

Ancient Earthmovers Of the Amazon

The forested western Amazon was once thought barren of complex human culture. But researchers are now uncovering enigmatic earthworks left by large, organized societies that once lived and farmed here

Alceu Ranzi was a geography student in 1977 when he helped discover half a dozen huge, prehistoric rings carved into the landscape in his home state of Acre in western

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S Hear author Charles C. Mann discuss the earthworks left by the early Amazonians.

ing worldwide protests. The earthworks came to light on newly logged land.

The find attracted little attention. The Smithsonian-sponsored National Program of Archaeological Research in the Amazon Basin did not formally announce the rings for 11 years, and even then only in a little-read report. And Ranzi, who went on to become a respected paleontologist, most recently at the Federal University of Acre in Rio Branco, didn't get back to studying the ditches until more than a decade after that. On a flight to Rio Branco in 1999, he spotted

the earthworks again from the air and soon began looking for more. Within a year, he says, "we had found dozens more" of what he calls geoglyphs.

Shaped like circles, diamonds, hexagons, and interlocking rectangles, the geoglyphs are 100 to 350 meters in diameter and outlined by trenches 1 to 7 meters deep. Many are approached by broad earthen avenues, some of them 50 meters wide and up to a kilometer long. The geoglyphs "are as important as the Nazca lines," Ranzi says, referring to the famed, mysterious figures outlined in stone on the Peruvian coast. But even though the Acre geoglyphs had been observed 20 years before, "nobody still knew anything about them."

Today, Ranzi co-leads a research team with Martti Pärssinen of the University of Helsinki and Denise Schaan of the Universidade Federal do Pará in Belém. More than 150 geoglyphs have been identified in Acre and the adjoining states of Amazonas and Rondônia—a figure, Pärssinen believes, that represents "less than 10%" of the total; indeed, on a recent overflight

with a *Science* reporter, Schaan and Ranzi spotted three more. So far, the sole published carbon date suggests that the Acre geoglyphs were constructed relatively recently, in about 1250 C.E. And their purpose remains unclear. Nonetheless, Schaan says, enough is known to be sure that they are "very difficult to fit in with what we thought in the past."

For most of the last century, researchers believed that the western Amazon's harsh conditions, poor soils, and relative lack of protein (in the form of land mammals)

precluded the development of large, sophisticated societies. According to the conventional view, the small native groups that eked out a living in the region were concentrated around the seasonally flooded river valleys, which had better soil; the few exceptions were short-lived extensions of Andean societies. Meanwhile, the upland and headwaters areas—which include nearly all of western Amazonia—had been almost empty of humankind and its works.

Yet during the past 2 decades, archaeologists, geographers, soil scientists, geneticists, and ecologists have accumulated evidence that, as the geoglyphs team puts it, the western Amazon was inhabited "for hundreds of years" by "sizable, regionally organized populations"—in both the valleys and the uplands. The geoglyphs, the most recent and dramatic discovery, seem to extend across an area of about 1000 kilometers (km) from the Brazilian states of Acre and Rondônia in the north to the Bolivian departments of Pando and the Beni in the south (see map, p. 1150). Much of this area is also covered by other, older forms of earthworks that seemingly date as far back as 2500 B.C.E.: raised fields, channel-like



Farsighted. Brazilian researchers Denise Schaan and Alceu Ranzi believe fewer than 10% of the region's geoglyphs have been found.



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Squared off. The Fazenda Atlântica geoglyph in Acre is 250 meters on a side.

canals, tall settlement mounds, fish weirs, circular pools, and long, raised causeways (*Science*, 4 February 2000, p. 786), suggesting the presence of several cultures over a long period. And on page 1214 of this issue of *Science*, a U.S.-Brazilian team proposes that indigenous people in the south-central Amazon, 1400 km from Acre, lived in dense settlements in a form of early urbanism and created ditches and earthen walls that some say resemble the geoglyphs (see sidebar).

