



Heavy footprint. Humans have been transforming landscapes, such as these ancient Philippine rice fields, for thousands of years.

rally just as the humans arrived, it's still not clear whether hunting, climate, or both killed off the megafauna, Braje says. He noted 2011 work led by Eske Willerslev of the University of Copenhagen, which concluded that climate alone best explains some extinctions, but that both climate and human hunting drove Eurasian steppe bison and wild horses extinct, for example. Thus, human-caused extinctions go back thousands of years.

Instead of focusing on the Anthropocene's measurable effects, which accumulated over time, some archaeologists argued that perhaps a more scientific way to define the epoch is by the onset of the most important cause of the global human footprint: agriculture. "Rather than focus on greenhouse gases, we should identify when in the archaeological record humans first developed a significant ability to modify the Earth's ecosystems," Smith said in a talk co-written with fellow NMNH archaeologist Melinda Zeder. Agriculture arose nearly simultaneously in the Near East, Asia, and the Americas, and "is the lever that humans have used" to refashion the planet, Smith said.

The origins of agriculture about 11,500 years ago coincide with the beginning of the Holocene, which already has an official golden spike—the end of the last ice age. If the marker was early agriculture, no additional spike would be needed, and the current epoch could be called the Holocene, the Anthropocene, or both, Smith said.

Support for using agriculture as a dividing line comes from the dramatic impacts made by early farmers, described in the case of East Asia by archaeologist C. Melvin Aikens of the University of Oregon. Beginning about 9000 years ago, villages fed by millet, wheat, and barley fields began sprouting all over China. This was much more than just a few clearings in the forest: Early rice farmers carved out landscapes and waterways, and "over the millennia vast reaches of southern China were wholly transformed by dams, canals, and vast paddy fields," Aikens said.

Even regions once thought to be relatively untouched by humans, such as the Amazon, were radically changed by prehistoric peoples, who built extensive earthworks and causeways at least 4000 years ago (*Science*, 29 August 2008, p. 1148), panelists noted.

Whatever agriculture's impacts, using it to define the Anthropocene may well encounter resistance from earth scientists. Indeed, in a 2011 article in the *Philosophy*

ARCHAEOLOGY

Archaeologists Say the 'Anthropocene' Is Here—But It Began Long Ago

HONOLULU—A vocal group of geologists and other scientists are pushing to define a new geological epoch, marked by climatic and environmental change caused by humans. They've got a catchy name—the Anthropocene or "Age of Man"—plus an eponymous journal starting up this month and an international working group considering whether to make the designation official (*Science*, 7 October 2011, p. 32). At a session at the Society for American Archaeology* meetings here, archaeologists argued that it's high time for their field, which studies humans and their activities over geological time, to have a greater voice in the debate.

Most all the speakers at the standing-room-only session agreed that human impacts on the Earth are dramatic enough to merit a new epoch name—and that drawing attention to our changed relationship with the planet is a good idea. But all felt that such an epoch should start thousands of years ago. Rather than focusing on a relatively sudden planet-wide change—a line in a sedimentary deposit where one could plant a "golden spike" as is traditionally done to mark an epoch—the archaeologists outlined an unbroken chain of human influence stretching far back into prehistory. "Humans have been modifying ecosystems over a long period of time," said archaeologist Bruce Smith of the Smithsonian Institution's National Museum of Natural History (NMNH) in Washington, D.C.

Such a view of the Anthropocene contrasts with that of most geologists and ecologists behind the movement, many of whom have

sought a clear time marker for the "golden spike." The most popular suggestion for a time point to end the recognized Holocene epoch, which began 11,700 years ago after the end of the last ice age, is the beginning of the Industrial Revolution about 1750 C.E., when manufacturing began to take hold and human-caused global warming is thought to have begun. Only then, proponents argue, did humans begin to change the chemistry of the atmosphere and oceans worldwide, alter the course of rivers, and transform the landscape, among other impacts. Others have suggested fallout from nuclear bombs as a distinctive Anthropocene signature.

But although the 23-member Working Group on the Anthropocene has no archaeologists or anthropologists, those fields also have bountiful data on major human impacts on the planet, said session chair Todd Braje, an archaeologist at Humboldt State University in Arcata, California. Those data show that humans began making global and large-scale transformations of the Earth long before the 18th century, panel members said.

Jon Erlandson, an archaeologist at the University of Oregon in Eugene, noted that people began transforming continents about 60,000 years ago, when our ancestors began to spread out from their ancestral home in Africa. That's when large-scale hunting, burning vegetation, and cutting down forests, etc., began, and "set the stage for human domination of the earth," Erlandson said.

Shortly after humans arrived in many regions, including most islands and several continents, many large mammals went extinct. Because the climate changed natu-

*Society for American Archaeology 78th Annual Meeting, 3–7 April, Honolulu.

ical *Transactions of the Royal Society A*, a team led by climate change expert Will Steffen of the Australian National University in Canberra, argued that warming of the planet is a key feature of the Anthropocene and that increases in greenhouse gases due to early farming were too small to trigger climate change. The authors also argued against tying the Anthropocene to megafaunal extinctions, claiming that the megafauna had little “appreciable impact on the func-

tioning of the Earth system as a whole.”

