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Pygmy mammoths *Mammuthus exilis* from Channel Islands National Park, California (USA)

Agenbroad, L.D., Morris, D. & Roth, L., 1999 – Pygmy mammoths *Mammuthus exilis* from Channel Islands National Park, California (USA) - in: Haynes, G., Klimowicz, J. & Reumer, J.W.F. (eds.) – MAMMOTHS AND THE MAMMOTH FAUNA: STUDIES OF AN EXTINCT ECOSYSTEM – DEINSEA 6: 89-102 [ISSN 0923-9308]. Published 17 May 1999.

A unique skeleton of pygmy mammoth (*Mammuthus exilis*) discovered in a sand dune is described and its significance interpreted. The specimen was exposed on a +30 degree slope, approximately 10 m above a vertical cliff, which dropped ca. 20 m to the surf zone. A recent drainage channel had cut through the dune, and erosion had removed several elements. The specimen is the first virtually complete pygmy (dwarf) mammoth individual to be recovered, and is exceptionally intact, including hyoid bones and sternum in life position. The individual represents an adult male that had reached sexual maturity, and the skeleton showed signs of arthritis. Stature from field measurements was calculated to be less than 2 m at shoulder height, approximately $^1/_2$ the height of the mainland mammoth (*Mammuthus columbi*), its probable ancestor.

Dwergmammoeten Mammuthus exilis *van Channel Islands National Park, California (USA)* – In dit artikel wordt een uniek skelet van een dwergmammoet (*Mammuthus exilis*) beschreven dat werd gevonden in een zandduin op Santa Rosa Island, California. De betekenis van de vondst wordt geinterpreteerd. Het exemplaar werd gevonden op een helling van meer dan 30 graden, ongeveer 10 m boven een ca. 20 m hoge verticale afgrond die eindigt bij de zee. Een recent ontstane geul had het duin ingesneden en een aantal botten was als gevolg van erosie verdwenen. Hier is sprake van de eerste vrijwel complete dwergmammoet ooit gevonden. Zelfs de tong- en borstbeenderen zijn in de oorspronkelijke positie. Het dier was een volwassen mannetje dat leed aan arthritis. De schouderhoogte is berekend aan de hand van veldmetingen, en bedroeg minder dan 2 meter. Dit is ongeveer de helft van de schouderhoogte van de mammoet van het Amerikaanse vasteland (*Mammuthus columbi*), de waarschijnlijke voorouder.

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Keywords: *Mammuthus exilis*, Channel Islands (California), insular proboscideans

INTRODUCTION

In 1986 the Channel Islands, lying off-shore of Ventura and Santa Barbara, California (Fig. 1), were acquired by the National Park Service to become one of the newest national parks in the USA. Each island is different and has its own particular natural resources. These resources include the marine environment, the island terrestrial environment, and even the air above both environments. Beneath the waves are historic resources in the form of shipwrecks. On the islands are both prehistoric and historic human settlements - from Chumash, Spanish, Chinese, and Anglo (English-speaking) operations, including

World War II military bases and radar stations. One resource is unique to the Channel Islands. That is the presence of pygmy (dwarf) mammoth remains. Remains of pygmy mammoths from the Channel Islands were first reported in the scientific literature in 1873 (Stearns 1873). Oliver Hay (1927) also referred to the presence of *Elephas imperator*, and that of an undetermined species from the islands. It was not until 1928 (Stock & Furlong 1928) that any paleontological attention was paid to the fossils. Stock & Furlong proposed the name *Elephas exilis*, the exiled mammoth, for the Santa Rosa Island elephants. The small size suggested insular isolation as a dwarfing mechanism, similar to the pygmy proboscideans of Malta, Sicily, and other islands in the Mediterranean Sea (Caloi *et al*. 1989, Lister & Bahn 1994).

Stock (1935) referred to the Santa Rosa Island mammoths as *Elephas* (*Archidiskodon*) *exilis,* inferring a closer relationship to the Imperial mammoth (referred to as *Archidiskodon imperator* in 1935) than to the Columbian Mammoth (referred to as *Paraelephas columbi* in 1935), the two common mainland mammoths. He also postulated the presence of a land bridge connection, allowing mainland mammoths access to the region that is currently the Channel Islands. Almost as an aside, he notes that at that date (1935) no small mammoth remains had been found in mainland California deposits, although large mammoths (*M. columbi* and *M. imperator*) had a wide distribution. During the interval 1940 to 1965 Phil Orr, of the Santa Barbara Museum of Natural History, conducted archaeological investigations of portions of the islands, particularly Santa Rosa. He was convinced the small mammoths and ancient Chumash people were contemporaries on the island, until the mammoths were hunted to extinction (Orr 1968). Wenner & Johnson (1980) gave considerable study to the land bridge hypothesis proposed by Stock and others. They concluded that no such dry-land connection existed in the late Pleistocene epoch, therefore, the parent stock of mainland mammoths, as ancestors to the Channel Island mammoths, had reached the island by swimming. That feat is made even more plausible by two factors: (1) recorded accounts of modern elephant swimming abilities; and (2)

