Research News

Science on The Roof of the World

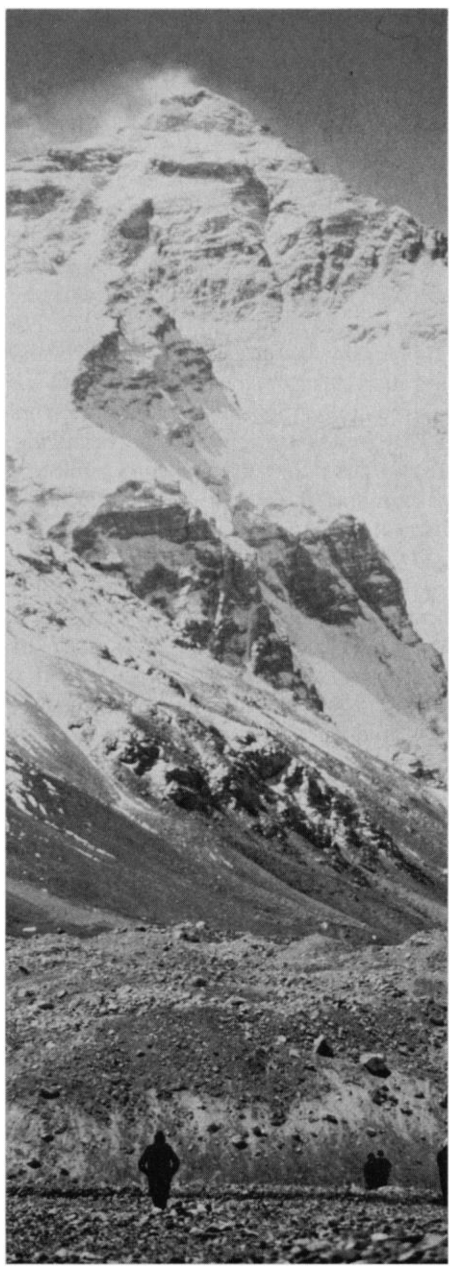
The recent open-door policy of the Chinese government has initiated an exciting new era of research in Tibet, which, scientifically, is one of the last uncharted regions of the globe

TIBET: to the Chinese it is The Roof of the World; to the rest of the world it is pretty much terra incognita, a physical and biological unknown waiting to be explored. That exploration is just beginning, as was graphically displayed at a recent symposium* at the National Academy of Sciences. "Researchers have been enjoying unprecedented field access to China in the past few years," noted the Academy's president Frank Press. "We are experiencing a beginning step towards exciting collaborative research."

Robert McC. Adams, secretary of the Smithsonian Institution, also commented on the rapidity of the recent change. "Five years ago it would have seemed highly unlikely that we could have expected a collaborative research effort on any significant scale with Chinese scientists in the near future, but in just a few years we have exceeded all predictions." Nevertheless, he cautioned, "patience and flexibility are going to be crucial in the development of this collaboration. We must be careful not to impose either the schedule or the components of collaboration."

Tibet is the product of the tectonic forces that some 40 million years ago rammed India into Asia, and continue to this day. The result is a high plateau with an average elevation close to 5000 meters over an area of 1.2 million square kilometers, which dwarfs anything that Europe or the Americas have to offer by comparison. Look at a map of the earth showing regions of permafrost, and Tibet stands out again. For all these reasons the roof of the world is a natural laboratory for geological, climatological, biological, and anthropological research.

Geologists were among the first Western scientists to be invited to Tibet for major collaborative work as a result of a more open attitude to the rest of the world that followed the fall of the Gang of Four. Since 1979 researchers from Britain, France, and the United States have been studying the complex tectonic underpinning of the Tibetan plateau, which, says Peter Molnar of the Massachusetts Institute of Technology, "is the key to understanding mountain building in general" (see box).



Dave Bartruff/FPG

Two giants. *Mount Everest looms over the southern edge of the Tibetan high plateau.*

Because of its huge extent and elevation, the Tibetan plateau has a tremendous potential for influencing atmospheric circulation, both locally and globally. "It sits up there like a huge heating plate on a table," observes Elmar Reiter of Colorado State University, who in collaboration with Zheng Qingling of the Chinese Academy of Meteorological Science, recently began measurements of heat absorption and radiation on the plateau.

