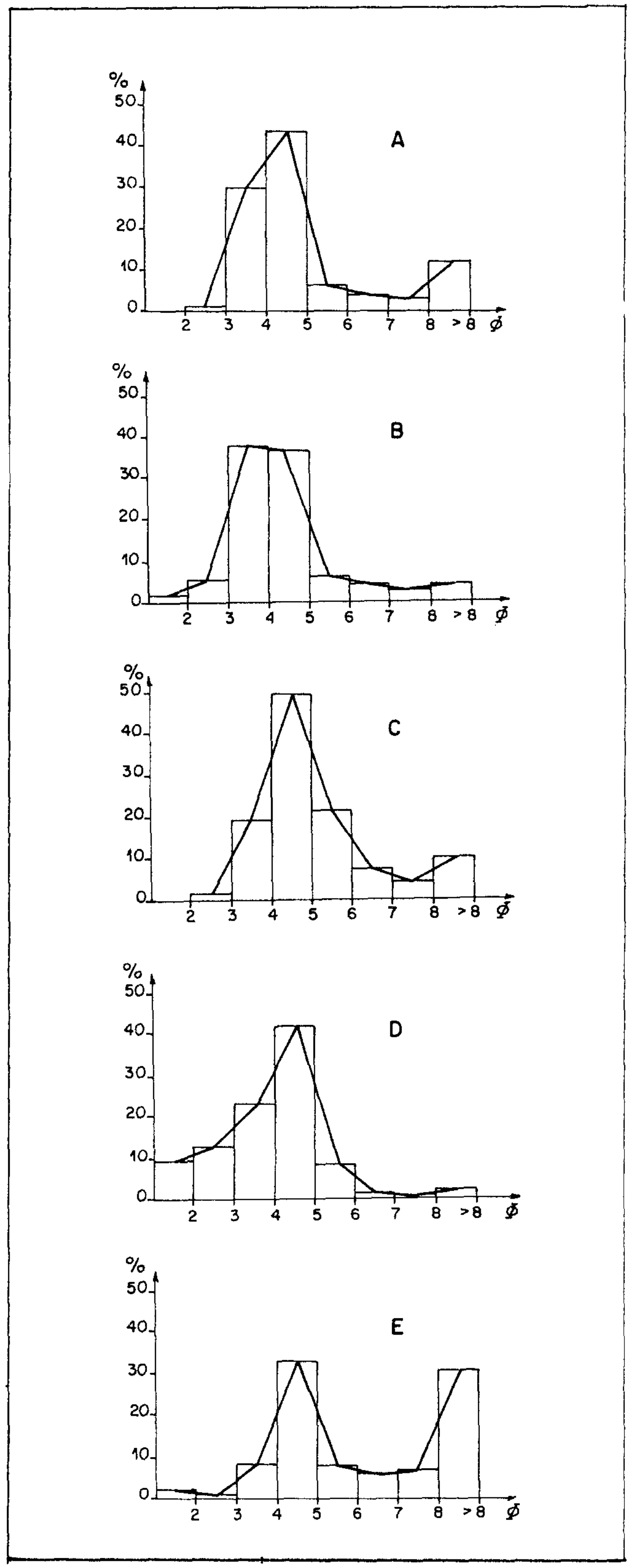

Fig 3 Grain-size histograms and frequency polygons of selected samples.
A) unit 1 at Lobería locality; B) unit 2 at Cerro La China; C) unit 3 at Loberiá; D) unit 4 at Cerro La China; E) unit 2 modified by pedogenesis at Cerro La China

Tab 1
Granulometric analyses and statistical parameters of selected samples.

