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GEOCHRONOLOGY OF TYPE SANTACRUCIAN (MIDDLE TERTIARY) LAND MAMMAL AGE, PATAGONIA, ARGENTINA[1]

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ABSTRACT

Mammal-bearing lacustrine and tuffaceous sediments from three localities of the Santa Cruz Formation, type fauna of the Santacrucian Land Mammal Age, in Patagonia, southern Argentina, are calibrated by radioisotope dating with the aid of magnetostratigraphy. The strata range from about 17.6 Ma to perhaps 16.0 Ma, and are thus of late-early Miocene age. The Santacrucian Land Mammal Age ranges from about 18.0 Ma to about 15.0 Ma.

INTRODUCTION

The mammal-bearing Santa Cruz Formation in Patagonia, southern Argentina, is one of the most widespread and richly fossiliferous continental deposits in South America (Simpson 1940). The best known fossil localities are in Santa Cruz Province (fig. 1) along the Atlantic coast between Monte León and Río Gallegos, and in the Andean foothills between Lago Argentino and Lago Pueyrredón (Feruglio 1938; Marshall 1976). The formation exceeds 800 m in thickness in the west and thins to about 200 m in the east (Russo and Flores 1972). The sediments are predominantly of fluvial origin dominated by mudstones and sandstones with large quantities of volcanic ash and some gravel and other detrital material derived from the magmatically active Andes (Simpson 1940).

The mammal faunas from scattered localities of the Santa Cruz Formation serve as the conceptual and operational basis for recognition of the Santacrucian Land Mammal age, conventionally regarded as early Miocene (Patterson and Pascual 1972; Savage and Russell 1983). Santacrucian time is very important in the history of the South American land mammal fauna for three principal reasons. First, Santacrucian age faunas (i.e., those from the Santa Cruz Formation) are the best represented in terms of known taxa and specimens of all South American Tertiary age land mammal faunas. Extensive collections made at the turn and beginning of this century by the Argentine collector Carlos Ameghino (six trips, 1887–1893), the French collector André Tournouër (1898–1904), and the North American collectors John Bell Hatcher (three trips, 1896–1899), Handel T. Martin (one trip, 1903–1904), and Elmer S. Riggs (one trip 1922–1923) provide excellent reference collections deposited in Argentine, French, and North American museums (for more details about these expeditions and the localities

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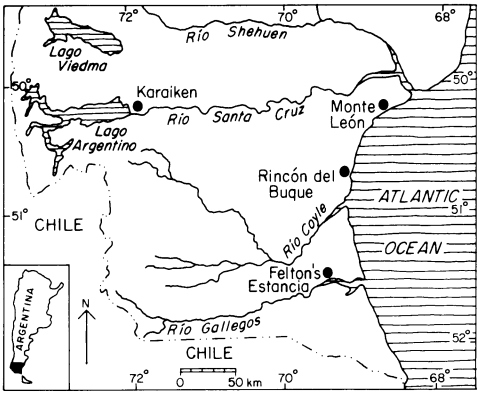

FIG. 1.—Map of southern part of Santa Cruz Province, Argentina, showing the localities of the Santa Cruz Formation for which geochronologic data are available.

where the collections were made see Marshall 1976). Second, the Santacrucian Land Mammal Age is taxonomically the most diverse in terms of known mammalian genera of all Tertiary land mammal age faunas in South America (for a list of genera see Marshall et al. 1983, table 9; and for a "spindle diagram" showing total or cumulative generic diversity of all South American land mammal ages see Marshall 1985, fig. 2). And third, the Santacrucian fauna is dominated by endemic, autochthonous taxa which reflect the fact that South America had no direct land connection with any other continental land mass during the Tertiary and that the fauna was evolving in what G. G. Simpson (1980) called "Splendid Isolation."

