same budgets as for Arctic and Antarctic research and logistics.

There are non-fiscal threats as well. A natural gas pipeline, if it's built, would mean more people, more traffic, more way stations, and more gravel excavation. One of Shaver's sites is right next to an old gravel pit that, if reactivated, could destroy the site either directly or by increasing silt and other runoff sufficiently to invalidate longitudinal studies.

To counter these possible problems and more, Barnes and his colleagues at the University of Alaska are beginning to seek support from federal and state officials for a 44.5-hectare research park that would protect the study plots against potential intrusions. The U.S. Bureau of Land Management leases 10.8 hectares to the University of Alaska Institute of Arctic Biology as the station's grounds and has zoned the 31,000 hectares around Toolik Lake as a Research Natural Area. Expanding the size of the protected zone to include the upper Kuparak River watershed, a site of some long-term studies, would safeguard research without impeding oil and natural gas development, says Barnes.

It would also protect Toolik's future and avoid, in Gholz's words, NSF's having made "a huge investment that's thrown out." Toolik deserves special attention, Bingham and others would argue, because of its ability to monitor a key component of global climate change. "Arctic ecosystems are some of the most endangered habitats and organisms on earth," she says. **–ELIZABETH PENNISI**

Archaeology

Unraveling Khipu's Secrets

Researchers move toward understanding the communicative power of the Inca's enigmatic knotted strings, which wove an empire together

In 1956, Peruvian archaeologists uncovered a vessel hidden in the floor of a high-status home in the Inca administrative center of Puruchuco, near present-day Lima, Peru. Inside, they found a kind of treasure: a set of 21 of the knotted strings called khipu. The Inca relied on sets of khipu (or quipu in Spanish) to keep records of their far-flung realm, which extended more than 5500 kilometers, the distance from Stockholm to Cairo.

The Spanish who conquered the empire discovered that it was held together by a highly efficient bureaucracy that controlled the distribution of labor, goods, and services, using streams of khipu to issue orders and record the results. So essential were khipu to the native population, according to Galen Brokaw, an expert in Andean texts at the State University of New York at Buffalo, that the early colonial government reluctantly approved their continued use until they could be displaced by alphabetic texts the Spaniards could understand. Today, only perhaps 600 pre-Hispanic khipu survive.

For more than a century, researchers have sought to understand how these distinctive objects were used within the empire, and whether they functioned as a unique kind of three-dimensional, textile-based "writing." On page 1065 of this issue, anthropologist Gary Urton and mathematician-weaver Carrie J. Brezine, both at Harvard University in Cambridge, Massachusetts, take a step toward answering both questions. Through a computer-aided analysis of seven of the Puruchuco khipu, Urton and Brezine have identified one way that data and instructions were passed up and down the hierarchy from local villages to the powerful central government in Qosqo (modern Cusco). In the process, they also have tentatively made the first-ever identification of a khipu "word."

Almost simultaneously, archaeologist Ruth Shady Solis of the National University of San Marcos in Lima has independently unveiled what is seemingly the oldest khipu—or, perhaps, proto-khipu—ever discovered. Found in a cache buried inside a pyramid at Caral, an ancient city north of Lima that Shady's team has been excavating since 1994 (*Science*, 7 January, p. 34), the object resembles an Inca khipu, except that the pendant strings are twisted around small sticks.

First strings. This artifact from the ancient city of Caral may be a khipu as old as 4500 years.

CREDIT: PILAR OLIVARES/REUTERS

According to Shady, it is more than 3000 years older than the oldest previously known khipu, which date from the 9th century C.E. If so, then khipu, though younger than the world's first writing systems of Sumerian cuneiform and Egyptian hieroglyphics, arose in the third millennium B.C.E. and are among humankind's oldest means of communication.

The Caral artifact's apparent great age of 4000 to 4500 years "indirectly strengthens the case" that the khipu were "more than numeric," notes Daniel H. Sandweiss of the University of Maine in Orono. Ancient writing methods such as cuneiform evolved over many centuries from accounting records, as scribes invented symbols to identify what was being counted. "If what Ruth has found really is a khipu ancestor," Sandweiss says, "then khipu would be following the pattern of other writing systems."

Inca khipu consist of a main cord from which dangle as many as a thousand smaller strings, the latter of which contain clusters of knots. In the 1920s, Leland Locke, an amateur scientist, argued that khipu were simply lists of numbers, with individual knots representing digits and groups of knots on a strand representing successive powers of 10. (Blank spaces function as zeroes.) Locke's rules held true for many khipu, and his view of them as mnemonic devices largely held sway until the 1970s, when the Cornell University husband-wife team of Robert and Marcia Ascher overhauled his work, assembling a detailed khipu database (http://instruct1.cit.cornell.edu/research/quipu-ascher/). They argued that khipu were more akin to writing—and indeed that about 20% of surviving khipu do not fit Locke's rules.

If khipu were a form of writing or proto-writing, they were unlike any other. Scribes "read" the khipu by running their fingers along the strings, sometimes while manipulating small black and white stones—in striking contrast to other cultures' ways of recording symbols, which involve printing or incising