		SAMPLING LOCALITY	SAND:SILT:CLAY RELATION (Z)	STATISTICAL PARAMETER Md (Ø)	Mz (Ø)	δ_1 (Ø)	Sk (Ø)	Kg (Ø)
NOT MODIFIED BY PEDOGENESIS	UNIT 1	Cerro La China	56:41: 3	4.00	4.23	1.43	0.42	2.45
		Cerro La China	47:46: 7	4.10	4.53	1.65	0.40	2.25
		Ea. El Rincòn	35:50:15	4.30	5.35	2.37	0.72	1.65
		Lobería	31:56:13	4.30	5.06	2.03	0.71	2.83
		Chapadmalal	37:51:12	4.25	4.95	1.91	0.70	4.15
	UNIT 2	Cerro La China	45:50: 5	4.05	4.27	1.25	0.40	2.09
		Ea. El Rincòn	37:56: 7	4.20	4.53	1.43	0.55	2.79
		Lobería	37:50: 13	4.30	4.97	1.80	0.63	2.08
		Chapadmalal	41:46:13	4.20	4.86	1.90	0.73	4.44
	UNIT 3	Cerro La China	24:61:12	4.60	5.20	2.01	0.50	1.43
		Ea. El Rincòn	14:74:12	4.35	5.30	2.28	0.83	9.63
		Lobería	19:72: 9	4.40	4.90	1.55	0.55	1.56
	UNIT 4	Cerro La China	40:58: 2	4.40	4.30	1.25	−0.12	1.17
		Cerro La China	46:52: 2	4.00	3.63	1.30	−0.05	2.04
		mean statistical parameters		4.24	4.72	1.72	0.52	2.89
modified by pedogenesis	UNIT 2	Cerro La China	19:54:27	4.80	5.86	2.81	0.72	1.10
		Cerro La China	13:45:42	7.00	8.03	3.98	0.36	0.72
	UNIT 3	Cerro La China	13:56:31	5.60	6.83	3.18	0.58	1.05
		Cerro La China	19:52:29	5.30	6.30	2.85	0.61	0.83
		mean statistical parameters		5.67	6.74	3.20	0.56	0.92

Fig 4 depicts the grain-size distribution of a representative sample.

The coarse size subpopulation of Buenos Aires loess is made up of fine to very fine sand; it represents 1 to 10% of the total frequency; the rather low slope of its segment reveals a moderate sorting. The medium-size subpopulation is partially composed of very fine sand and coarse silt; it makes up 50 to 80% of the total distribution; the relative steep slope of its segment suggests a good sorting. It constitutes the most important subpopulation. The fine-size subclass comprises the medium silt to clay granulometric interval; it makes up 4 to 30% of the total distribution.

In recent years, experiments in wind tunnels and studies on modern dust storms provided new evidence in relation to the modes of transport of fine eolian sediments. The result were summarized by Pye (1987) (Fig 4; Fig 5). This author showed that very fine sand is moved by saltation and modified saltation; medium to coarse silt is transported mainly in short-term suspension or modified saltation and the fine silt and clay fractions are moved by long-term suspension. According to this evidence, it can be inferred that the coarse size subpopulation would be moved by saltation; the medium size subpopulation by modified saltation and short-term suspension; and the fine size subpopulation would be related to long-term suspension material mixed by turbulence at low levels. Notwithstanding, in the latter case, granulometric analysis procedures may account for part of the clay-size particles which may have been transported either as sand or silt aggregates or coatings (Pye 1987).

In summary, the granulometric data reveal that loess would have been chiefly transported by modified saltation and short-term suspension during local dust storms (Fig 5).

Mineralogical Composition

The qualitative analysis of the mineralogical composition was focused on the modal fraction (3 to 5 phi) of selected samples. The very fine sand and coarse silt fractions were examined with the petrographic microscope.