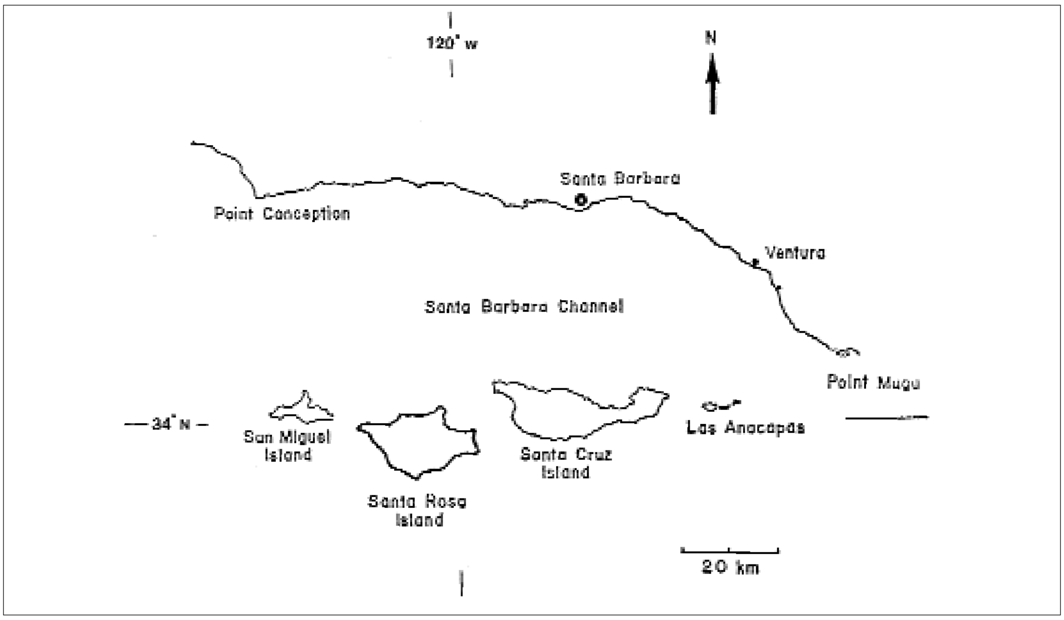


Figure 1 Location map of the Califo mia Channel Islands

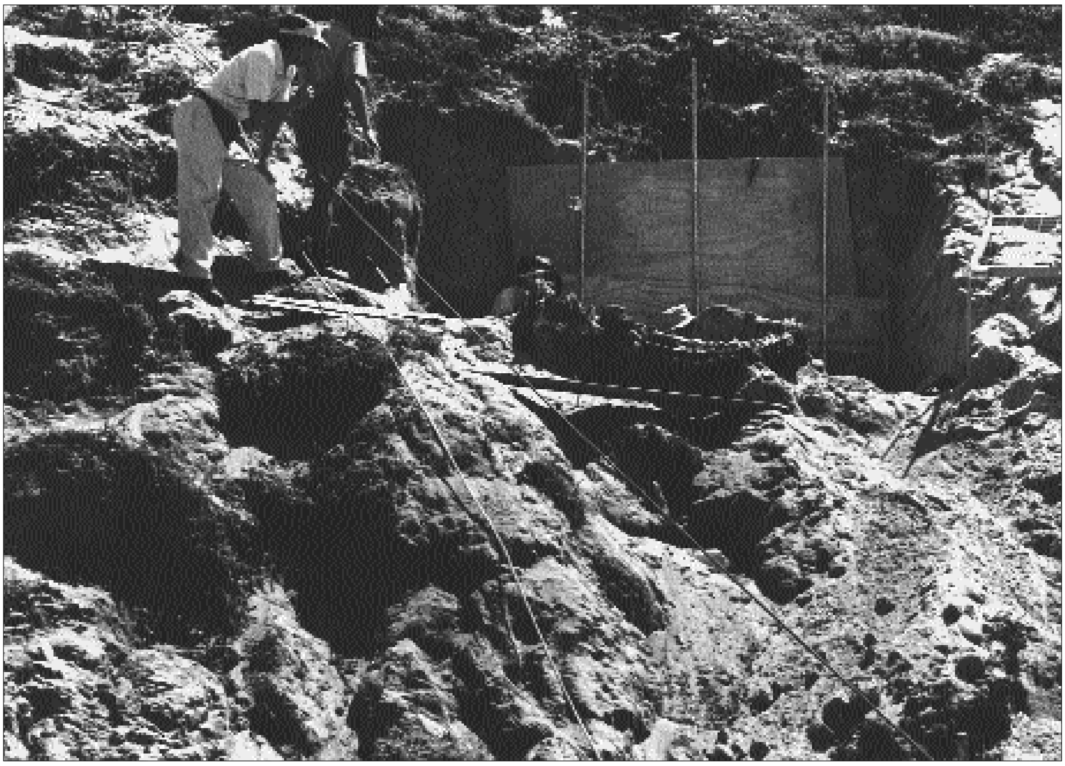


Figure 2 The excavation pit with the axial skeleton in the position in which it was discovered.

the fact that during the last ice age, water was held in storage on the continents as glaciers, ice sheets, and snow and ice. There was a consequent lowering of eustatic sea level by approximately 100 m, that would have exposed a very large island - which Orr called 'Santarosae' – and which was separated by as little as 6.5-8 km from the Pleistocene coast of California. Computer maps based on bathymetry, produced by Dr. Tom Rockwell, a structural geologist at San Diego State University, suggest that as much as 76% of ancient Santarosae is now submerged by the melting of the continental ice sheets and glaciers, which caused a subsequent rise in sea level. The modern Channel Islands of Anacapa, Santa Cruz, Santa Rosa, and San Miguel are the remnant high portions (uplands) of ancient Santarosae. Fossil mammoth remains are known from the three outermost islands. Roth (1982) conducted a zoological investigation of museum specimens of the island mammoths, but research has been limited on the channel island proboscideans.

DISCOVERY AND EXCAVATION OF THE 1994 *M. EXILIS* SKELETON

On June 29,1994, Tom Rockwell, and one of his graduate students, Kevin Colson, observed strange, white objects protruding through vegetation on a steep sand slope of an elevated marine terrace (Figs. 2, 3). The objects turned out to be bones of the axial skeleton of a pygmy mammoth (*Mammuthus exilis*). The National Park Service contacted Dr. Mead and Dr. Agenbroad, on a field excavation at the Mammoth Site of Hot Springs, South Dakota. At the request of the National Park Service, they flew to Ventura, California, and went to Santa Rosa Island to verify the discovery. Once verified, they urged salvage excavation of the specimen prior to the advent of winter storms. January, 1995 had more than 76 cm of precipitation; February had an addi-

