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Pleistocene Radiometric Geochronology and Vertebrate Paleontology in México: Overview and Critical Appraisal[1]

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ABSTRACT. The combined radiometric and paleontologic approach drove a qualitative leap in understanding Earth's geologic history and evolution, yet it is still not widely used in México in spite of its early start. In order to stimulate others to apply this fruitful approach, and thus to contribute to better comprehension of México's Quaternary biotic and geologic make and evolution, here we report 21 Pleistocene sites with dated vertebrate-bearing units where such an approach was applied; their space/time distribution is quite uneven, leaving whole regions, morphotectonic provinces, and geochronologic intervals little studied or unstudied. The sites occur only in five of the 11 existing morphotectonic provinces, as follows: Northwestern Plains and Sierras, one Rancholabrean; Sierra Madre Oriental, two Rancholabrean; Trans-Mexican Volcanic Belt, 14 Rancholabrean; Sierra Madre del Sur, two Rancholabrean; and Sierra Madre de Chiapas, two Irvingtonian. No dated sites have been reported for the following provinces: Baja California Peninsula, Sierra Madre Occidental, Chihuahua-Coahuila Plateaus and Ranges, Central Plateau, Gulf Coastal Plain, and Yucatan Platform.

Analysis of the 21 sites treated here discloses the need to describe or revise their lithostratigraphic settings. Nonetheless they are of prime importance for understanding the regional Quaternary environmental change (climatic and otherwise, including timing, extent, and biotic impact). The mammal assemblages from these sites belong to three chronofaunas: Irvingtonian (three sites), Early Rancholabrean (one site), and very Late Rancholabrean (Wisconsinan, 17 sites).

From the beginning to the end of the Pleistocene the fauna underwent a profound change, drastically modifying its taxonomic composition, its biogeographic distribution, and its entire physiognomy with strong trends toward losing meso- and megabaryc taxa by taxonomic depauperation (through selective extinction and/or emigration) and biogeographic shuffling. Thus, the Holocene fauna is an impoverished version of its Pleistocene counterpart.

Finally, during this epoch our own species appears in México. In fact, some of the oldest records of humans in the American continent, based on direct dating of human skeletal material, are from México.

RESUMEN. El enfoque radio-isotópico/paleontológico combinado impulsó un salto cualitativo en el entendimiento de la historia y evolución de la Tierra, empero no se utiliza ampliamente en México, a pesar de su temprano inicio. Con el propósito de estimular a otros en el empleo de este enfoque, y contribuir así a un mejor entendimiento del Cuaternario, se reportan aquí reportan 21 sitios con unidades fechadas que portan vertebrados, donde se empleó este enfoque; su distribución espacio/temporal es dispareja quedando regiones/provincias morfotectónicas y/o intervalos geocronológicos poco o nada estudiados. Los sitios yacen sólo en cinco de las once provincias morfotectónicas existentes, como se muestra a continuación: Sierras y Planicies del Noroeste (NW), 1 Rancholabreano. Sierra Madre Oriental (SMOr), 2 Rancholabreanos. Faja Volcánica Transmexicana (TMVB), 1 Irvingtoniano y 13 Rancholabreanos. Sierra Madre del Sur (SMS), 2 Rancholabreanos. Sierra Madre de Chiapas (SMCh), 2 Irvingtonianos. No se han reportado este tipo de sitios en estas provincias: Península de Baja California (BCP), Sierra Madre Occidental (SMOc), Mesetas y Sierras de Chihuahua-Coahuila (CH-CO), Altiplanicie Central (CeP), Planicie Costera del Golfo Costal (GCP), y Plataforma de Yucatán (YP).

El análisis de los 21 sitios aquí considerados, evidencia la necesidad de describir o revisar su marco litoestratigráfico; a pesar de ello, son de gran importancia para entender el cambio ambiental del Cuaternario (climático y de otro tipo, incluyendo cronología, alcance e impacto biótico). Sus ensambles mamiferianos pertenecen a tres cronofaunas: Irvingtoniana (tres registros) y Rancholabreana (un registro temprano y 17 muy tardíos Wisconsinanos.

En este período, la fauna sufrió un cambio profundo a lo largo del continuo tempo/espacial, modificando drásticamente su constitución taxonómica, distribución biogeográfica y su propia fisonomía, con una fuerte tendencia hacia la pérdida de taxa meso- y megabáricos, empobrecimiento taxonómico (mediante extinción/expatriación) y rearreglo biogeográfico.

Es así que la fauna holocénica es apenas una versión empobrecida de su contraparte pleistocénica. Finalmente, durante esta época, apareció nuestra propia especie en México; de hecho algunos de los registros humanos más antiguos del Continente Americano, basados en fechamiento directo (de material esquelético humano), son de México.

INTRODUCTION

Paleontology, particularly vertebrate paleontology, benefitted immensely from the advent of radiocarbon dating at affordable prices that occurred in the early 1950s, allowing calibration of the Quaternary Period, which in turn made possible a more precise long-range correlation of geologic events in marine and terrestrial stratigraphic sequences across distant regions and continents.

The application of radiometric dating techniques started early in México with the pioneering effort of Arnold and Libby (1950) on the Cuicuilco site—disclosing human occupation in the Basin of México's southern part as early as 2422 ± 250 years BP—and on remains of the famous Tepexpan Man (4430 ± 350 to 3800 ± 450 years BP). A major advance was the establishment in 1975 of the Radiocarbon Laboratory at the Instituto Nacional de Antropología e Historia (INAH) in México City. This is chiefly devoted to dating archaeolog-

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ically significant sites, which frequently include vertebrate remains, thereby providing ages measured in units of the sidereal time system that we use in our everyday life. The biochronological dating afforded by the fossils themselves enhances precise correlation of sites and vertebrate faunas across the country, places time brackets on climatic events such as changes in temperature and/or humidity, and facilitates the study of biotic succession and faunal turnover at specific sites. These facts are of great archaeological and paleontologic significance.

Unquestionably, the INAH has led the effort to radiometrically date significant archaeological sites in México. A subsequent welcome addition was the foundation in 2004 of the Laboratorio Universitario de Radiocarbono, a radiocarbon dating facility shared by the Instituto de Geología, the Instituto de Geología Geofísica, and the Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México, also in México City.

Radiometric dating of Quaternary sites in México has been primarily focused on solving archaeological questions rather than on vertebrate paleontological problems; however, both disciplines share common cognitive areas and so a great deal of paleontologically significant information has resulted from this effort. For instance, two sites in the Sierra Madre Oriental morphometric province (MP) that yield large and diverse mammal faunas were ^{14}C dated: San Josecito Cave, Nuevo León (Arroyo-Cabrales and Johnson, 1995), and El Cedral, San Luis Potosí (Lorenzo and Mirambell, 1986a), the latter also yielding bonfire charcoal, an indirect evidence of humans in central México. Numerous sites that lie in the Trans-Mexican Volcanic Belt's eastern part were dated, for example, Tlapacoya (González et al., 2003), Tepexpan (Lamb et al., 2009), and Santa Lucía, Estado de México (Arroyo-Cabrales et al., 2004); Peñon III, Distrito Federal, now Ciudad de México (Mercer et al., 2003); and Valsequillo, Puebla (González et al., 2001). The dating of other sites discovered while doing geologic work has enhanced their interpretation, for example, Punta de Llano (Ferrusquía-Villafranca, 1996) and Chiapa de Corzo, Chiapas (Ferrusquía-Villafranca and McDowell, 1991). Other sites, though not bearing human remains or cultural records, were nonetheless dated, because of their large and interesting vertebrate fauna, for example, Térapa, Sonora (Mead et al., 2006).

This overview shows the fruitful results of combining radiometric dating and paleontologic research in México. This helps to better understand this country's vertebrate faunistic evolution, which in turn has a strong bearing in understanding Quaternary climate change and the dramatic physiognomic change of the mammal fauna across Pleistocene time and the Pleistocene/Holocene boundary.

METHODS

An exhaustive bibliographic search was undertaken for sites that have radiometrically dated lithostratigraphic units with vertebrate fossil assemblages or are stratigraphically related to such vertebrate-bearing units, thereby furnishing constraints on the assemblage age and providing minimum/maximum time limits (Table 1 and Fig. 1). The dates were obtained from coal zones, charcoal remains, carbonized plant remains (excluding wood), carbonized wood fragments, and collagen-bearing bone fragments.

From this search, we detected 21 sites across the country from which a reliable analysis can be made. The sites are plotted in Figure 1, a map of the morphotectonic provinces of México (Ferrusquía-Villafranca et al., 2010). The geological/paleontological significance of the sites could be better perceived on a morphotectonic provinces map than on a political-division or state map in which the state boundaries are quite artificial and frequently cut across geologic features.

The morphotectonic provinces include Baja California Peninsula (BCP), Northwestern Plains and Sierras (NW), Sierra Madre Occidental (SMOc), Chihuahua–Coahuila Plateaus and Ranges (CH-CO), Sierra Madre Oriental (SMOr), Gulf Coastal Plain (GCP), Central Plateau (CeP), Trans-Mexican Volcanic Belt (TMVB), Sierra Madre del Sur (SMS) Sierra Madre de Chiapas (CHI), and Yucatan Platform (YPL).

SUMMARY OF SITES INFORMATION PRESENTED AND DISCUSSED

In Table 1, the sites are listed in eight topically grouped columns that treat the following aspects: geographic, geologic, radiometric, and paleontologic-geochronologic aspects.

Geographic–Geologic Aspect

The first column indicates the morphotectonic province and state for each site. The sites are listed consecutively from north to south and from west to east. Within the text the sites are described and discussed in geochronologic order from oldest to youngest. To avoid any confusion, each site is properly named and numbered in the text. A particular site may include a single locality or a cluster of spatially close localities that are designated areas. The chief references, both radiometric and paleontological, are also given (bracketed number after the site name), and spelled out as footnotes.

The second column provides the fossil-bearing unit name from which radiometric ages were obtained; the unit's condition (named or unnamed) is stated. We have also qualified nomenclatural status of named unit as formal or informal according to whether or not they meet the provisions of the North American Stratigraphic Code (NACSN, 2005) or of the pertinent code at the time of their proposal. All unnamed units are informal.

The third column provides the site coordinates to the nearest minute based on published information, or is inferred from information given in the referred article; this last mode is expressed by an ampersand (&) as a footnote designator.

Radiometric Aspect

The fourth column bears the numerical ages, expressed as kiloanni (ka). The fifth column lists the dated material and the method of dating used: K-Ar (sensu Bonhomme et al., 1975), ^{40}Ar-^{39}Ar (sensu van der Pluijm et al., 2006), fission track (sensu Günther and Van den Haute, 1992), standard ^{14}C (sensu Libby, 1946; Anderson et al., 1947; Geyh and Schleicher, 1990), or accelerator mass spectrometer (AMS) ^{14}C (sensu Gillespie et al., 1984). Because AMS analysis is still quite expensive, it was performed only in a few significant sites; in most sites the standard ^{14}C method was used.

Paleontological–Geochronological Aspect

The sixth column lists the names of the fossil assemblages studied. These may be a local fauna (l.f., an assemblage collected from a single locality or spatially very close localities), or a single occurrence (s.o., vertebrate remain[s] that belong to a single individual/taxon). These assemblages are usually named after a geographic feature.

The seventh column states the biochronological age of each assemblage in terms of the North American Land Mammal Ages (NALMA) as presented in Woodburne (2004) or in Bell et al. (2004) for the Irvingtonian and Rancholabrean NALMAs.

The Wisconsinan Glacial Episode, originally the classical Fourth Glacial Stage of the Pleistocene Epoch in North America (Neuendorf et al., 2005), is at present the only numerically defined and widely used Pleistocene glacial episode and mammalian age. It corresponds to the ~40–10 ka interval, its lower boundary coinciding with the lower practical limit of ^{14}C dating, and its upper with the Pleistocene/

Table 1 Radiometrically dated Pleistocene lithostratigraphic units that bear vertebrates assemblages.