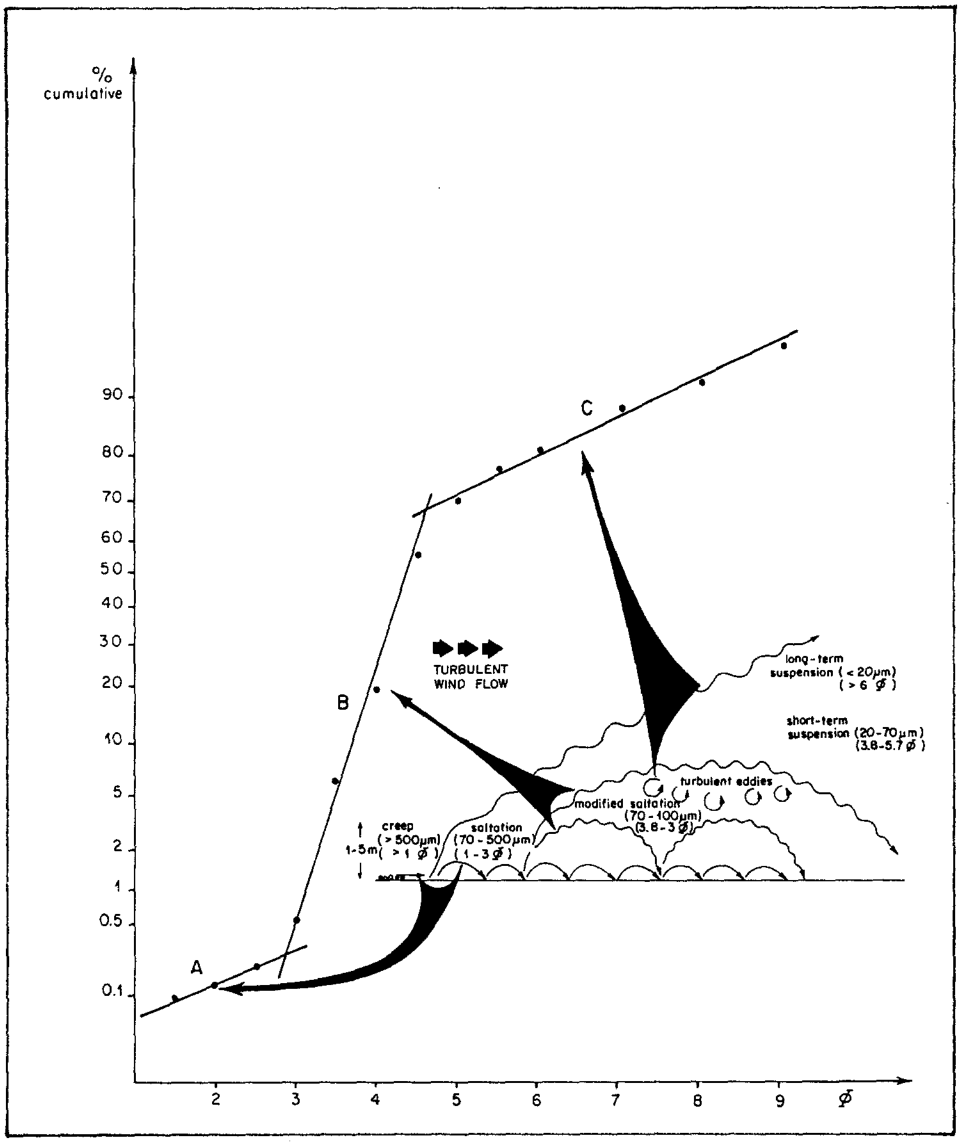

Fig 4
Probability plot of grain-size distribution of a representative sample. Tentative correlation with modes of transport of fine eolian sediments (after Pye, 1987)
(A) coarse-size subpopulation; (B) medium-size subpopulation; (C) fine-size subpopulation.

In general the light mineral suite is dominated by the abundance of volcanic glass; plagioclase feldspar, quartz and volcanic rock fragments are the other major components.