Researchers are still puzzling over whether and how these earthworks fit together and what they reveal about the people who created them. But already the implications of these enormous endeavors are clear, says Clark Erickson, a University of Pennsylvania researcher who has been working in the area with Bolivian colleagues since 1995. Far from being trapped by the Amazon's ecological obstacles, he says, these large populations systematically transformed the landscapes around them. One example: Because geoglyphs cannot readily be constructed or even seen in wooded areas, the researchers argue that people must have made them at a time when the region had little tree cover—meaning that in the not-too-distant

past the great forests of the western Amazon may have been considerably smaller.

Not only did the peoples of western Amazon alter their environments, but they also transformed the biota in them. Emerging evidence suggests that this little-known region may have been a place where long-ago farmers first bred some of the world's most important crops. In Erickson's view, western Amazonia serves as a model of how human beings create and maintain productive landscapes from even the most apparently limited environments.

The new findings show that the region was “a cosmopolitan crossroads” between the societies of the eastern Amazon and the Andes, of whom the most famous were the Inka, says Susanna Hecht, a geographer at the University of California, Los Angeles: “You have every language group in lowland South America represented there.” She adds, “It was a major cultural center—and it's incredible that this is just coming out.”

Counterfeit paradise, or a real one?

Archaeologists once regarded Amazonia as unpromising terrain. Clearing the forests for agriculture risks destroying fragile tropical

soils by exposing them to the tropics' punishing heat and rain, a contention that lay at the heart of Smithsonian archaeologist Betty Meggers's *Amazonia: Man and Culture in a Counterfeit Paradise* (2nd ed., 1996), probably the most influential book written about the area. Meggers reasoned that in consequence, settlements could not long survive with conventional farming; she once suggested that the river basin's ecological constraints limited maximum village size to about 1000 people. In addition, those people would have left little behind, because Amazonia has little stone or metal. As a result, “99% of material culture was perishable,” Erickson says. “Cane, chonta [palm wood], bones, baskets, wood—none of it survives these conditions.” Except for pottery, “the whole culture, even if it was there for thousands of years, seems to be gone.”

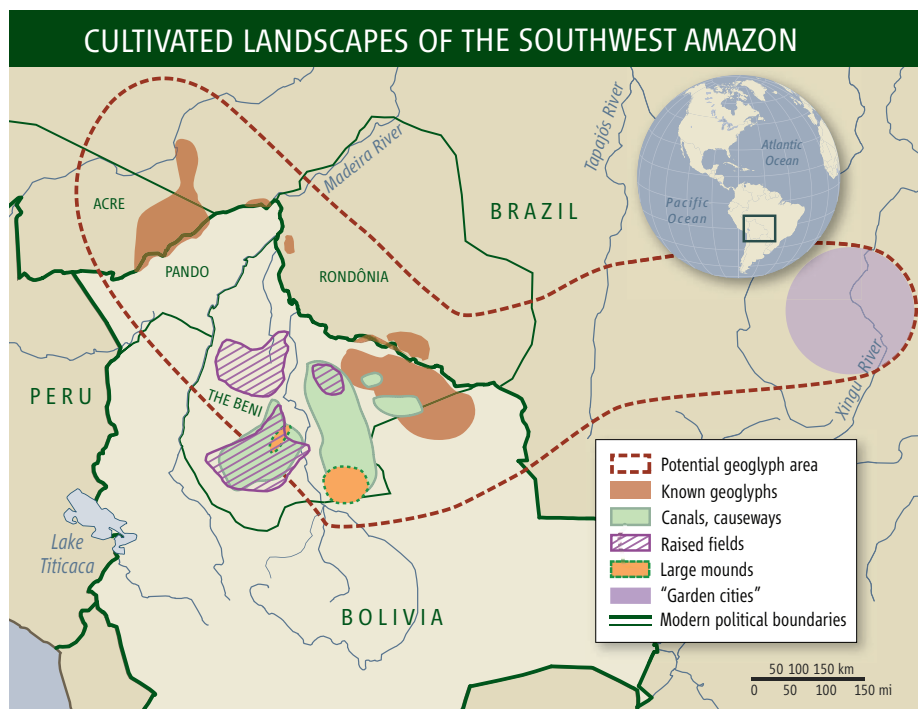
“In the Andes, the societies are easy to see,” says Sergio Calla, a student at the Universidad Mayor de San Andrés in La Paz who works with Erickson. “There is no forest covering up their traces. Also, they could build in stone, which is rare here. But this region is just as rich culturally. We just have to look harder and smarter.”