Morphotectonic Province (MP)	State Site [Ref.]	Formation	Site Coordinates	Radiometric Age (in ka)*	Method	Local Fauna (l.f.) or Single Occurrence (s.o.)	NALMA#	Epoch##
NORTHWESTERN PLAINS AND SIERRAS MP								
Sonora State								
1. Térapa	[1a]	Tonibabi basalt flow [Informal]	29°41′N-109°39′W&	0.44 ± 0.13 440 ± 130* [Maximal age]	^{40}Ar-^{39}Ar [Whole rock]]	Térapa l.f. **[Estimated age: 570 ka to ...	Middle Irvingtonian [Irvingtonian II]	Middle Pleistocene
				0.3 ± 0.1 300 ± 100*	^{40}Ar-^{39}Ar [Whole rock]	**...310 ka]	Late Irvingtonian [Irvingtonian III]-Early Rancholabrean**	Late Pleistocene
	[1a, 1b]	Unnamed Lower lava flow	29°39′N-109°28′W	1.7 ± 0.74 1,700 ± 740* [Maximal age]	^{40}Ar-^{39}Ar [Whole rock]		Rancholabrean**	Early Pleistocene
	[1a, 1b]	Unnamed Upper lava flow	29°41′N-109°28′W	0.61 ± 0.08 610 ± 80* [Maximal age]	^{40}Ar-^{39}Ar [Whole rock]		Rancholabrean**	Middle Pleistocene
				0.47 ± 0.006 470 ± 6* [Minimal age]	^{40}Ar-^{39}Ar [Whole rock]			
SIERRA MADRE ORIENTAL MP								
Nuevo Leon State								
2. San Josecito Cave	[2]	Unnamed	24°06′N-99°49′W&	44.52*	^{14}C [Standard]	San Josecito l.f.	Late Racholabrean	Late Pleistocene
	[2]			28.005*	^{14}C [Standard]		Wisconsinan	Late Pleistocene
San Luis Potosí State								
3. El Cedral	[3]	Unnamed	23°48′N-100°42′W&	33.3*	^{14}C [Standard]	El Cedral l.f.	Wisconsinan	Late Pleistocene
TRANS-MEXICAN VOLCANIC BELT MP								
Mexico State								
4. Santa Isabel Ixtapan	[4]	Unnamed	19°34′N-98°56′W&	16.0*	^{14}C [Standard]	Santa Isabel Ixtapan l.f.	Wisconsinan	Latest Pleistocene
	[4]		19°34′N-98°56′W&	11.003*	^{14}C [Standard]	Santa Isabel Ixtapan l.f.	Wisconsinan	Latest Pleistocene
	[4a]		19°34′N-98°56′W&	14.500*	^{14}C [Standard	Santa Isabel Ixtapan l.f.		
			19°34′N-98°56′W&	10.800*	^{14}C [Standard]	Santa Isabel Ixtapan l.f.		
5. Zohapilco [In Tlapacoya Municipio]	[4]	Unnamed	19°19′N-98°54′W&	14.77	^{14}C [Standard]	Zohapilco l.f.	Wisconsinan	Latest Pleistocene
6. Santa Lucía	[4]	Unnamed	19°38′N-99°38′W&	11.58*	^{14}C [Standard]	Santa Lucía l.f.	Wisconsinan	Latest Pleistocene
7. Santa Lucía I	[4]	Unnamed	19°38′N-99°38′W&	26.3*	^{14}C [Standard]		Wisconsinan	Late Pleistocene
	[4]		19°38′N-99°38′W&	23.9*	^{14}C [Standard]		Wisconsinan	Late Pleistocene
8. Santa Lucía II	[4]	Unnamed	19°38′N-99°38′W&	11.17*	^{14}C [Standard]		Wisconsinan	Latest Pleistocene
9. Tlapacoya	[4]	Unnamed	19°17′N-98°53′W&	33.5*	^{14}C [Standard]	Tlapacoya l.f.	Wisconsinan	Late Pleistocene
	[4]		19°17′N-98°53′W&	21.7*			Wisconsinan	Late Pleistocene
10. Tlapacoya I	[5]	Unnamed	19°17′N-98°53′W&	10.2 ± 0.065*	^{4}C [AMS]		Wisconsinan	Latest Pleistocene

Table 1 Continued.

Morphotectonic Province (MP)	State Site [Ref.]	Formation	Site Coordinates	Radiometric Age (in ka)*	Method	Local Fauna (l.f.) or Single Occurrence (s.o.)	NALMA#	Epoch##
11. Acambay	[6]	Unnamed	19°57′N-99°50′W[&]	1.2 ± 0.13 [Minimal age]	Fission Tracks [Zircon]	Acambay l.f.	Irvingtonian [Irvingtonian I] [Rancholabrean/ Blancan]**	Early Pleistocene
12. Tepexpan	[7]	Unnamed	19°37′N-99°56′W[&]	19.11 ± 90* [Maximal age]	^{14}C [AMS]	Tepéxpan l.f. or s.o.	Wisconsinan	Late Pleistocene
				16.73 ± 75* [Maximal age]	^{14}C [AMS]			
13. San Miguel Tocuila	[8]	Unnamed	19°31′N-99°54′W	12.615 ± 75*	^{14}C [AMS]	Tocuila s.o.	Wisconsinan	Late Pleistocene
				10.22 ± 75*	^{14}C [AMS]			
	[8a]			11.1 ± 0.08*	^{14}C [AMS]			
	[8b]			11.277 ± 139*	^{14}C Standard			
				11.274 ± 116*	^{14}C Standard			
				11.541 196*	^{14}C Standard			
				11.296 ± 230-270*	^{14}C Standard			
				10.553 ± 188*	^{14}C Standard			
	[8c]			11.225 ± 75*	^{14}C [AMS]			
DISTRITO FEDERAL = CIUDAD DE MEXICO								
14. San Bartolo Atepehuacan	[4]		19°29′N-99°08′W[&]	31.85*	^{14}C [Standard]	San Bartolo Atepehuacan l.f.	Wisconsinan	Late Pleistocene
15. Ciudad de los Deportes	[4]	Unnamed	19°24′N-99°05′W[&]	18.7*	^{14}C [Standard]	Ciudad de los Deportes l.f.	Wisconsinan	Latest Pleistocene
16. Peñon III	[6]	Unnamed	19°26′N-99°04′W[&]	10.755 ± 0.075*	^{14}C [AMS]		Wisconsinan	Latest Pleistocene
PUEBLA STATE								
17. Valsequillo	[4]	Unnamed	18°54′N-98°06′W[&]	20.78*	^{14}C [Standard]	Valsequillo l.f.	Wisconsinan	Late Pleistocene
	[9]			38.9 ± 0.8*	^{14}C [AMS]			
				36.95 ± 0.6*				
				30.62 ± 0.14*				
				27.88 ± 0.12*				
				25.08 ± 130*				
SIERRA MADRE DEL SUR MP								
OAXACA STATE								
18. San Marcos Necoxtla	[4]	Unnamed	18°33′N-97°21′W[&]	14.96*	^{14}C [Standard]	San Marcos Necoxtla l.f.	Wisconsinan	Latest Pleistocene
19. Guilá Naquitz	[4]	Unnamed	16°57′N-96°22′W[&]	10.7*	^{14}C [Standard]	Guilá Naquitz l.f.	Wisconsinan	Latest Pleistocene
SIERRA MADRE DE CHIAPAS MP								
CHIAPAS STATE								
20. Punta de Llano	[10]	Punta de Llano [Formal]	16°48′N-92°52′W	0.56 ± 0.07 560 ± 70* [Minimal age]	K-Ar [Amphibole]	Arroyo Limas s.o.	Early Irvingtonian [Irvingtonian II]	Middle Pleistocene
	[10]		16°48′N-92°52′W	0.37 ± 0.26 370 ± 260* [Minimal age]	K-Ar [Plagioclase]		Late Irvingtonian [Irvingtonian III]	Late Pleistocene

Table 1 Continued.

Morphotectonic Province (MP)	State Site [Ref.]	Formation	Site Coordinates	Radiometric Age (in ka)*	Method	Local Fauna (l.f.) or Single Occurrence (s.o.)	NALMA#	Epoch##
21. Chiapa de Corzo	[11]	Unnamed	16°42′N-92°59′W[&]	0.45 ± 0.13 450 ± 130* [Minimal age]	K-Ar [Plagioclase]	Arroyo Nandalumí s.o.	Middle Irvingtonian [Irvingtonian II]	Middle Pleistocene
	[11]		16°42′N-92°59′W[&]	0.35 ± 0.19 350 ± 190* [Minimal age]	K-Ar [Plagioclase]		Late Irvingtonian [Irvingtonian III]	Late Pleistocene

Ref. = **References** [two kinds: **RCH**, radiometric references, and **BCH**, biochronologic references; both are indicated by a number in brackets besides the locality name].
*Asterisked numbers indicate ka (ione kiloannum, 1000 years), numbers without asterisk indicate Ma (one mega-annum, one million years before the present).
** Double-asterisked NALMA is the age assigned by the original authors; it differs from the corresponding numerical age, see text for details.
#Geochronometric NALMA [North American Land Mammal Age] boundaries after Woodburne (2004), particularly Bell et al. (2004, Blancan-Rancholabrean, Pliocene-Pleistocene).
##Geochronometric Stage/Age, and Epoch boundaries after Gradstein et al. (2004).
[&] Latitude-Longitude of RCH sampling site not stated by author; coordinates inferred from information presented in the referred article.
Ref. [1RCH]: 1a and 1b, Paz-Moreno et al. (2003). **[1BCH]:** 1a, Mead et al. (2006, 2007); 1b, Carranza-Castañeda and Roldán-Quintana (2007). **[2RCH]:** Arroyo-Cabrales et al. (1995). **[2BCH]:** Ferrusquía-Villafranca et al. (2010 and lit. therein). **[3RCH]:** Lorenzo and Mirambell (1986a). **[3BCH]:** Ferrusquía-Villafranca et al. (2010 and lit. therein). **[4RCH]:** Arroyo-Cabrales et al. (2002). **[4aRCH]:** González et al., 2015. **[4BCH]:** Arroyo-Cabrales et al., 2002, 2005. **[5RCH]:** González et al. (2003). **[5BCH]:** Ferrusquía-Villafranca (2010). **[6RCH]:** Mercer et al. (2003), Mercer (2004). **[6BCH]:** Israde-Alcántara et al. (2010). **[7RCH]:** Lamb et al. (2009). **[7BCH]:** Lorenzo and Mirambell (1986b). **[8RCH]:** Siebe et al. (1999); **[8aRCH]:** Arroyo-Cabrales et al., 2002, 2005. **[8bRCH]:** Morett et al. (2003). **[8cRHC]:** González et al., 2014. **[9RCH]:** González et al. (2006). **[9BCH]:** Ferrusquía-Villafranca et al. (2010). **[10RCH]:** Ferrusquía-Villafranca (1996). **[10BCH]:** Ferrusquía-Villafranca et al. (2010). **[11RCH]:** Ferrusquía-Villafranca and McDowell (1991). **[11BCH]:** Ferrusquía-Villafranca et al. (2010).

Holocene boundary, commonly set at 10 ka to 11.5 ka (Bell et al., 2004; Gradstein et al., 2004). The Calibrated Polarity Geochron Timetable was not used for this project because the Brunhes (normal) Chron starts at 780 ka, (Gradstein et al., 2004), and thus spans the Wisconsinan Glacial Episode as well as the Middle and Late Pleistocene.

The eighth column lists the geochronological information expressed in epochs and periods sensu Gradstein et al. (2004).

Footnotes

The footnotes provide the radiometric geochronological and biochronological references used here, which are keyed to the bracketed number on the right of the first column. Some papers refer to two or more sites. When sites have been independently studied by two different research teams, we have cited both; and in the "Discussion" section we provide our parsimonious assessment of such data.

The acronym QMMDB (Quaternary Mexican Mammals Data Base) refers to the so-named database housed and maintained in the Laboratorio de Arqueozoología Ticúl Alvarez Solórzano, Subdirección de Investigación, INAH, Moneda 16, Centro Histórico, Ciudad de México. This database includes geographical, paleontological, and, in some instances, radiometric information. It was used as data source for some sites/faunas. Arroyo-Cabrales et al. (2002) described the QMMDB and made it known to the interested community.

Terminology

The sedimentary petrographic nomenclature follows Folk (1974) and Boggs (1995), the pyroclastic terminology used is that of Fisher and Schmincke (1984), and the sedimentary facies nomenclature follows Miall (2006, 2010) for the fluvial facies and Collinson (1996) for the lacustrine facies. In some instances, old descriptions were redescribed or interpreted using current terminology and/or conceptions. The mammalian systematics is that of McKenna and Bell (1997). Finally, it should be noted that the acronyms used are defined the first time they appear in the text.

RESULTS AND DISCUSSION

Table 1 provides a summary of the geographical, geologic, and geochronological information for sites/localities where both radiometrically dated lithostratigraphic units and studied vertebrate fossils co-occur. These are treated in geochronological order. For each site, the geologic setting is presented and discussed first; then its radiometric dating and vertebrate fossil assemblage is treated and discussed, together with the regional significance of both the geologic and paleontological data.

INTRODUCTORY REMARKS

México's continental Pleistocene is stratigraphically undifferentiated for the most part. Detailed geologic information for the 21 sites considered is largely nonexistent and formal lithostratigraphic units are the exception. Hence, the summary presented below largely draws from regional sources: Mooser (1975); Servicio Geológico Mexicano (SGM 1992, 1996a, 1996b); Instituto Nacional de Estadística, Geografía e Informática (INEGI 1982a, 1982b, 1983); some local sources, for example, Schlaepfer (1968); INEGI (1971, 1974, 1979a, 1979b); Mooser et al. (1996), Mercer (2004), Mead et al. (2006), Carranza-Castañeda and Roldan-Quintana (2007), and firsthand knowledge of some sites.

Fourteen out of the 21 sites lie in the Trans-Mexican Volcanic Belt morphometric province (TMVB MP), two in the Sierra Madre Oriental MP (SMOr), two in the Sierra Madre de Chiapas MP (SMOr hereafter), and two each in the Northwestern Plains and Sierras MP (NW hereafter) and the Sierra Madre del Sur MP (SMS hereafter); see

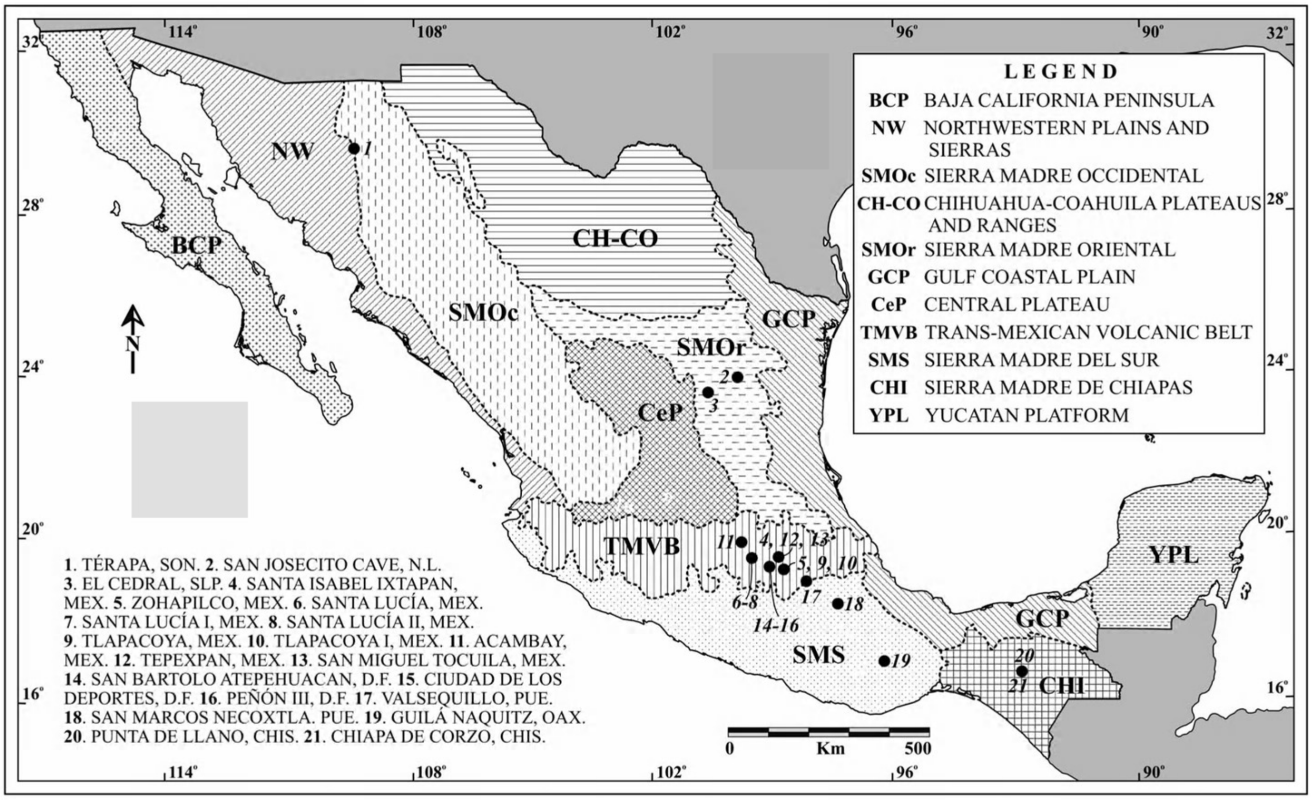

Figure 1 Morphotectonic provinces map of México showing the location of Pleistocene sites with radiometrically dated lithostratigraphic units that bear studied vertebrates.

