Earthmovers

Humans take their place alongside wind, water, and ice

By RICHARD MONASTERSKY

Twenty-five years after his historic moonwalk, Buzz Aldrin wants to put to rest a nagging myth. For the record, Apollo astronauts could not see the Great Wall of China or any other evidence of human existence from a distance of 400,000 kilometers. "That's a misconception. Journalists have fallen into that trap just to be sensationalistic," he decries.

If the truth be told, Aldrin didn't spend much time peering homeward or cogitating his place in the cosmos. "The human astronaut is not able to look for the Great Wall on Earth. He's not able to philosophize on the meaning of life. He's focused on his job in front of him, which is not tripping over the television cable."

From their vantage point only a few hundred kilometers above Earth's surface, astronauts aboard the space shuttle can easily make out *Homo sapiens'* handiwork. Urban sprawl, ribbons of roads, quilted croplands, razed patches of forest, and some national boundaries show up. Yes, even the Great Wall stands out amid the Chinese countryside when the sun hits it just right.

"We do clearly see ways in which human beings are changing the surface of the planet," says shuttle astronaut Jeffrey Hoffman.

In fact, humans are now outstripping geologic processes in their power to sculpt the face of the globe, according to a study by Roger L. Hooke of the University of Minnesota in Minneapolis. Through both brute force and indirect influences, people move roughly 40 billion tons of soil and rock each year, a value that equals or exceeds the material transported by any other single agent such as water, wind, or ice. Thus after 4.5 billion years of shaping this planet, the elements must now take a back seat to a scrawny, squawking ape that had enough intelligence to magnify its own meager muscle power with machinery.

Hooke's findings suggest that humans rearrange an average of 7 tons of earth each year for every man, woman, and child on the planet.

The load would fill more than 100 million coal cars, making a train that stretched to the moon and back two times.

As a geomorphologist — one who studies the shapes of landforms — Hooke has spent his career investigating how glaciers scour and mold Earth's ever evolving face. The effects of humans would also seem to fall within the discipline's purview, because people have been altering the landscape for tens of thousands of years. But Hooke realized that most geomorphology journals and textbooks make little mention of animals, including our own species. So he set out to tally the human impact.

For his simple study, Hooke focused on house building, mining, and highway construction — three cornerstones of civilization that play the greatest roles in modifying Earth's surface. Of the 1.3 million housing starts in the United States in 1992, roughly half required foundation holes or regrading which displaced 800 million tons of earth, Hooke estimated. Domestic mining operations haul about 3.8 billion tons of rock each year, while road construction shifts approximately 3 billion tons annually in the United States.

To calculate global figures, Hooke noted that the world gross national product equals four times that of the United States. Global energy consumption totals almost five times the U.S. amount. He reasons, then, that humanity's total influence on the landscape equals some four to five times the U.S. figure, or about 30 to 35 billion tons of dirt and stone each year.

Such numbers reflect only the land that people transport directly. Other activities, such as deforestation and agriculture, move material indirectly by increasing erosion. That factor causes about 10 billion tons of sediment to wash into river systems each year.

Added together, the direct and indirect effects push people up to the top of the geomorphic ladder, when matched one for one against other land-shaping forces, Hooke reports in the September GSA TODAY, published by the Geological Society of America.

For instance, from figures in the geologic literature, Hooke estimates that plate tectonic forces lift about 14 billion tons of rock per annum in the construction of continental mountain ranges. Volcanic activity in the ocean creates about 30 billion tons of elevated terrain each year. Glaciers around the world transport 4.3 billion tons of sediment annually, while the wind blows a billion tons around.

Only rivers truly rival humanity as earthmovers. After he subtracts the effects of enhanced erosion caused by people, Hooke figures that rivers annually transport 14 billion tons of sediment to lakes or oceans. But waterways both great and small move even more mass short distances through the process of meandering — which shifts the position of a river's channel. The meandering figure alone reaches almost 40 billion tons.

The simplistic approach that Hooke followed leaves his study wide open to critics who might question the numbers. One researcher privately categorized some of the estimates as "SWAGs" (strictly wild-assed guesses). But Hooke says he wasn't aiming for exactitude, merely to point out that geomorphologists must start examining humanity's overall impact on the landscape.

"We aren't having an insignificant effect. We are having an effect that's comparable to that of most other geomorphic agents," he says.

What's more, unlike other forces, humans often push material uphill against gravity and follow no regular physical rules. "Consequently, the visual impact of human geomorphic activity is vastly greater than that of most traditional geomorphic agents," Hooke writes in GSA TODAY.

"Even though we might quibble over some of the numbers, Hooke did us a service by putting this out," comments John F. Shroder Jr. of the University of Nebraska in Omaha, who studies erosion in the Himalayas. Shroder will chair a session on erosion at next year's meeting of the American Association for the Advancement of Science, where Hooke is scheduled to present his findings.

Shroder says humans have so altered the landscape in certain regions that some geomorphologists have had to abandon studies in such areas — the (no longer) Fertile Crescent and China's Loess Plateau, for example. "It's making it progressively harder to study natural processes because they get influenced

so much by man."

As geologists try to understand the evolution of Earth's surface, they have no choice but to adapt. "To future generations of scientists, anthropogenic [human-caused] geomorphology will become a very dominant issue," Shroder predicts.