Because of the lack of geochronological data, the early Miocene age assignment for the Santacrucian Land Mammal Age, established during the 1940s and 50s, was based primarily on knowledge of the "stage of evolution" of the mammal fauna (Simpson 1940; Patterson and Pascual 1972). Three facts acquired in the 1960's and 70's endorsed this age assignment. First, a K-Ar date on a plagioclase concentrate from a tuff collected from the Santa Cruz Formation near Felton's Estancia (fig. 1) yielded an age of 21.7 ± 0.3 Ma (KA 1252, table 1; Evernden et al. 1964). Another K-Ar date of 18.4 ± 0.9 Ma (KA 2944, table 1) was obtained on a glass concentrate of a tuff from the Santa Cruz Formation at Monte León (fig. 1; Marshall et al. 1977; Marshall and Pascual 1978), the nominal type locality of the Santa Cruz Formation and the Santacrucian Land Mammal Age (Marshall et al. 1983). Second, an average age of 14.5 Ma was obtained on K-Ar dates of mineral separates from an ignimbrite in the Collón Cura Formation in northwest Patagonia associated with a mammal fauna of early Friasian age (Marshall et al. 1977; Marshall and Pascual 1978). The Friasian age, conventionally regarded as middle Miocene, succeeds the Santacrucian age without any apparent break in faunal succession (Marshall and Pascual 1977, 1978; Marshall et al. 1983). Third, at Monte León the Santa Cruz Formation is conformably underlain by the marine Monte León Formation (Camacho 1974) which contains planktonic foraminifera regarded as late Oligocene to possibly early Miocene in age (Bertels 1979). Collectively, these data supported an early Miocene age assignment for the Santa Cruz Formation and suggested that the Santacrucian Land Mammal Age may have spanned a time interval of about 6.0 m.y. (22.0 Ma to 16.0 Ma; Marshall et al. 1977, 1983; Marshall and Pascual 1978).

New radioisotopic and/or magnetostratigraphic data presented here for the Santa Cruz Formation at Karaiken, Monte León, and Rincón del Buque (fig. 1) securely demonstrate that this formation and hence the Santacrucian Land Mammal Age are considerably younger and of shorter duration than previously envisioned.

LOCALITIES

1. Karaiken.—(fig. 1) is located about 3 km NE of the Estancia La Laurita on the SW slope of the Meseta Fernando Fernández, about 25 km NE of the point where the Río Santa Cruz leaves Lago Argentino (Feruglio 1938; Marshall 1976). This is the "Notohipidense" horizon of Ameghino (1902, 1906, fig. 57) which represents about the lower 80 m of the Santa Cruz Formation at this locality (Feruglio 1938, fig. 6). Stratigraphic sections showing the fossil mammal levels are given by Feruglio (1944, fig. 20) and Marshall and Pascual (1977, fig. 1). The underlying marine unit (fig. 2) is named the Centinela Formation (Furque 1973) and is regarded as late Oligocene to perhaps early Miocene in age. It is probably a temporal and possibly even a lithologic equivalent of the Monte León Formation at Monte León (W. J. Zinsmeister pers. comm.).