Would moving the start of the Anthropocene back into prehistory blunt the epoch’s impact? “When originally proposed, this was a strategy for getting the public to appreciate the extent to which humans were destroying the world,” Smith noted in the question and answer session. But Zeder said that if the Anthropocene does become official in 2016 as proposed, it should be based on solid science. “We are backing away from

coming up with arbitrary markers, and asking what are the human and environmental interactions that are driving it.”

Geologists are apparently willing to hear such ideas. The new journal, *Anthropocene*, plans a special issue on archaeological perspectives, largely drawn from the Honolulu talks, says editor-in-chief and geomorphologist Anne Chin of the University of Colorado, Denver.

—MICHAEL BALTER

EXOPLANETS

Kepler Snags Super-Earth-Size Planet Squarely in a Habitable Zone

The Kepler spacecraft has achieved plenty of milestones in the 4 years and counting that it’s been orbiting the sun. Kepler team members have reported the discovery of ever-smaller exoplanets—down to Earth-size and below—and more and more exoplanets that are in the habitable zone, where a solid, Earth-size planet could have liquid, life-sustaining water on its surface.

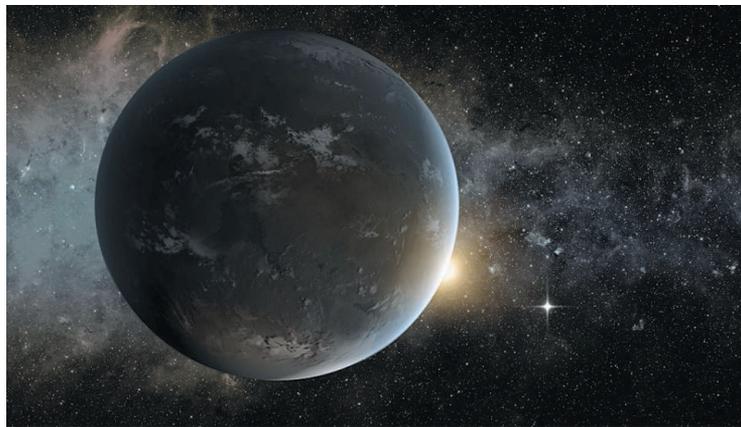
Now, the Kepler team is reporting the discovery of what could be the Holy Grail of exoplanetology: a rocky planet enveloped by a nurturing, warming atmosphere and sporting streams, lakes, and seas. Or maybe not. Team members point out in their paper, published online this week in *Science* (<http://scim.ag.WJBorucki>), that they don’t know whether their new find has water, an atmosphere, or even a solid surface. Indeed, no current, planned, or perhaps even conceivable mission could show that this particular exoplanet is habitable.

None of that is Kepler’s fault. The spacecraft’s only job, after all, is to determine how often Earth-size planets orbit in the habitable zone of sunlike stars. And it has already discovered more than 100 new exoplanets down to the size of Earth’s moon. It has done that by staring year after year at more than 100,000 stars, waiting for the few hundredths of a percent dip in a star’s brightness that signals that a planet is orbiting across the star’s face.

Kepler’s latest find is a system of five planets orbiting a star designated Kepler-62.

The planets range from half the size of Earth to twice its size in terms of diameter. Their “years” range in length from 6 days—no doubt making that planet too hot for life—to a more promising 9 months for the system’s outermost known planet, called Kepler-62f.

Although transit observations yield precise measures of an exoplanet’s size and orbital distance from its star, determining



Imagination run free. Exoplanet Kepler-62f’s rising star and neighboring planet (bright point) are known; the presence of clouds, land, and sea are purely speculative.

whether it actually falls in a star’s habitable zone requires some big assumptions. Calculating how much of its star’s radiant energy an exoplanet intercepts is straightforward enough. But what happens next to that energy depends on a host of characteristics of the exoplanet, none of which is usually known.

The big unknown is the nature of an exoplanet’s atmosphere. The Kepler team follows convention and assumes that the exoplanet has a greenhouse atmosphere of nitrogen, carbon dioxide, and water. The habitable zone—the range of orbital dis-

tances within which this greenhouse would keep working—would extend from an outer boundary beyond which carbon dioxide freezes out to an inner boundary within which the greenhouse would overheat, as may have happened on Venus.

In the case of the Kepler-62 system, only Kepler-62f—super-Earth-size at 1.41 times the size of Earth—falls in this strictly defined habitable zone, but it is well within it. Kepler-62e, slightly closer to its star than 62f, falls outside the strictly defined habitable zone but inside a more loosely defined one. Two other relatively small exoplanets in other systems fall in their stars’ habitable zones, but their sizes are not known, only their minimum masses; they could be super-Earth-size or much larger.

Kepler’s discovery of this possibly habitable exoplanet is another grand achievement for the mission, says exoplanet researcher Sara Seager of the Massachusetts Institute of Technology in Cambridge. But she’s worried about the public’s perception of the discovery. “Kepler has achieved great milestones,” she says, but its mission is “not to say ‘that’s habitable, let’s go there.’ Kepler’s stars are too faint; the amount of information will be too low to demonstrate habitability.”

To characterize the atmospheres of potentially habitable exoplanets, astronomers need systems nearer Earth with brighter stars. The Transiting Exoplanet Survey Satellite (TESS) mission approved earlier this month by NASA for a 2017 launch will find those brighter systems, Seager notes. Still, fully characterizing TESS’s exoplanets will challenge even NASA’s next great orbiting observatory, the James Webb Space Telescope, scheduled for launch in 2018.

—RICHARD A. KERR