Monte Verde: Seaweed, Food, Medicine, and the Peopling of South America

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The identification of human artifacts at the early archaeological site of Monte Verde in southern Chile has raised questions of when and how people reached the tip of South America without leaving much other evidence in the New World. Remains of nine species of marine algae were recovered from hearths and other features at Monte Verde II, an upper occupational layer, and were directly dated between 14,220 and 13,980 calendar years before the present (~12,310 and 12,290 carbon-14 years ago). These findings support the archaeological interpretation of the site and indicate that the site's inhabitants used seaweed from distant beaches and estuarine environments for food and medicine. These data are consistent with the ideas that an early settlement of South America was along the Pacific coast and that seaweeds were important to the diet and health of early humans in the Americas.

Most scholars now accept that people entered the Americas through Beringia before 16,000 calendar years ago (*1*–*3*). After entering, it is not known whether people colonized the hemisphere by moving along the Pacific coast, through interior routes, or along both areas. Early coastal migrants probably obtained much of their food from the sea, including sea mammals, shellfish, and seaweed (*4*, *5*). Convincing data have not yet been recovered to support the coastal model, although a few early littoral sites have been reported (*6*–*11*). A coastal route along which resources are similar would more easily explain the rapid movement of people into South America and their presence at Monte Verde II, Chile, the upper layer of the Monte Verde site, dated at ~14,600 calendar years before the present (cal yr B.P.) (*12*, *13*) [supporting online material (SOM) text, section 2]. Here we report the recovery of three marine, two estuarine, and one terrestrial shoreline algae species new to the site and three additional stone artifacts, one with the remains of seaweed on a worked edge, that suggest a strong reliance on coastal resources for food and medicine.

Monte Verde II is buried in the terraces of a small creek in the Maullín river basin, located midway between the Pacific coast and the Andean mountains. Today, the area is characterized by a cool temperate climate, by wetlands composed of various hydrophytic communities and their successive species, and by remnants of a partly deciduous rainforest (*12*). During the late Pleistocene, temperatures were cooler, the site was drier, and the coast was situated ~90 km to the west, where sandy beaches, rocky shores, and delta estuaries offered a wide variety of marine and brackish water resources (Fig. 1). The inland marine bay of Seno de Reloncavi, dominated by a rocky shoreline, was ~15 km to the south. Monte Verde was ~120 m above sea level at the time of human occupation (SOM text, section 1). Today, the sea is ~55 km west and ~11 km south of the site and ~59 m below it.

At Monte Verde II, organic remains are well preserved under a peat stratum that covers the ~14,600 cal yr B.P. archaeological layer. Previous research recovered wood tent remains, hut foundations and floors, hearths and braziers, wooden lances, mortars and digging sticks, medicinal and edible plants, animal bones, hide and soft tissue, human footprints, numerous stone tools, and other materials demonstrating human occupation (*13*). This evidence suggests that the site was occupied year round

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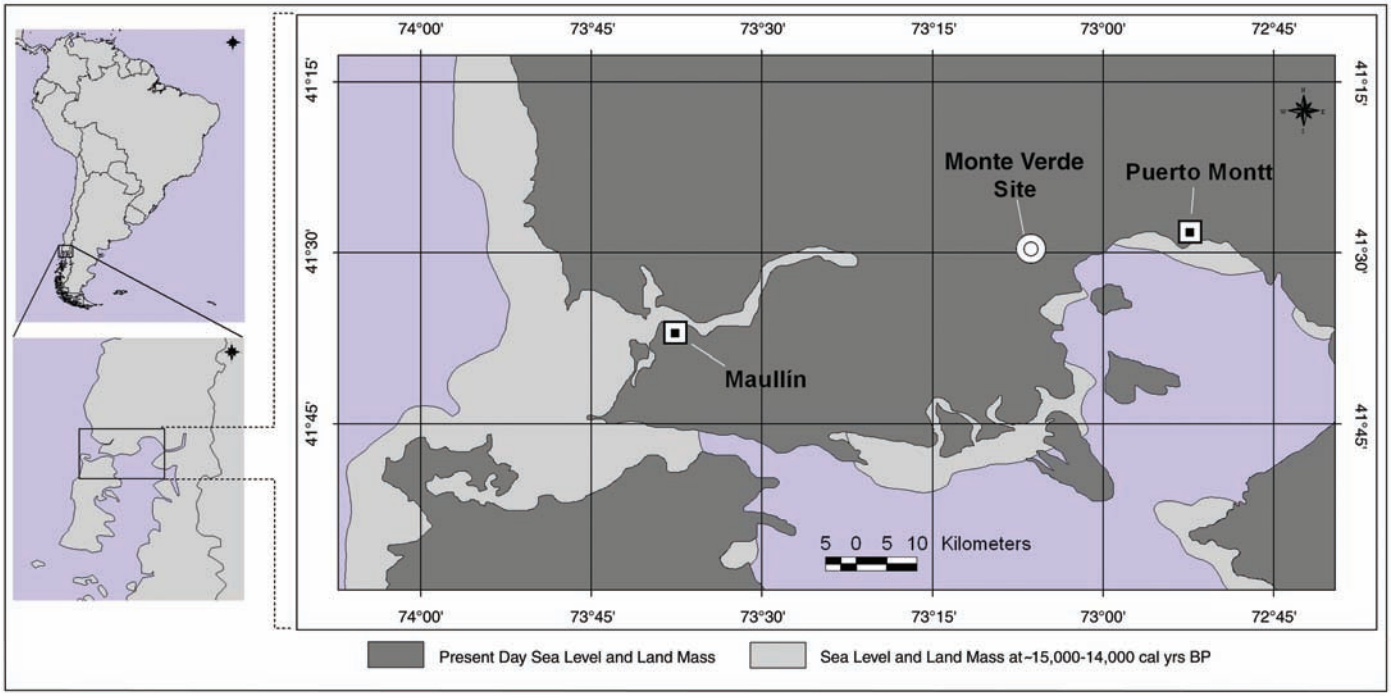

