NEW LOCALITIES, CHRONOLOGY, AND COMPARISONS FOR THE PYGMY MAMMOTH (*MAMMUTHUS EXILIS*): 1994-1998

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ABSTRACT

The 1994 discovery, excavation, and recovery of a nearly complete (+90%) skeleton of the pygmy mammoth (*Mammuthus exilis*) on Santa Rosa Island initiated a new phase of research on these unique proboscideans. In January, 1996 an intensive, Global Positioning System (GPS) controlled, pedestrian survey of the mammoth remains on San Miguel, Santa Rosa and Santa Cruz islands was initiated. In addition to recording more than 140 new localities, specimens in imminent danger of loss by erosion were collected, prepared and curated. These new specimens are housed in the National Park Service repository at the Santa Barbara Museum of Natural History, joining the collections made by Phil Orr in the 1940s and 1950s and those of Boris Woolley, collected in the 1970s. Metric analyses of teeth and selected post cranial elements are compared with a large, local, primary deposit of mainland mammoths (*Mammuthus columbi*) from the Mammoth Site of Hot Springs, South Dakota. Preliminary comparisons are also made with the Holocene mammoths (*Mammuthus primigenius*) from Wrangel Island in the Siberian Arctic Ocean. New radiocarbon dates include an accelerator-mass spectrometer (AMS) bone date from the 1994 skeleton.

Keywords: California Channel Islands, pygmy mammoth, dental metrics, long bone metrics, *Mammuthus columbi, Mammuthus exilis*.

INTRODUCTION

Dwarf, or pygmy, proboscideans are known from four island locations in the Northern Hemisphere. These include pygmy elephants from several islands in the Mediterranean Sea; pygmy stegodons from several islands in the Indonesian archipelago; the three northern islands of the California Channel Islands; in 1993 it was announced that there were dwarf woolly mammoths (*M. primigenius*) on Wrangel Island in the Siberian Arctic Ocean. In November 1997, it was published that the Wrangel Island mammoths were no longer considered to be dwarf (Thikonov 1997). That announcement provides a new status to the Channel Island mammoths (*Mammuthus exilis*) as the only pygmy mammoths in the world!

Channel Islands Mammoths

Mammoth remains have been known to exist on the northern Channel Islands of California since 1856 when noted by a Coast and Geodetic Survey party. The first published account was not until 1873 in the Proceedings of the California Academy of Sciences (Stearns 1873). Oliver Hay (1927) mentioned the Channel Island proboscideans, Chester Stock and E.L. Furlong (1928), published a short article in which they proposed the name *Elephas exilis* (exiled elephants) for the Santa Rosa Island mammoths. They were mentioned again in two shorter articles by Stock (1935, 1943). The generic designation "*Elephas*" was replaced by *Mammuthus*.

In the late 1940s Phil Orr of the Santa Barbara Museum of Natural History (SBMNH) initiated archaeological research on Santa Rosa Island. He collected mammoth remains to support his theory that early human settlers (ancient Chumash) on the islands had hunted the pygmy mammoths to extinction (Orr 1956a, b, c, 1959, 1960, 1967, 1968). He also established the osteological collection and mounted a composite skeleton of *Mammuthus exilis* at SBMNH. An avocational collection was amassed by Boris Woolley, from Santa Rosa Island in the 1970s. That collection is now curated at SBMNH. A doctoral dissertation in zoology was completed on studies of museum collections by Louise Roth (Roth 1982).

Interest in the Channel Island mammoths was rekindled in 1994 when a nearly complete skeleton of one individual was discovered by Tom Rockwell and Kevin Colson while doing geophysical investigations on Santa Rosa Island. Excavation and recovery of the specimen produced more than 90% of the articulated skeleton of a mature male *Mammuthus exilis* (Figure 1). The depositional environment was a sand dune on an elevated marine terrace. The sand dune must have covered the mammoth almost immediately post mortem as it preserved even small foot bones in correct articular

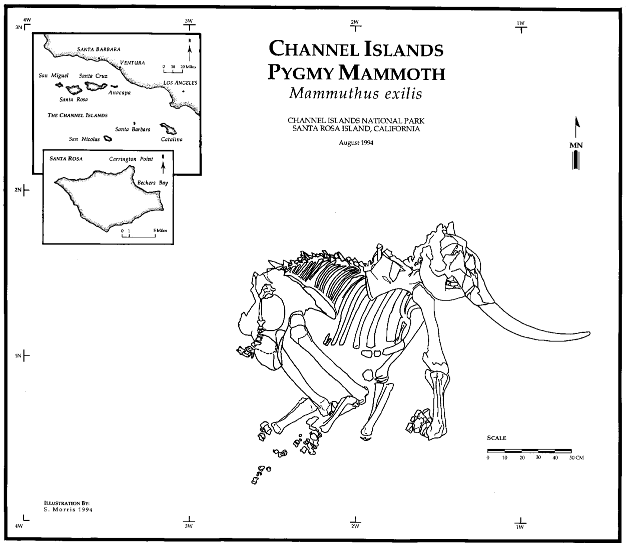

Figure 1. A bone map of the articulated *M. exilis* skeleton of 1994 (artwork by Susan Morris).