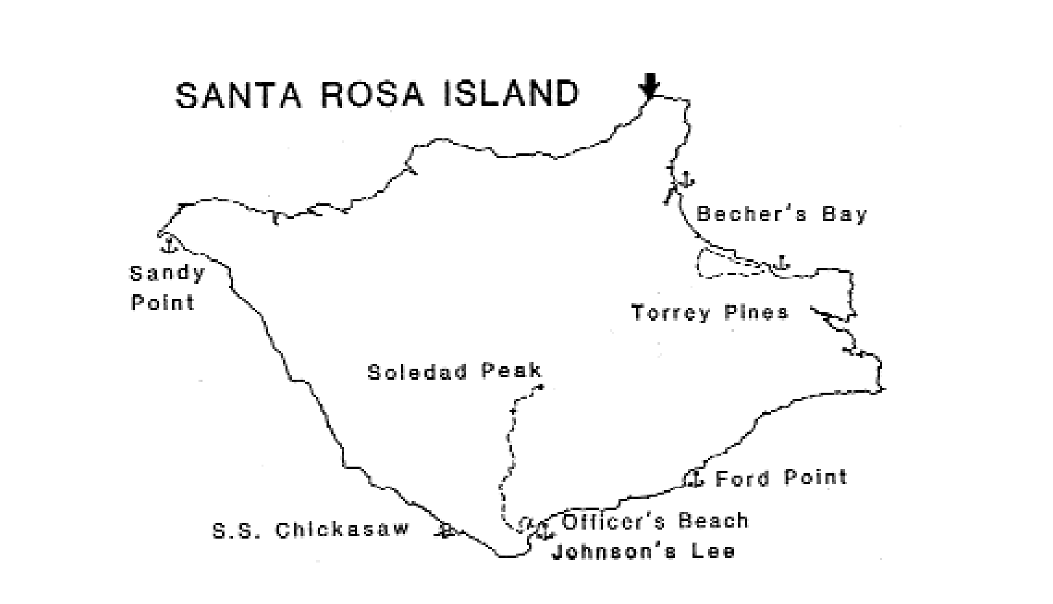


Figure 3 Location map of the excavation site (indicated by the arrow), Santa Rosa Island.

tional +50 cm. In our opinion, the skeleton would have been eroded and lost.

Excavation took place from August 9-19, 1994 by a crew consisting of Agenbroad and his son, Brett, Don Morris, Louise Roth and Tom Rockwell. Dr. Mead was unable to assist in the period of field work. The skeleton was in an extended position, lying on its left side with the cranium to the east, legs extended to the south (Figs. 4, 5). The bone was in exceptionally good shape, except for erosional damage by a post-depositional alluvial channel. The channel had exposed the skeleton, but had also damaged and removed portions of it. Primary damage was done to the right tusk, right maxilla and alveolus, the right scapula, dorsal spines of the vertebral column (especially in the thoracic region), and the right pelvis. The skeleton had apparently served as a check dam in the channel course, as we exposed a plunge pool which had removed the entire left manus. The proximal portion of the right scapula was recovered, ca. 1.7 m below the skeleton's position. It was associated with cobbles and stained sand, indicative of a continuation of the channel and its fill. The right front foot was curled back against the radius and ulna. The rear legs were slightly flexed, with the right foot in articulation and the left partially disarticulated. Osteoarthritic spurs occurred in several of the joints of the feet. Hyoids (stylohyoids) were *in situ* in the cranium. The three components of the sternum were also preserved, in life position (Fig. 6). A slight pelvic rotation, to the right, produced a tilt, but it was still in articulation with the sacrum and both femur heads were still in articulation in the acetabula. An encrustation of calcium carbonate cemented sand was encountered on the upper (medial) surface of the left tusk. When wetted with acetone, it flaked off as a sandy encrustation, but was much thicker and more resistant at most of the articular surfaces of the limb bones. Due to its tenacity and hardness, it was referred to as 'calcrete' during the exposure, disarticulation, and casting of the skeletal material. We attempted to remove the calcrete from joints, using dental tools, but ultimately resorted to a 'tap' with a cold chisel to complete the separation. The recovery was relatively uneventful until we attempted to cut through the central pedestal supporting the ver-

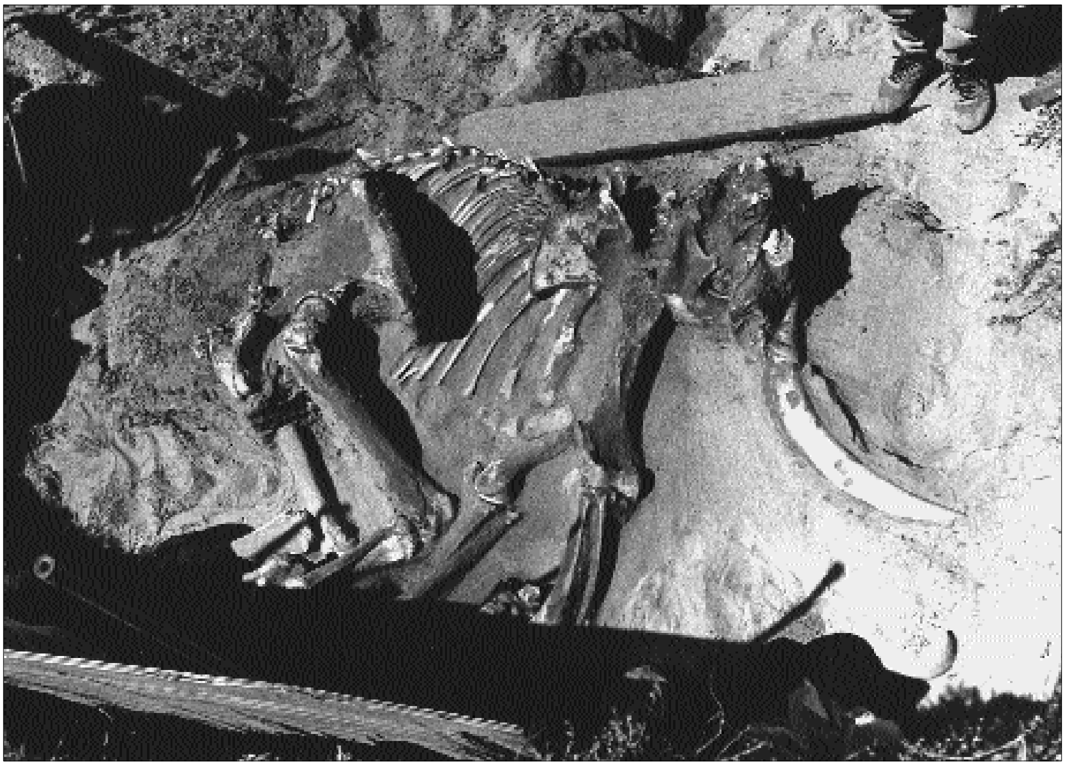


Figure 4 Photograph of the excavated skeleton, *in situ*, August 1994.