Figure 1. The sites from the Basin of México will be treated elsewhere (see "Latest Pleistocene" section).

The sedimentary sequence in most sites is a few dozens of meters thick and horizontal-lying, so that it unconformably overlies the usually tilted Tertiary units, and it commonly includes both fluvial and lacustrine deposits. The fluvial ones largely consist of fine to coarse-grained, cross-bedded, friable to moderately indurated volcarenitic sandstone, siltstone, and claystone set in thin to medium strata (channel and overbank facies); smaller amounts of clast-supported, pebble to cobble conglomerate of volcanic clasts set in medium to thick strata (largely channel facies). In addition, the sequence includes parallel-bedded, friable to moderately indurated, fine-grained clayey siltstone, claystone –silty at times—set in laminar to thin strata (clastic lacustrine facies); frequently the lake facies bear diatoms, ostracods, palynomorphs, and other microfossils. Thin sheets of felsic ash–fall tuff (pyroclastic facies) are sparsely interbedded in the sequence (fluvial, lacustrine, or mixed) at various stratigraphic levels.

In the sites where both fluvial and lacustrine deposits are present, they exhibit a variety of space-stratigraphic relationships as follows: (a) one lies above the other through gradual or, less commonly, abrupt contacts; (b) they alternate in a rhythmic to pattern-less fashion and the lacustrine and fluvial stratal packages may be of different thickness (or less commonly of similar thickness); (c) they intertongue, forming sequences of complex sedimentary architecture; and/or (d) a combination of two or more space relationships.

The fossil vertebrates commonly occur in the fine-grained fluvial facies; however, not infrequently, the lacustrine facies has also yielded such fossils. The terrestrial vertebrate fossils belong to communities living on the lowlands/valleys commonly associated with fluvial courses, ponds, or lakes, and/or on the slopes of the mountainous countryside. Aquatic vertebrates like turtles, crocodiles, and fish are well represented in fluvial and lacustrine deposits; a few mammals (e.g., hydrochoerids) are also represented in this kind of deposits. Along the Trans-Mexican Volcanic Belt, numerous lakes were formed, probably not simultaneously but within a short time span (Ferrari et al., 2012); some are still present, for example, Chapala, Jalisco; Cuitzeo, Michoacán; Texcoco, México.

Two sites have a different geologic setting: Site 2, San Josecito Cave, Nuevo León, is formed by "cave deposits" (largely fine-grained clastic debris fills, underground pond/fluvial deposits, and, less commonly, speleothems). Site 13, San Miguel Tocuila, Estado de México, is a ~1.3-m-thick lahar (i.e., a volcanic mud flow deposit) bearing the remains of at least seven mammoths, as well as scattered bones and fragments (González et al., 2001:705); both will be discussed in the Part 3-Other Wisconsinan Sites.

The main geologic contribution derived from the Pleistocene sites and their mammal faunas is threefold:

1. They document the far more humid environment prevailing during this epoch in México.
2. They document greater mammalian biodiversity during this time.
3. They document dramatic environmental changes that took place at the Pleistocene's end, which drastically modified both the landscape and the mammal assemblages in México by the Early Holocene (see Ferrusquía-Villafranca et al., 2010 for a general review of this subject).

LATE EARLY–MIDDLE PLEISTOCENE

Acambay Site (México State, Trans-Mexican Volcanic Belt MP, Fig. 1, Site 11)

Table 2 Acambay local fauna, Irvingtonian, México State, TMVB MP.

CLASS MAMMALIA
ORDER PERISSODACTYLA
Equidae
Equus simplicidens
ORDER ARTIODACTYLA
Camelidae
Genus and *species* indet.
ORDER PROBOSCIDEA
Gomphotheriidae
Rhynchotherium sp.

Source: Israde-Alcántara et al. (2010).

GEOLOGIC SETTING. The vertebrate-bearing sequence according to Israde-Alcántara et al. (2010) is ~70 m thick and includes three units. The lowest unit is ~50 m thick, consists of diatomite, fine-grained volcaniclastics, and claystone intruded by sand dikes. The middle unit unconformably overlies the lower one, is 2–22 m thick, and comprises diatomite and siltstone that grades upward into a thick bed set of laminated diatomite, covered by a 0.01-m-thick, felsic-ash fall sheet, in turn covered by a ~2-m-thick layer of slump-structured diatomite. The uppermost unit (of unstated thickness) is capped by siltstone and sandstone beds that show liquefaction structures. The mammals reported from them by Israde-Alcántara et al. (2010:82) were collected from undescribed "...upper units beneath this ash." These authors also mention that undescribed Pleistocene mammals have been collected earlier in this site by local people, but their precise provenance is unknown; they include horse, camel, bison, and mammoth.

RADIOMETRIC/BIOCHRONOLOGICAL DATING AND REGIONAL SIGNIFICANCE. The tuff sheet overlying the mammal-bearing strata yielded a fission track age of 120 ± 0.13 ka (Table 1; Mercer et al., 2003; Mercer, 2004), which places it in the late Early Pleistocene (Gradstein et al., 2004). The mammals collected below the tuff sheet (depth/distance not stated), here designated Acambay local fauna (Table 2), comprise perissodactyls (Equidae), artiodactyls (Camelidae), and proboscideans (Gomphotheriidae; Israde-Alcántara et al., 2010). Largely on the basis of the equid *Equus simplicidens*, this fauna is assigned to the Blancan (Israde-Alcántara et al., 2010:87); however, the evidence is not compelling: As late as 1987 (Lundelius et al., 1987), the Blancan was not formally defined (sensu Woodburne, 1977), but characterized by several taxa including *Equus (Dolichohippus) simplicidens* (Bell et al., 2004:249), which is no longer regarded as a Blancan index in the current definition and characterization of this NALMA (Bell et al., 2004:250). The Blancan/Irvingtonian boundary is diachronous, being set at 1.9–1.7 Ma (Bell et al., 2004) but older than the 1.2 ± 0.13-Ma age yielded by the overlying tuff. On these grounds, we assigned the Acambay l.f. to the Irvingtonian NALMA (probably Irvingtonian I). The stratigraphic uncertainty regarding the provenance of other unstudied mammals collected by local people precludes assigning them a more precise age beyond Pleistocene.

Punta de Llano Site (Chiapas State, Sierra Madre del Sur MP, Fig. 1, Site 20)

Chiapa de Corzo Site (Chiapas State, Sierra Madre del Sur MP, Fig. 1, Site 21)

GEOLOGIC SETTING. The sequence from the Punta de Llano site belongs to the Punta de Llano Formation (Ferrusquía-Villafranca, 1996), a 20–30-m-thick unit largely consisting of fine-grained, tabular cross-bedded, volcarenitic sandstone and siltstone set in thin to medium strata (fluvial, mainly channel facies), and lesser amounts of friable silty claystone set in thin strata (fluvial, overbank facies), as well as a clast-supported, pebble, polymictic, cross-bedded litharenitic conglomerate set in medium to thick strata (fluvial, channel facies); additionally, thin sheets of felsic, largely ash-fall and ash-flow tuff, sparsely interbed and/or cover the epiclastic strata (pyroclastic facies). The unnamed sequence from the Chiapa de Corzo site is thinner (~12–15 m thick), but otherwise similar to that of the Punta de Llano site.

RADIOMETRIC/BIOCHRONOLOGICAL DATING AND REGIONAL SIGNIFICANCE. The tuff sheets overlaying mammal-bearing strata at both sites yielded ages as follows: Punta de Llano site, 560 ± 0.007 ka (K-Ar) and 370 ± 260 ka (K-Ar); and Chiapa de Corzo site, 450 ± 130 ka (K-Ar) and 350 ± 190 ka (K-Ar, Table 1; Ferrusquía-Villafranca, 1996; Ferrusquía-Villafranca et al., 2010). These dates place the sequence of both sites in the Middle Pleistocene (Gradstein et al., 2004).

The only mammal taxon recovered from these sites is the long-lived proboscidean gomphotheriid *Cuvieronius* sp. (Miocene to Pleistocene; McKenna and Bell, 1997); here the radiometric dating allows us to assign it to the Middle Pleistocene, that is, Irvingtonian, probably the Irvingtonian II NALMA (Bell et al., 2004). Irvingtonian faunas in México are little known, in fact the Sonoran El Golfo fauna (Shaw, 1981; Shaw and McDonald, 1987), is the only one reported; therefore, the *Cuvieronius* finds from Chiapas significantly add to this meager record.

LATE PLEISTOCENE

Térapa Site (Sonora State, Northwestern Plains and Sierras MP, Fig. 1, Site 1)

GEOLOGIC SETTING. The site lies in the Quaternary Moctezuma Volcanic Field (QMVF herein) in northeastern western Sonora (Paz-Moreno et al., 2003). The fossiliferous sequence occupies a small basin (2 km^2), seemingly formed by a basalt flow diversion of the river course in the upper Río Moctezuma valley (Mead et al., 2006). The basin is delimited on the north, west, and south by tholeiitic basalt flows, informally designated by Mead et al. (2006) as the Tonibabi Basalt Flow. In this basin, a fine-grained clastic sequence was deposited. It is ~11 m thick as reported by Mead et al. (2006) or 20 m thick according to Carranza-Castañeda and Roldán-Quitana (2007). Seemingly unaware of the work by Mead et al. (2006), Carranza-Castañeda and Roldán-Quitana (2007) studied the same site and reported a small mammal assemblage. The sequence description that follows draws from both sources.

The sequence largely consists of parallel-bedded, friable to moderately indurated, richly fossiliferous silty claystone set in thin strata (lake or probably marsh facies) and lesser amounts of medium- to fine-grained, tabular cross-bedded volcarenitic sandstone and siltstone set in thin to medium strata, as well as a few strata of clast-supported conglomerate (fluvial facies). Friable sandstone and conglomerate strata unconformably overlie the sequence.

According to Mead et al. (2006:229), this sequence overlies and abuts the Tonibabi Basalt Flow, which, in the nearby La Carbonera Canyon, yielded a ^{40}Ar-^{39}Ar age of 440 ± 130 ka, thus placing the flow in the Middle Pleistocene (Gradstein et al., 2004). They also stated that the relationship between this flow and those basalt flows studied by Paz-Moreno et al. (2003) is not well understood. On the other hand, Paz-Moreno et al. (2003), who studied the QMVF, mentioned that the fissure-erupted tholeiitic basalt flows that form the best part of this field yielded a ^{40}Ar-^{39}Ar age of 1700 ± 740 ka (Paz-Moreno et al., 2003:table 1; Ma converted to ka), and also reported that monogenetic cone-erupted alkaline basalt flows geochemically related to the tholeiitic ones, have yielded a K-Ar age of 530 ± 200 ka (Paz-Moreno et al., 2003:443), as well as ^{40}Ar-^{39}Ar ages of 610 ± 80 ka, 470 ± 60 ka, and 300 ± 11 ka (Paz-Moreno et al., 2003:table 1; Ma converted to ka), concluding that the latter volcanism was younger than the tholeiitic one. However, in their abstract, they stated that the youngest such flows have an age of 530 ka, thus omitting younger-aged flows.

Radiometric datum reported by Mead et al. (2006), and those from the monogenetic cone-erupted flows (Paz-Moreno et al., 2003:table 1), led them to postulate that the sedimentary sequence was laid down at some time between 510 and 310 ka. On the other hand, Carranza-Castañeda and Roldán-Quintana (2007:84), mention that the sequence overlies olivine basalt flows of ages between 170 ± 074 ka and 610 ± 80 ka (quoting as source Paz-Moreno et al., 2003), which places the flows in the Early–Middle Pleistocene (Gradstein et al., 2004). However, in their figure 4, Carranza-Castañeda and Roldán-Quintana, (2007:84), label the basalt flows as >1700 ka. Thus, the stratigraphic interpretations of Mead et al. (2006) and Carranza-Castañeda and Roldan-Quintana (2007) are clearly different, but do not furnish enough information to select one over the other. We have left them as alternative interpretations. Clearly, additional work is needed to assess these different interpretations.