position. Post depositional erosion had removed, or damaged minor portions of the skeleton. After cleaning, preservation, and casting, the remains were deposited in the Channel Islands National Park (CHIS) paleontological repository at SBMNH. The majority of curated remains of *M. exilis* now reside in two institutions, the SBMNH and Los Angeles County Museum (LACM).

MATERIALS AND METHODS

In January 1996 we initiated an intensive pedestrian survey of San Miguel, Santa Rosa, and Santa Cruz islands. These are the only known locations of *M. exilis* remains. The majority of the survey effort was conducted on Santa Rosa Island due to National Park Service (NPS) logistical support. The survey is on-going but has produced more than 140 new mammoth localities on the three islands (a locality is designated as one, or more, *M. exilis* bones considered to be new occurrences). Each locality is precisely located by a hand held global positioning system (GPS) instrument.

Using the osteological collections of Phil Orr, Boris Woolley, and the National Park Service, all housed at SBMNH, I undertook metric analyses of the dentition and limb bones. These data were compared to similar information derived from a large, local population of *M. columbi*, in primary deposition, from Hot Springs, South Dakota (Agenbroad and Mead 1994). The Hot Springs population is dominated by adolescent and immature male mammoths (Lister and Agenbroad 1994). These animals were preserved in a hydrogeologic natural trap which was selective for young male mammoths (Agenbroad and Mead 1994).

RESULTS

Dentition

Metric analyses of the dental remains of *M. exilis* have yielded a preliminary tooth-in-sequence plot for mandibular teeth as compared to *M. columbi* (Figure 2). Additionally, comparison of the line of best fit for the 5th and 6th molars (M_2 and M_3 in alternative designations) signifies a very close match (Figure 3), indicative of *M. columbi* as the most appropriate ancestral mammoth from which *M. exilis* evolved.

Using the *M. exilis* collections housed at LACM and SBMNH an age-structure analysis of the island mammoths was constructed (Figure 4). Three conclusions can be drawn from these data: 1) the island death assemblage approximates an attritional death assemblage as contrasted to a