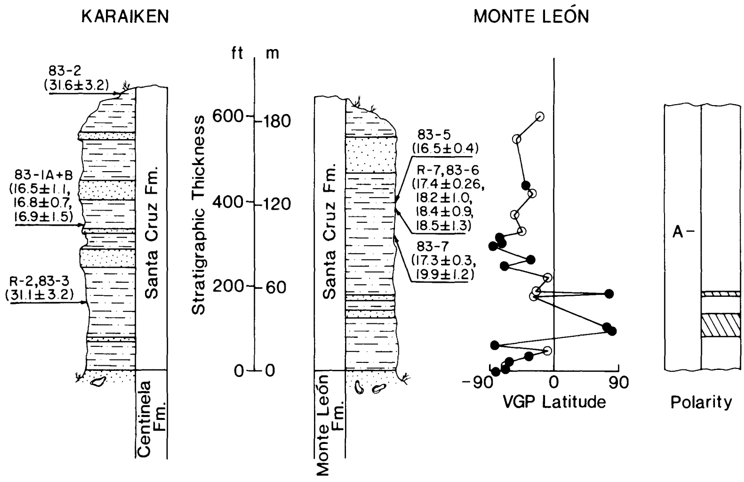

FIG. 2.—Lithostratigraphy, magnetostratigraphy, and radioisotopic sample distribution at Monte León and Karaiken. Dot-dash pattern in lithostratigraphic columns indicates siltstone, while dot pattern indicates sandstone. Site mean virtual geomagnetic pole (VGP) latitudes following AF cleaning are shown for the Monte León section. Filled data points indicate within-site clustering of the NRM vectors which is significant from random at 95% confidence level (Fisher 1953); open data points are for sites with poorer clustering. Positive (negative) VGP latitude indicates normal (reversed) polarity. Interpreted polarity column is shown at right.

2. *Monte León.*—(fig. 1) is located on the Atlantic coast at Cerro Monte León, about 43 km SW of the town of Santa Cruz (Marshall 1976). Our section (fig. 2) was taken on the NE slope of Cerro Monte León. The underlying marine unit (fig. 2) is named the Monte León Formation (Camacho 1974) and is regarded as late Oligocene to possibly early Miocene in age (Bertels 1979, fig. 10). We observed, but did not collect, fossil mammal bones at nearly every level within the section studied.

3. *Rincón del Buque.*—(fig. 1), a large amphitheater opening toward the sea, is located about 23 km N of Coy Inlet. The amphitheater is about 4 km across in a N-S direction, and is labeled "Media Luna" on all recent maps (Marshall 1976). The dated rock sample (table 1) was collected from the NE side of the amphitheater about 20 m above the base of the exposures, although no detailed stratigraphic section was taken. The fossil mammals from this locality are discussed by Bordas (1941), but we did not observe any fossil remains during the course of our study.

RADIOISOTOPIC AGE DETERMINATIONS

In the following analysis, several criteria are used for interpreting the reliability of K-Ar dates. First, any date with a high error (i.e., the ±) is treated permissive, but not diagnostic of age. Second, the geologic context and/or study of mineral separates may indicate the possibility of an older detrital component which could correspond to anomalous results. Thus, if replicate dates are available for a particular sample of reworked tuff, then the younger date(s) is (are) more likely correct. Some minerals, particularly biotite and glass, are often suspect because of possible air argon loss resulting from post eruptive alteration. This alteration is readily apparent when the sample is analyzed under a light microscope and the degree of alteration often correlates with anomalously young ages. Third, the overall interpretation of a suite of dates is made by comparing all the dates, taking into consideration their stratigraphic relations, analytical quality, and their internal consistency on dates for different minerals. This process inevitably remains somewhat subjective and it is therefore important to have, whenever possible, multiple dates for each mineral and to date as many phases per sample as possible. The multiple dates presented in this study thus establish a more objective basis for rejection of some dates, particularly if suspect dates correlate with observable problems such as alteration and/or contamination.