RADIOMETRIC/BIOCHRONOLOGICAL DATING AND REGIONAL SIGNIFICANCE. Radiometric dating has already been discussed. The Térapa local fauna (Table 3), a name coined by Mead et al. (2006), contains crocodiles and the following mammal taxa (Mead et al. 2006, 2007; Carranza-Castañeda and Roldán-Quintana, 2007): xenarthrans (Pampatheriidae and Glyptodontidae), carnivorans (Canidae, Felidae, and Procyonidae), rodents (Geomyidae, Hydrochoeridae, and Muridae), lagomorphs (Leporidae), perissodactyls (Equidae and Tapiridae), artiodactyls (Antilocapridae, Bovidae, Camelidae, Cervidae, and Tayassuidae), and proboscideans (Elephantidae and Gomphotheriidae). Largely based on the presence of *Bison*, a Pleistocene index taxon (Bell et al., 2004), as well as of *Equus conversidens* and *E. excelsus*, both Mead et al. (2006) and Carranza-Castañeda and Roldán-Quintana (2007) assigned the Térapa l.f. to the Rancholabrean NALMA (Bell et al., 2004), but that of the latter seems to be older. However, the beginning of the Rancholabrean NALMA is usually placed at 0.12 Ma (Bell et al., 2004), being largely identified by the presence of *Bison*, a datum ~200 ka later than the postulated deposition time of the vertebrate-bearing sequence proposed by Mead et al. (2006). Attempting to solve this timing incongruity, they claimed that earlier records of *Bison* are known, for example, those from the Ten Miles Hill beds, North and South Carolina, between 240 and 200 ka (Sanders, 2002), and from other records (see Sanders, et al., 2009) published later than Mead et al. (2006), so that the Térapa *Bison* might be one such early record. Again, further work is needed to clarify this issue.

Additionally, it should noted that the presence of aquatic vertebrates (e.g., crocodiles, tapirs, and hydrochoerids) in the Térapa l.f., which at present live in tropical regions hundreds of kilometers (even thousands in the case of hydrochoerids) south of northwestern Sonora, where very arid conditions prevail today, evidences the profound environmental change that must have occurred in Sonora since the Late Pleistocene/ Early Holocene. In this regard alone, this fauna is quite significant.

LATEST PLEISTOCENE

San Josecito Cave Site (Nuevo León State, Sierra Madre Oriental MP, Fig. 1, Site 2)

Tlapacoya Site (México State, Trans-Mexican Volcanic Belt MP, Fig. 1, Site 9)

Tepexpan Site (México State, Trans-Mexican Volcanic Belt MP, Fig. 1, Site 12)

San Bartolo Atepehuacan Site (Distrito Federal State, now Ciudad de México, Trans-Mexican Volcanic Belt MP, Fig. 1, Site 14)

Valsequillo Site (Puebla State, Trans-Mexican Volcanic Belt MP, Fig. 1, Site 17)

El Cedral Site (San Luis Potosí State, Sierra Madre Oriental MP, Fig. 1, Site 3)

Santa Isabel Ixtapan Site (México State, Trans-Mexican Volcanic Belt MP, Fig. 1, Site 4)

Zohapilco Site (México State, Trans-Mexican Volcanic Belt MP, Fig. 1, Site 5)

Santa Lucía Site (México State, Trans-Mexican Volcanic Belt MP, Fig. 1, Site 6)

Santa Lucía I Site (México State, Trans-Mexican Volcanic Belt MP, Fig. 1, Site 7)

Santa Lucía II Site (México State, Trans-Mexican Volcanic Belt MP, Fig. 1, Site 8)

Tlapacoya I Site (México State, Trans-Mexican Volcanic Belt MP, Fig. 1, Site 10)

San Miguel Tocuila Site (México State, Trans-Mexican Volcanic Belt MP, Fig. 1, Site 13)

Ciudad de los Deportes Site (Distrito Federal State, now Ciudad de México, Trans-Mexican Volcanic Belt MP, Fig. 1, Site 15)

Peñón III Site (Distrito Federal, now Ciudad de México State, Trans-Mexican Volcanic Belt MP, Fig. 1, Site 16)

San Marcos Necoxtla Site (Puebla State, Sierra Madre del Sur MP Fig. 1, Site 18)

Guilá Naquitz Site (Oaxaca State, Sierra Madre del Sur MP, Fig. 1, Site 19)

PART 1—GENERAL ASPECTS

Geologic Setting. Excluding the sites already discussed, that is, Site 1, Térapa; Site 11, Acambay; Site 20, Punta de Llano; and Site 21 Chiapa de Corzo, the remaining 17 sites listed in Table 1 have yielded Wisconsinan faunas (see below), and could be regarded as local samples of a single chronofauna; on this basis, they are discussed together.

Geochronological Framework. The Middle/Late Pleistocene boundary is set at 0.126 Ma and that of the Late Pleistocene/Holocene at 0.0115 Ma (Gradstein et al., 2004). The Late Pleistocene interval includes the Rancholabrean NALMA, which spans the ~0.120–0.010-Ma interval (Bell et al., 2004). It should be noted that the numerical divisions of the NALMAs (Woodburne, 2004) have been established using the geochronometric dates afforded by the radiometrically calibrated Geomagnetic Polarity Time Table (or Time Scale). However, this is not possible for the Rancholabrean NALMA, because the Brunhes (normal) Polarity Chron spans the Rancholabrean–Holocene time interval (Gradstein et al., 2004), thus precluding numerical subdivision in smaller time units or "subages"; the Wisconsinan SubNALMA is the only exception.

This term originally referred to the Fourth Glacial Stage of the Pleistocene Epoch in North America (Neundorf et al., 2005), but currently it corresponds to the chrono-interval whose starting time is determined by the maximal practical limit/time-resolution of the ^{14}C dating methods (i.e., ~40 ka), and its termination by the Pleistocene/ Holocene time boundary, usually set at 10 to 11.5 ka (Bell et al., 2004; Gradstein et al., 2004). The Wisconsinan is widely used in Quaternary studies and here we use it for the youngest portion of the Rancholabrean NALMA.

Chronological Spread of the Sites. The 17 Wisconsinan mammal faunas listed in Table 1 show the following time spread: only San Josecito Cave (Site 2) has an age >40 ka; three faunas, Tlapacoya (Site 9), San Bartolo Atepehuacan (Site 14), and El Cedral (Site 3) have ages between 40-30 ka; two, Valsequillo (Site 17) and Santa Lucía I (Site 7)

Table 3 Térapa mammal local fauna, Early Rancholabrean, Sonora, Northwestern Plains and Sierras MP.

- XENARTHRA
  - Dasypodidae
    - *Pampatherium mexicanum* †
  - Glyptodontidae †
    - *Glyptotherium cylindricum* †
- CARNIVORA
  - Canidae
    - *Canis dirus* †
  - Felidae
    - *Lynx rufus*
  - Procyonidae
    - *Procyon lotor*
- RODENTIA
  - Geomyidae
    - *Geomys* sp.
  - Hydrochoeridae
    - *Hydrochoerus* sp.
  - Muridae
    - *Neotoma* sp.
    - *Sigmodon* sp.
- LAGOMORPHA
  - Leporidae
    - *Sylvilagus* sp.
- PERISSODACTYLA
  - Equidae
    - *Equus* sp.
  - Tapiridae
    - *Tapirus* sp.
- ARTIODACTYLA
  - Antilocapridae
    - *Capromeryx* sp.
    - *Stockoceros* sp.
  - Bovidae
    - *Bison* sp. †
  - Camelidae
    - *Camelops* sp. †
  - Cervidae
    - *Odocoileus* sp. †
  - Tayassuidae
    - *Platygonus* sp. †
- PROBOSCIDEA
  - Elephantidae
    - *Mammuthus* sp. †
  - Gomphotheriidae †
    - *Cuvieronius* sp. †

† Extinct taxon.
Source: Mead et al. (2006, 2007) and Carranza-Castañeda and Roldán Quintana (2007).

have ages between 30-20 ka; another two, Tepexpan (Site 12) and Ciudad de los Deportes (Site 15) have ages between 20-15 ka; the remaining nine faunas, Santa Isabel Ixtapan (Site 4), Zohapilco (Site 5), Santa Lucía (Site 6), Tlapacoya I (Site 10), San Miguel Tocuila (Site 13), Peñón III (Site 16), San Marcos Necoxtla (Site 18), and Guilá Níquitz (Site 19) have ages between 15-10 ka. Methodologically, three faunas, Tepexpan (Site 12), Peñón III (Site 16), and Tlapacoya I (Site 10) have only been dated by AMS ^{14}C techniques; 12 faunas have been dated by standard ^{14}C techniques; and two, San Miguel Tocuila (Site 13) and Valsequillo (Site 17) have been dated using both techniques. It should be noted that, except for San Miguel Tocuila (Site 13), the more expensive AMS ^{14}C technique has only been applied in those faunas where human fossils or artifacts have been recorded.

Geographical Distribution of the Sites. The Wisconsinan sites/faunas (Fig. 1) show the following space distribution: San Marcos Necoxtla, Puebla (Site 18), and Guilá Naquitz, Oaxaca (Site 19), lie in the Sierra Madre del Sur MP; San Josecito Cave, Nuevo León (Site 2), and El Cedral, San Luis Potosí (Site 3) lie in the Sierra Madre Oriental MP; the other 13 lie in the Trans-Mexican Volcanic Belt MP (one in Puebla: Valsequillo Site 17); three in the Distrito Federal, now Ciudad de México: San Bartolo Atepehuacan (Site 14), Ciudad de los Deportes (Site 15), and Peñón III (Site 16); the remaining nine lie in the State of México: Santa Isabel Ixtapan (Site 4), Zohapilco (Site 15), Santa Lucía (Site 6), Santa Lucía I (Site 7), Santa Lucía II (Site 8), Tlapacoya (Site 9), Tlapacoya 1 (Site 10), Tepexpan (Site 12), and San Miguel Tocuila (Site 13).

PART 2—BASIN OF MÉXICO SITES

Geologic Setting. Out of the 17 Wisconsinan mammal-bearing sites, 15 are set in fluvial/lacustrine sequences, and most lie in the Basin of México, in the eastern part of the Trans-Mexican Volcanic Belt MP (Fig. 2); therefore it is necessary to review/discuss its geology. This basin has been the subject of numerous studies, including geological and (Bryan, 1948; Arellano, 1951/1953; Zeevaert, 1953, Mooser 1961, 1975; Schlaepfer, 1968; Vázquez-Sánchez and Jaimes-Palomera, 1989; Enciso de la Vega, 1992) geological/geophysical studies (de Cserna et al., 1987) as well as those examining vertebrate paleontology (Hibbard, 1955), palynology (Sears and Clisby, 1955), limnology/environmental factors (Bradbury, 1971, 1989; Lozano-García and Ortega-Guerrero, 1997; Caballero-Miranda and Ortega-Guerrero, 1998; Caballero-Miranda et al., 1999), and paleosols (Bryan, 1948; Cabadas-Baez, 2007). Even so, its stratigraphy is far from being fully understood, largely because lack of detailed coordinated surface and subsurface studies. Nonetheless, integrating parsimoniously the relevant available multidisciplinary information (see Pleistocene Introductory Remarks above for other sources), it is possible to establish a highly plausible physical scenario for the Basin of México during the Wisconsinan.

Basin of México's Theoretically Plausible Geographic/Geologic Wisconsinan Scenario. Basin Topographic Setting. The Basin of México lies in a high-altitude plateau surrounded by rugged country, which roughly defines a trapezoid-like outline (longer than wide), set NE–SW, it is $\sim$115 km long (NE–SW) and $\sim$68 km wide (minimal width, normal to basin length at middle part), and has an areal extent of $\sim$9,600 km^2 (Fig. 2). Politically, the basin (Fig. 2) is part of the states of Hidalgo, Puebla (a very small part), Tlaxcala, México, and Distrito Federal and the cities of México and Pachuca; numerous towns and villages are located here.

Basin Boundaries and Interior Ranges. The basin, then as now, was largely surrounded by the Sierras de Pachuca, Chichicuatla, and Tepozán (in the northeast); Sierras de Calpulalpan, de Río Frío, and Nevada (in the southeast); Sierras del Chichinautzin (chiefly developed during the Early–Middle Wisconsinan), de las Cruces, de Monte Alto, and de Monte Bajo (in the south and southwest); and Sierras de Tezontlalpan, Tolcayuca, and Tepotzotlán (in the northwest). In general, such ranges stand $\sim$200–1,000 m above the local basin floor, and even more so in the major volcanoes, being higher in the south and southeast (Fig. 2).

Smaller ranges within the basin, such as the Sierras de los Pinos, de Patlachique, de Guadalupe, and de Santa Catarina, stand $\sim$200–400 m above the local basin level (Fig. 2). Some isolated mountains—Cerros Gordo, de Chiconautla, and del Peñón—stand $\sim$120–300 m above its floor level. Both sierras and mountains were formed by Late Cenozoic volcanic successions, largely of intermediate to mafic composition. The rhyolitic to rhyodacitic component is less abundant. Geochronologically, those of the northeast are somewhat older.