Volcanic glass is a colourless to, rarely brown, acidic variety consisting of very angular fragments (Fig 6 a, b) According to the morphological characteristics of volcanic shards, two main types are recognized: dense and pumiceous (Fig 6 b). Dense shards are either curved or platy commonly with an Y-shape. They are thought to enclose originally rounded or large flattened bubbles. Pumiceous shards (Fig 6 a, b) are frothy or more frequently fibrous when fragments come from vesicles drawn out in tube-like forms. Volcanic glass is frequently fresh. In this case, both dense and in minor proportion pumiceous shards exhibit a clear to slightly cloudy transparency. Other fragments, mainly pumiceous types, do not show very clear transparency owing to infilling clay in cellular pumice or alteration of intercellular walls.

Plagioclase tends to occur as fresh irregular or fractured euhedral fragments in the form of subangular to subrounded grains. The composition ranges from albite to sodic labradorite. Normal oscillatory zoning is well developed. Albite and combined albite-Carlsbad twinning are typically common.

The group of K-feldspar is dominated by orthoclase. It usually consists of subrounded grains, partially or totally altered. Scarce unaltered grains of microcline are also present.

Quartz, although common, is not as abundant as in other loess deposits of the world. It is colourless or redish due to ferric coatings. Grains are subangular to subrounded without showing inclusions. At Cerro La

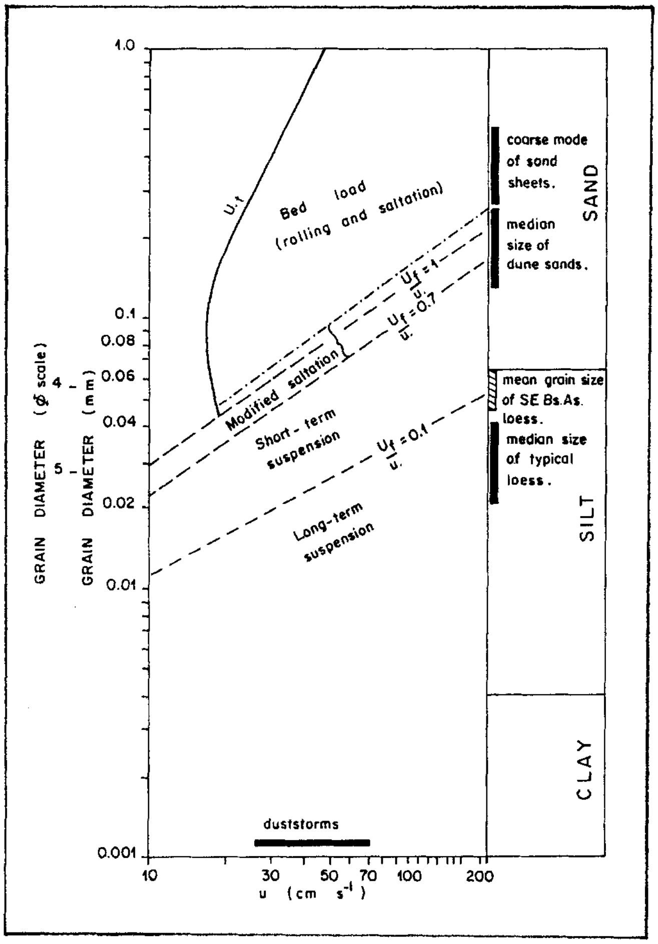

Fig 5 Grain diameter and modes of eolian transport (after Pye, 1987): relationship of SE Buenos Aires loess with other eolian deposits

China locality in the Tandilia range, policrystalline quartz is present in traces.

Volcanic rocks are very common; in some cases they are nearly as abundant as volcanic glass. Grains are usually rounded. Sometimes, alteration and impregnation by iron-oxides make their identification difficult. The fragments consist mainly of volcanic groundmasses; rhiolithic clasts with felsitic textures, basaltic and andesitic lithic fragments are recognized.

In all the samples, there is a variable amount of reddish brown grains, opaque or showing very cloudy transparency, that cannot be precisely determined. They seem to be strongly weathered volcanic groundmasses.

Chalcedony, sparitic and micritic grains are also present in traces in the light mineral fraction.