The plateau traps a surprisingly large proportion of the sun's energy, says Reiter, which is then pumped back into the atmosphere as sensible heat. It is this radiation that has the potential to influence circulation over great distances, certainly throughout Asia and possibly into the Americas. Once the plateau becomes snow-covered in winter, atmospheric circulation patterns change dramatically, because of the greatly increased albedo: the plateau no longer works as a heating plate. "There's known to be a good correlation between snow cover in Tibet and the seasonal climate in India," notes Reiter. "For instance, a late winter in Tibet is usually associated with a poor summer monsoon in India."

Reiter speculates that Tibet's heating-plate effect may have been substantially modified in recent times. He points out that trees are able to grow there at altitudes exceeding 4000 meters, and yet most areas at this elevation are virtually treeless. Perhaps deforestation has occurred through the overexploitation of trees for domestic fuel, as has happened in several parts of the world, Reiter wonders. "If so, this would have had an enormous effect on the albedo of the plateau in winter," he suggests. "With large areas forested, the albedo would have been significantly lower than it is now, even under heavy snows." The consequence of loss of this forest cover would be "one of the largest man-made impacts on global energy flow in history."

The "open-door" policy that very quickly allowed geologists and other physical scientists entry to China was not, however, open to social scientists and anthropologists. "Anthropologists are always perceived as more

*"Tibet: Science on a high plateau," jointly sponsored by the Committee on Scholarly Communication with the People's Republic of China and the Smithsonian Institution, Washington, D.C., 5 May.

of a potential threat to politically sensitive systems," says Melvyn Goldstein of Case Western Reserve University. "Unlike geologists, who can often accomplish their work in the space of a few weeks and can be kept under the watchful eye of guides and away from the people, anthropologists need to stay in one place for a long time, they speak the language, and get to know the people very well."

Partly for this general reason of caution toward the social probing of anthropologists, and partly because of the inflammatory case of Steven Mosher, a Stanford anthropology graduate student who in 1981 was accused of "unethical conduct" while researching rural family planning practices in China, it took Goldstein 3 years of persistent effort finally to get permission to do a linguistic study in Tibet. Goldstein, a specialist in Tibetan language and culture, says "I decided to do a linguistic study initially, because it is less political." The 5-month project, which started in May 1985, involved collecting "a very large corpus of new lexical terms . . . and two social-linguistic surveys" and was carried out in conjunction with the Tibet Academy of Social Sciences.

A year later Goldstein returned, together with Cynthia Beall, also of Case Western Reserve, to embark on a much more ambitious project, this time an anthropological and physiological study of the Phala Shang nomads of Western Tibet. "These people live at altitudes of between 4800 and 5400 meters and are the highest natural populations ever studied," says Goldstein. "They live in a unique ecosystem, which is dominated by grassland, where they herd yaks, sheep, and goats. We are taking a grassland ecologist with us on our next trip, because we are very interested in studying the cultural ecology of these people."

The anthropological literature has a somewhat romantic view of nomads, says Goldstein, portraying them as free spirits roaming a landscape that is regarded as theirs by right if not in fact. "It is different with the Phala," says Goldstein. "Until 1959, when the Chinese took over, they were serfs of Tashilhunpo, the seat of Tibet's second great incarnation, the Panchen Lama. Soon after that the commune period was instigated under the Cultural Revolution. Then, in 1981, the commune property—the sheep, goats, and yaks—was equally divided among the individuals."

This unusual background gives the anthropologist an opportunity, in studying the nomadic system of the Phala, "to try to understand what is intrinsic nomad, what derives from Tibetan culture, and what comes from the Chinese system." One thing

Making the World's Roof

On average, India creeps 5 centimeters closer to central Asia every year. This collision between continents has been going on for about 45 million years, so something had to give—the northern edge of India to form the Himalaya, Tibet to form a huge, towering plateau, and perhaps much of Southeast Asia to form a patchwork of displaced crustal blocks.

Until recent years geophysicists wondering exactly how these processes work—and which of them predominate in the world's premier example of an active continent-continent collision—had to ponder the problem from afar. But, as highlighted at the recent National Academy of Sciences symposium, researchers can now stand on the rocks and the faults that are crucial to unraveling the problem.

Peter Molnar of the Massachusetts Institute of Technology pointed out the grand scale on which the 45-million-year-long collision between India and Eurasia has elevated the crust. With Mount Everest to its credit, the Himalaya has a deserved reputation for extreme altitude. But more than half of the Tibetan Plateau, which is the size of Alaska, stands higher than 5 kilometers. Nothing at all in the conterminous United States is that high, and only a few small areas in all of North America reach that height. Mountains as high as 7 kilometers dot the plateau, Molnar noted, but in his recent 500-kilometer traverse out of Lhasa he encountered no incline steeper than the hill he lives on in Boston. The plateau is surprisingly flat.