Basin Floor. Regionally, the basin floor consists of a large plain gently dipping southward, and can be divided in three subregions: *Pachuca* (in the north), *Apan-Tecocomulco-Tochac* (in the northeast), and *Anahuac,* making up the southern part (see Fig. 2). *The first subregion* is the smallest, and stands between 2400 meters above sea level (masl) near

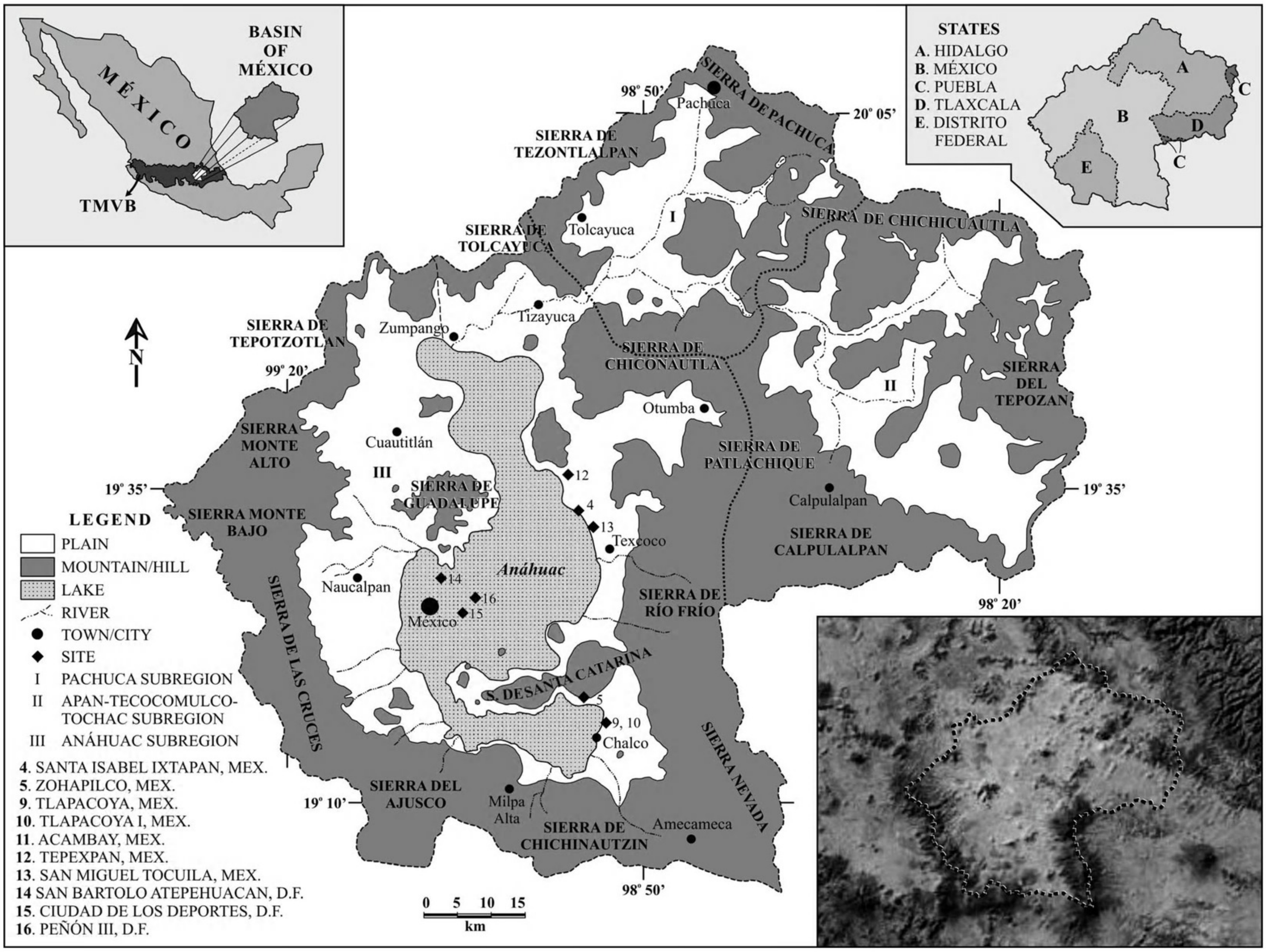

Figure 2 Map showing the Basin of México's generalized topographic setting inferred for Wisconsinan time.

Pachuca and 2315 masl by the Sierras de Tezontlalpan, Tolcayuca, Chiconautla, and Pachuca. The *second subregion* includes the Apan, Tecocomulco, and Tochac valleys, which bear in their lowest parts the namesake remnant lakes. Such valleys stand at a different elevation: Tecocomulco (in the "local" west) at 2554 masl, Tochac (in the "local" east) at 2505 masl, and Apan (in the local center) at 2455 masl. *The third subregion*, Anahuac, is the largest, and stands at 2240 masl; México City lies here. It is bounded by the Sierras de Tolcayuca, Tepotzotlán, Monte Alto, Monte Bajo, de las Cruces, del Ajusco, Chichinautzin, Nevada, Río Frío, Patlachique, and Chiconautla. Within this subregion lie the Sierras de Guadalupe and Santa Catarina, as well as the Lakes Zumpango, Texcoco, Chalco, and Xochimilco.

Basin Drainage. The basin plain is traversed by an axial drainage (Fig. 2) that used to discharge in the south until blocked by the Sierra de Chichinautzin volcanic emplacement bracketed between 0.3959 and 0.014 Ma (Bloomfield, 1975; Martín del Pozzo, 1989; Siebe et al. 2004, 2005). This major event probably took place during the ~0.04–0.01 Ma interval (Velasco-Tapia and Verma, 2001).

The "axial channel" was arc-like, N–S trending, and set toward the west (it probably included the Río de las Avenidas). The largely E–W trending, longest tributary was set toward the north, barely connecting the Pachuca and Apan-Tecocomulco-Tochac subregions. The main channels received water currents from the sierras' foothills, for example, Ríos Tepotzotlán, Tlalnepantla, de los Remedios, San Juan de Dios (on the west), San José, and Amecameca (in the southwest). As mentioned above, in the subregions' lowlands, lakes developed. In the Anahuac subregion, the now-separated Zumpango, Xaltocan, Texcoco, Xochimilco, and Chalco remnant lakes formed, in the recent past, the *Lago de Anahuac* (over 70 km long and ~40 km wide). The drainage blockage driven by the Chichinautzin event (Early–Middle Wisconsinan) probably played a significant role in its genesis.

Basin Sedimentary Processes. The fluvial network laid down alluvial fans in the foothills and basin floor interphase and surroundings, channel deposits along the stream floor, and overbank deposits, mainly floodplain facies, located in the river's medium to distal parts; such facies frequently/intermittently became subaerially exposed, developing soils and a vegetation cover. Where the streams reached lakes, fluvial and lake deposits of complex sedimentary architecture were formed. The lake deposition was chiefly clastic, that is, clay, silt, and fine-grained sand; chemical deposition, mainly freshwater lime, was much less common. The lake shores and surrounding areas were partly marshy.

Volcanic Activity. Regional volcanic activity chiefly occurred in the surrounding sierras, producing ash-fall and ash-flow tuffs and lapilli tuffs that partly or fully covered the basin floor, forming thin pyroclastic/tephra sheets that became incorporated into the sedimentary lacustrine and fluvial sequences. It should be noted that three tephra layers have been extensively used as marker horizons within local lithostratigraphic site sequences, for example, Peñón Woman III, Tlapacoya, Metro Man, Chimalhuacan Man, and Tocuila (González et al., 2014, 2015). These are the Great Basalt Ash (GBA; *volcanic source*, Santa Catarina; *date*, 28,600 ± 200 years BP; Mooser, 1997; but see Ortega-Guerrero et al., 2015, who claim that the source is the monogenetic Teuhtli Volcano), Upper Toluca Pumice (UTP; *volcanic source*, Nevado de Toluca; *date*, 10,500 ± 50 years BP; Arce et al., 2003), and Pumice with Andesite tephra (PWA; *volcanic source*, Popocatépetl, *date*, 14,600 years BP; Mooser, 1967); it coincides with the Tutti Frutti Plinian fall deposit (see Siebe and Macías, 2004). Mafic lava flows, erupted from monogenetic volcanoes or through fissures, were also emplaced within the basin. The lava eruptions were less frequent than the pyroclastic ones.

Basin Sedimentation Controls and Paleocommunities. Both rivers and lakes responded to the short-term and/or long-term climatic events (including glaciations) and tectonic controls, thus generating a complex sedimentary/stratigraphic record that as yet is not well understood. The basin was home to large terrestrial and limnic communities that left an extensive record embedded in the basin's complexly structured sequence, which is only incompletely known.

Theoretically Plausible Geographical/Geologic Wisconsinan Scenario and the Currently Known Basin of México's Lithostratigraphy. The theoretically plausible Wisconsinan geographic/geologic scenario involves the known geomorphic features, that is, confining sierras/ranges, inner ranges and hills, basin shape, basin floor slope, basin drainage (axial channel, major tributary channels), and lakes. In this scenario, the geomorphic features are portrayed in a dynamic fashion:

1. Ranges and high lands are portrayed as source of pyroclastic and/or epiclastic sediments (from blocks to clay particles).
2. The fluvial network are portrayed as an efficient transporter of clastic sediments, as well as a multifacetic depositional agent that generates particular deposits at different sedimentary settings: (a) alluvial fans and talus deposits near the foothills, (b) channel deposits along the main current channels, (c) overbank deposits—chiefly floodplain fines, frequently subaerially exposed—in the medial and distal parts of a given stream, and (d) deposits of very complex sedimentary architecture at fluvial/lake interphases.
3. Lakes are portrayed as depo-centers largely of fine-grained clastic sediments. Freshwater limestone and other chemical precipitates are rather rare: for example, the travertine platform surrounding the Cerro del Peñón, generated by hot springs (González et al., 2015).
4. Frequent coeval volcanic activity is expressed as pyroclastic eruptions that generate thin tuff/tephra sheets that partly or fully covered the basin floor and/or surrounding slopes of hills and/or mountains, whereby piedmonts of complex makeup and architecture involving lake, fluvial, and pyroclastic/tephra facies are formed. This way, a dynamic linkage between the volcanic mountains, lakes, and fluvial network is established. Another expression of volcanic activity is the local emplacements of mafic lava flows related to monogenetic volcanoes (see Mooser, 1961, 1975).

The tangible record of such processes and events largely consists of depositional systems and volcanic rock bodies. The first include sedimentary sequences of particular attributes regarding general shape and configuration, grain size and shape, lithic and/or mineral makeup, bed thickness (and how beds are expressed vertically and horizontally), binding surfaces, "bed structure," bed makeup, sedimentary layers and structures laid down in a particular sequential order, along or within a particular geographic space, during a given time. The second include both lava flow(s) and pyroclastic/tephra sheets, which could be spatially related to the depositional systems.

Both components make up the Basin of México's Wisconsinan lithostratal record, which in principle could be ascertained by means of lithostratigraphic research resulting first in adequately proposed, described, mapped, dated, and correlated formations (or units of lower/higher rank), and subsequently, in the discrimination and characterization of the depositional systems that make them up.

Basin of México's Surface Lithostratigraphic Setting. Here we draw from the information presented in key papers on the geology of this basin that established its lithostratigraphic setting, as currently accepted. There are eight Quaternary epiclastic "formations" proposed for the Basin of México (Bryan, 1948; de Terra, 1948; Arellano, 1951/1953). However, their proposals and descriptions did not meet the stratigraphic and nomenclatorial conventions in use at the time (Ashley et al., 1933), and none has yet been adequately mapped in detail. It follows that such lithostratigraphic units must be regarded as informal. Nonetheless, out of the eight "formations," these three—"Tarango," "Tacubaya" and "Becerra Formations" (Bryan, 1948)—merit further consideration, because they subsequently have been widely used in geologic descriptions of this basin. All three "formations" resulted from studies in the basin's western margin.

The "Tarango Formation" is a ~200–300-m-thick fluvial sequence formed by thickly bedded tuffs and volcarenitic crasso-epiclastics, as well as by thin sheets of pumicite. According to Schlaepfer (1968:fig. 2), this unit occupies the lowest position in the lithostratigraphic column, and unconformably overlies Pliocene volcanic units; in turn it is overlain by or intertongued with Pleistocene volcanic units and unconformably overlain by an alluvial/lacustrine sequence of Pleistocene/Holocene age. The sequence includes the "Tacubaya" and "Becerra Formation" sensu Bryan (1948) and Zeevaert (1953, see below). On the other hand, Arellano (1951/1953:181) interpreted the top of the "Tarango Formation" as the local Pliocene/Quaternary boundary. Later on, Mooser (1961) divided the "Tarango Formation" into lower and upper parts. The upper is largely epiclastic, and unconformably covers the lower part, which is pyroclastic, and thickly bedded.

The "Tacubaya Formation" is defined by a limonitic pedalfer developed in a humid climate, and it is spatially associated with fine-grained epiclastic strata that make up most of the unit's thickness/volume. Stratigraphically, the "Tacubaya Formation" lies above the "Tarango Formation" and below the "Becerra Formation" (Schlaepfer, 1968:fig. 3).

The "Becerra Formation" is also defined by a pedalfer locally developed in an altered humid climate regime; as in the "Tacubaya Formation," it is spatially associated with fine-grained epiclastic strata that make up the bulk of the unit's volume. At Tequixquiac, México, located ~17 km NW of Zumpango, in the basin's north-central part (see Fig. 4), the "Becerra Formation" has yielded a large vertebrate fauna (Hibbard, 1955).

Basin Of México's Subsurface Lithostratigraphic Setting. Zeevaert (1953), using shallow well information from the western part of the basin, described an at least 170-m-thick fluvio-lacustrine sequence as follows: The lower ~20 m consist of fluvial sediments, covered by an undescribed paleosol (at ~150 m depth), followed upward by an alternation of lacustrine (claystone) and fluvial (sandstone/siltstone) sediments; the lowest strata are very coarse. This in turn is covered by fluvial sediments designated *Tarango Sand II,* overlain by lake sediments consisting of highly compressible montmorillonitic clay bearing diatoms and ostracods, interbedded by thin ash-fall tuff sheets, in turn covered by well-indurated, calcite-cemented sandstone designated *Tarango Sand I,* which is overlain by 30 m of friable, largely fluvial sediments.

On the other hand, Schlaepfer (1968), based on her unpublished "Report of the Texcoco 1 Deep Well" (later included in SHCP, 1969; *maximal depth reached,* ~1650 m; *drilled in the Basin's eastern part*), mentioned that between depths of 180–450 m lies a sequence formed by sand and gravel strata interbedded by thin sheets of tuff and pumice, and by basalt flows. In the lower part (at ~450 m depth) marls [sic] and fresh water limestone are present. She assigned this sequence to the "Tarango Formation," and dated it as Late Pliocene–Pleistocene. Additionally, this author (Schlaepfer, 1968) upheld Fries's (1960) contention that the "Tarango" is correlative to the "Atotonilco El Alto Formation," which lies in south-central Hidalgo (see Segerstrom, 1956).