Fig. 1. Map of the Monte Verde area showing the location of the sea level and coastline at ~15,000 to 14,000 cal yr B.P. and at the present day.

and that resources were exploited from a wide variety of habitats, including the coast and the mountains. Fifteen species of aquatic plants from freshwater marshes of the distant Maullín floodplain and from coastal dunes and brackish water estuaries of the delta, along with gomphothere (*Cuvieronicus sensu* Casamiquela) and paleocamelid (*Paleolama* sp.) meat, wild potatoes (*Solanum maglia*), and 45 other plant species from inland forests and wetlands provided the bulk of the Monte Verdeans' diet (*12*, *13*). Included in the plant inventory were four previously reported varieties of seaweed, *Durvillaea Antarctica* (*cochayuyo*), *Porphyra* sp. (*luche*), *Gracilaria* sp. (*pelillo*), and *Sargassum* sp., from sandy and rocky shorelines (*14–16*). All of these species are edible and have important medicinal properties. Also recovered were the remains of 19 other probable medicinal species, 5 of which came from coastal environments (*14–16*). Other coastal resources collected from beaches and transported to the site were discoidal pebbles made into stone tools, bitumen used as adhesive to attach tools to wooden shafts, and marine fossils (*12*, *13*).

Our new analyses are from 27.2 liters of previously excavated but unstudied sediment fill from 24 hearths and braziers in the floors of two structures thought to be the remains of a medicinal hut and a residential tent. We recovered the remains of seaweed and other economically important plants (SOM text, section 2, and table *S*1) and three stones, one of which is a flake tool. Identified were *Porphyra* sp. and *Durvillaea Antarctica* (Fig. 2) and five new species of seaweed: *Gigartina* sp. (*luga roja*); *Mazzaella* sp. (*luga cuchara*); *Porphyra columbina*; probably *Sarcothalia crispata* (*luga negra*, Fig. 3); and *Macrocystis pyrifera* (*huiro*) (*13*). We also recovered *Trentepohlia* sp., an algae that is available exclusively on trees (*Aextoxicon punctatum* and *Griselinia jodinifolia*) and rocks in the littoral zone. The excellent preservation of the specimens allowed species-level identifications based on cellular structure, plant morphology, and color. Two accelerator mass spectrometry radiocarbon dates derived from fragments of *Gigartina* sp. on the floor of a wishbone-shaped hut and from *Mazzaella* sp. in a brazier on a tent floor are respectively between 14,190 and 13,990 cal yr B.P. (~12,290 ± 60 C^{14} yr B.P., Beta Analytic radiocarbon dating service sample number 238355) and 14,220 and 13,980 cal yr B.P. (~12,310 ± 40 C^{14} B.P., Beta Analytic sample number 239650). These dates agree with those derived from wood artifacts and charcoal in hearths at Monte Verde II, which range between 14,600 and 14,200 cal yr B.P. (*13*).

It was difficult to count the soft remains of the 10 species of algae because many were fragmented and mixed with other plants in masticated cuds, thought to be representative of an ancient pharmacopeia (*14*, *15*) (SOM text, section 3, and fig. S1), or were trampled and embedded in hut floors. However, the dry weight total of all excavated seaweed remains was ~125 g. Several algae fragments were partially burned, suggesting that they had been dried, probably for transport from the coast or for storage, or were cooked. The fragility of soft leafy seaweeds, their unlikely preservation in archaeological sites, and yet their widespread dispersion in hearths and braziers across the site and their combination with other medicinal plants in the form of masticated cuds suggest their value for both food and medicinal purposes.