Looking smarter, in Erickson's view, means going beyond archaeology's traditional focus on the individual site to entire landscapes. "What Amazonian peoples did in constructing/building environments was more visible and permanent at a regional scale than at the site scale," he argues. To study at this scale, archaeologists are adopt-

grassland. These low, interconnected berms change direction, zigzag-style, every 10 to 30 meters. At the angles are funnel-like openings for nets or traps. Built as early as the 13th century, they fell into disuse only in the 18th century. "Think of it as aquaculture," Erickson says. "The weirs allowed people to manage and harvest the catch."

Because the mounds, weirs, and fields required enormous labor to construct and maintain, Erickson believes these societies must have had large populations—"tens or even hundreds of thousands of people." Some early Jesuit accounts back this view.

To move people and goods around, Indians built networks of ruler-straight causeways and canals, some of them as long as 7 km. Puzzlingly, the causeways and canals are common near raised fields but not around settlement mounds. To make sense of the pattern, Erickson and Patrick Brett—a Wall Streeter taking time off to pursue his academic dreams—are trying to apply the techniques of network analysis to search for key nodes in the networks of connected causeways, canals, mounds, and fields. The hope, he says, is "to stop us from flailing around, trying to figure out which of the thousands of *islas* we should put a trench into." Early analysis, Erickson says, "shows a few key forest islands in control of a vast network of communication and interaction covering 550 square kilometers: as large as many early states."



Ancient crossroads? Researchers suspect that prehistoric earthworks across the western Amazon may be related.

ing new methods, from soil chemistry to network theory.

The Beni in Bolivia, where Erickson's team focuses its efforts, is an example. Exceptionally low and flat, much of the department is covered for up to 4 months of the year by a slowly moving wash of water—snowmelt from the Andes and heavy local rainfall—that is typically 30 to 100 centimeters deep. During the dry season, the water evaporates and the Beni becomes a hot, arid savanna, kept open by annual burning. In the low areas, early inhabitants avoided the flood by using natural knolls known as *islas* and by constructing thousands of *lomas* (mounds typically 1 to 5 hectares) as dwelling places. Most *lomas* were small—artificial hummocks barely above the water—but a small percentage were up to 18 meters in height. Some are still inhabited by native groups.

Living on this artificial inland archipelago, Amazonian peoples ate a diet heavy in fish, which migrate and spawn in the flooded savannas. Today, as Erickson discovered in 2000, networks of earthen fish weirs still crisscross a 500-square-kilometer area in the

When the waters receded, the area's early inhabitants ensured that they drained into hundreds of artificial fish ponds. Typically about 30 meters across, they are often full of fish today.

Agriculture was just as intensive. In a broad, 50,000-square-kilometer swath of savanna around the mounds, the Beni's indigenous peoples built raised fields—artificial platforms of soil that lift crops above the floodwaters, according to research by geographer William Denevan, a professor emeritus at the University of Wisconsin, Madison, who in 1963 was one of the first to call attention to them. Like raised beds in temperate-zone gardens, the mounds promote drainage and increase the amount of topsoil. From the few carbon dates available, Erickson says, "we see raised fields coming in and out of production from 3000 B.P. to 500 B.P."—or until roughly the time the conquistadors arrived, bringing diseases that wiped out much of the native population. "Like any agricultural fields, these were not used forever. They go in and out of production, which suggests to me a long-term but dynamic system."

Birthplace of crops

Even as archaeologists try to work out how the area's early inhabitants reshaped their physical environment, botanists are beginning to trace out their impacts in its genetic heritage. "The Amazon is world-famous as a center for biodiversity," says botanist Charles R. Clement of Brazil's National Institute for Amazonian Research in Manaus. "But its role in agricultural biodiversity remains still too little known." In his view, the western Amazon was a center for plant domestication—a "Vavilov center," as botanists call them, after pioneering Soviet botanist Nikolai Vavilov, who invented the concept.