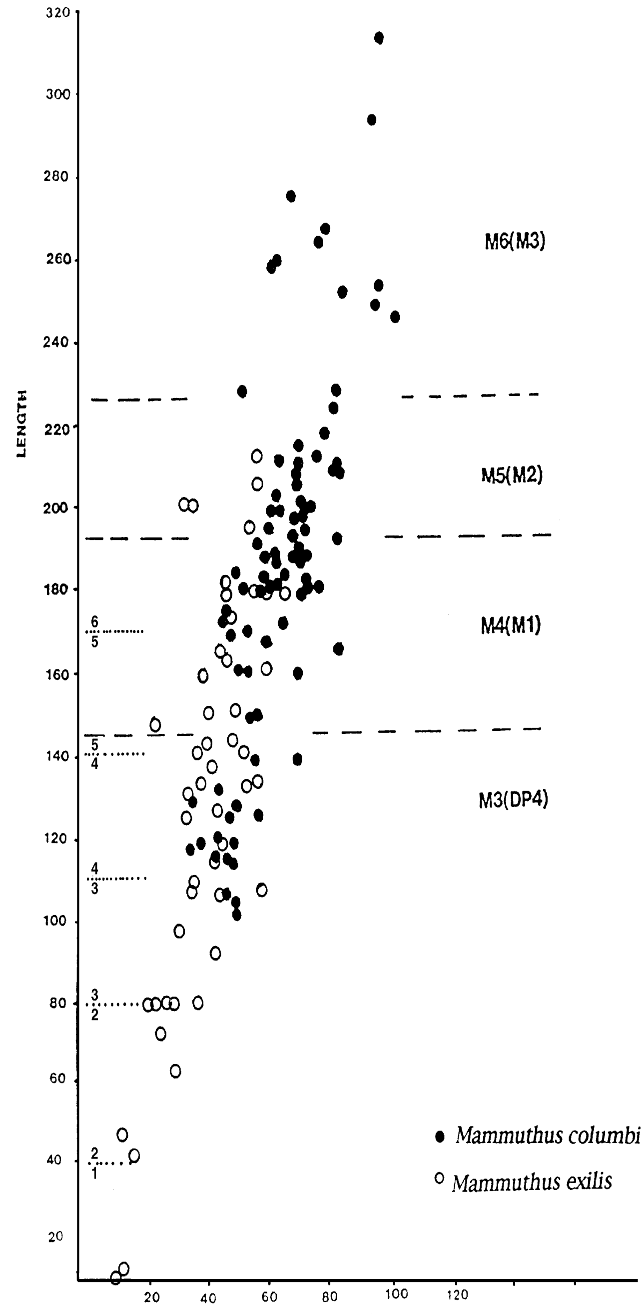

Figure 2. A length-width plot for *M. columbi* (solid) and *M. exilis* (open) mandibular dentition. It allows a tooth-in-sequence designation for *M. exilis* teeth.

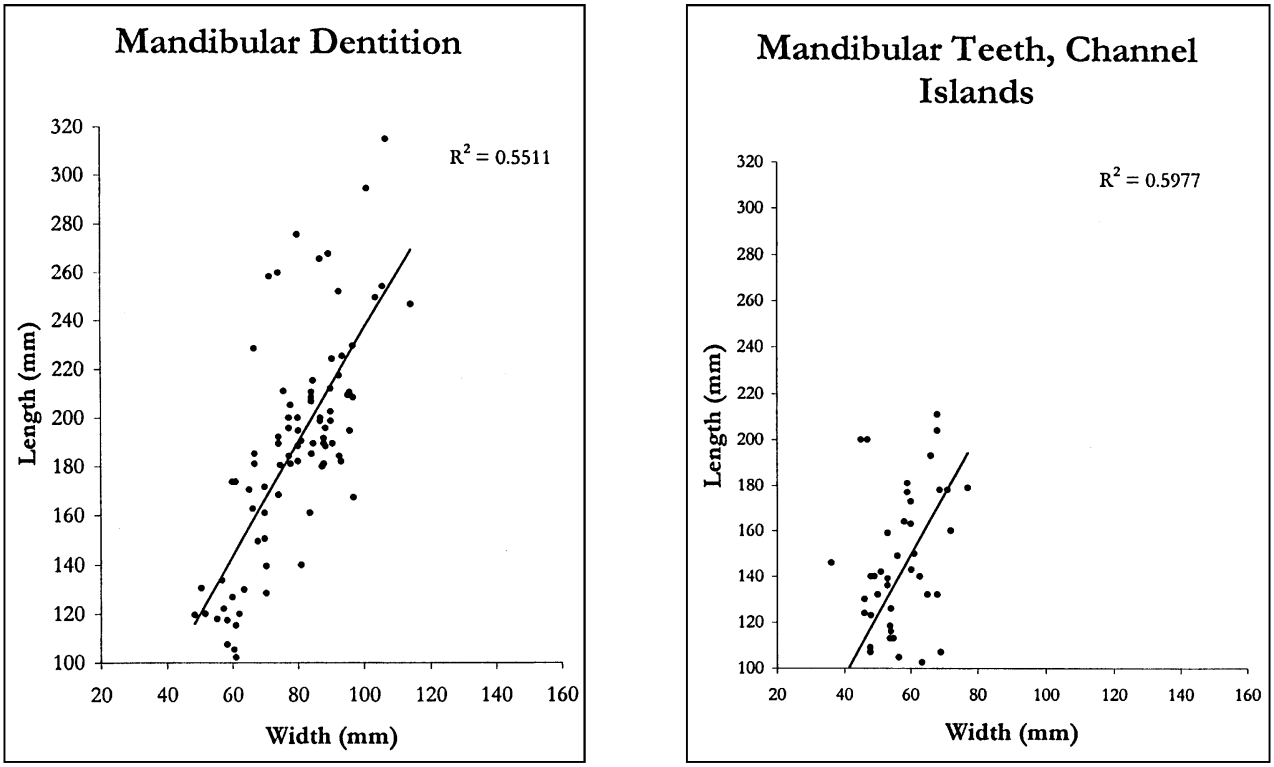

Figure 3. Length width plots of M5 and M6 mandibular teeth of *M. columbi* (a) and *M. exilis* (b) with lines of best fit for the data (computer graphs by D. Hallman).

"behavioral" death assemblage at the Hot Springs Mammoth Site (Agenbroad 1994); 2) there are relatively few animals surviving much past 50 years of age; 3) there is an inference that island mammoth mortality rates are highest in the 0- to 30-year age range.