The Quaternary epiclastic sediments that overlain the "Tarango Formation" (i.e., those placed above the 180 m depth level), were assigned by Schlaepfer (1968) to her Late Pleistocene–Holocene *Lacustrine Beds* and *Alluvium units* (the alluvial/lacustrine sequence mentioned above), as quoted below:

Se comprenden en esta unidad las facies lacustres de las formaciones pleistocénicas Tacubaya y Becerra y de las demás de Bryan tales como fueron definidas por Zeevaert (1953:7). (Translation by present authors: "This unit includes the lacustrine facies of the Pleistocene Formations Tacubaya and Becerra, as well as the other units of Bryan, as they were defined by Zeevaert [1953:7].") Elsewhere this alluvial/lacustrine sequence is also partly overlain by the volcanic lavic Chichinautzin Formation.

Schlaepfer (1968:fig. 2) shows the Lacustrine Beds and Alluvial Unit as mutually intertonguing among themselves, and with Plio-Quaternary volcanic rock units. Figure 3 of the same paper (her acknowledged interpretation of Bryan, 1948, and Zeevaert, 1953, stratigraphic schemes) depicts the marginal and lacustrine facies of the "Tacubaya" and "Becerra Formations." Both units are placed in the Wisconsinan.

Basin of México's Lithostratigraphy: Subsequent Developments. In their Basin of México structural and geophysical study, de Cserna et al. (1987) briefly reviewed the stratigraphy, accepting (de Cserna et al.:19, 21) the "Tarango," "Tacubaya," and "Becerra Fromations" largely as proposed by Bryan (1948), de Terra (1948), and Arellano (1951/1953). They acknowledged though, that none of them have been mapped. Notwithstanding this, Vázquez-Sánchez and Jaimes-Palomera (1989), as well as Enciso de la Vega (1992), accepted de Cserna et al. (1987) position.

Regarding the lack of mapping, Mooser (1975) compiled a 1:200,000 geologic map of the Basin of México, where he discriminated the "Tarango Formation" in the eastern and western parts of the basin, describing them as consisting of "Volcanic fans [sic] containing lahars, ignimbrites, pumicite beds, ash, soils and some fluvial deposits." Mooser et al. (1996) produced a new Basin of México geologic map with a scale of 1:50,000, differentiating units by lithic composition and age, designating them by acronyms, for example, Qv, Qial; the "Tarango Formation" is the only lithostratigraphic unit recognized as such. Hernández-Espriú et al. (2014) in their hydrological study of the southwestern part of the Basin of México, present a very small-scale geologic map discriminating informal ("chrono-lithic") units.

Recently, Arce et al. (2015) report the geology of the San Lorenzo Tezonco Deep Well (depth, 2008 m) and surroundings, largely formed by volcanic rock units ("packages"). Comparing and integrating the surface geology information with the well samples, they recognize, from bottom to top, these units: (a) Package Tepoztlán Formation (depth, 2008–875 m; ages, 20.4–13.5 Ma; largely andesite lava flows); (b) Package Sierra de las Cruces (depth, 875–580 m; ages, 5.0–0.9 Ma; andesitic lava flows and dacitic pyroclastics); (c) Package Cerro de la Estrella-Santa Catarina (depth, 580–70 m; age, 25 ka; basaltic andesite to dacitic lava flows); and (d) Package Lacustrine (depth, 70–0 m; age, post-25 ka; largely lacustrine with subordinate pyroclastics; it is not assigned to a particular lithostratigraphic unit). The differences with Schlaepfer's well description are evident. Finally, these authors (Arce et al., 2015) also plot these packages on a surface elevation model of Basin of México's southern part (Arce et al., 2015:fig. 10), where such packages are implicitly referred to as geologic units of an undetermined class (see NACSN, 2010), namely from bottom to top: Sierra de las Cruces, Cerro Estrella, Sierras de Santa Catarina, and Chichinautzin.

Concluding Remarks on the Basin of México's Lithostratigraphy.

1. The foregoing review shows that in spite of considerable information on the basin's surface and subsurface, its Quaternary lithostratigraphic makeup and geologic history are far from settled. The units involved are only grossly known; their precise thickness (volume), areal extent, space stratigraphic relationships with adjacent units, and dating remain to be established. The same applies to the Tertiary component.
2. The "Tarango, Tacubaya, and Becerra Formations," although widely used, remain informal, because their proposals did not meet the stratigraphic norms then accepted (Ashley et al., 1933), nor did subsequent users attempt to fulfill this requirement, conforming it to the corresponding norms (ACSN, 1961, 1970; NACSN, 1983). Therefore, if at present such units are to serve a useful purpose, they must be formally proposed according to the currently acknowledged stratigraphic and nomenclatorial procedures (see NACSN, 2005; Spanish translation, Barragán-Manzo et al., 2010). This must include (a) a thorough description of the unit; (b) discrimination and description of boundaries, both vertical and lateral; (c) discrimination of the unit in a geologic map at the appropriate scale; (d) designation of the type area; and (e) designation and description of the stratotype.
3. The extensive and uncritical use of the North American Pleistocene Glacial Stage Chronology in the Basin of México, a place located thousands of kilometers south from the areas where it was developed, on the basis of a tangible glacial deposition record actually hampered establishing a sound chronological framework where the geologic events/records could confidently be placed. This fact plagued the early studies, which set the still-prevailing stratigraphic interpretation; such a framework has not been established yet.
4. There is a need for an in-depth review of the lithostratigraphy of the basin, redescribing the already known units (including dependable dating) or proposing new units, and/or attempting to use other kind of units, such as the allostratigraphic ones, if they prove to be more appropriate.

PART 3—OTHER WISCONSINAN SITES

Geologic Setting. The following details the geologic setting of Site 2, San Josecito Cave, Nuevo León, SMOr, and Site 13, San Miguel Tocuila, Estado de México, TMVB.

San Josecito Cave Site. This includes deposits formed in an extensive cave complex developed by dissolution of limestones in Nuevo León, northern Sierra Madre Oriental. Deposits include fine-grained clastic debris fills, thin pond and fluvial sequences, and a few speleothems (sensu Neuendorf et al., 2005). Following a local lead, this cave complex was initially prospected for vertebrates by Chester Stock (1943, 1948, 1950), and extensively studied afterwards (see Ferrusquía-Villafranca et al., 2010, for a summary review of such studies); the fauna is a sample of the community that lived in the cave surroundings.

Seemingly different taphonomic mechanisms and processes were involved in assembling the fauna. Small mammals such as rodents and

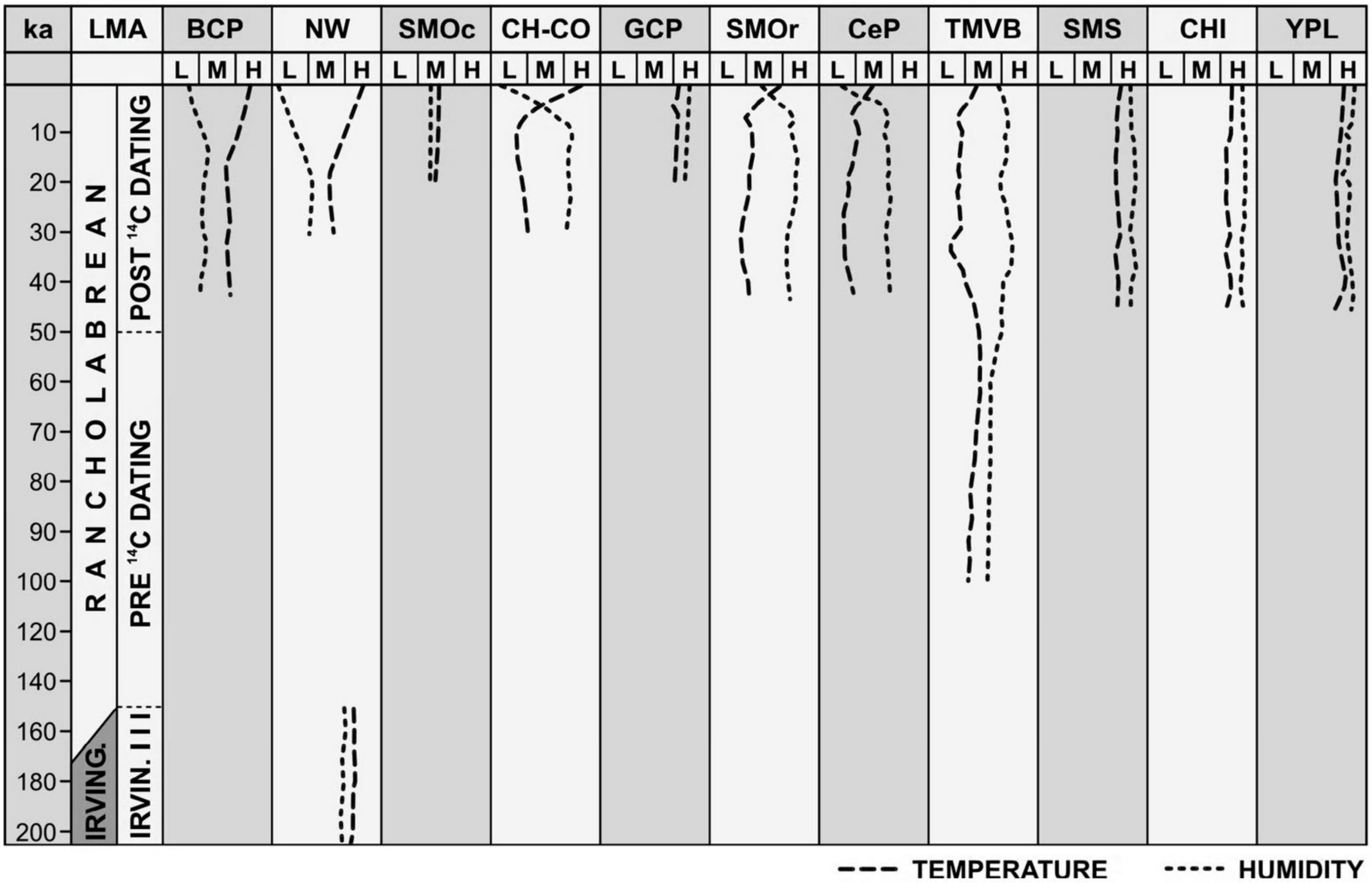

Figure 3 Late Pleistocene probable climate trends in México's morphotectonic provinces. (Source: Ferrusquía-Villafranca et al. 2010:fig. 16, with permission from Quaternary International/Elsevier). Time frame adapted from Bell et al. (2004). The reviewed palynologic, paleosol, lake sediment, and mammal records/data sets were used to assess the trends. **ABBREVIATIONS**: (from left to right): **L,** Low; **M,** Medium; **H,** High; **LMA**, North American Land Mammal Ages; **BCP**, Baja California Peninsula; **NW**, Northwestern Plains and Sierras; **SMOc**, Sierra Madre Occidental; **CH-CO**, Chihuahuan-Coahuilan Plateaus and Ranges; **GCP**, Gulf Coastal Plain; **SMOr**, Sierra Madre Oriental; **CeP**, Central Plateau; **TMVB**, Trans-Mexican Volcanic Belt; **SMS**, Sierra Madre del Sur; **CHI**, Sierra Madre de Chiapas; **YPL**, Yucatan Platform. (For further information pertaining specific data sets used to assess the climatic trends, taxonomic listings of mammal faunas of each morphotectonic province, and/or supplementary references, see Ferrusquía-Villafranca et al., 2010).

chiropterans might have lived there, and were entombed in situ, or they might have been brought in by prey birds. Medium and large mammals might accidentally have fallen through surface fissures and/or holes and, unable to get out, perished there; fallen carcasses might have subsequently become scattered by cave water currents. Finally, it is possible that large predators, for example, bears or wolves, might have used accessible bigger cave areas as temporary or permanent dwellings, bringing in medium to large mammal prey to eat there. Although important advances have been made in the study of this site (see Arroyo-Cabrales, 1994), much more work still remains to be done.

San Miguel Tocuila Site. This comprises a lahar deposit bearing numerous mammoth bones (*Mammuthus columbi*, 11.1 ± 0.13 ka, AMS ^{14}C; Morett et al., 2003) and lies ~40 km ENE from México City Center. The mammoth-bearing layer is a 1.3-m-thick lahar stratum, seemingly derived from loose pyroclastic material laying at high altitude in the Popocatépetl Volcano, placed ~44 km SSE from Tocuila, which was generated during the ~14-ka major eruption, and subsequently removed some 3 ka later, during a warming episode that partly melted the glacier (Siebe et al., 1999). Unfortunately, no detailed geologic map and/or information of the site and surroundings have been presented. The local stratigraphic column, based on the site excavation (Siebe et al., 1999:fig. 3), shows an ~4.5-m-thick succession of pyroclastics and pyroclastic-derived sediments that include the 1.3-m-thick mammoth-bearing lahar bed, concordantly covered by another 0.68-m-thick lahar bed, on top of which lies a silty-sandy mixture ("loam") that defines a paleosurface. This is in turn unconformably overlain by a 67-cm-thick lahar bed covered by a 0.34-m-thick hard sand mixture ("loam"), on top of which modern soil has developed.

The stratigraphic column of the same site presented by Morett et al. (2003:fig. 3) differs in the following features from that of Siebe et al. (1999): total thickness of the sequence (~3.6 m versus 4.5 m), interpretation of the fine-grained clastic mixtures (the lower one is a paleosol, and the upper is a caliche layer), thickness of the mammoth-bearing lahar layer [1.7 versus 1.3 m], and location of the lahar source (it came from the Nevado de Toluca Volcano, which lies 98.7 km SW of Tocuila, or from the Popocatépetl). Both Siebe et al. (1999) and Morett et al. (2003) agreed that the lahar flow incorporated already disarticulated mammoth bones (AMS ^{14}C age of 11.1 ± 0.08 ka; Morett et al., 2003), laying on the ravine surface where the flow traveled. It follows that such flow did not kill the mammoths.