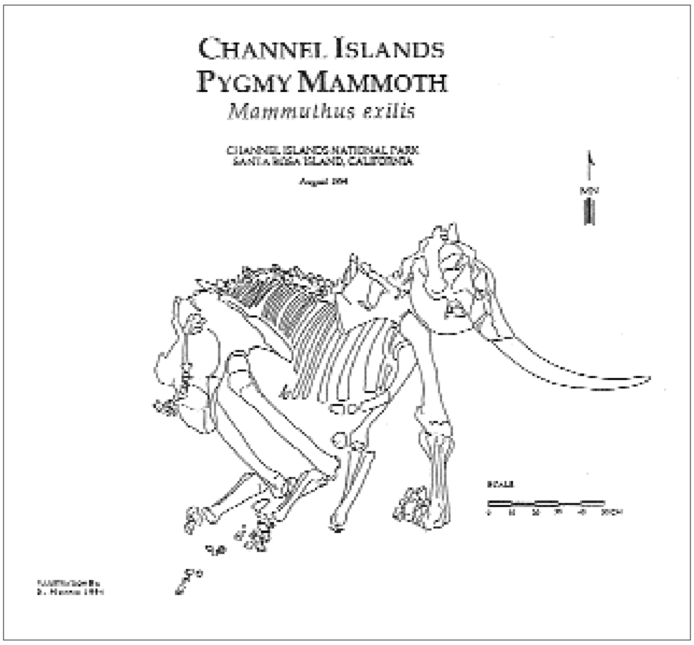


Figure 5 A bone map of the skeleton by S. Morris.

tebral column and rib cage. The pedestal, formed of very hard calcrete, was extremely difficult to work through.

Soil organic matter decomposition and root respiration generate CO_2 gas in the soil column. This gas plus water generates carbonic acid, which can disassociate to hydrogen and bicarbonates. Bicarbonate plus calcium leached from bone apatite produce calcium carbonate, cementing the sand into 'calcrete', approximated by the following chemical equations:

organic material and root respiration-----> CO_2 (gas)

$$CO_2 (g) + H_2O \longleftrightarrow H_2CO_3 + O$$

$$H_2CO_3 \longleftrightarrow HCO_3 + H$$

$$HCO_3 + Ca \longleftrightarrow CaCO_3 + H$$

The skeleton was divided into 10 separate jacketed segments, the largest of which was the articulated vertebral column including the ribs and scapulae. The jacketed casts were air lifted to the Vail Ranch headquarters by a contract helicopter. From that location, they were hoisted to a National Park Service boat and transported to Ventura, California.

TAPHONOMY OF THE SITE

The remains were nearly horizontal, apparently having come to rest on a flat, smooth surface near the foreset beds of a sand dune. From the extended position of the skeleton, lying on its left side, with its back to the sea it is interpreted as a natural death. Finding the sternum and other small bones in articulated positions also indicates a natural death, unaffected by predators or scavenging of the carcass. Bone spurs between the joints in the hind feet may be arthritic, and argue for advanced age. The dental wear confirms this. Using Laws' (1966) criteria, the age of the animal at the time of death was calculated to be 56 +/- 2 AEY (African Elephant-equivalent Years). Pelvic ratios (Lister &Agenbroad 1994) and the large basal diameter of the left tusk indicate it was a mature male.

Figure 6 A photograph of the sternum, *in situ*, August 1994.

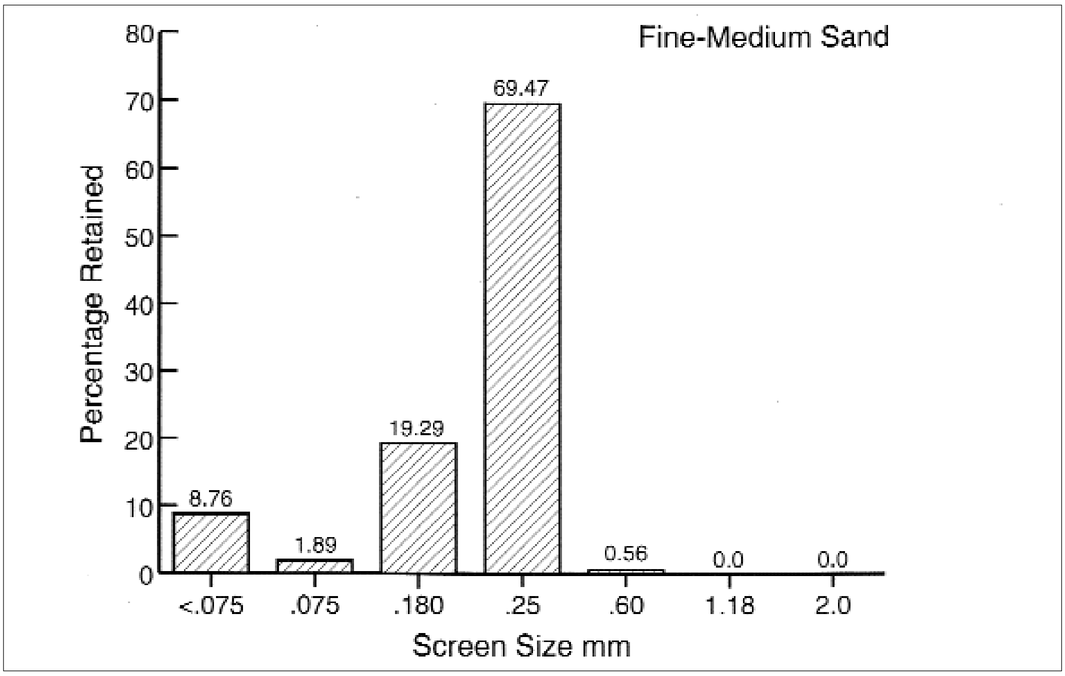


Figure 7 Size-fraction analysis of the dune sand which entombed the skeleton.