In addition to the age distribution plot, a plot of the Index of Hypsodonty (100 ht/w) against the lamellar frequency (lamella/100 mm), as produced by Cooke (1960) and Whitmore et al. (1967) was produced. The *M. exilis* plot places nearly twice as much overlap with the *M. primigenius* envelope as the *M. columbi* envelope with several on the borderline of the two envelopes. This should be expected of a species that is reducing in overall body size. There should be more overlap with the smaller *M. primigenius* than with the large, ancestral *M. columbi*. A diagram of the Index of Hypsodonty versus the length/lamellar ratio (R = number of lamella/tooth length) produces a slightly different plot (Figure 5). Again, the *M. exilis* plot indicates strong overlap with the *M. primigenius* envelope. The shrinkage of the maxilla and mandible accompanying the dwarfing process accounts for this.

Using the method of Laws (1966), estimates of age at death were determined, based on metric attributes of the teeth. Few individuals exceed 50 African Elephant Years (AEY) in age in the island population. Possible exceptions were two mandibular specimens from which the teeth were missing due to advanced age, yet the animal continued mastication with the jaw bone.

Long Bone Analyses

Table 1 provides the metric attributes of length (width for pelvis) of the limb bones of *M. columbi* and *M. exilis*. Figure 6 graphs the percentage of the mean for each species for each bone. Both the table and the figure illustrate longer scapulae, humeri, and femora, and wider pelves, but correspondingly shorter ulnae, radii, tibiae, and fibulae. The *M. exilis* femur is markedly longer than expected, just as the tibia and fibula are markedly shorter. Only mature *M. exilis* specimens were included in the comparison, as evidenced by epiphyseal fusion. Paul Sondaar (1977) states that shortening of lower limbs allows an advantage in negotiation of steep terrain which may allow access to resources denied to "mainland" skeletal proportions.

Using the method of Harington et al. (1974) a second graph (Figure 7) provides the calculated shoulder height of living and extinct proboscideans. The range of *M. exilis* groups below the two meter height and represents mature (epiphyseal fusion of proximal and distal humerus) specimens representing both male and female individuals. It tends to negate an often repeated statement that there are two sizes of dwarfed mammoths on the islands (Hay 1927; Stock 1935; Orr 1956a, 1968). The more probable explanation is sexual dimorphism, with males averaging 15 to 30% larger than females (Haynes 1991).

Center of Gravity and Slope Negotiation

The comparison of long bones in the previous section, combined with the island topography, suggest a

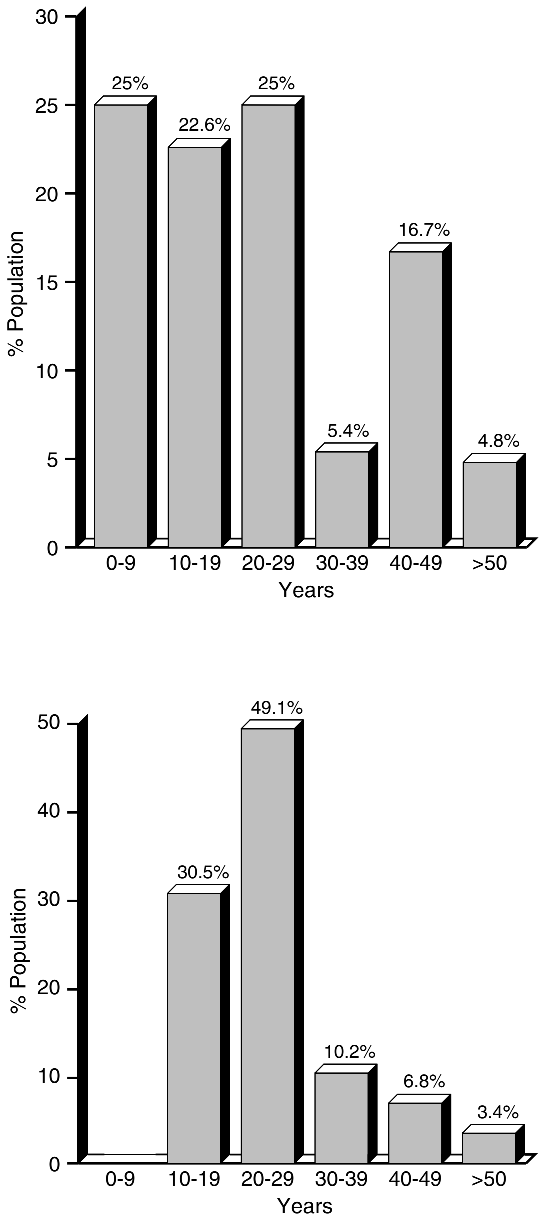

Figure 4. The age-structure analysis of *M. exilis* (top) from the Channel Islands compared to the *M. columbi* (bottom) population of Hot Springs, South Dakota.