Based on excavations of other parts of the site, Morett et al. (2003:272) claimed that below the mammoth-bearing lahar lies a "complex sequence of volcanic ash, lake silts and laharic deposits," which does not crop out in the Tocuila site proper, but pinches out just before reaching the site (see Morett et al., 2003:fig. 3). They mentioned that the sequence yields remains of *Equus*, *Bison*, *Camelops hesternus*, and

Table 4 Representative Wisconsinan mammal chronofauna of México as recorded in the chief local faunas. ^{14}C dated faunas are set in bold. [Modified from Ferrusquía-Villafranca et al., 2010, Tab.12]

	NW	CH-CO		SMOr					CeP	GCP	TMVB					SMS	YPL	
Class Mammalia	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**
DIDELPHIMORPHIA																		
Didelphidae																		
Didelphis marsupialis																	X	
Didelphis virginiana				**X**					X		X							
Mamosa canescens																	X	
Marmosa lorenzoi †																	X	
Marmosa mexicana											X						X	
XENARTHRA																		
Dasypodidae																		
Cabassous centralis ○																		X
Dasypus novemcinctus											X							
Holmesina septentrionalis †									X		X	X		**X**				
Pampatherium mexicanum †											X			**X**	X			
Glyptodontidae †																		
Glyptotherium cylindricum †											sp			**X**				
Glyptotherium floridanum †												X						
Glyptotherium mexicanum †						**X**						X						
Megalonychidae †																		
Megalonyx jeffersoni †				**X**										**X**				
Megalonyx wheatleyi †				**sp**		**sp**							**X**					
Megatheriidae †																		
Eremotherium laurillardi †											X	X						
Nothrotheriops mexicanum †				**X**								X						
Nothrotheriops shastensis †				**X**	X	**X**	X		X		X	X		**X**				
Mylodontidae †																		
Paramylodon harlani †						**X**			X		X	X						
Paramylodon sp. †	sp																	
INSECTIVORA s.l.																		
Soricidae																		
Cryptotis mayensis																	X	
Cryptotis mexicana				**X**														
Cryptotis parva			X					X										
Notiosorex crawfordi			X															
Sorex milleri				**X**														
Sorex saussurei				**X**														
CHIROPTERA																		
Antrozoidae																		
Antrozous pallidus ○			X															
Emballonuridae																		
Peropteryx macrotis																	X	
Molossidae																		
Eumops bonariensis																	X	
Eumops perotis ○		X																
Eumops underwoodi ○																	X	
Molossus rufus																	X	
Nyctinomops laticaudatus																	X	
Promops centralis																	X	
Tadarida brasiliensis			X															
Mormoopidae																		
Mormoops megalophylla				**X**	X								**X**				X	X
Pteronotus davyi																	X	
Pteronotus parmellii																	X	X
Natalidae																		
Natalus stramineus																	X	
Phyllostomidae																		
Artibeus jamaicensis																	X	X
Artibeus lituratus																	X	
Carollia brevicauda																	X	
Centurio senex																	X	
Chiroderma villosum																	X	
Choeronycteris mexicana				**X**														
Chrotopterus auritus																	X	X
Desmodus cf. *D. draculae* †																	X	
Desmodus rotundus										X							X	
Desmodus stocki †				**X**	X	**X**							**X**					

Table 4 Continued.

	NW	CH-CO		SMOr					CeP	GCP	TMVB					SMS	YPL	
Class Mammalia	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**
Diphylla ecaudata																	X	
Glossophaga soricina																	X	
Leptonycteris curasoae					X													
Leptonycteris nivalis				**X**														
Macrotus californicus ○					X													
Mimon bennettii																		X
Sturnira lilium																	X	
Vespertilionidae																		
Corynorhinus townsendii				**X**														
Eptesicus brasiliensis																		X
Eptesicus furinalis																		X
Eptesicus fuscus				**X**													X	
Lasiurus cinereus				**X**														
Lasiurus ega																	X	
Lasiurus intermedius																	X	
Myotis californicus				**X**														
Myotis keaysi			sp		sp	**sp**											X	
Myotis thysanodes				**X**														
CARNIVORA																		
Canidae																		
Canis cedazoensis †									X									
Canis dirus †				**X**		**X**	X		X		X	X		**X**			X	
Canis familiaris										X	X			**X**			X	
Canis latrans		X	X	**X**	X	**X**			X		X	X	**X**	**X**			X	
Canis lupus				**X**		**X**	X	X			X	X		**X**				
Canis rufus •						**X**						X						
Cuon alpinus •				**X**														
Urocyon cinereoargenteus		X		**X**	X				X								X	
Felidae																		
Herpailurus yagouaroundi				**X**													X	
Leopardus pardalis																		X
Lynx rufus		X	X	**X**				X	X			X	**X**					
Panthera atrox †	X			**X**					X		X	X						
Panthera onca	X	X		**X**				X	X									
Puma concolor		X	X	**X**						X	X					X	X	
Smilodon fatalis †				**X**					X		X	X						
Smilodon gracilis †														**X**				
Mustelidae																		
Conepatus leuconotus										X								
Conepatus mesoleucus		X		**X**							X							
Lontra longicaudis											X		**X**					
Mephitis mephitis		X		**X**														
Mustela frenata				**X**	sp												X	
Mustela nigripes ○			X															
Spilogale putorius ○		X		**X**	X												X	X
Taxidea taxus		X		**X**					X				**X**	**X**				
Procyonidae																		
Bassariscus astutus	X	X		**X**													X	
Bassariscus ticuli †					X													
Nasua narica		X															X	
Procyon lotor		X									X		**X**					X
Ursidae																		
Arctodus pristinus †									X			X		**X**				
Arctodus simus †						**X**			X		X	X		**X**				
Tremarctos floridanus †				**X**														
Ursus americanus ○		X	X	**X**		**X**						sp	**X**					
RODENTIA																		
Cuniculidae																		
Cuniculus paca																	X	
Erethizontidae																		
Erethizon dorsatum ○		X		**X**	X				X									
Coendou mexicanus																	X	
Geomyidae																		
Cratogeomys castanops		X	X	**X**		**X**		X	X			X	**X**					
Cratogeomys gymnurus											X							
Cratogeomys merriami													**X**					

Table 4 Continued.

	NW	CH-CO		SMOr					CeP	GCP	TMVB					SMS	YPL	
Class Mammalia	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**
Cratogeomys tylorrhinus												X						
Orthogeomys hispidus																	X	
Orthogeomys onerosus †				**X**														
Thomomys umbrinus		X	X	**X**					X			X		**X**				
Heteromyidae																		
Chaetodipus nelsoni		X																
Chaetodipus penicillatus ○		X																
Dipodomys nelsoni	sp		X		sp													
Dipodomys spectabilis		X	X															
Heteromys gaumeri																	X	
Liomys irroratus				**X**									**X**					
Perognathus flavus			sp		X/sp													
Hydrochoeridae ◆																		
Neochoerus aesopi †											sp		**X**					
Muridae																		
Baiomys intermedius†												X						
Baiomys musculus														**X**				
Baiomys taylori			X					X										
Hodomys alleni ○								sp										
Hodomys sp. nov.†					X													
Microtus californicus ○												X						
Microtus meadensis†												X						
Microtus mexicanus				**X**		**X**		X					**X**					
Microtus oaxacensis																X		
Microtus pennsylvanicus ○			X			**X**												
Microtus quasiater												X						
Neotoma albigula ○	sp	X	X	**X**	X	**sp**		X			X		**X**					
Neotoma anomala†													**X**					
Neotoma cinerea •			X															
Neotoma floridana •				**X**														
Neotoma lepida			X															
Neotoma magnodonta†												X						
Neotoma mexicana				**X**				X					**X**	**X**				
Neotoma micropus			X					X										
Neotoma phenax ○											X							
Neotoma tlapacoyana†													**X**					
Neotomodon alstoni												X						
Onychomys leucogaster	sp		sp															
Oryzomys couesi											X						X	
Oryzomys melanotis																	X	
Otonyctomys hatti																	X	
Ototylomys phyllotis																	X	
Peromyscus boylii			sp	**X**		**sp**		X	sp									
Peromyscus dificilis				**X**	X			X										
Peromyscus eremicus					X													
Peromyscus leucopus																	X	
Peromyscus levipes				**X**														
Peromyscus maldonadoi†												X	**X**					
Peromyscus maniculatus				**X**	X			X				X						
Peromyscus pectoralis					X													
Peromyscus yucatanicus																	X	
Reithrodontomys fulvescens			X			**sp**		X			X							
Reithrodontomys megalotis			X	**X**				X			X							
Sigmodon curtisi †	sp		sp															
Sigmodon hispidus		X		**X**	X						X	sp					X	
Synaptomys cooperi ○				**X**														
Sciuridae																		
Ammospermophilus interpres		X																
Cynomys ludovicianus ○			sp		sp													
Marmota flaviventris ○				**X**														
Sciurus alleni				**X**														
Sciurus yuctanensis																	X	
Spermophilus mexicanus		X																
Spermophilus spilosoma		X	X	**X**	X													
Spermophilus variegatus		X	X															

Table 4 Continued.

	NW	CH-CO		SMOr					CeP	GCP	TMVB					SMS	YPL	
Class Mammalia	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**
LAGOMORPHA																		
Leporidae																		
Aztlanolagus agilis †			X															
Lepus alleni								sp										
Lepus californicus		X	X		X	**X**	X											
Sylvilagus audubonii		X	X		X	**X**	X	sp			sp							
Sylvilagus brasiliensis																	X	
Sylvilagus cunicularius					X								**X**					
Sylvilagus floridanus				**X**	X	**X**							**X**				X	
Sylvilagus leonensis †				**X**	X			X										
PERISSODACTYLA																		
Equidae ◆																		
Equus calabatus †									X				**X**					
Equus conversidens †	sp		sp	**X**	sp	**X**	X	sp	X		X	X		**X**			X	
Equus excelsus †									X			X		**X**				
Equus giganteus †												X						
Equus mexicanus †						**X**					X	X	**X**	**X**				
Equus occidentalis †							X					X		**X**				
Equus pacificus †						**sp**			X			X						
Equus parastylidens †									X									
Equus tau †	X											X						
Tapiridae																		
Tapirus bairdii ○											sp	sp		**X**				
Tapirus haysii †				**X**		**X**	X											
ARTIODACTYLA																		
Antilocapridae																		
Antilocapra americana		X	X				X							**sp**				
Capromeryx mexicana †			sp		sp	**X**			X	X		X		**X**				
Capromeryx minor †	X																	
Stockoceros conklingi †				**X**	X			X	X	X		X		**X**	X			
Tetrameryx mooseri †	sp								X			sp						
Tetrameryx shuleri †										X	X			**X**	X			
Tetrameryx tacubayensis †									X									
Bovidae																		
Bison alaskensis †	sp					**sp**			X		X	X		**X**				
Bison antiquus †										X	X	X		**X**				
Bison bison ○		X															X	
Bison latifrons †											X	X	**X**					
Bison priscus †							X											
Euceratherium collinum †				**X**		**X**						X						
Oreamnos harringtoni †				**X**														
Ovis canadensis ○		X																
Camelidae ◆																		
Camelops hesternus †	X					**X**	X		X		X	X	**X**	**X**	X			
Camelops mexicanus †												X						
Camelops minidokae †														**X**				
Camelops traviswhitei †					X				X									
Eschatius conidens †												X						
Hemiauchenia blancoensis †					sp				sp				**sp**				sp	
Hemiauchenia macrocephala †						**X**	X					X		**X**				
Hemiauchenia vera †						**X**												
Procamelops minimus †														**X**				
Cervidae																		
Cervus elaphus •		X										sp						
Mazama americana										X							X	
Navahoceros fricki †				**X**					X							X		
Odocoileus halli †						**X**			X			sp	**X**					
Odocoileus hemionus	X	X						X			X							
Odocoileus virginianus		X			X		X			X			**X**				X	X
Tayassuidae																		
Platygonus alemanii †				**sp**					sp									
Platygonus compressus †												X		**X**				
Platygonus ticuli †						**X**					X							
Tayassu tajacu												sp					X	X

Table 4 Continued.

	NW	CH-CO		SMOr					CeP	GCP	TMVB					SMS	YPL	
Class Mammalia	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**
PROBOSCIDEA																		
Elephantidae ◆																		
Mammuthus columbi †	sp					**sp**	X		sp		X	X	**sp**	**X**				
Mammuthus primigenius †											X	X						
Gomphotheriidae †																		
Cuvieronius tropicus †											sp	X		**sp**				
Stegomastodon cf *S. mirificus* †											X	X						
Mammutidae †																		
Mammut americanum †						**sp**	sp		X		sp	X		**X**			X	
?LITOPTERNA †																		
?Macrauchenidae †															X			
Gen. et sp. indet. †															X			

Source: Modified from Ferrusquía-Villafranca et al. (2010, Tab. 12).

Symbology: † Extinct taxon. ◆ Suprageneric taxon extinct in Mexico, but extant outside Mexico. • Species extinct in Mexico, but extant outside this country. ○ Species extinct in the morphotectonic province(s) bearing the fossil locality(ies), but extant elsewhere in Mexico. X = Recorded species in a local fauna. sp = Recorded genera in a local fauna, but species is undetermined.

Morphotectonic Province Abbreviations: NW, Northwestern Plains and Sierras. **CH-CO**, Chihuahuan-Coahuilan Plateaus and Ranges. **SMOr**, Sierra Madre Oriental. **CeP**, Central Plateau. **GCP**, Gulf Coast Plain. **TMVB**, Trans-Mexican Volcanic Belt. **SMS**, Sierra Madre del Sur. **YPL**, Yucatan Platform.