The seaweeds represent contrasts in environment and seasonal availability. Four genera (*Durvillaea*, *Porphyra*, *Mazzaella*, and *Sarcothalia*) derive from rocky coastlines and intertidal pools located west and south of Monte Verde (*16*, *17*), whereas three (*Gracilaria*, *Gigartina*, and *Macrocystis*) originate only from sandy coastlines west of the site. The peak availability of three (*Mazzaella*, *Gigartina*, and *Sarcothalia*) occurs from early spring to early summer, one (*Gracilaria*) is available from late spring to early summer, one (*Porphyra*) is found in midsummer, and one (*Durvillaea*) occurs in late summer to early fall (*18–21*). *Sargassum* sp. (Fig. 4) is a warm-water species with a wide Pacific natural range. Its growth anywhere in Chile, where the cold Humboldt Current sweeps the coast, is doubtful (*17–22*). *Sargassum* probably reached Chile through violent storms or major El Niño events, or perhaps the configuration of ocean currents was different at the time of site occupation. *Trentepohlia* sp. is available year round along the littoral. Seaweed collection by Monte Verdeans was thus conducted at various coastal locales from early spring to early fall. Today, the tidal range of the sea varies from 6.5 m near Puerto Montt in the Reloncavi Bay to 4 m at the mouth of the Maullín River, in both areas producing a wide and abundantly available resource-rich intertidal beach. With the exception of *Sargassum* sp., moderate quantities of all varieties of seaweeds are deposited along the shoreline during storm surges. All nine seaweed species recovered at Monte Verde II are excellent sources of iodine, iron, zinc, protein, hormones, and a wide range of trace elements, particularly cobalt, copper, boron, and manganese (*23–29*). Secondary beneficial effects of these seaweeds include aiding cholesterol metabolism, increasing the calcium uptake of bones, antibiotic effects, and increasing the body's ability to fight infection. These species have medicinal uses that closely correspond to common contemporary health problems in the study area today (SOM text, section 3). Two species, *Gigartina* and *Sargassum*, are non-edible and were evidently used exclusively for medicinal purposes. Collectively, the seaweeds and 10 other plant species at Monte Verde II suggest a medicinal stock derived from the cool temperate environment of the region. These same species are used today as medicinal plants by local indigenous populations.

We also recovered a total of 268 edible seeds, fruits, and other plant parts (SOM and table S1) from the processed feature fills, which correspond with the genera previously reported

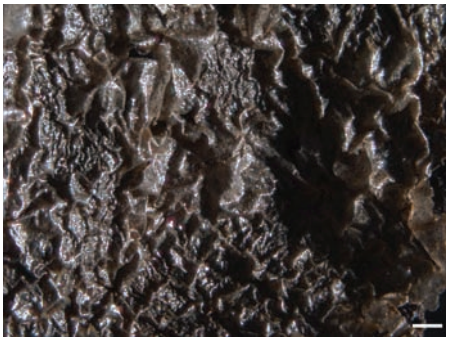

Fig. 2. Microscopic view of an archaeological specimen of *Durvillaea antarctica* from a hearth matrix located in the remains of a domestic hut. Scale bar, ~100 μm.

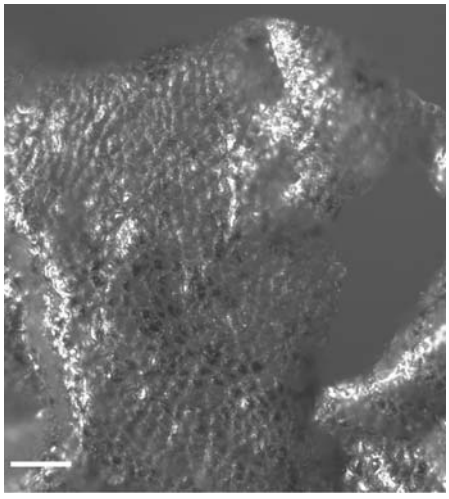

Fig. 3. Microscopic view of an archaeological specimen of *Sarcothalia crispata* from a hearth matrix located in the remains of a domestic hut. Scale bar, ~ 200 μm.