Agricultural geneticists have long accepted that the western Amazon was the development ground for peanuts, Brazilian broad beans (*Canavalia plagioperma*), and two species of chili pepper (*Capsicum baccatum* and *C. pubescens*; see *Science*, 29 June 2007, p. 1830). But the list is much longer, Hecht says. For example, she would add rubber, made from the sap of *Hevea brasiliensis*. Used for countless purposes by pre-Columbian populations, "it is at least a semi-domesticated, and it was clearly distributed by humans." Also on her list are tobacco, cacao, the tuber *Xanthosoma sagittifolium*, peach palm (*Bactris gasipaes*, a major Amazonian crop), and, most important, the worldwide staple *Manihot esculenta*, better known as manioc, cassava, or yuca.

Because the domestications of manioc and peach palm apparently occurred before

the earthworks were built, agriculture may have, as in other cultures, created the surplus necessary for complex societies to emerge. But a “note of caution” is appropriate in such speculations, says anthropologist Peter Stahl of Binghamton University in New York. Although “tending to agree” that the region was a center for domestication, he notes that it’s possible that ancestral species still survive in southwestern Amazonia “because it’s

out of the way” rather than because domestication happened there.

Strikingly, one of the Amazon’s most important agricultural innovations may have originated soon after the breeding of modern manioc and peach palm. Known as *terra preta*, it consists of patches of soil ranging from less than 1 hectare to several hectares that have been modified by adding huge quantities of crumbled charcoal (*Science*, 9 August 2002, p. 920).

An informal Brazil-Germany-U.S. collaboration has been investigating this artificial soil, which maintains its fertility for long periods despite the harsh tropical conditions. Earlier this year, five researchers led by Christoph Steiner of the University of Bayreuth in Germany reported that adding charcoal and soot to weathered Amazonian soils caused a “sharp increase” in microbial activity: Soils damaged by exposure became, so to speak, more alive.

The Western Amazon’s “Garden Cities”

IN 1902, BRITISH PLANNER EBENEZER HOWARD PUBLISHED *GARDEN Cities of To-Morrow*, which argued that the coming century’s cities—metropolises ringed by bedroom communities—should be replaced by more livable, medium-sized “garden cities,” linked by railroads and girdled by agricultural green belts. Howard inspired planners in the United Kingdom and Germany, but by the 1970s his views had been forgotten. Now, on page 1214, a U.S.-Brazilian research team led by archaeologist Michael Heckenberger of the University of Florida, Gainesville, reports finding a set of urban settlements startlingly similar to Howard’s garden cities—built in the forests of the south-central Amazon as early as 1250 C.E.

The paper identifies dozens of densely packed “towns, villages, and hamlets” covering perhaps 30,000 square kilometers—an area the size of Belgium—in the headwaters of the Xingu River. The settlements, built by indigenous peoples, were tied together by “well-planned road networks” and embedded in a matrix of agricultural land. (By coincidence, the Xingu complexes are also where famed British adventurer Percy Fawcett disappeared in 1925 while searching for a mythical lost city known as “Z.”)

The new claims are sure to stir controversy. “Some urbanists may say, ‘In your dreams,’” Heckenberger says, laughing. But he argues that the key comparison is not to big centralized cities such as Uruk or Athens, “but the other thousand poleis [in ancient Greece] that were *not* Athens.” Like them, he says, the Xingu polities “have sophisticated systems of regional planning, a strongly hierarchical spatial organization, and a basic core-hinterland division within clearly marked territories.”

The new work “raises huge and important questions,” says Susanna Hecht, an Amazon specialist at the University of California, Los Angeles. It further contradicts the once-dominant view that the Amazonian uplands and headwaters regions were nearly empty. Indeed, the earthworks are similar enough to the geoglyphs to the west in the Beni (see main text), says geographer William Denevan of the University of Wisconsin, Madison, that “they must be related, though we don’t know how.” Hecht also notes that the Xingu settlements challenge the implicit belief that “current urbanism with its hyperconcentration is a kind of historical norm,” when “smaller agglomerations interacting with forest and agriculture” may have been widespread, too.

Since the early 1990s, Heckenberger has focused on the upper Xingu River, much of which is a 2.6-million-hectare reserve set aside for 14 indigenous groups, including

the Kuikuro, who number about 500. Two weeks after Heckenberger arrived, community leader (and co-author of the *Science* paper) Afukaka Kuikuro showed him the ruins of an earthen wall more than a kilometer long. Heckenberger realized that the wall, which was associated with a moatlake ditch 10 or more meters wide, was from before the time of Columbus. Then, he says, “I found out the Kuikuro knew about a lot of these walled settlements, and they weren’t small.”