Local Faunas: A, La Brisca, Son. **B**, Cuatro Ciénegas, Coah. **C**, Cueva Jiménez, Chih. **D**, San Josecito, NL. **E**, La Presita, SLP. **F**, El Cedral, SLP. **G**, Minas, NL. **H**, Mina San Antonio, SLP. **I**, El Cedazo, Ags. **J**, Mixtequilla, Ver. **K**, Chapala-Zacoalco, Jal. **L**, Tequixquiac, Mex. **M**, Tlapacoya, Mex. **N**, Valsequillo, Pue. **O**, Hueyatlaco, Pue. **P**, San Agustín, Oax. **Q**, Gruta de Loltún, Yuc. **R**, Actún Spukil, Yuc.

Sylvilagus cunicularius. Unfortunately though, Morett et al. (2003) did not thoroughly describe this sequence, its stratigraphic spatial relationships along the excavated places, or the geology of the site and surroundings. Further, they (Morett et al., 2003) did not elaborate on the purported Nevado de Toluca lahar-flow provenance.

It should be noted that neither Siebe et al. (1999) nor Morett et al. (2003) explain the enormous mammoth bone concentration (including the seven carcasses mentioned above) in a mere 28-m^2 area (Siebe et al., 1999:1550, fig. 2; Morett et al., 2003:fig. 2). On the other hand, González et al. (2001:705) proposed that the seven mammoths present in Tocuila were probably killed by an eruption of the Nevado de Toluca that took place ca. 11.6 ka, and that shortly after, a lahar flow from the same volcano picked up the *Mammuthus columbi* carcasses and moved them a short distance to Tocuila. Although they mentioned that the lahar included tephra from different sources—Popocateptl ca.14 ka, Tutti Frutti (= PWA) and Gray Pumice (~70.7 % SiO_2 content), and Nevado de Toluca Pumice (ca. 11.6 ka, ~61 % SiO_2 content)—they did not discuss proportions of each source in the tephra, or the mixing mechanisms.

Subsequently González et al. (2014, 2015) restudied in detail the Tocuila site, describing the ~4.0-m-thick trench exposure as a fine-clastics (largely clay and silt) lake sequence intercalated by pyroclastic and/or tephra sheets. These were unconformably overlain by a channel lahar infill ~1.3 m thick, seemingly formed by four beds with convoluted top and bottom surfaces, the lower part of which yielded the mammoth bones (González et al., 2014:fig. 6). The mammoth bones yielded AMS ^{14}C ages of 11,100 ± 80 years BP to 11,255 ± 75 years BP (see González et al., 2003). The fossil accumulation is thought to be the result of lahar funneling through a narrow channel. However, the fossil:lahar volume ratio preserved, roughly 1:4 at least (see González et al., 2014:fig. 6a), seems rather low to have accomplished this fossil removal and concentration.

The sequence below the lahar deposit includes GBA and PWA bed markers respectively 28,600 ± 200 years BP and 14,600 ± 65 years BP, the former is reworked and was identified by its geochemical makeup. There is also a 10-cm layer that contains Fe spherules (~0.065 mm), and microtektite particles (smaller than the spherules), which have been interpreted as evidence of an airburst meterorite (González et al., 2014, 2015). Similar evidence has also been detected in Lake Cuitzeo beds, Michoacán (Israde-Alcántara et al., 2012), and in South America (Firestone et al., 2007). This airburst meteorite occurred close to the Younger Dryas cooling event, and is interpreted as a possible cause of the Late Pleistocene megafaunal extinction; this hypothesis has not gone unchallenged (Haynes, 2008; Scott et al., 2010).

RADIOMETRIC/BIOCHRONOLOGIC DATING AND REGIONAL SIGNIFICANCE: MÉXICO'S WISCONSINAN CHRONOFAUNA

The radiometric data of the Wisconsinan sites are presented in Table 1, and were largely discussed above (see above, "Chronological Spread of the Sites"). All sites bear vertebrate faunas; their individual diversity varies greatly but they have considerable taxonomic overlap (i.e., shared taxa), as would be expected from chronologically similar faunas. The "major" faunas belong to Sites 2, San Josecito Cave, Nuevo León; 3, El Cedral, San Luis Potosí; 9, Tlapacoya (including 10, Tlapacoya I), Estado de México; and 17, Valsequillo, Puebla; taken together, these sites display a wide geographic spread and could confidently be used to draw a meaningful characterization/representation of México's Wisconsinan chronofauna (Table 4, modified from Ferrusquía-Villafranca et al., 2010:fig. 16). The chronofauna includes the following taxa: Didelphimorphs ("possums;" Didelphidae, only in San Josecito Cave, hereafter SJC), Dasypodidae (only in Tlapacoya), Pampatheriidae (only in Tlapacoya), Glyptodontidae (absent in SJC), Megalonychidae (only in El Cedral), Megatheriidae (only in El Cedral), Mylodontidae (only in El Cedral), Soricidae (only in SJC), Mormopidae (only in SJC and Tlapacoya), Phyllostomatidae (only in SJC, and Tlapacoya), Vespertilionidae (only in SJC), Canidae (only in Tlapacoya and Valsequillo), Felidae (only in Tlapacoya and Valsequillo), Mustelidae (only in Tlapacoya and Valsequillo), Procyonidae (only in Tlapacoya), Ursidae (present in all major faunas), Erethizontidae (only in SJC), Geomyidae (only in SJC and Tlapacoya), Heteromyidae (only in SJC and Tlapacoya), Hydrochoeridae (only in Tlapacoya), Muridae (only in SJC), Sciuridae (only in SJC), Leporidae (absent in Valsequillo), Equidae (absent in Valsequillo), Tapiridae (absent in Valsequillo), Antilocapridae (absent in Tlapacoya), Bovidae (absent in SJC), Camelidae (absent in SJC), Cervidae (absent in Valsequillo), Tayassuidae (absent in Tlapacoya), Elephantidae (absent in SJC), Gomphotheriidae (only in Valsequillo), and Mammutidae (absent in SJC).

The taxonomic composition of this chronofauna, includes Asian immigrants long established and differentiated in temperate North America (e.g., proboscideans, bovids), South American late-comers (e.g., xenarthrans and hydrochoerid rodents), and Late Cenozoic indigenous North American taxa (e.g., insectivores, sciurids, equids, and canids) and has a characteristic Wisconsinan outlook (see Bell et al., 2004). On this basis, it is assigned to the Wisconsinan SubNALMA, an age assignment well supported by the associated radiometric data (see Table 1).

Environmental Significance of the Wisconsinan Fauna of México

Locally, this chronofauna shows tropical taxa (e.g., vampire bats, most xenarthrans, hydrochoerids) and temperate taxa (e.g., insectivores, antilocaprids, sciurid rodents, leporids) coexisting side by side. Present-day mammal faunas have an ecologically and biogeographically harmonious composition, whereas that of the Pleistocene faunas are disharmonious (Bell et al., 2004), and evidence significant ecologic and biogeographic shifts of the component taxa, which are related to major Late Pleistocene/Early Holocene environmental changes. This subject is further developed in Ferrusquía-Villafranca et al. (2010).

México's Wisconsinan chronofauna is strikingly different from that of the Holocene (Ceballos and Oliva, 2005) by the presence of large-sized mammals, for example, equids, proboscideans, the majority of carnivores, xenarthrans, artiodactyls, and hydrochoerids, or the extirpation of others, for example, tapirs and phyllostomatid vampire bats that today characterize tropical regions. The Wisconsinan fauna was much more diverse at higher taxon level (e.g., family and order) than the Holocene one (Ferrusquía-Villafranca et al., 2010). Thus, the Holocene fauna of México is a taxonomically impoverished version of its Wisconsinan counterpart, and small-sized mammals overwhelmingly dominate. This phenomenon is part of the worldwide major extinction that took place by terminal Pleistocene–Early Holocene time (ca. 10 ka), a subject much discussed, but not yet settled (see Martin and Klein, 1989; Firestone et al., 2007).

These differences attest to the profound environmental changes that occurred at the Wisconsinan/Holocene "transition," a matter still widely discussed by many authors (see Urrutia-Fucugauchi et al., 1997, and literature therein; Caballero-Miranda et al., 1999, 2002; Metcalfe et al., 2000; Lozano-García et al., 2005). On the other hand, Ferrusquía-Villafranca et al. (2010) employed a multidisciplinary approach, using mammal species, palynomorphs/palynofloras, paleosol features, and lake sedimentary records (both physical and biotic) as climatic and environmental indicators to show that (a) the limited and strongly time/space–biased available information across the country only allows one to portray broad countrywide climatic/environmental changes (i.e., trends, see Ferrusquía-Villafranca et al., 2010:fig. 16, here reproduced as Fig. 4); (b) the necessary dependable, discipline-specific, countrywide data sets/databases require much additional work across the country; such effort is anticipated to extend many years into the future to complete the existing databases, for example, geologic s.l (stratigraphic and sedimentological), radiometric-geochronologic, and magneto-geochronologic studies; development of stable isotopes (for establishing "absolute" paleothermal parameters); studies of paleosols (as climatic indicators); and paleontological sensu lato studies (largely on palynomorphs and vertebrates as biotic components and climatic indicators); and (c) parsimonious integration of the discipline-specific data sets/databases through multidisciplinary and interdisciplinary research, from which the environmental change occurred since the Wisconsinan, could accurately and quantitatively be portrayed for México as a whole.

BEARING OF THE WISCONSINAN CHRONOFAUNA ON THE PEOPLEING OF MÉXICO/THE AMERICAN CONTINENT

México's Wisconsinan record holds two of the earliest occurrences of humans in the American continent based on direct human skeletal material, namely those of the Peñon III (Site 16) and Tlapacoya I (Site 10), Mexican Basin, TMVB MP, central México, which respectively yielded AMS ^{14}C ages of 10.775 ka and 10.21 ka (González et al., 2003). Further, the lithic tools found within tephra layers in the Santa Isabel Ixtapan (Site 4), dated between 14.5 and 10.8 years BP (see Table 1), suggest even earlier dates for human occupation in the Basin of México.

Comparable South American early human records are not older than 9.72 ka (Neves and Pucciarelli, 1991). The older (12.5-ka) Chilean human habitation Monte Verde site was not dated on human skeletal material (Dillehay, 1989). Thus, the Mexican Basin human records are older than those of South America, being quasi-contemporaneous with the Clovis people of southwestern United States, who lived ca. 11.5 ka, and with other records based on human skeletal material from North America include those of Arlington Springs, Santa Rosa Island, California (10.96 $\pm$ 0.08 ka, Johnson et al., 2000), and Buhl, Idaho (10.675 $\pm$ 0.95 ka, Green et al., 1998).

Certainly, there are claims for earlier records of humans in México, for example, those of Tlapacoya (Site 9, dated at 35 to 21.7 ka; Lorenzo and Mirambell, 1986b); or the purported 40-ka human footprints from Valsequillo (González et al., 2006). In the very interesting archaeologic/paleontologic Tlapacoya site, vertebrate fossils are associated with coarse-grained clastic strata that bear pebble-like, "faceted" objects interpreted as human-made artifacts ("tools"), as well as charcoal, organic matter, and hearths thought to be human-generated and dated by standard-method ^{14}C yielding ages $\sim$24 ka. Unfortunately, little if any stratigraphic detail of the dated material-bearing strata was furnished. Outside México, the reported dates of such an early presence of humans in the American continent have been met with skepticism, which is based on methodological and stratigraphic caveats (González et al., 2001). Further, new local stratigraphic studies (González et al., 2015) yielded no evidence to support such age. Therefore, the Peñón III and Tlapacoya I records based on direct human skeletal material remain as the earliest (10.755 $\pm$ 0.075 ka, and 10.2 $\pm$ 0.065 ka, respectively) undisputed evidence of humans in México.

CONCLUSIONS

1. The combined radiometric and paleontological approach has improved biochronology, allowed dependable and more precise long-range correlation, and been the driving force behind a qualitative leap in understanding Earth's geologic history and evolution. Even so, this approach is still not widely used in México despite its early start. Here we report 21 sites where this approach was applied. Their space and time distribution is quite uneven, omitting many morphotectonic provinces (BCP, SMOc, CH-CO, CeP, GCP, and YP) and geochronologic intervals, for example, Irvingtonian and Early Rancholabrean. The combined space and time spread (Table 1) shows this arrangement of sites: NW, one Early Rancholabrean; SMOr, two Late Rancholabrean; TMVB, one Irvingtonian and 13 Rancholabrean; SMS, two Rancholabrean; and SMCh, two Irvingtonian. Patchiness or skewness aside, the results from the sites' geologic setting and fossil content are quite significant.

2. The 21 Pleistocene sites dealt with here (from NW, one; SMOr, two; TMVB, 14; SMS, two; and SMCH, two) disclose the need to describe or revise their lithostratigraphic settings. However, despite current limitations in their lithostratigraphic documentation, they are of prime importance for understanding the Quaternary environmental change (climatic and otherwise, including timing, extent, and biotic impact). Their mammal assemblages belong to three chronofaunas: Irvingtonian (three records) and Early Rancholabrean (one record), and very Late Rancholabrean (Wisconsinan; 17 records). During this interval, the fauna underwent a profound change through time and space, drastically modifying its taxonomic makeup, its biogeographic distribution, and its entire physiognomy with a strong trend toward losing meso- and megabaryc taxa, taxonomic depauperation (by means of selective extinction/expatriation), and biogeographic shuffling. Thus, the Holocene fauna is an impoverished version of its Pleistocene counterpart. Finally, during this epoch our own species appears in México. In fact some of the oldest records of humans based on direct dating of human skeletal material are from this country.
3. The present study documents 21 sites with radiometric dates and studied vertebrate assemblages. The stage is set to extend this methodology to other Pleistocene localities throughout the country; this would considerably improve our understanding of México's Late Cenozoic biotic and geologic history and evolution.

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