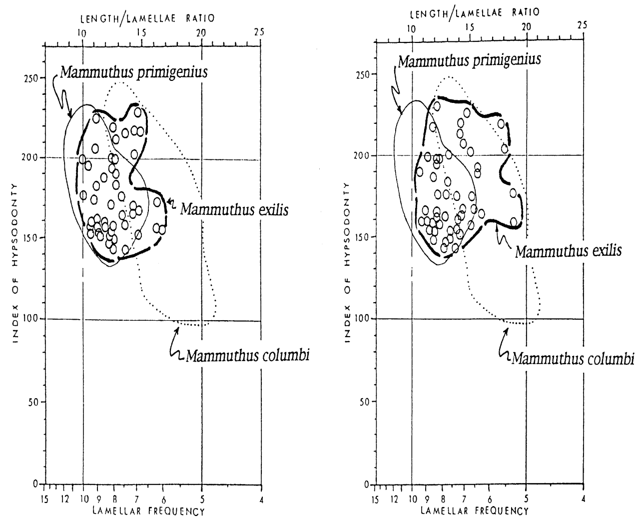

Figure 5. Plots of (a) the Index of Hypsodonty (100 height/ width) versus lamellar frequency (lamella/100 mm) and (b) Index of Hypsodonty versus the length/lamellar ratio R (number of lamella/tooth length). (Lamella=enamel tooth plate) (After Cooke 1960; Whitmore et al. 1967).

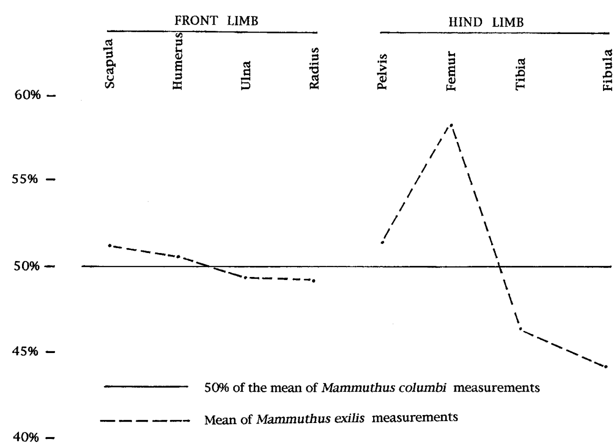

Figure 6. A graph of the mean measurements of limb bones of *M. exilis* plotted versus the 50% mean of the *M. columbi* values.

possible explanation for full size continental mammoths (*M. columbi*) being selected against in favor of their smaller island dwelling progeny. Nearly half of Santa Rosa Island is dominated by steep slopes and deep canyons (Figure 8) (Dibblee et al. 1998). Smaller animals with a lower center of gravity, and more agility would have a selective advantage if they could gain resources from the rugged island areas which denied access to larger forms. This advantage would be further enhanced when periods of natural environmental stress, such as drought, or even wild fires, occured with reduction of island land area and overcrowding as the late Pleistocene sea level rose.

DISCUSSION

Comparisons of selected *M. exilis* remains were made with *M. columbi* remains from the Hot Springs Mammoth Site, South Dakota (Table 1; Figure 6). Both populations are samples of local populations and the mainland animal is the most probable ancestor of *M. exilis* based on dental and osteological comparisons. Limb bones indicate slightly larger scapulae humeri, pelvi and femora. The femora are relatively much longer than the other limb bones as compared to 50% of the mean of the *M. columbi* measurements. Similarly the lower limb bones are shorter than expected, especially the tibia and fibula. The mid-length cross section of the femora show a rounded elliptical, or round shape as contrasted to the flat ellipse *of M. columbi,* reflecting smaller mass and less robust muscle attachments. That, combined with

Table 1. Metric attributes of limb bones of *M. columbi* and *M. exilis*. (OR=observed range; m=mean; n=number of samples).