As an initial interpretation, an adult male *M. exilis* lay down on a flat, sandy surface of an elevated marine terrace on the north coastline of Santa Rosa Island, and expired. The body was covered rather quickly by fine to medium size dune sand (Fig. 7). Foreset beds advanced west to east (the dominant wind direction) covering the body. The fact that even the smallest bones of the feet are still in articulation attests to a gentle, relatively rapid, postmortem burial. At 700 + 60 yBP (Beta 76532) erosion cut an arroyo (a gully) into the dune deposit, removing the left front foot bones in the turbulent action of a plunge pool. The waters rose over the skeleton (which served as a check dam) and poured over the cranial-vertebral column-pelvic areas, doing damage to these portions of the skeleton. Major damage was the loss of the right tusk and portions of the nuchal crest of the cranium. Most of the dorsal vertebral spines were also broken off. The proximal right scapula was removed, but recovered from the arroyo channel, downslope from the skeleton.

PRELIMINARY COMPARISONS

The results of the field effort included: (1) the recovery of the first nearly complete skeleton of a single individual of *M. exilis*; (2) transportation of the field casts to the Mammoth Site of Hot Springs, South Dakota, for the preparation, preservation, molding and casting of pygmy mammoth skeletal elements in fiberglass; (3) metric analyses of selected skeletal elements of *M. exilis* and comparison of those results with similar analyses of *M. columbi*, the large mainland mammoth. As a preliminary comparison, selected skeletal elements of the August, 1994 skeleton of *M. exilis* from Santa Rosa Island were contrasted to the same elements of *M. columbi* (Table 1) from the Mammoth Site of Hot Springs, South Dakota (Agenbroad 1994). In each case, the specimens are male animals. A plot (Fig. 8) of selected long bones reveals a similar slope when comparing the length of similar bones in both species. An anomaly is noted in the *M. exilis* humerus length, however, it is ca. 50% shorter than would

Table 1 Comparative metric attributes of selected skeletal elements of *M. columbi* and *M. exilis*. Column numbers indicate different measurement locations. For these locations and fusion notations see Agenbroad (1994). HSMS = Hot Springs Mammoth Site; CHIS = Channel Islands, California.

HUMERUS (meas. in cm)

Specimen	Side	1	2	3	4	5	6	7	Fusion
***M. columbi* (HSMS)**									
89-076	R	115.4	88.3	112.1	14.6	29.1	25.1	--	F/F
Napoleon	R	122.2	--	121.7	15.9	30.7	28.4	31.4	F/F
HS-00076	R	129.8	--	125.9	17.3	30.1	28.4	34.0	F/F
HS-00069	R	128.3	--	--	17.5	--	(26.5)	(28.1)	F/T
***M. exilis* (CHIS)**									
		63.2	30.4	63.5	6.9	14.3	13.5	14.8	F/F

ULNA (meas. in cm)

Specimen	Side	1	2	3	4	5	6	7	Fusion
***M. columbi* (HSMS)**									
HS-00143	L	110.4	75.3	13.0	95.7	--	--	18.3	F/N
HS-00138	R	105.3	--	--	91.7	13.8	--	19.4	F/F
HS-00089	R	97.5	--	10.1	88.2	15.0	--	--	F/F
HS-89-070	R	94.8	--	14.2	79.1	13.1	--	--	F/F
HS-0222		98.1	--	13.2	85.7	18.9	--	--	F/F
***M. exilis* (CHIS)**									
		60.1	48.8	6.0	49.9	13.5	21.0	12.0	F/F

RADIUS (meas. in cm)

Specimen	Side	1	2	3	4	Fusion
***M. columbi* (HSMS)**						
89-069	R	88.2	--	5.0	13.0	F/F
HS-00223		90.9	7.3	15.4	15.9	F/F
***M. exilis* (CHIS)**						
		50.4	3.5	7.0	7.5	F/F

FIBULA (meas. in cm)

Specimen	Side	1	2	3	4	5	Fusion
***M. columbi* (HSMS)**							
Murray	R	79.7	--	3.0	--	--	F/F
***M. exilis* (CHIS)**							
		39.3	31.5	2.4	4.8	6.8	F/F

TIBIA (meas. in cm)

Specimen	Side	1	2	3	4	5	Fusion
***M. columbi* (HSMS)**							
Murray	R	83.1	--	25.0	--	--	F/F
***M. exilis* (CHIS)**							
		40.5	5.9	12.0	8.5	--	F/F