TABLE 1

ANALYTICAL DATA FOR ^{40}K-^{40}AR DATES ON VOLCANIC ROCKS OF THE SANTA CRUZ FORMATION, SOUTHERN ARGENTINA

Sample Number (KA)	Material Dated	Sample Weight (g)	K (%)	^{40}Ar[a] ($\times 10^{-11}$ mole/g)	^{40}Ar[a] (%)	Age ± 2σ (Ma)	Collection Number (LGM)
1. *Felton's Estancia*							
1252[b]	plagioclase	2.35	.180	.695	88.0	21.7 ± .3	. . .
2. *Monte León*							
4619	glass	1.61	3.305	9.48	67.9	16.5 ± .4	83-5
4623	plagioclase	4.41	1.315	3.99	81.8	17.4 ± .26	83-6
4627	glass	3.46	3.220	10.37	19.6	18.5 ± 1.3	83-6
4627R	glass	.99	3.220	10.23	16.7	18.2 ± 1.0	86-6
2944[b]	glass	4.17	2.327	7.49	62.1	18.4 ± .9	R-7
4593	glass	1.38	2.071	6.24	66.5	17.3 ± .3	83-7
4869	biotite	.21	4.702	16.32	29.7	19.9 ± 1.2	83-7
3. *Rincón del Buque*							
2948[b]	glass	1.88	2.166	6.02	32.1	16.0 ± .8	R-10
4. *Karaiken*							
4618	basalt (WR)	9.46	.853	.393	50.7	2.66 ± .14	83-4
4626	plagioclase	3.80	.272	1.504	45.6	31.6 ± 3.2	83-2
4558	plagioclase	1.66	.271	.793	16.8	16.8 ± .7	83-1A
4611	plagioclase	1.24	.273	.802	8.7	16.9 ± 1.5	83-1A
4587	plagioclase	1.94	.335	.965	30.1	16.5 ± 1.1	83-1B
4594	plagioclase	1.18	.278	1.511	56.7	31.1 ± 3.2	83-3

NOTE.—Calculations are based on the radioactive decay constants for $^{40}K_{\lambda\beta} = 4.962 \times 10^{-10} yr^{-1}$ and $\lambda e + \lambda e^1 = 0.581 \times 10^{-10} yr^{-1}$ and on the isotopic abundance ^{40}K = 0.01167% of total K. For sample locations see text and figures 1 and 3.

[a] Radiogenic ^{40}Ar.

[b] The ages for KA 1252, 2944, and 2948 were calculated using the above decay constants.

Karaiken.—Three tuffaceous units within a 210 m section of the Santa Cruz Formation at Karaiken (fig. 1) were sampled, and plagioclase concentrates from each were dated (table 1, fig. 2). The upper (LGM 83-2) and lower (LGM 83-3, fig. 2) units are reworked tuffaceous sands. The anomalously old dates (i.e., 31.6 ± 3.2 Ma, KA 4626; 31.1 ± 3.2 Ma, KA 4594, respectively, table 1) for these units indicate that the samples contain an older feldspar component. The middle tuff (LGM 83-1, fig. 2) contains small lenses of rhyolite pebbles from which uncontaminated plagioclase phenocrysts were extracted for dating. The three dates obtained (16.8 ± 0.7 Ma, KA 4558; 16.9 ± 1.5 Ma, KA 4611; 16.5 ± 1.1 Ma, KA 4587; table 1) on this unit are technically identical in age, and average 16.7 ± 0.2 Ma.

A fission track date of 15.7 ± 1.8 Ma (DF-1220, table 2) was obtained on six zircon grains from the lowest tuff (LGM R-2 = LGM 83-3) sampled at Karaiken. Although the error bars for this date are large, the date is concordant (within the error limits) with the 16.7 Ma average date for the plagioclase concentrates from LGM 83-1.

A whole rock sample of a basalt capping the Santa Cruz Formation at Karaiken yielded a date of 2.66 ± 0.14 Ma (KA 4618,

TABLE 2

ANALYTICAL DATA FOR ZIRCON FISSION TRACK DATE

Sample Number	Material Dated	Fossil Track Density $\times 10^6$ t/cm^2	Induced Track Density $\times 10^6$ t/cm^2	Neutron Dose $\times 10^{15}$ n/cm^2	Age ± 2σ (Ma)	Number of Grains	Correlation Coefficient	U ppm
DF-1220 (LGM R-2)	Zircon	2.93 (448)	12.31 (940)	1.10	15.7 ± 1.8	6	.95	360

NOTE.—Based on the radioactive decay constant $7.03 \times 10^{-17} yr^{-1}$.

table 1). The exact stratigraphic position of this basalt relative to the top of our section was not recorded, although the basalt is clearly of Pliocene age and thus has no direct bearing on the age of the underlying Santa Cruz Formation. This basalt was sampled and dated with the hope that it had been deposited at the end of Santacrucian time at this locality.