	Scapula	Humerus	Ulna	Radius	Pelvis	Femur	Tibia	Fibula
M. columbi								
OR	798-1047	1000-1288	948-1104	824-997	1460-1650	1147-1317	831	797
n	17	10	5	2	3	5	1	1
m	908.9	1165.9	1012.2	910	1566.7	126.2	831	797
M. exilis								
OR	354-577	466-656	411-600	367-517	790-942	649-842	314-505	315-388
n	6	11	5	3	3	11	15	2
m	463.67	593	500.4	448.7	805	733.45	385.4	351.5
%m Me/Mc	51.01	50.86	49.44	49.31	51.38	58.15	46.38	44.1

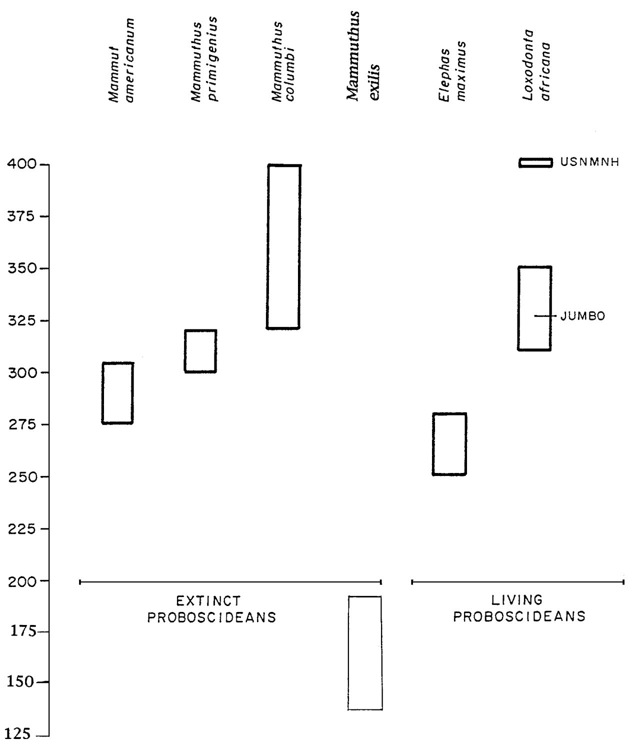

Figure 7. A graphic representation of the shoulder height of living and extinct proboscideans (after Haynes 1990; Agenbroad 1994).

humeri modification suggest a smaller, more gracile mammoth approximating the size of a large steer. This more gracile animal, with a lower center of gravity was able to negotiate slopes and steep canyons that were inaccessible to the large mainland mammoths. In times of evironmental stress, smaller size animals were at an advantage due to increased mobility, less food intake, and the ability to exploit environments denied to large animals.

We are currently at a loss to quantify the rate at which dwarfing took place. In fact, the chronology of the Channel Island mammoths is the weakest aspect of the research. Prior

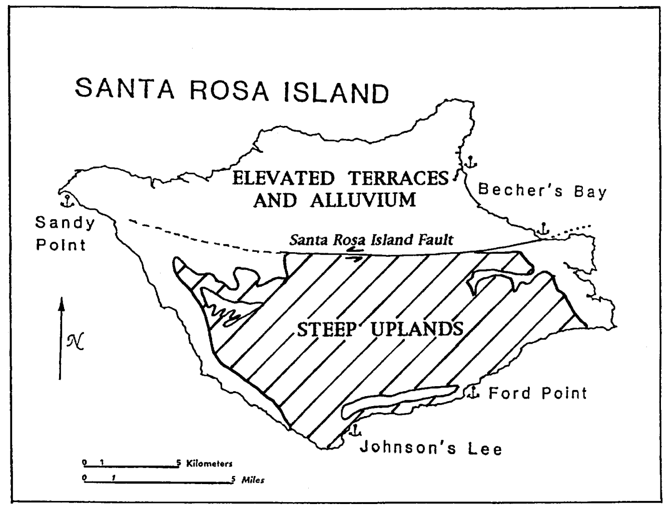

Figure 8. A sketch map of Santa Rosa illustrating the approximate area of steep uplands versus the gentle topography of elevated terraces.

to 1998, there were only eleven published absolute dates pertaining to mammoths. These had been branded as "equivocal" (Wenner et al. 1991). Similarly, it has been stated that all mammoth remains are secondary (i.e., redeposited) (Orr 1959, 1968; Cushing et al. 1986; Wenner et al. 1991; Roth 1982, 1996), therefore do not reflect age of the animal. The discovery and dating of the 1994 specimen negated many of these arguments. The specimen was in situ (primary deposition) and the accelerator-mass spectrometer (AMS) radiocarbon date was from bone collagen derived from the interior of the right femur, yielding a date of 12840 ± 410 (CAMS - 24429). Four additional mammoth-related, post-1994 radiocarbon dates have been produced on associated charcoal and one AMS date of a land snail shell within the skull of a San Miguel Island specimen (Table 2). Erlandson et al. (1996), have demonstrated an excellent charcoal versus mollusc shell radiocarbon chronologic correlation from Daisy Cave, San Miguel Island. That record of correlation

Table 2. Radiocarbon dates: Channel Islands National Park: 1996.