Explanations of how so much of Tibet got so high have been around for 60 years. They run the gamut from a relatively buoyant India sliding all the way under Tibet and floating it to its present height, to India ramming Eurasia and squashing it upward. Molnar prefers squashing to explain the elevation of at least the plateau's northern half, but he concedes that the data are as yet too few to prove it.

Thickening of the Tibetan crust is not the only way that Eurasia has accommodated the intruding India, as Paul Tapponnier of the Earth Physics Institute in Paris emphasized in his segment of the symposium. Northern Tibet, for instance, is apparently being extruded to the east out of India's path at a rate of roughly 2 centimeters per year, according to Tapponnier, which is almost as fast as India is slipping beneath southern Tibet. Extrusion of crustal blocks has probably played a significant role in this collision and in mountain building in general, said Tapponnier. Many of the particulars are speculative at this point, he noted, but India may have pushed aside Indochina, the Sunda Islands, and Malaysia.

Understanding how the India-Eurasia collision builds mountains that may resemble the early Appalachians would have more than purely intellectual rewards. Clarence Allen of the California Institute of Technology told the symposium of his trip with colleagues into southwestern China (the former Kam region of Eastern Tibet) to study the Xianshuihe fault system, which seems to form one of the boundaries between Tapponnier's extruded blocks. The system has generated four earthquakes larger than magnitude 6.8 in this century.

On the basis of geological analyses made during Allen's trip, the fault is slipping about 15 millimeters per year, which is slower than but in the same range as slippage on the San Andreas. In fact, says Allen, the Xianshuihe fault is a fine analog for the San Andreas. In particular, the geologic products of the Xianshuihe fault's motion that are used to reconstruct its behavior are well preserved—erosion is slow at high altitude and, unlike the situation on the San Andreas, no shopping malls are built across the fault. All in all, the Xianshuihe fault presents promising opportunities for research on earthquake prediction and hazard evaluation, he said.

In a discussion period at the end of the morning's talks, these geophysicists agreed that although the new access to Tibet is heartening, work there is still more difficult than they would like. But, they quickly noted, fieldwork can be complicated by bureaucratic obstacles and delays in any number of other countries. In addition, the logistics of working in remote, high-altitude regions puts a strain on the hosts of visiting scientists that would be a burden anywhere.

Not too surprisingly, the interests of host and visitor in Tibet are somewhat divergent, Molnar and Tapponnier noted. Although they want to know how crustal motions lead to mountain building, their hosts are primarily interested in what rocks are there and what resources they might contain. The prospects for mutually beneficial cooperation would appear to be good. ■ Richard A. Kerr that has happened since the splitting up of the commune property 6 years ago is a significant degree of economic differentiation between families, or "tentholds." Some families now own ten times as many animals as some other families. "This is very important to us," says Goldstein, "because it is a very live issue in the rest of China just now and here we have an opportunity to examine on a microlevel what led some people to succeed while others failed."

Beall's principal interest is in the physiological adaptation of the Phala to high altitude. "The textbook case is the Andean Indians," she says, "who have very high hemoglobin levels, barrel-shaped chests, and enormous lung volumes." Beall recently had an opportunity to study Tibetan-speaking populations in Nepal, but these people live at 1000 to 1500 meters lower than the Phala. With new data on 180 Phala people, the early indications from the Nepal results appear to be confirmed. "Although these Tibetan populations live at higher altitudes than the Andean Indians, the Tibetans have lower hemoglobin levels than would have been predicted, they don't have barrel-shaped chests, and their average lung volume is not as high."

Assuming the Phala have been living on the Tibetan plateau for a very long time, for which there is some archeological evidence that needs to be confirmed, these new results seem to imply that human adaptation to reduced oxygen levels at high altitude can take different directions.

Although there is a considerable degree of excitement about the newly available opportunity to carry out research in China in general and Tibet in particular, there are problems. "We are charged outrageously high costs for everything we need," one geologist told *Science*. "Our last expedition cost $200 a day for each member of the party, which is much higher than you'd expect virtually anywhere else in the world."