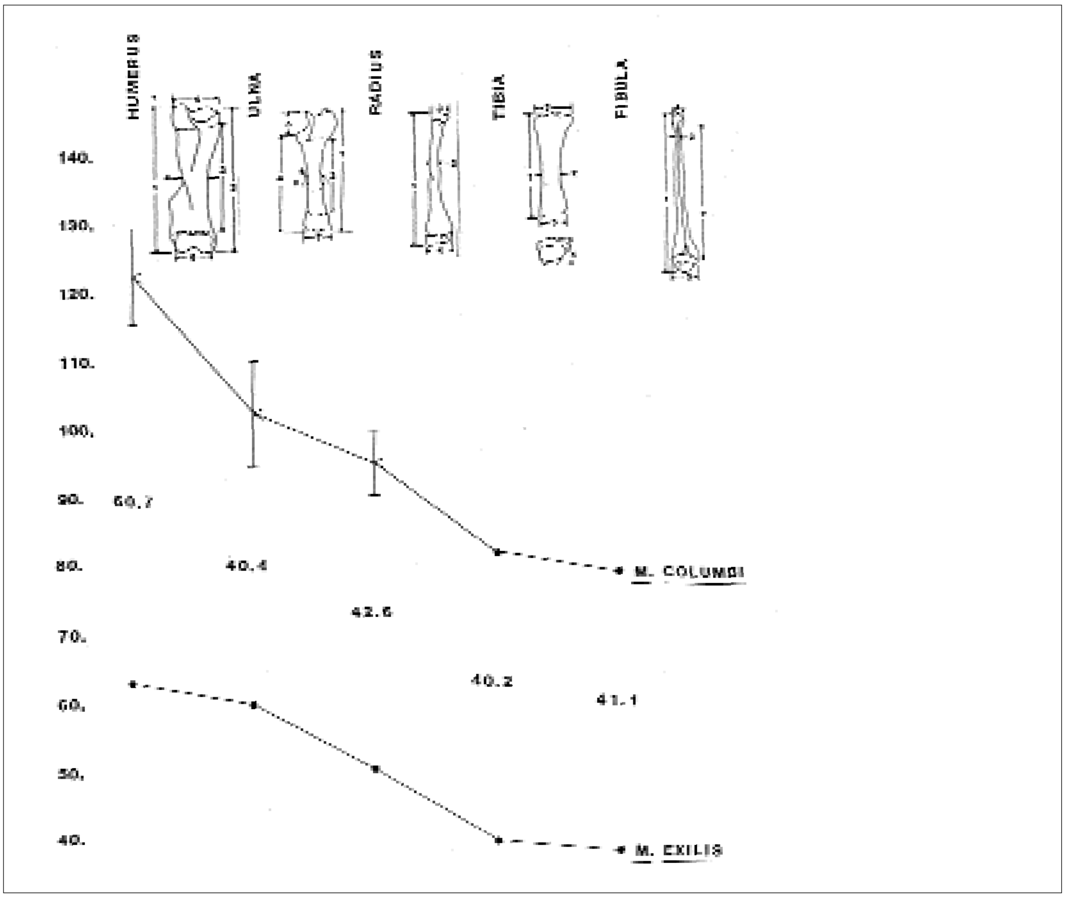


Figure 8 A plot of the length of selected bones of *M. exilis* and *M. columbi.*

have been predicted from the length of the other long bones. Since the animal was a mature male, with completed bone fusion, it suggests that some factor was causing early ephyseal fusion in the humerus of the pygmy mammoths. This would have a large effect on shoulder height, profile of the spinal column, and perhaps even modified gait and locomotion, as contrasted to the mainland mammoths. This tentative hypothesis, based on a single individual, will be pursued with additional studies.

DISCUSSION

Tom Rockwell's reconstruction of the landmass of the Pleistocene super-island Santarosae (Fig. 9), showing the Late Pleistocene sea level (lowered by ca. 100 m) and coast of California, reveals a deep water channel ca. 6-8 km wide. Mainland mammoths apparently swam this channel to gain access to the large island ecosystem.

Why would mammoths swim to an island they possibly could not even see? We suggest that onshore winds would carry the island's odor of ripening vegetation to the mainland, tempting animals in dietary or ecological stress (during drought, or perhaps a mainland brush fire) to swim the channel. Once on the large island, mammoths would have faced fewer predators or competitors, compared to the mainland, and the population grew, although the ancient island landmass would have provided limited food resources for the mammoths. As sea level rose at the end of

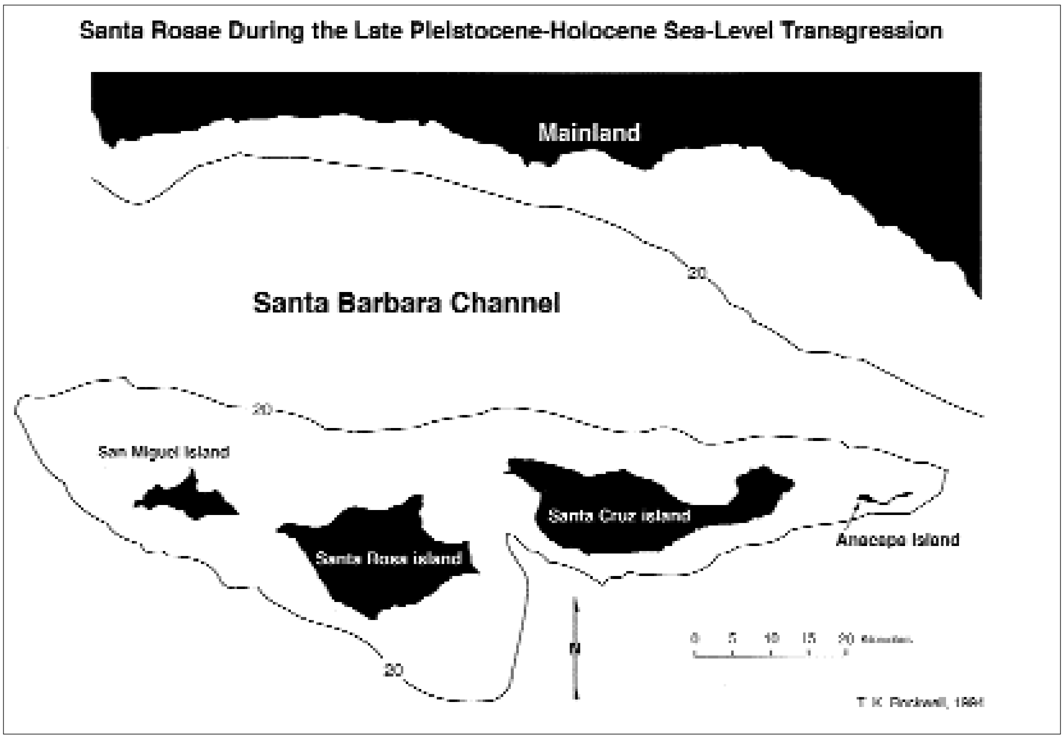


Figure 9 A reconstruction of the Pleistocene super-island (by Tom Rockwell, San Diego State University).

the Pleistocene, the ancient island landmass was slowly inundated, leaving only the highest portions of Santarosae to remain as the four isolated Channel Islands of the present. The already limited food supply on the islands was made more stressful for the mammoth populations by an approximate 76% reduction of available habitat, giving a selective advantage to smaller body-size. A smaller body-size for mammoths would have meant that each individual made less use of the available resources and reached its maximum growth sooner. Measurements of selected bones and teeth indicate the Santa Rosa pygmy mammoth skeleton was that of a mature male, 56 ± 2 AEY (African elephant-equivalent years) old at the time of death. Calculations based on the humerus measurements indicate the animal had a shoulder height of 1.7-1.8 m while living. This contrasts to a shoulder height of 3.9 m for comparable age *M. columbi* from the Hot Springs, South Dakota, site. As the island landmass shrank to ca.1/4 its original size, the mammoths which survived had shrunk to ca. 46% the size of their mainland contemporaries, in as little as 9000 years (Fig. 10).

Dwarf proboscideans are known from at least nine islands in the Mediterranean Sea (Caloi et al. 1989, Lister & Bahn 1994), several islands of Indonesia (Hooijer 1970), two islands of the Philippines (Nauman 1890, von Koenigswald 1956, Sondaar 1976), and one island from the Siberian Arctic Ocean (Vartanyan *et al.* 1993, Lister 1993; see Figure 11 and Table 2). The California Channel Islands have the only dwarf individuals derived from mammoths of temperate North American ancestry.