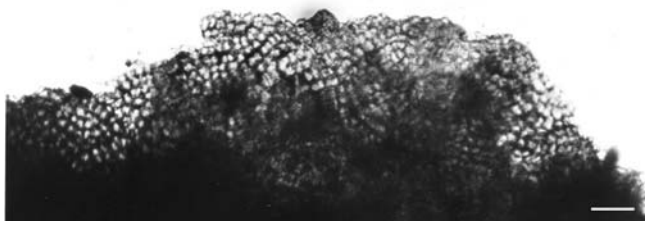

Fig. 4. Microscopic view of *Sargassum* sp. from the floor of the wishbone-shaped hut. Scale bar, ~100 μm.

from the site (*13*–*16*). Also recovered were three stone tools, one of which exhibits microparticles of *Gigartina* sp. on a used edge (SOM text, section 4, and fig. S2), suggesting that it was used for cutting and preparing seaweed. Fragments of *Porphyra* sp. and *Sargassum* sp. were reported previously on other stone tools (*13*). The remaining two stones show indeterminate human modification (SOM and figs. S4 to S6).

Not known is whether people arrived at Monte Verde through an interior or coastal route. However, these new data indicate that the people inhabiting Monte Verde II were accustomed to frequently exploiting coastal resources year round, which, coupled with interior foods, allowed them to remain in the area. Prior evidence suggests that the Monte Verdeans also regularly moved up and down the Maullín basin to exploit resources and/or to exchange them with other people living in the area (*13*, *16*). Assuming that other late Pleistocene people operated under similar subsistence and settlement practices, our data imply that if groups traveled along the Pacific coast, they may have migrated slowly and exploited the interior resources of the hundreds of river basins descending the long mountain chain from Alaska to Tierra del Fuego to the sea. Several recent archaeological findings support the idea of early coastal migration and specialized maritime sites, but this evidence also indicates contacts with interior people or transhumance between coastal and interior areas and thus broad-spectrum economies (*7*, *8*, *10*, *11*).

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Supporting Online Material

www.sciencemag.org/cgi/content/full/320/5877/784/DC1
SOM Text
Figs. S1 to S6
Table S1
References

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DNA from Pre-Clovis Human Coprolites in Oregon, North America

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The timing of the first human migration into the Americas and its relation to the appearance of the Clovis technological complex in North America at about 11,000 to 10,800 radiocarbon years before the present (^{14}C years B.P.) remains contentious. We establish that humans were present at Paisley 5 Mile Point Caves, in south-central Oregon, by 12,300 ^{14}C years B.P., through the recovery of human mitochondrial DNA (mtDNA) from coprolites, directly dated by accelerator mass spectrometry. The mtDNA corresponds to Native American founding haplogroups A2 and B2. The dates of the coprolites are >1000 ^{14}C years earlier than currently accepted dates for the Clovis complex.

The timing, route, and origin of the first human migration into the Americas remain uncertain. Some archaeological (*1*) and genetic [reviewed by (*2*)] evidence has been used to argue for a settlement by 30,000 years ago (ka) (calendar years) or even earlier, but both lines of evidence remain controversial. The most widely accepted dates of occupation relate to the Clovis complex, ~11,000 to 10,800 ^{14}C years before the present (yr B.P.) (13.2–13.1 to 12.9–12.8 ka), a distinct technology that appears to have originated and spread throughout North America in as little as 200 to 300 years (*3*).

The oldest directly dated human osteological remains from the Americas are no more than 11,000 ^{14}C yr B.P. (~12.9 ka) (*3*, *4*) and appear to be congruent with the "Clovis-first" model of colonization (*5*, *6*). However, this theory is complicated by Monte Verde, in southern Chile, which contains artifacts dated to ~12,500 ^{14}C yr B.P. (~13.9 to 13.8 ka) that exhibit little technological connection to Clovis (*7*). Although a number of pre-Clovis occupation sites have been reported from North America (*8*), their age and cultural origins remain controversial, primarily because of the lack of directly dated human remains or artifacts (*9*).

Here we present evidence for human presence in North America before the Clovis complex, through the identification and genetic profiling of coprolites directly dated to 12,300 ^{14}C yr B.P. (~14.27 to 14.0 ka) at the Paisley 5 Mile Point Caves in south-central Oregon (Fig. 1A). The Paisley Caves are wave-cut shelters located on the highest shoreline of pluvial Lake Chewaucan, which once filled the Summer Lake–Chewaucan–Lake Abert basins (Fig. 1A). As the lake level fell since the last glacial maximum (*10*, *11*), the caves began filling with aeolian-transported silt and sand, gravel, roof spall, and organic material (bones, coprolites, plant remains, and artifacts) deposited by humans and animals. Sheltered from moisture, these extremely dry deposits contain perishable human artifacts: manufactured threads of sinew and plant fibers, hide, basketry, cordage, rope, and wooden pegs, as well as animal bones and diverse kinds of feces, in an un-