Monte León.—Three crystal, vitric tuffaceous sand units within a 200 m section of the Santa Cruz Formation at Monte León were sampled (figs. 1, 2, table 1). The lowest unit (LGM 83-7, fig. 2) is a 1-m thick, fine-grained tuffaceous sand. Biotite (KA 4869) and glass (KA 4593) were separated and yielded dates of 19.9 ± 1.2 Ma and 17.3 ± 0.3 Ma, respectively (table 1). Since the glass is less likely to be contaminated than is the biotite, the age of this tuffaceous unit is probably closer to the glass date of 17.3 ± 0.3 Ma then to the less precise biotite date. The two upper tuff units (LGM 83-5, 83-6) are located 20 m and 18 m, respectively, above LGM 83-7 (fig. 2). Both units yielded glass, and LGM 83-6 a plagioclase, which were dated (table 1). These dates and an earlier date (KA 2944) on sample LGM R-7 (= LGM 83-6) average 17.8 ± 0.8 Ma. However, the two youngest dates are the most precise, and indicate an average age for these two upper tuffaceous units of about 17.0 ± 0.5 Ma. Thus, the Santa Cruz Formation exposed at Monte León appears to be bracketed between 17.3 Ma and 17.0 Ma. However, considering the spread in dates from this section, a maximum age range of 18.5 Ma to 16.5 Ma is possible.

Rincón del Buque.—A glass concentrate of a tuffaceous sand unit in the Santa Cruz Formation at Rincón del Buque (fig. 1) yielded a date of 16.0 ± 0.8 Ma (KA 2948, table 1). The stratigraphic position of this unit within the formation is unknown because the contact with the underlying marine formation is not exposed at this locality. Nevertheless, this date of 16.0 ± 0.8 Ma, along with those dates from Karaiken (16.7 ± 0.2 Ma) and Monte León (17.3 ± 0.3 Ma to 17.0 ± 0.5 Ma), collectively indicate an overall age of about 17.3 Ma to about 16.0 Ma for the Santa Cruz Formation. Furthermore, these new dates (two on plagioclase, three on glass) indicate that the two previously determined dates (21.7 ± 0.3 Ma, KA 1252; 18.4 ± 0.9 Ma, KA 2944) were too old due to possible contamination.

PALEOMAGNETIC ANALYSIS

Paleomagnetic samples were collected at 25 sites (three or four samples/site) within each of the sections at Monte León and Karaiken. The base of each section begins at the conformable contact with the underlying marine formation (fig. 2), and the top of each section is the upper limit of available outcrop. Paleomagnetic and rock-magnetic studies were performed by RFB and KMF. Strong-field thermomagnetic results on one magnetic separate from Monte León and another from Karaiken reveal reversible heating and cooling curves with a single Curie temperature of 580° C, indicating that the dominant ferrimagnetic mineral is magnetite.

Natural remanent magnetization (NRM) was measured using a cryogenic magnetometer. For the Monte León samples, NRM intensities ranged from 1.4×10^{-4} to 8×10^{-3} A/m with a mean of 5×10^{-4} A/m. Samples from the Karaiken section had NRM intensities ranging from 4×10^{-4} to 2×10^{-1} A/m with a mean of 1×10^{-2} A/m. Progressive alternating-field (AF) and thermal demagnetization experiments were performed on representative samples to investigate the stability of the NRM and to determine the magnetic cleaning technique which would best remove secondary components of NRM. Vector diagrams illustrating AF and thermal demagnetization behaviors for two representative samples from the Monte León section are presented in figure 3.

AF demagnetization results (e.g., fig. 3*a*) indicate the presence of large components of viscous remanent magnetization (VRM) parallel to the present magnetic field at the sampling localities. For the majority of sites in the Monte León section, AF demagnetization to peak fields of 15–30 mT removed the present field VRM component, and higher peak fields produced a general trend of the remaining NRM toward the origin. However, the AF demagnetization behavior is far from ideal. Although a general trend toward the origin is established for peak fields >30 mT, significant scatter is present. The weak intensity of the NRM for samples from the Monte León section accounts for some of the scatter, but the major difficulty in obtaining stable