The heavy mineral suite ranges from 1 to 2%. It is composed of opaques, amphiboles, orthopyroxenes, clinopyroxenes and micas. Also present are epidote, garnet, tourmaline and collophane. In general heavy minerals are extremely fresh to slightly weathered.

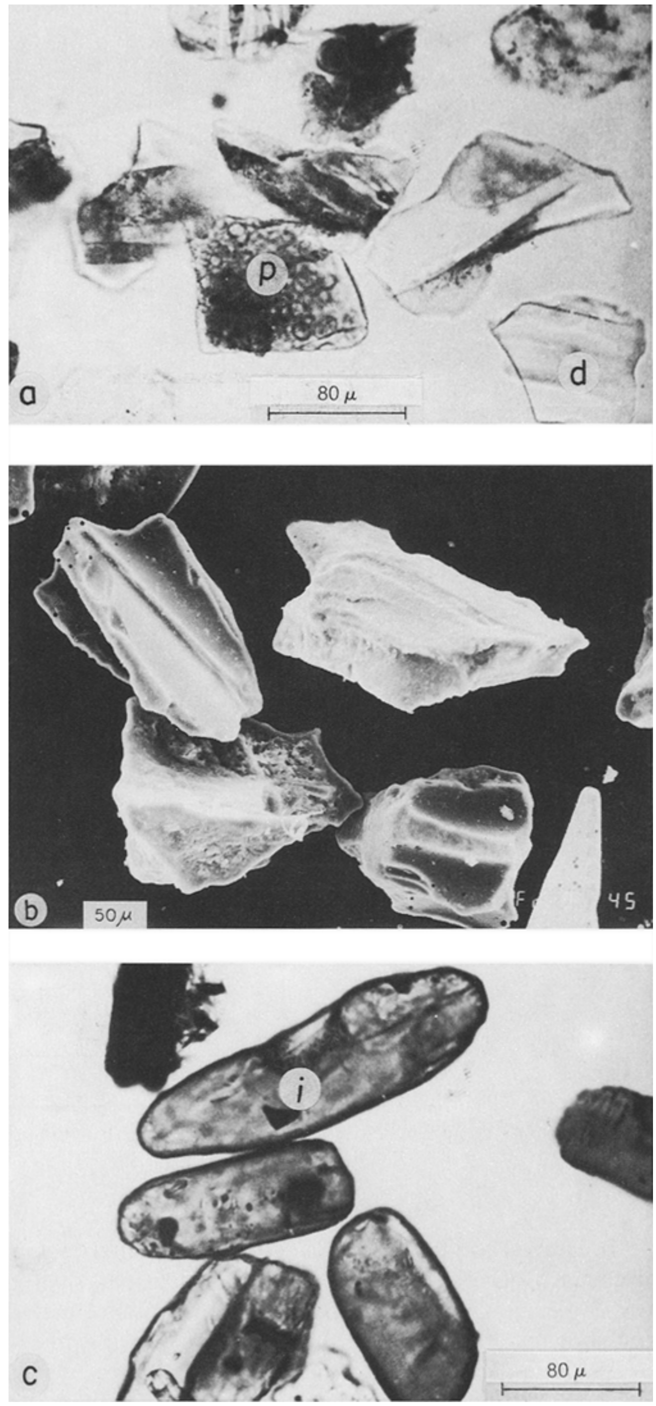

Fig 6 Mineralogical composition of loess deposits
a) Volcanic glass; (p) pumiceous shards; (d) dense shards
b) Volcanic glass; angular fragments of pumiceous shards
c) Heavy minerals; well rounded grains of hyperthene with (i) opaque inclusions

Opaques make up a great part of the heavy mineral group. Magnetite, which appears as well rounded grains, is the most frequent. Hematite is also present.

The amphiboles include green or brown green varieties of hornblende and small amounts of lamprobolite. Grains exhibit usually a tabular habit, being subrounded to subangular.