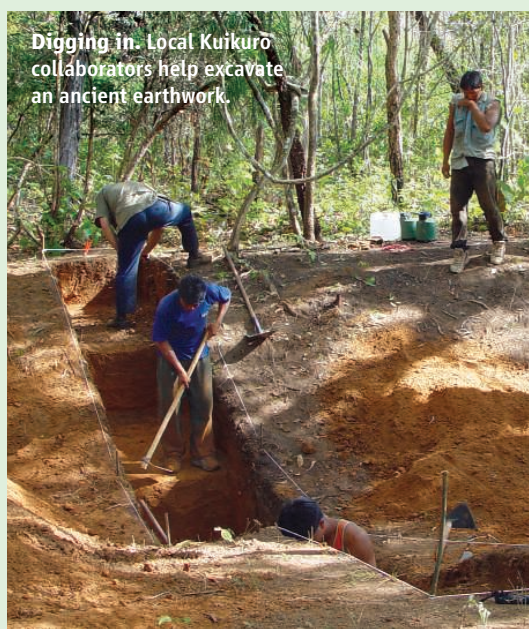
Patiently converting indigenous knowledge into GPS-verified mapping and archaeological excavation, Heckenberger’s team discovered that the present-day Kuikuro forest concealed what had been two regional polities, each about 250 square kilometers, comprised of small villages and towns centered on plazas 120 to 150 meters across. Each polity had a kind of capital with roads radiating out to other villages and towns. “The settlements are packed in the region along the Xingu,” Heckenberger says, “one after another, always in this highly regular pattern.” Each center has equidistant towns to its north and south, for example, as well as smaller towns east and west, with the two axes being of constant lengths. Similarly, the prehistoric plazas in the towns are regularly patterned, with the primary and secondary leaders’ houses facing each other at opposite ends. “All their roads are amazingly straight, too,” Heckenberger says. “If there was a wetland, they just built causeways and bridges over it.” In his view, this careful layout suggests that the capitals had a ritualistic function.

To Heckenberger, the settlements represent a novel kind of urbanism. As he readily agrees, “No *single* Xingu settlement merits the term ‘city.’ But what do you do with a core of five settlements a few kilometers away from each other? A fast walk from one to another would take you 15 minutes, maximum.”

Radiocarbon dating suggests that these communities were at their height from the 13th to the 16th centuries, with a regional population greater than 50,000, based on extrapolation from current settlements. Soon after Europeans reached Brazil in 1500, diseases killed two-thirds or more of the native population, and forest quickly grew into cleared areas; colonists later tended to believe that the forest was of great antiquity.

These pre-Columbian urban concentrations may have lessons for today’s planners. “Given the complexity of Amazonian biotic and water regimes, a decentralized model may have been more adapted to address very large volumes of water that hang around for a long time,” Hecht says. Because tropical areas today are dominated by huge centralized cities, she says, it is striking to note that their original inhabitants chose a different path.

—C.C.M.



Digging in. Local Kuikuro collaborators help excavate an ancient earthwork.

Terra preta is believed to have been an essential part of a distinctive agricultural system. According to the *terra preta* team, Indians slowly cleared off the forest to create farm plots and planted annual crops such as manioc and peanut. In the past, researchers argued that as the exposed soil lost its fertility, farmers shifted to other areas in a pattern called “slash and burn.” But researchers now suggest that Indians instead took steps to retain soil fertility by creating *terra preta*. According to studies by Wisconsin’s Denevan, removing trees with stone axes was so difficult that the logical path for native peoples would not have been to clear additional forest every few years but to replant the enriched fallow earth with tree species useful to humankind—rotating annual and tree crops over time.

The oldest *terra preta* patches yet known, carbon-dated to about 2500 B.C.E., are in



Walking on water. Early Amazonians built causeways to adjust to annual floods.