People, of course, are not the only organism modifying Earth's surface. Grazing animals denude fields, trample soils, and can increase erosion. Plants and microbes help break apart rock. And the 10^{18} insects estimated to populate the planet also do their share, along with earthworms and other burrowing animals.

"On the microscale, humanity is far outpaced," says Harvard University biologist Edward O. Wilson, an international ant aficionado. "The world is alive at your feet and it's in constant motion," he adds. But while tiny animals can jostle the interior of a hill, they can't actually move a mountain, notes Wilson. Their effect is only evident if one takes a close look at the ground.

While larger animals can have a greater impact, their overall influence remains limited because bigger creatures generally have smaller populations. Humans, however, have found a way to break that rule by multiplying in numbers unprecedented for such a large mammal. "It is probable that no other single species of large land animal — we're talking 10 kilogram class or larger — has ever existed with the abundance of human beings," says Wilson.

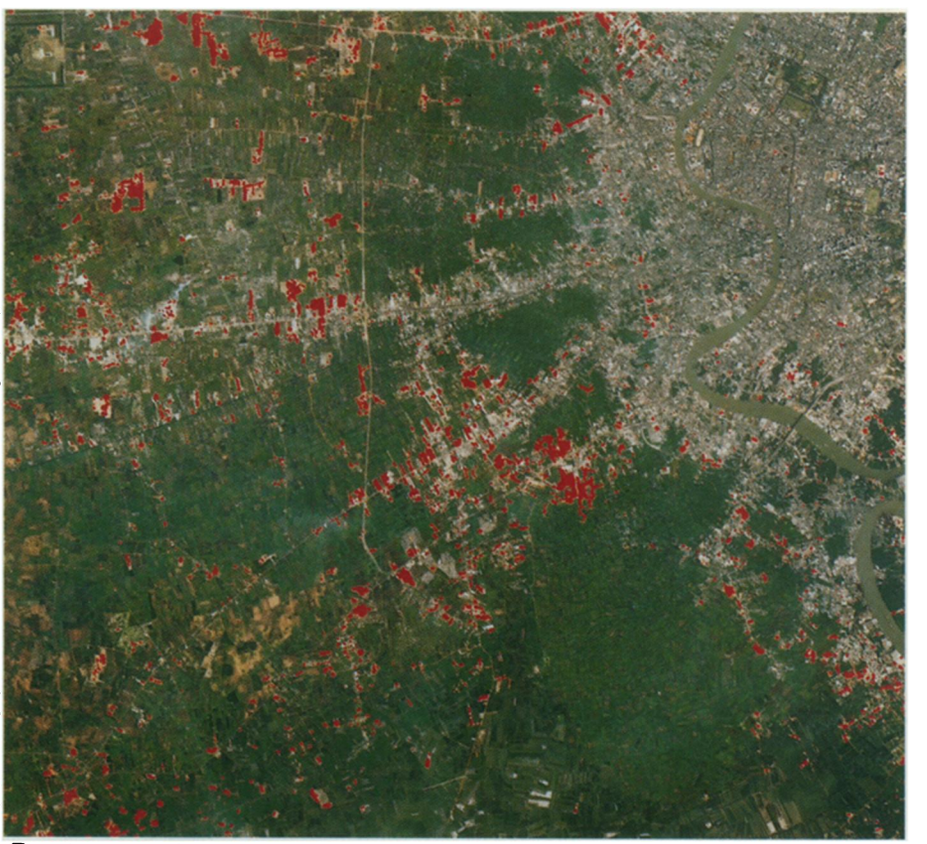
That trend seems unlikely to reverse itself anytime soon. The United Nations estimates that the global population of 5.7 billion people today will swell to between 7.8 billion and 12.5 billion by 2050.

Hooke's study makes no value judgments about the effects of human earth-moving, and reactions to this work break down predictably along ideological divisions. To some, the findings only confirm their ever growing fears of damage to a fragile and endangered environment. Others may take pride in humanity's ability to transform a harsh world into a more suitable and survivable planet.

Both camps, though, should not forget Earth's own power to shape itself. In a single day, 10 billion to 25 billion tons of rock and ash exploded out of Mt. Pinatubo in the Philippines when that volcano erupted in June 1991. Tambora in 1815 may have ejected more than 10 times that amount, while earlier volcanic blasts equaled 100 Pinatubos.

According to astronaut Hoffman, the Philippine eruption dramatically altered the shuttle's view of Earth. "For over 6 months, the atmosphere was so dirty in the equatorial region that you could almost not take pictures of the Earth from space unless you used infrared photography," he says. "That's an unbelievable amount of material put out by a natural process. It makes you realize that some things that people do are fairly small." □

The Big (Blue) Apple: In this false-color image of New York City, taken by the SPOT satellite, pavement and buildings appear as blue, vegetation as red. On the island of Manhattan, Central Park (white oval) stands out as the only major red patch.



Development of the western fringe of Bangkok, Thailand, one of the fastest-growing cities in the world. This shot illustrates Bangkok's rapid expansion by combining data collected by the SPOT satellite in March 1986 with data collected by Landsat in December 1989. Red areas denote agricultural fields that had been transformed for residential, commercial, or industrial uses in the intervening 3.5 years.