Hypersthene is the most abundant member of orthopyroxenes. It occurs as prismatic and bipyramidal crystals often slightly fractured (Fig 6 c). Grains are usually well rounded; inclusions of euhedral iron-ore minerals are common (Fig 6 c)). Enstatite is present in very low amount.

Clinopyroxenes include augite which appears as subangular prisms and subrounded grains.

Micas, both muscovite and biotite, occur as flakes.

In relation to the clay mineralogy, it was found that this fraction is composed mostly of illite with traces of kaolinite. Where loess is modified by pedogenesis, it contains similar amounts of illite and montmorillonite.

According to this mineralogical association, the Late Pleistocene and Holocene loess deposits can be classified as volcaniclastic sandy silts. According to Fisher (1961) volcaniclastic sediments consist of pyroclastic debris and terrigenous volcanic detritus of epiclastic origin. Similar mineralogical assemblages have been reported for both the Rio Negro Formation (Andreis 1965) and the present fluvial deposits of the Colorado river (Blasi 1986).

The Rio Negro Formation (Upper Miocene?-Pliocene?) crops out in the extra Andean region of northern Patagonia about 400 km SW of the studied area in this work. This stratigraphic unit constitutes a considerable part of the middle and lower valley bedrock of the Colorado and Negro rivers (Fig 1).

The Colorado river drains from the Andes to the Atlantic ocean. Along the stream, which flows through and arid to semiarid region, two kinds of deposits are present: proximal sands and gravels, derived from a volcanic arc, and distal sands showing the same provenance (Blasi and Manassero, 1990). Consequently, in its lower valley, the present overbank deposits are derived from both upstream erosion of Andean volcanic and pyroclastic rocks and valley floor erosion of the bedrock (Blasi 1986)

This evidence permits to conclude that the lower Colorado valley could be the main provenance area from where the sediments were blown northeast towards the Buenos Aires province.

On the other hand, the abundance of fresh volcanic glass could be partially explained by direct incorporation due to volcanic ash falls. This process is still active in the pampean region.

Conclusions

In the southeastern part of Buenos Aires province, the last cycle of loess is composed of four episodes of deposition represented by four allostratigraphic units. The first and the second episodes took place in Late Pleistocene times; they account for the bulk of loess sedimentation. During the Holocene, loess deposition was far more restricted. The third depositional episode occurred in Mid-Holocene time when marine regression began. The fourth episode is a historical event of quite localized significance.

Very fine sand and coarse silt make up most of the loess deposits that are classified as sandy loess. Loess is made up of three grain-size subpopulation. The coarse subpopulation, composed of fine sand and part of the very fine sand fraction, was transported by saltation. The medium-size subpopulation, which consists of most of the very fine sand and coarse silt, was moved by modified saltation and short-term suspension. The fine subpopulation, made up of the medium silt to clay granulometric interval, would correspond to long-term suspension material mixed by turbulence at low levels.

The volcaniclastic assemblage of loess derives mainly from reworked pyroclastic deposits (i.e. tuffs), primary tephra units and volcaniclastic sediments. The source area is located in the lower Colorado river valley where these materials form both the present overbank deposits and the fluvial bedrock. Besides, part of the material was directly incorporated by volcanic ash falls.

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References

Ameghino, F.: Las formaciones sedimentarias de la región litoral de Mar del Plata y Chapalmalán. An. Mus. Nac. Buenos Aires 3, 343–428 (1908)

Andreis, R.: Petrologia y paleocorrientes de la Formacion Rio Negro (tramo Gral Conesa-Boca del rio Negro) 1965. Rev. Museo de la Plata. Nueva Serie Tomo V Geol., 36, La Plata, 245–310 (1965)

Blasi, A. M.: Sedimentologia del rio Colorado. 1986 PhD Thesis FONM University of La Plata (unpubl.) 1986. 238 p.

