Channel Islands (USA) pygmy mammoths (*Mammuthus exilis*) compared and contrasted with *M. columbi*, their continental ancestral stock

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SUMMARY: Remains of the pygmy mammoth *Mammuthus exilis* have been known on the Channel Island of California since 1856. After initial colonization of Santa Rosa Island by *M. columbi*, the process of island adaptation noted as Foster's Rule came about. After the available radiocarbon chronology, it appears that they have been there, in essentially unchanged pygmy form, for more than 47,000 years (i.e. beyond the limits of radiocarbon chronology). They may have survived until the early Holocene colonization of the islands by the ancestors of the ancient Chumash people.

With the reconsideration of the dwarf status of the woolly mammoths (*M. primigenius*) of Wrangel Island (Mol 1995; Tikhonov 1997), the only island dwelling truly diminutive mammoths are those from the Channel Islands of California. Remains of these pygmy mammoths have been known on the islands since discovered in 1856 by a coast and geodetic survey. The first publication of the animals was in a brief report in the Proceedings of the California Academy of Sciences (Stearns 1873). Further paleontological studies were conducted by the City College of Los Angeles (Stock & Furlong 1928). Sporadic field collections by the Los Angeles County Museum were halted with the advent of World War II. Phil Orr, of the Santa Barbara Museum of Natural History, collected mammoth remains in the 1950's and 1960's, to substantiate his archaeological theory that the ancestral Chumash Indians decimated the island proboscideans (Orr 1956, 1968). Orr was unable to convince his scientific peers and island paleontology met a hiatus until the 1990's with a salvage collection of a San Miguel Island specimen, by Bob Gray of Santa Barbara City College, for the National park Service (NPS). In 1994 the discovery, excavation and recovery of a nearly complete, adult, male, *M. exilis* skeleton took place (Agenbroad 1998, 1999). During the nearly 30 year hiatus between the Orr's work and the 1990's salvage excavations, amateur collecting was done by Boris Woolley, a member of the ranching families in control of Santa Rosa Island.

Beginning with the recovery of the 1994 skeleton, a methodical pedestrian survey of the islands was begun, using Global Positioning System (GPS) coordinates to pinpoint each discovery. This on-going system has produced more than 140 new mammoth localities on the three outermost islands (a new locality being defined as one or more mammoth remains that in all probability do not represent a previous location). The survey has tended to destroy some of the myths about the distribution and types of mammoth remains on the islands.

During the Pleistocene glacial advances water was held on the continents as snow, glaciers, and ice sheets. As a result, sea level was lowered by 100 to 125 m in the last major glacial cycle. The lowering of sea level exposed a large island off the coast of California, designated as 'Santarosae' in Phil Orr's research. Postglacial warming caused melting of the continental ice and snow, recharging the ocean, causing sea level to rise to the current position. Santarosae became gradually inundated, leav-

ing only four islands which reflect the highest elevations of the Pleistocene 'super island'. San Miguel, Santa Rosa, Santa Cruz, and Las Anacapas Islands are all that remain exposed of Santarosae. Seventy-six percent of the Pleistocene island is now submerged, with the last connections between the island having been inundated between 12,000 and 11,000 radiocarbon years ago. Of the four modern islands, all but Las Anacapas produce mammoth remains.

After initial colonization of Santarosae by *M. columbi*, the process of island adaptation noted as Foster's Rule (Foster 1964) came about. Large continental mammals became smaller and small continental mammals became larger. Pleistocene Santarosae had "giant" deer mice (*Peromyscus*) and "pygmy" mammoths (*M. exilis*).

In the island survey, a ratio of approximately 1:10 large mammoth remains/small mammoth remains was encountered. All of the Columbian mammoth remains, thus far, have been located in elevated marine terrace remnants. Pygmy mammoth remains have been located in marine terraces, alluvial stream terraces, and stream channels near the island uplands. Approximately 50% of the island of Santa Rosa consists of uplands, with slopes exceeding thirty degrees. Using Columbian mammoths of Hot Springs, South Dakota as a representative continental population (Agenbroad 1994), various metric and morphological comparisons were made with the island mammoths. Calculations based on the center of gravity of large and small mammoths revealed that the pygmy mammoths were able to negotiate slopes that were as much as 10 degrees steeper than Columbian mammoths could travel. This suggests one of the reasons that the diminutive forms became the dominant island mammoth population. It should be noted that pygmy mammoths have not been discovered on the continental coast.

In 1977, Paul Sondaar, studying stegodons in Indonesia, concluded there was a shortening of lower limb bones, to allow "low gear locomotion" (akin to 4 wheel drive in modern vehicles) needed in ascending and descending steep slopes. This gave smaller animals access to upland pasturage which may have been crucial to survival in periods of climatic or dietary stress. Bone metric analyses confirm Sondaar's conclusions for *M. exilis*, the island adapted mammoth.

Analyses of the femora, humerii and dentition reveal additional characteristics. Femora of the island mammoths are significantly longer, as contrasted to the mean of the Hot Springs Columbian mammoths, and the femoral cross section of the pygmy mammoth is more circular, as compared to the flat ellipse of the continental mammoths. Studies of humeri suggest rotation of some of the muscle functions and attachments. The humerus takes on the added use, as a braking mechanism for a quadruped descending steep slopes. Analysis of dentition has produced a plot of all molar generations, which shows a line of best fit to be coincidental for *M. columbi* and *M. exilis*, supporting the probable ancestral relationship of the mainland mammoth for the island form. Dental age assignments, on the relative, 'African Elephant Year' scale, imply high mortality rates in the '0-30 year' range; few individuals survive past '50 years' of age. Two individuals represent animals whose mandibular teeth were missing due to advanced age and wear, yet the animals continued to masticate against the jaw bone.

Chronology for pygmy mammoths has been one of the weakest points of Channel Islands paleontology. Published dates have been obtained from charcoal associated with mammoth remains. Wenner *et al.* (1991) have branded all such dates as 'equivocal' and suggest they should be discarded. In part, this is because it has been stated that all mammoth remains on the islands are secondarily deposited (Orr 1959, 1968; Cushing *et al.* 1986; Roth 1982, 1996; Wenner *et al.* 1991). They (Wenner *et al.* 1991) even go so far as to infer, "...there is no natural charcoal on the islands".

The 1994 skeleton was sampled for bone from the marrow-producing segment of the right femur. The resulting accelerator-mass spectrometry (AMS) date for the animal was 12,840 +/- 410 yr BP (CAMS 24429). Not only was this date from mammoth bone itself, there

was no question as to the remains being in primary deposition, as even the smallest bones of the phalanges were still in articular position. Since that time, other AMS dates on bone collagen have been obtained, as well as dates from associated charcoal. Some samples differ as little as 10 to 20 years between the bone date and the associated charcoal date. This tends to refute some of the claims made by Wenner *et al.* (1991).

Summarizing the available radiocarbon chronology of the Channel Island Mammoths, it appears they have been on the islands, in pygmy form, essentially unchanged, for more than 47,000 years (beyond the limits of radiocarbon chronology). It also appears that they may have survived until the early Holocene colonization of the islands by the ancestors of the ancient Chumash people, first recorded between 10,800 and 11,300 years ago.

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