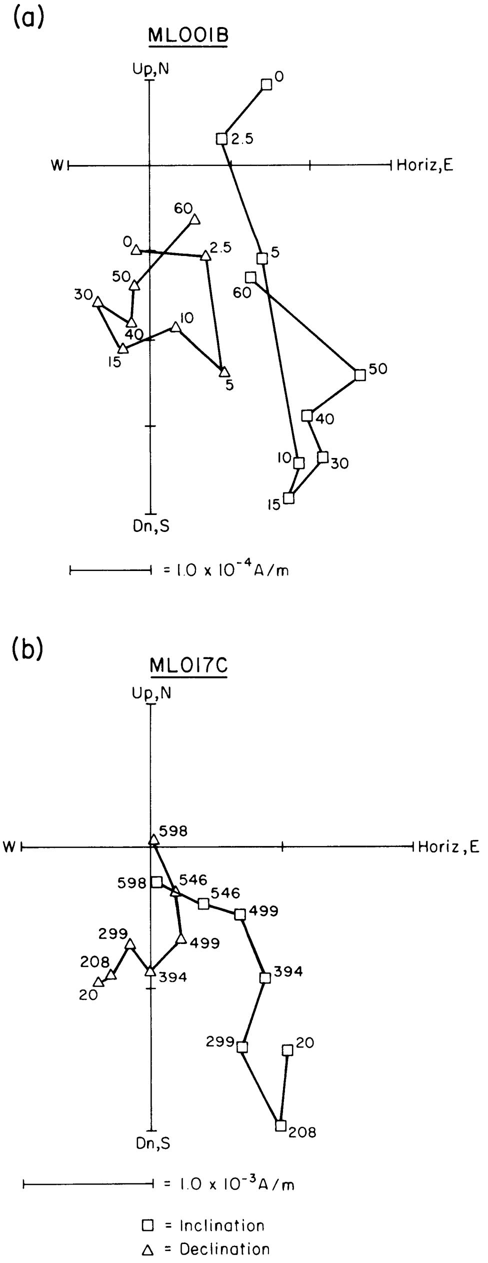

FIG. 3.—Vector demagnetization plots of (*a*) progressive alternating-field demagnetization and (*b*) progressive thermal demagnetization (following AF demagnetization to 20 mT) of two representative samples from the Monte León section. Projection of NRM vectors into the horizontal plane is shown by triangles while the vertical versus horizontal plot is shown by squares. Peak alternating-field (in mT) or temperature (in °C) is indicated adjacent to data points.

end point behavior was acquisition of VRM components on short time scales in the laboratory. This tendency to acquire VRM during the measurement procedures became more severe at higher demagnetizing fields. Thus, while a general trend toward the origin of the vector demagnetization diagram can be established for peak fields >30 mT, considerable scatter does exist. However, for the Monte León section, consistency of within-site NRM directions cleaned in AF of 30–40 mT peak field and general stratigraphic consistency between sites provide additional evidence that the primary component of NRM was isolated by this demagnetization treatment. Accordingly, AF demagnetization to peak fields of 30–40 mT was used as the blanket demagnetization.

Thermal demagnetization (following AF demagnetization to 20 mT) of samples from the Monte León section (e.g., fig. 3*b*) revealed a general trend of the NRM toward the origin of the vector demagnetization diagram. Again, the data are somewhat scattered, but do reveal blocking temperatures distributed dominantly between 200 and 600° C. No evidence of low blocking temperature components (such as due to goethite) was observed. Both the AF and the thermal demagnetization results indicate that the primary NRM component is carried by magnetite. This primary component is interpreted as a depositional remanent magnetization.

Severe problems with VRM components were encountered for samples from the Karaiken section. Present field VRM components dominated the NRM. For most sites within this section, components of VRM acquired during measurement procedures prevented isolation of a primary NRM component. Thus, no useful polarity data could be obtained from the Karaiken section. Although VRM was a difficulty for samples from the Monte León section, the problem was less severe and the reversed polarity directions obtained at most sites following AF treatment indicate that the present field VRM was successfully removed from those sites. Paleomagnetic polarity results from the Monte León section are summarized in figure 2.