Blasi, A. M.; Manassero, M.: The Colorado river of Argentine: source, climate and transport as controlling factors in plate tectonic sand compositions. (1990) Journal of South American Earth Science 3 (1): 65–70

Fidalgo, F.; Tonni, E. P.: Sedimentos eólicos del Pleistoceno tardio y reciente en el área interserrana bonaerense. VIII Congreso Geológico Argentino, ACTAS III: 33–39 (1981)

Figini, A. J.; Carbonari, J. E.; Gómez, G. J.; Tonni, E. P.; Fidalgo, F.: Datación de restos óseos de la Formación La Postrera en el partido de Loberia, provincia de Buenos Aires, Argentina X Congreso Geológico Argentino, Tucumán, ACTAS: 185–188 (1987)

Fisher, R. V.; Proposed classification of volcaniclastic sediments and rocks. Geol. Soc. Bull. 72, 1407–1414 (1961)

Flegenheimer, N.; Zárate, M.: Sitios arqueológicos y geocronologia de los ultimos 10000 años en las sierras de Tandil. (1989) Simposio Internacional sobre el Holoceno de América del Sur, noviembre, Paraná, Argentina, ACTAS (1986): 171–174

Folk, R.: The distinction between grain size and mineral composition in sedimentary rock nomenclature. Jour. Sed. Petrol. 62, 344–359 (1954)

Folk, R.; Ward, W. C.: The Brazos river bar: a study on the significance of grain-size parameters. Jour. Sed. Petrol. 27, 1, 3–27 (1957)

Frenguelli, J.: Observaciones geológicas en la región costanera sur de la provincia de Buenos Aires. Univ. Nac. Lit. Fac. Cienc. Educ., Anales Paraná, II 1–145 (1928)

Frenguelli, J.: Loess y limos pampeanos. 1955. Serie Técnica y Didáctica. n° 7 Facultad de Cien. Nat. y Museo. UNLP. Min. Educ. de la Nación, pp. 88 (1955)

Frenguelli, J.; Neozoico: En Geografia de la República Argentina. Soc. Arg. de Est. Geograf., GAEA, II, 1–212 (1957)

Heusser, J. C.; Claraz, G.: Essai pour servir a une description physique et geognostique de la province argentine de Buenos Ayres. Mém. Soc. Helvetique Sci. Natur, 21, 139 (1866)

Kraglievich, J. L.: El perfil geológico de Chapadmalal y Miramar, provincia de Buenos Aires. Rev. del Museo de Mar del Plata 1, 8–37 (1952)

Pye, K.: Aeolian dust and dust deposits. Academic Press, pp. 334 1987

Rabassa, J.; Brandani, A.; Politis, G.; Salemme, M.: La "pequeña Edad de Hielo" (Siglos XVI a XIX) y su posible influencia en la aridización de áreas marginales de la Pampa húmeda (provincia de Buenos Aires) Iras Jorn. Geol. Bonae., Tandil (11–15 noviembre 1985) Resúmenes: 15–16 CIC, La Plata (1985)

Tapia, A.: Las cavernas de Ojo de Agua y Las Hachas. Historia geológica de la región de la Brava en relación con la existencia del hombre prehistórico. Bol. Direcc. Gen. Industria Minera, 43, 1–126 (1937)

Teruggi, M. E.: The nature and origin of Argentine loess. Jour. Sed. Petrol. 27, 322–332 (1957)

Tricart, J. L. F.: Geomorfología de la Pampa Deprimida. INTA Colección Cient. Buenos Aires, 12, pp 202 (1973)

Visher, G. S.: Grain size distributions and depositional processes. Jour. Sed. Petrol. 39, 1074–1106 (1969)

Zárate, M.; Fasano, J. L.: The Plio-Pleistocene record of the Central Eastern Pampas, Buenos Aires Province, Argentina: The Chapadmalal case study. Palaeogeography, Palaeoclimatology, Palaeoecology 72, 27–52 (1989)