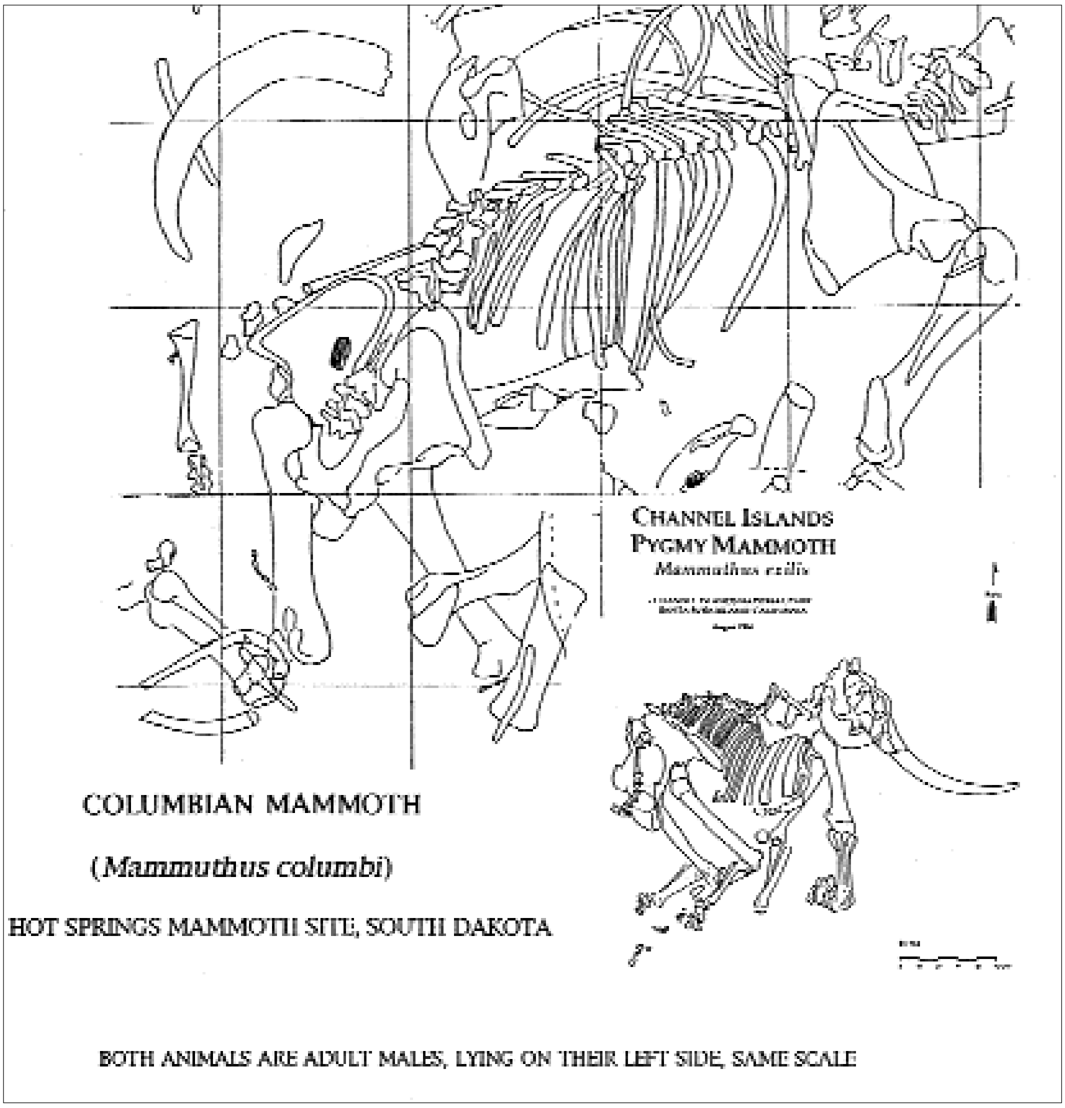


Figure 10 A skeletal comparison of two male mammoths, each lying on its left side. The scale is the same for each animal. The large animal is at the Mammoth Site of Hot Springs, South Dakota; the smaller individual is the August, 1994 skeleton from Santa Rosa Island.

SUMMARY AND CONCLUSIONS

Discovery and excavation of the first nearly complete skeleton of *Mammuthus exilis* was undertaken in the interval between June 29 and August 19, 1994. The remains are of a mature male animal, judged to be 56 ± 2 AEY at the time of death. The animal apparently lay down on a level surface of foreset beds from an active sand dune, where it died and was covered with sand, swiftly and gently. A drainage channel dated at 700 yBP cut through the dune to the skeleton. The skeleton acted as a check dam in that channel, with a plunge pool forming between the front and rear legs, then overflowing across the cranium, vertebral column, and pelvis. Damage