Experiments on acquisition of VRM over a 10 month period were performed on representative samples from both sections. Acqui-

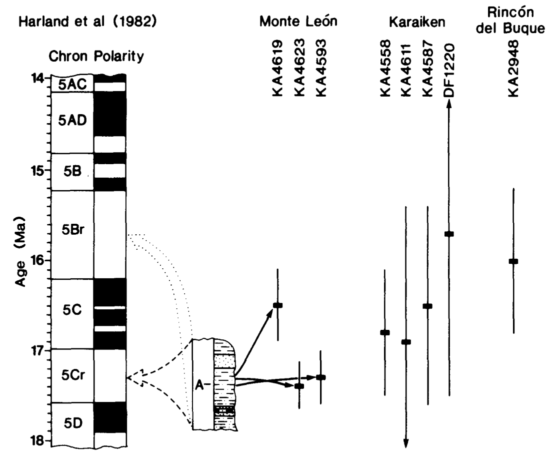

FIG. 4.—Radioisotopic age determinations from Monte León, Karaiken, and Rincón del Buque along with magnetic polarity and stratigraphic section from Monte León compared with magnetic polarity time scale of Harland et al. (1982). Radioisotope sample number is given at top of figure. Preferred correlation of Monte León A- with chron 5Cr is shown by dashed arrow, while alternative correlation with chron 5Br is shown by dotted arrow.

sition of VRM was rapid, especially for samples from Karaiken. In accordance with the progressive demagnetization results, large VRM components acquired during the Brunhes normal polarity epoch are anticipated for the Monte León samples, while the NRM of Karaiken samples is clearly dominated by such components.

In summary, because of the large VRM components, we are not confident that the three sites with apparent normal polarity in the lower part of the Monte León section (fig. 2) are reliable indicators of geomagnetic polarity at the time of deposition. Nevertheless, it is possible to conclude that the stratigraphic section at Monte León is dominantly, if not entirely, of reversed polarity. The reversed polarity zone observed at Monte León is designated "Monte León A-" (fig. 2).

DISCUSSION AND CONCLUSIONS

In figure 4, the most precise and youngest radioisotope results from Monte León, Karaiken, and Rincón del Buque are plotted along with the magnetic polarity results from Monte León and are compared with the magnetic polarity time scale of Harland et al. (1982). Since the K-Ar age of the Santa Cruz Formation at Monte León is concluded to approximate 17.0 Ma to 17.3 Ma, the Monte León A- polarity zone most likely correlates with chron 5Cr. Given the collective spread of radioisotope ages, it is possible, but less likely, that Monte León A- could correlate with the next younger reversed polarity chron 5Br. However, our preferred interpretation is to correlate Monte León A- with chron 5Cr. According to Harland et al. (1982), the age limits of chron 5Cr are approximately 17.6 Ma to 17.0 Ma and, on the basis of the available radioisotopic and paleomagnetic data, these ages provide the best estimates for the age limits of the Santa Cruz Formation at Monte León.

These new geochronologic data permit reassessment of the duration and boundaries of the Santacrucian Land Mammal Age. Two levels of age resolution are provided by these data. First, the K-Ar and paleomagnetic data at Monte León suggest an age limit of 17.6 Ma to 17.0 Ma for the Santa Cruz Formation at this locality. Second, the range of "acceptable" K-Ar dates from Karaiken, Monte León, and Rincón del Buque suggest a time span of about 17.3 Ma to perhaps 16.0 Ma for the parts of the formation which they represent. In all cases, these geochronologic data relate to faunas regarded as "middle" Santacrucian age at these localities (Marshall et al. 1983).

A third consideration must be given to aspects of knowledge of "stage of evolution" of the Santacrucian faunas from these localities, as well as those of faunas of preceding (Colhuehuapian) and succeeding (Friasian) ages.