Lab Number	C-14 Date	Technique	Material Dated
CAMS 24429	12,840 – 410	AMS	bone collagen
B 96610	13,770 – 60	AMS	charcoal
B 92053	18,130 – 70	AMS	charcoal
B 85077	18,880 – 190	std.	charcoal
B 94256	+ 47,100	AMS	charcoal
B 94609	41,360 – 660	AMS	land snail

NOTE: AMS = accelerator-mass spectrometer method; std = standard (gas) method; due to small sample sizes of material in association with *M. exilis* remains, AMS method was required; CAMS 24429 required chemical extraction and pretreatment of bone collagen.

lends credibility to the shell date for the San Miguel *M. exilis* skull. Currently the radiocarbon chronology (post-1994) for mammoth remains and mammoth-associated material extends from 12,840 to greater than 41,000 yr B. P. (Agenbroad 1998). An increased chronologic data base is essential for a better understanding of the California island mammoths.

An ongoing pedestrian, GPS controlled survey of the islands has produced more than 140 localities for mammoth remains and has weakened another myth about Santa Rosa Island, that "skeletal remains are concentrated in a very limited area of the northwest coast" (Stock 1935; Orr 1959, 1968; Johnson 1972; Roth 1982, 1996). On the contrary, there have been mammoth localities in all but one of the regions of Santa Rosa that have been surveyed. The anomalous region is the marine terrace from the Vail and Vickers ranch headquarters, south to Skunk Point. It is of interest to note that this is also the area relatively devoid of archaeological sites, and similarly, devoid of land snails.

Serge Vartanyan (pers. comm. 1997) informed me that the femur of *M. exilis* is 3 cm shorter and the tibia is 4 cm shorter than his smallest specimen from Wrangel Island. He returned to Wrangel Island in August 1998, but I do not yet have results of his search for a larger population of limb bones. Jeffry Saunders of the Illinois State Museum just returned from Wrangel Island (pers. comm. 1998) and stated limb bones were scarce.

LITERATURE CITED

Agenbroad, L. D. 1994. Taxonomy of North American *Mammuthus* and biometrics of the Hot Springs mammoths. Pages 158-207 *in* Agenbroad, L. D. and J. I. Mead (eds.), The Hot Springs Mammoth Site: a decade of field and laboratory research in paleontology, geology, and paleoecology. The Mammoth Site of Hot Springs, South Dakota, Inc. Hot Springs.

Agenbroad, L. D. 1998. New pygmy mammoth (*Mammuthus exilis*) localities and radiocarbon dates from San Miguel, Santa Rosa, and Santa Cruz Islands, California. Pages 169-175 *in* Weigand, P. (ed.), Contributions to the Geology of the Northern Channel Islands, Southern California. Pacific Section of the American Association of Petroleum Geologists, Bakersfield, CA.

Agenbroad, L. D., D. Morris, and V. L. Roth. 1999. Pygmy mammoths (*M. exilis*) from Santa Rosa Island, Channel Islands National Park, California, USA. Pages 89-102 *in* Haynes, G., J. Klimowicz, and W. F. Reumer (eds.), Mammoths and the mammoth fauna: Studies of an extinct ecosystem. Proceedings of the first international mammoth conference, St. Petersburg, Russia, Deinsea, Natural History Museum of Rotterdam.

Agenbroad, L. D., and J. I. Mead (eds.). 1994. The Hot Springs Mammoth Site: A decade of field and laboratory research in paleontology, geology, and paleoecology, Mammoth Site of Hot Springs, South Dakota, Hot Springs, SD, 457 p.

Cooke, H. B. S. 1960. Further revision of the fossil Eliphantidae of Southern Africa. Palaeontologia Africana 89:46-58.

Cushing, J. E., A. M. Wenner, E. Noble, and M. Daily. 1986. A groundwater hypothesis for the origin of "fire areas" on the Northern Channel Islands, California. Quaternary Research 26:207-217.

Dibblee, T. W., Jr., J. R. Woolley, and H. E. Ehrenspeck. 1998. Geologic map of Santa Rosa Island: Santa Barbara California. Dibblee Geological Foundation Map DF-68.

Erlandson, J., D. Kennett, B. Ingram, D. Guthrie, D. Morris, M. Tveskov, G. West, and P. Walker. 1996. An archaeological and paleontological chronology for Daisy Cave (CA-SMI-261) San Miguel Island, California. Radiocarbon 38:1-19.