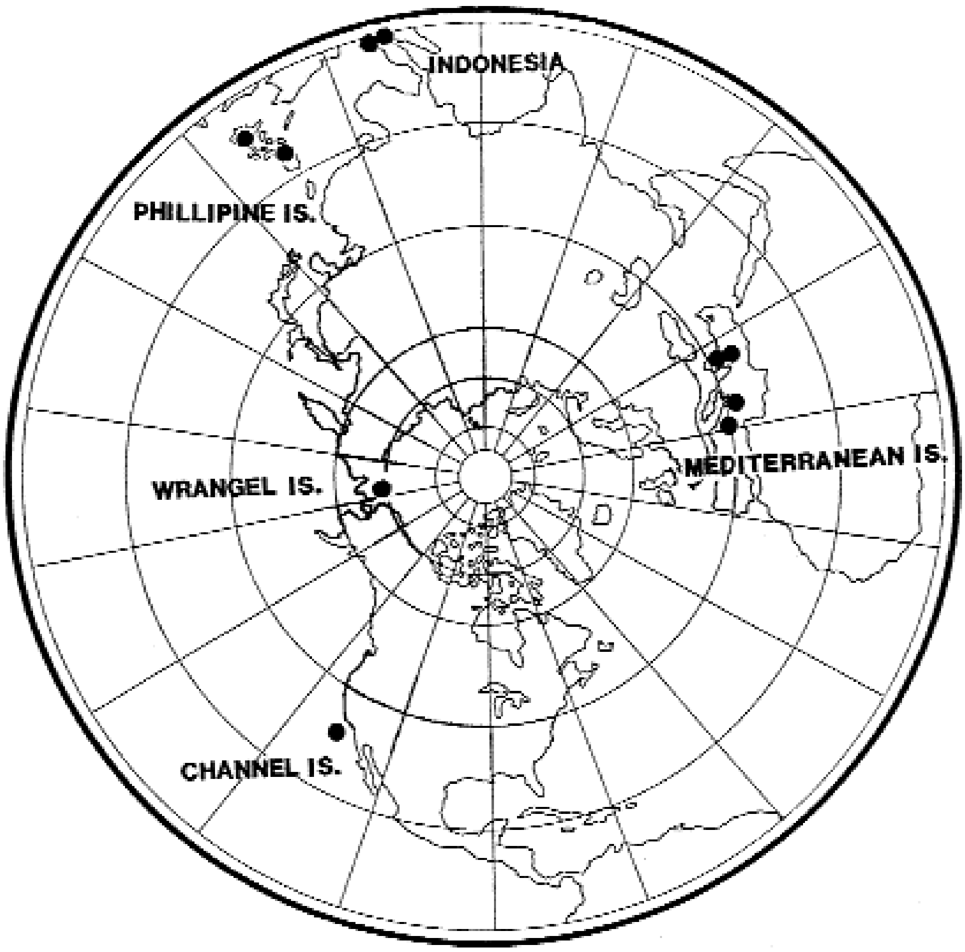
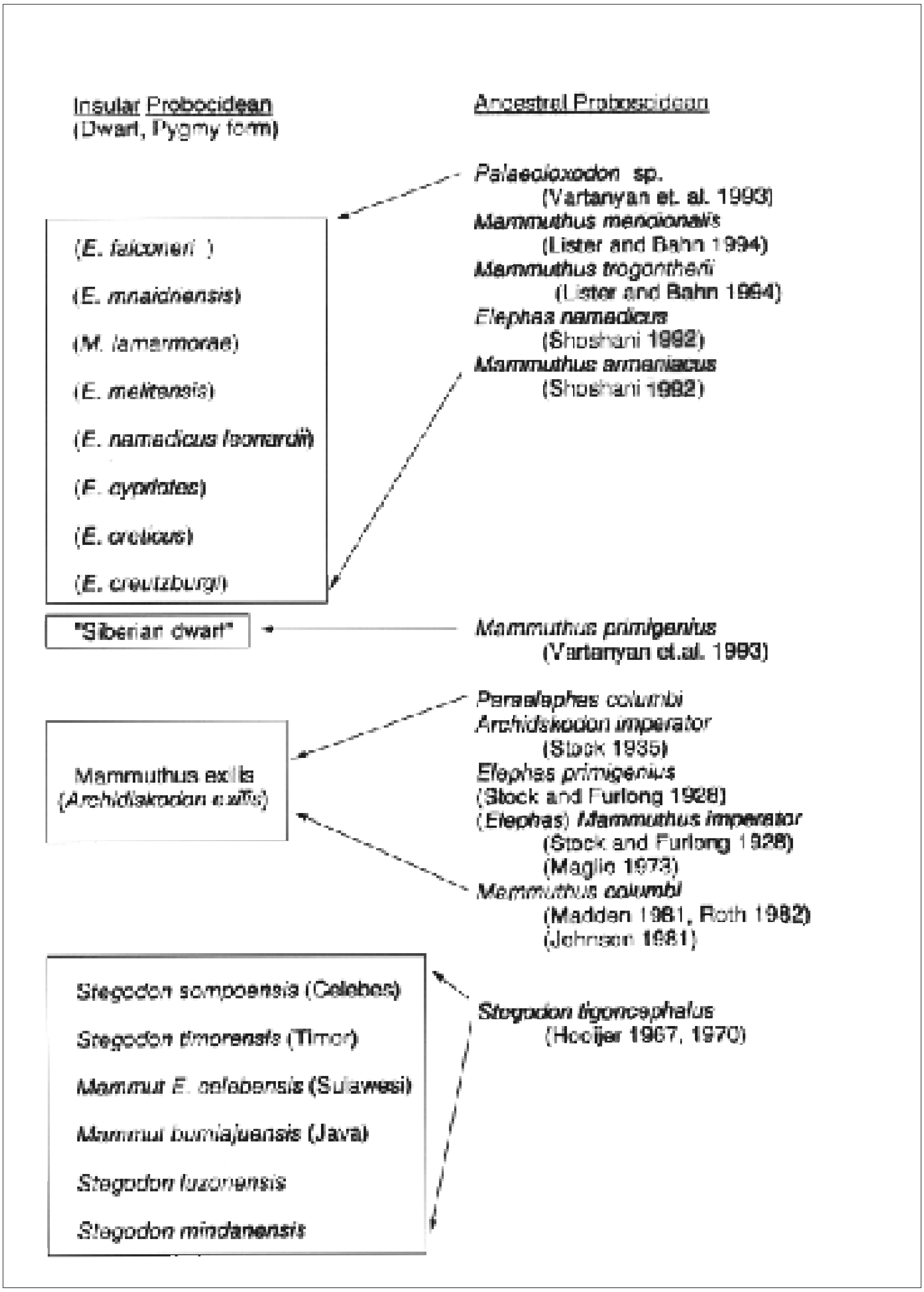


Figure 11 Locations of diminutive insular proboscideans. Mammoths of the Califo mia Channel Islands, Wrangel Island and the elephants of the Mediterranean islands; stegodonts and gomphotheres of the Philippine and Indonesian islands.

was relatively minor, and the erosion exposed the axial skeleton, for later discovery. Field measurements indicate this mammoth was approximately 1.7-1.8 m high at the shoulder, in the living animal. That stature equates to ca. 46% of the stature of a similarly aged Columbian mammoth in the Mammoth Site of Hot Springs, South Dakota. We assume that *M. columbi* was the most probable ancestral animal, from which the pygmy forms were derived. This hypothesis was initially proposed by C. Madden (1981), and the current research clearly supports it.

Table 2 Diminutive insular proboscideans and their proposed ancestry.



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