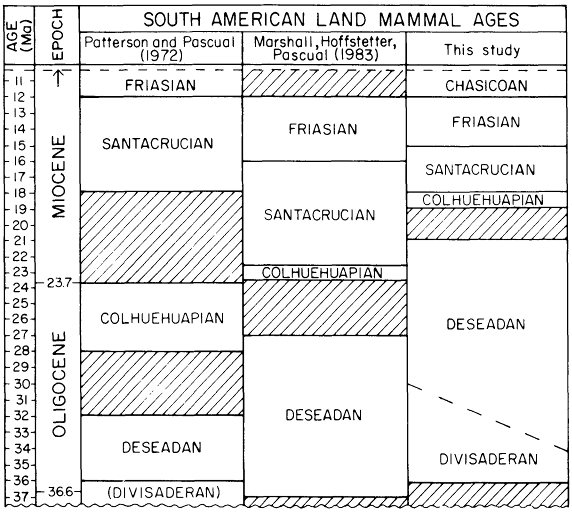

FIG. 5.—Chronology of Oligocene through Middle Miocene Land Mammal Ages in South America as recognized in this and in two previous studies. Hatching denotes hiatuses in knowledge of fossil land mammal faunas. Geologic time scale follows that of Palmer (1983).

The mammal fauna from the basal part of the Santa Cruz Formation at Karaiken is regarded as transitional with that of Colhuehuapian age faunas and is regarded as "early" Santacrucian in age (Marshall and Pascual 1977; Marshall et al. 1983). The tuffs dated in this study are all above this "early" Santacrucian fauna, and some time must be permitted to encompass "early" Santacrucian time. It is therefore reasonable to assume that a date of 18.0 Ma approximates the Colhuehuapian-Santacrucian age boundary (fig. 5). This lower boundary assignment for the Santacrucian Land Mammal Age is still consistent with a late Oligocene to early Miocene age for the marine Centinela and Monte León Formations which comformably underlie the Santa Cruz Formation at Karaiken and Monte León, respectively (fig. 2).

The Santacrucian-Friasian age boundary is approximated by a date of 15.0 Ma based on knowledge that faunas of "late" Santacrucian age are reported from the Santa Cruz Formation at Lago Pueyrredón (Marshall et al. 1983), and an average age of 14.5 Ma was obtained on biotite and plagioclase concentrates from an ignimbrite in the Collón Cura Formation which dates or approximates the age of an "early" Friasian age fauna (Marshall and Pascual 1978; Marshall et al. 1977, 1983). Thus, an approximate age range of 18.0 Ma to 15.0 Ma for the Santacrucian Land Mammal Age is suggested by these data (fig. 5).

A revised chronology of Oligocene land mammal age faunas based on data reported by Marshall et al. (in press) and of early and middle Miocene land mammal age faunas based on geochronologic data presented in this study is shown in figure 5, along with chronologies for these same time periods as presented in two previous studies. This comparison demonstrates how knowledge of the ages of these faunas have changed over the last 15 years because of the acquisition of new geochronologic (radioisotopic, magnetostratigraphic) data. The significance of the revised calibration to aspects of mammalian evolution in South America include: (1) the Santacrucian Land Mammal Age is of shorter duration than previously believed and is younger than believed by Marshall et al. (1983); (2) Santacrucian age faunas are now known to equate with North American land mammal faunas of upper Hemingfordian and lower Barstovian age; and (3) the Colhuehuapian Land Mammal Age is now regarded as late-early Miocene rather than late Oligocene as conventionally believed (Patterson and Pascual 1972; Marshall et al. 1983). These facts and the demonstration that the Deseadan Land Mammal Age extends from about 34.0 Ma to about 21.0 Ma (Marshall et al. 1986), convincingly indicate that all middle

Tertiary land mammal ages in South America are about five to six million years younger than previously envisioned. This new time scale has important implications with regard to considerations of aspects of "stage of evolution" among South American land mammal age faunas and with comparisons of "stage of evolution" to mammal faunas on other continents as well.

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