It has to be acknowledged that materials inevitably are more expensive in Tibet, simply because of the costs of getting them up to the high plateau. But it is also true that from the local trader to the highest official, there is often a tendency to charge foreign scientists what some consider to be exorbitant prices for everything from lavatory paper to vehicle hire. As a result the National Science Foundation recently protested at fees being levied by Chinese officials for U.S.-funded field trips.

As Adams says "patience and flexibility" are clearly going to be required while the Chinese and visiting scientists come to grips with the opportunities and responsibilities that flow from the new era of collaborative research efforts. ■ ROGER LEWIN

Ocean Drilling Details Steps to an Icy World

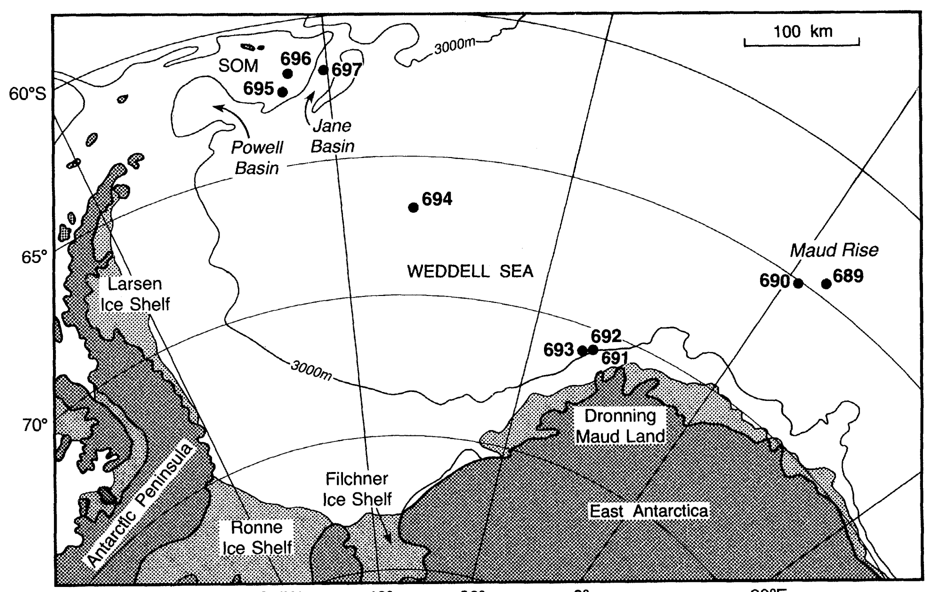
From the most southerly scientific ocean drilling in a decade, researchers are tracing Earth's jerky slide into glacial times

FOR 2 months early this year the deep-sea drilling ship JOIDES *Resolution* played tag with encroaching icebergs as it collected almost 2 kilometers of sediment cores from beneath the far southern sea floor near Antarctica. In those cores are clues to how 40 million years ago the Antarctic region, a pivotal cog in the global climate machine, began slipping step-by-step from a warm, ice-free climate into its present deep freeze in which it harbors 24 million cubic kilometers of ice.

Shipboard analyses of cores are already adding further support to the existence of an early ice-free East Antarctica (the continental landmass of Antarctica), the appearance of ice as early as 35 million years ago, and the durability of the smaller West Antarctic ice sheet that, contrary to recent fears, can stand up to a less frigid climate.

The Ocean Drilling Program's (ODP) strategy during its Leg 113 cruise in high southern latitudes was to follow close behind the breakup of summer sea ice as it progressed around the Weddell Sea, the embayment formed by East Antarctica and the Antarctic Peninsula, which is opposite the tip of South America. The strategy worked, with the help of an ice picket vessel that towed threatening icebergs off a collision course with the immobilized JOIDES *Resolution*. The ship recovered cores from 22 holes at nine sites that sampled sediments influenced by, depending on the location, the biological productivity of surface waters, East Antarctic climate, the production of cold, salty bottom water that flows as far north as New Jersey, and the glacial history of West Antarctica.

According to the initial reports from the shipboard party, there is every indication that Antarctica was unglaciated before about 40 million years ago. The variety of marine microfossils suggests that Antarctic waters were warm, the types and amount of clay are reasonable only if continental erosion oc-



Drill sites in the search for a climate history. *Although sea ice prohibits drilling at these sites except during a few months of the year, and even then poses a threat to the drill ship, the area of the Weddell Sea has a rich record of changing climate on land and in the sea. In addition, much of the water that flows through the deep sea and refreshes it first sinks from the surface of the surface of the Weddell Sea. The tip of South America would be just off the upper left corner of this map.*