Harington, C. R., H. W. Tipper, and R. J. Mott. 1974. Mammoth from Babine Lake, British Columbia. Canadian Journal of Earth Science 11:285-303.

Hay, O. P. 1927. The vertebrated fauna of the western United States. Carnegie Institution Publication 322B:42-43, 51.

Haynes, G. 1991. Mammoths, Mastodonts and Elephants: Biology, behavior and the fossil record. Cambridge University Press. Cambridge.

Johnson, D. L. 1972. Landscape evolution on San Miguel Island, California. Ph.D. dissertation. University of Kansas, Lawrence, KS. 376 p.

Laws, R. M. 1966. Age criteria for the African elephant, *Loxodonta africana*. East African Wildlife Journal 4:1-37.

Lister, A. M. 1996. Sexual dimorphism in the mammoth pelvis: an aid to gender determination. Pages 254-259 *in* Shoshani, J. and P. Tassy (eds.), The Proboscidea. Oxford University Press, Oxford.

Lister, A. M. and L. D. Agenbroad. 1994. Gender determination of the Hot Springs mammoths. Pages 208-214 *in* Agenbroad, L. D. and J. Mead (eds.), The Hot Springs Mammoth Site: A decade of field and laboratory research in paleontology, geology, and paleoecology. The Mammoth Site, Inc., Hot Springs, SD.

Orr, P. C. 1956a. Radiocarbon, mammoths, and man on Santa Rosa Island. Geological Society of America Bulletin 67:1777.

Orr, P. C. 1956b. Radiocarbon dates from Santa Rosa Island I. Bulletin of the Santa Barbara Museum of Natural History 2:1-10.

Orr, P. C. 1956c. Dwarf mammoth and man on Santa Rosa Island. University of Utah Anthropological Papers 26:75-81.

Orr, P. C. 1959. Santa Rosa Island dwarf mammoths. Museum Talk. Santa Barbara Museum of Natural History. p. 25-29.

Orr, P. C. 1960. Radiocarbon dates from Santa Rosa Island II. Bulletin of the Santa Barbara Museum of Natural History 3:1-10.

Orr, P. C. 1967. Geochronology of Santa Rosa Island, California. Pages 317-325 *in* Philbrick, R. N. (ed.), Proceedings of the Symposium on the Biology of the California Islands. Santa Barbara Botanic Garden, Santa Barbara, CA.

Orr, P. C. 1968. Prehistory of Santa Rosa Island. Santa Barbara Museum of Natural History.

Roth, V. L. 1982. Dwarf mammoths from the Santa Barbara, California Channel islands: Size, shape, development and evolution. Ph.D. Dissertation. Yale University, New Haven, CT.

Roth, V. L. 1996. Pleistocene dwarf elephants from the California Islands. Pages 249-253 *in* Shoshani, J. H. and P. Tassy (eds.), The Proboscidea. University of Oxford Press, Oxford, United Kingdom.

Sondaar, P. Y. 1977. Insularity and its effect on mammal evolution. Pages 671-707 *in* Hecht, M. K., P. C. Goody, and B. M. Hecht (eds.), Major patterns in vertebrate evolution. NATO Advanced Study Institute Series 14.

Stearns, R. E. C. 1873. [no title: paraphrase of comments attributed to Stearns in minutes of Academy's regular meeting] Proceedings of the California Academy of Sciences 5:152.

Stock, C. 1935. Exiled elephants of the Channel Islands, California. Scientific Monthly XLI:205-214.

Stock, C. 1943. Foxes and elephants of the Channel Islands. Los Angeles County Museum of Natural History Quarterly 3:6-9.

Stock, C. and E. L. Furlong. 1928. The Pleistocene elephants of Santa Rosa Island, California. Science LXVIII:140-141.

Thikonov, A. 1997. (brief report) Zoological Institute Russian Academy of Sciences, St. Petersburg, Russia. Department of History of fauna. EuroMam Newsletter 4:14-15.

Wenner, A. M., J. Cushing, E. Noble, and M. Daly. 1991. Mammoth radiocarbon dates from the northern Channel Islands, California. Proceedings of the Society for California Archaeology 4:1-6.

Whitmore, F. C., Jr., K. O. Emery, H. B. S. Cooke, and D. J. P. Swift. 1967. Elephant teeth from the Atlantic Continental shelf. Science 156:1477-1481.

SOURCES OF UNPUBLISHED MATERIALS

Saunders, Jeffrey. Illinois State Museum, Springfield, IL 62703. Personal Communication December 1998.

Vartanyan, Serge. Zoological Institute of the Russian Academy of Science, St. Petersburg, Russia. October 1997.