Rondônia, not far from the Brazil-Bolivia border, suggesting to Eduardo Goes Neves of the University of São Paulo that these techniques may have been invented there. In surveys this year and last, Neves discovered “*terra preta* almost everywhere we looked.” Pärssinen, though, says that the geoglyphs team has not yet found big patches of *terra preta* in Acre. “How these large groups supported themselves there without it is a mystery,” he says.

If the rest of the Rondônia *terra preta* is as old as the dated patches, Neves says, “we’re looking at a huge jigsaw puzzle” of an ancient culture—or cultures. As he sees it, “in the west and southwest, there’s the mounds and canals, there’s the development of manioc and peach palm, there’s the fish weirs that Clark [Erickson] found—and we don’t know how any of it fits together. On top of that, there’s the geoglyphs all over the place.”

Digging deep

Around and atop many of the Beni forest islands are deep ditches, commonly oval or ring-shaped. Analogs of the geoglyphs found by Ranzi in Acre, they are typically 100 to 200 meters across, though some are as much as 1 km in diameter. Many are surprisingly deep; Erickson and his Bolivian co-investigator, Patricia Alvarez of the Universidad Mayor de San Simón in Cochabamba, discovered one ring originally dug to 10 meters. The region is now overgrown, so the team measures geoglyphs by slowly chopping through trees and vines; during *Science*’s visit, Erickson spent most of an afternoon hacking with a machete through thick forest to identify the track of a single big ditch on a Global Positioning System.

Partly because of the recent tree cover, nobody knows how many of these geoglyphs

exist. Erickson, for his part, says he “wouldn’t be surprised if almost every one of the artificial lomas had them.” Perhaps backing this view, anthropologist John Walker of the University of Central Florida in Orlando reports, in a forthcoming paper, the discovery of ditches on savannas and river-edge forests in north-central Bolivia, in an area where they had not previously been reported. “We found ceramics on four forest islands that we examined,” he told *Science* in an e-mail from Bolivia, “and each of them also had earthworks that I am willing to call ring ditches”—circular geoglyphs.

The relation of the geoglyphs to the other, often older, earthworks is unclear. “We have one set of people constructing the *zanjas* [ring ditches] and another set of people constructing the causeways and canals,” Alvarez says. “The question is whether they are the same people.” In her view, the variegated

cultural landscape of the region probably reflects “a patchwork of different ethnic groups working in different areas” with constant, intense “interethnic communication”—a crowded, jumbled social landscape that Alvarez believes extended for hundreds of kilometers in every direction. The sphere of intense interaction, she believes, may have lasted for centuries.

Researchers think it likely that the geoglyphs extend continuously between Acre and the Beni; Pärssinen notes the recent discovery of large geoglyphs near the city of Riberalta, on the northernmost tip of the Beni. But they cannot be sure, because between Riberalta and Rio Branco, in Acre, is about 150 km of the mostly forested department of Pando. “It seems unlikely there is no connection, but any connection is not yet proven,” Schaun says.

Nor is it known whether the geoglyphs served any practical function. Most of the Acre geoglyphs are on higher ground, making them of little use for drainage. Many have outer walls that look down on the central area, suggesting that they were not used for defense. To be sure, one of Walker’s earthworks was connected to a river “by a deep channel and had a connection to a swamp on the other side,” he says. “It could have been used to control water flow off of the savanna in the dry season. So at least some of these earthworks could have had a hydraulic function.” Many, though, are almost entirely without other traces of human presence, such as ceramics. “The immediate response is that they were symbolic places,” says Stahl. “But that’s the old archaeological canard: If you can’t figure out the function of something, you say it was for ritual.”

The late arrival and ubiquity of the geoglyphs may indicate that some type of cultural movement swept over earlier social arrangements. “But whatever was there, these societies have been completely forgotten,” says anthropologist Guillermo Rioja, director of sustainable development and indigenous peoples for the Pando. “It’s only been 400 years since they vanished. Why does nobody here know anything about them? They were living here for such a long time, and nobody knows who they were.”

One reason for the lack of attention, in his view, is archaeology’s long focus on Andean societies of Peru and Bolivia, with their grand stone ruins. “The idea is that the tribes in the lowlands were living like animals in the wild,” Rioja says. “When you tell them that there were great, important civilizations here in the western Amazon, they don’t believe it. But it’s true.”

—CHARLES C. MANN