one of the missions, Lunar Flashlight, an effort to confirm the presence of ice in permanently shadowed regions of polar craters by shining lasers into them.

Better propulsion could help solve another problem facing planetary small satellites: a lack of rocket rides. CubeSats often piggyback on larger mission launches, but rideshares beyond low-Earth orbit are rare. Solar electric propulsion systems could help craft released into low-Earth orbits make an escape. A small satellite equipped with a Hall thruster could spiral out from Earth to the moon in a few months, VanWoerkom says. Reaching Mars would take a few years.

Scientists are starting to have big dreams for their small packages. Tilak Hewagama, a planetary scientist at the University of Maryland in College Park, wants to send a small satellite to intercept a comet on its first arrival in the solar system. Most comets have swung around the sun many times, and their once-pristine surfaces have grown weathered. But nearly every year, astronomers discover a few that are swooping in for the first time. By then, it is too late to develop a spacecraft to study them, Hewagama says. But a small satellite already parked in a stable orbit could maneuver in time to witness the comet's passage up close—a risky plan that Hewagama says NASA wouldn't be willing to pursue for a larger, more expensive craft.

Timothy Stubbs, a planetary scientist at Goddard, wants to use two 30-kilogram satellites to explore the origin of curious bright swirls on the surface of the moon. One idea is that weak magnetic fields in moon rocks—implanted by comet impacts or a long-extinct magnetic dynamo—might be repelling the solar wind particles that weather and darken the surrounding soil. But understanding the interactions between the particles and the fields requires skimming the moon in a close, unstable orbit that would require large amounts of fuel to maintain. Stubbs's solution: Orbit two small satellites in tandem, linked by a thin Kevlar tether 25 kilometers long, so that a satellite in a higher orbit can stabilize its mate a mere 2 kilometers above the surface.

Both teams plan to submit proposals to the new NASA funding program—if they can whittle costs down to fit the $55 million cap. Small satellites may be cheap, but developing a deep-space mission traditionally requires a big team and lots of testing to pare down risk. Symposium organizer Geronimo Villanueva, a Goddard planetary scientist, says NASA officials are working on changing the rules for small satellites headed for deep space so that higher risk levels are acceptable. "We need to change the way we do business," he says. ■

PHOTO: THOMAS HIGHAM, UNIVERSITY OF OXFORD

EVOLUTION

Ancient DNA reveals tryst between extinct human species

Woman had a Neanderthal mother and a Denisovan father

By **Gretchen Vogel**

The woman may have been just a teenager when she died more than 50,000 years ago, too young to have left much of a mark on her world. But a piece of one of her bones, unearthed in a cave in Russia's Denisova valley in 2012, may make her famous. Enough ancient DNA lingered within the 2-centimeter fragment to reveal her startling ancestry: She was the direct offspring of two different species of ancient humans—neither of them ours. An analysis of the woman's genome, reported in this week's issue of *Nature*, indicates her mother was Neanderthal and her father was Denisovan, the mysterious group of ancient humans discovered in the same Siberian cave in 2011. It is the most direct evidence yet that various ancient humans mated with each other and had offspring.

This bone fragment harbors the most direct evidence yet of ancient interspecies mating.

Based on other ancient genomes, researchers already had concluded that Denisovans, Neanderthals, and modern humans interbred in ice age Europe and Asia. The genes of both archaic human species are present in many people today. Other fossils found in the Siberian cave have shown that all three species lived there at different times. But the new finding "is sensational" just the same, says Johannes Krause, who studies ancient DNA at the Max Planck Institute for the Science of Human History in Jena, Germany. "Now we have the love child of two different hominin groups, found where members of both groups have been found. It's quite a lot of things happening in one cave through time."

Viviane Slon, a paleogeneticist at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, who did the ancient DNA analysis, says when she saw the results, her first reaction was disbelief. Only after repeating the experiment several times were she and her Leipzig colleagues—Svante Pääbo, Fabrizio Mafessoni, and Benjamin Vernot—convinced. That a direct offspring of the two ancient humans was found among the first few fossil genomes recovered from the cave suggests, Pääbo says, "that when these groups met, they actually mixed quite freely with each other."

The bone fragment's characteristics suggested it came from someone who was at least 13 years old. After pulverizing small samples, extracting DNA, and sequencing it, Slon and her colleagues found that its owner was female, and that her genome matched that of Denisovans and Neanderthals in roughly equal measure. Moreover, the proportion of genes in which her chromosome pairs harbored different variants—so-called heterozygous alleles—was close to 50% across all chromosomes, suggesting the maternal and paternal chromosomes came directly from different groups. And her mitochondrial DNA, which is inherited maternally, was uniformly Neanderthal, so the researchers concluded she was a first-generation hybrid of a Denisovan man and Neanderthal woman. The evidence "is so direct, we almost caught them in the act," Pääbo says.

A closer look at the genome suggests her father also had some Neanderthal ancestry, possibly several hundred generations back. And the woman's Neanderthal genes are closer to those of a Neanderthal found in Croatia than those from remains found in the Siberian cave. That suggests distinct groups of Neanderthals migrated back and forth between western Europe and Siberia multiple times.

Along the way, apparently, they freely spread their genes to outsiders. That highlights the question, Krause says, of why Denisovans and Neanderthals nevertheless remained genetically distinct groups. "Why don't they come together as one population if they come together from time to time?" Geographic barriers probably played a role, he says, but researchers need more fossils with ancient DNA, from multiple sites, to understand the true legacy of these prehistoric couplings. ■