Chapter 1

Rediscovering the Desert Lab

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The tradition of an academic festschrift ("feast writing") by former students and colleagues in honor of some patriarchal "Herr Doctor Professor" (do Frau Doctor Professors succumb to these things?) is dubious. I'm told that herpetologist Carl Gans, a faculty member and former chairman of the Biology Department of the University of Michigan, was so honored, in a spoof, when he was a precocious graduate student at Harvard. To be sure, I was pleased when Jim Mead and Larry Agenbroad broached plans for a gathering at Mammoth Hot Springs, South Dakota, one of my favorite places. Then they invited me to write something, "... if you want," said Jim Mead, in his offhand way. I took this as a chance to shed some light on the Desert Laboratory, my home port, and the spawning ground of most of the guests at the Hot Springs gathering, as well as many that were not.

That's the rub. The location for our rendezvous meant that only a sample of the many alumni and friends of "The Hill" could be on hand. "The Hill" is Tumamoc, rising to almost 3000 feet above St. Mary's Hospital and overlooking the west side of Tucson in southern Arizona. "Tumamoc" is Tohono O'Odham (Desert Papago) for horned toad. Founded in 1903 by the Carnegie Institution of Washington as a desert botanical laboratory, the buildings became the launching pad in the late 1950s of the Program in Geochronology at the University of Arizona. The grounds comprise 870 acres (350 hectares) inside an ancient fence which is kindly honored by our neighbors. The vegetation is Sonoran Desert with creosote bush, palo verde, saguaro, brittle bush and 300 other species of native vascular plants along with 50 alien species (Burgess *et al.*,1991). There are permanent plots, repeat photo stations, maps of individual saguaros going back to 1909, and other data of unique value to desert ecologists. Currently, the Hill is being rejuvenated as a "Desert Laboratory" by various departments in the University and continues to be an academic ashram for those fortunate to be in residence. Wildlife ecologist Dave Brown calls the Desert Laboratory the "*Jerusalem of Desert Rats.*" Author Larry Clark Powell says, "If Tucson has an Acropolis, this is it, the "Hill of the Horned Toad."

I hope my sketches of some of the post-Carnegie research ferment on and off the "Hill" will entertain not only the principals but also friends and supporters. Even members of the Mammoth Site who do not know the Desert

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Lab on Tumamoc may take an interest in the place where Larry Agenbroad and Jim Mead cut their teeth. Finally, those devotees of the Desert Lab who find I have overlooked the really important events in the last few decades on the Hill or, worst of all, failed to mention their names, will have to settle for a heartfelt *mea culpa*. I am forgetful, and I often treat my favorites with less care than strangers. The Desert Lab deserves more than one voice. I encourage you to *schrift* for yourself.

The geochronology decade: 1956-1965

Organized research on the environment of the arid west began on Tumamoc Hill when Carnegie botanists undertook their studies over ninety years ago. Their findings yielded a rich harvest on physiology, taxonomy, distribution, community composition, and demography of desert plants (McGinnies, 1981; Bowers, 1988). What transpired after Carnegie and the U.S. Department of Agriculture (USDA) interregnum is poorly known beyond our portals. Outsiders may not be fully aware of the research on historical ecology ("deep history") and related fields based on new approaches to the fossil record of arid regions and emanating from Tumamoc and its Desert Lab in the second half of this century. It was the contribution of an energetic and enthusiastic cadre of University of Arizona graduate students, research associates, sabbatical leave visitors, and some faculty, joined by a small and very productive U.S. Geological Survey team. The devotees, the graduate students especially, loved the place. Their research resurrected a reputation established by our predecessors.

I first visited Tumamoc Hill in November 1957 when my new boss and the driving force behind the University of Arizona's new program in Geochronology, Terah (Ted) Smiley, invited me to his office which we would share. It is now the library and conference room in the main building. We discussed details of setting up our new National Science Foundation (NSF) grant on ice age and postglacial pollen analysis. Our budget would cover salaries (mine was $6100 a year), supplies and radiocarbon dates, a crucial ingredient in our proposal. I was fresh from the east coast, very glad to have a research opportunity in Arizona and very happy to be close to México where I had done some fieldwork and expected to do more.

Then, as now, "The Hill" featured a collection of three small stone buildings with three younger metal "tin" buildings immediately to the south. The Geochronology Program shared space with S. Clark Martin and Herb Hull of the USDA, both highly able botanists and researchers that we were glad to have as neighbors. The grounds were secured for the University in the late 1950s by legislation introduced by then Arizona Senator Carl Hayden on the initiative of then University of Arizona President Richard Harvill. Later, "The Hill" had two narrow escapes from assaults on its integrity. The first was the proposal to level the old stone buildings and replace the Desert Lab with a teaching hospital. Phil Krutzsch, a Professor of Anatomy, was on the Site Committee and successfully opposed the idea. The second was the proposal to move married student housing at "Polo Village," the grounds the University's teaching hospital would come to occupy, out to the Desert Lab. The Nature Conservancy helped scuttle that scheme.

At the lab I found Ted puffing his pipe behind his desk ready with a big surprise. My mind was on this beautiful old building enmeshed in desert. Ted handed over the contents of some paper bags filled with dry material that looked suspiciously like some sort of manure ("road apples"). The road apples looked too big to attribute to a horse.

"Have you ever seen anything like this?" Ted inquired. I certainly had not. "It's ground sloth coprolite," Ted explained. (In those days we didn't say "shit.") The fossil manure had

been carefully collected in stratigraphic sequence by anthropologist Richard Shutler from a dry cave in the western Grand Canyon. The samples had a distinctive pungent odor that was not offensive. One bag held pack rat midden debris including lozenge-size pellets of an artiodactyl which we later decided must be dung of Harrington's extinct mountain goat. The midden also yielded cactus aureoles and twigs of a conifer that UA taxonomist Charles T. Mason identified as Cupressaceae (juniper or Arizona cypress). Unwittingly we were looking at the dung deposits of extinct animals along with plant fossils of the last ice age. Much future research would follow study of similar material. The old Desert Lab seemed to be spinning through a time warp. I was enchanted. With such fossil material, new light could be shed on late Pleistocene climates and the mystery of late Pleistocene extinctions.

To initiate pre-Pleistocene palynology, paleobotanist Jane Gray arrived on the Hill on a Rockefeller Foundation grant to the University. She helped me cobble together a pollen diagram from the dung samples. Dick Shutler generated radiocarbon dates from Lamont Geophysical Laboratory and Bruno Sabels, assisted by geochemist Paul Damon, contributed chemical analysis of trace elements. Our findings did not reveal any obvious dietary explanation for sloth extinction, including trace metal deficiencies, one of the notions at the time.

Much happened in the next twelve years including travel to Poland, Costa Rica, Africa and Madagascar and I did not actually enter Rampart Cave itself until 1969. I flaunted a cardinal rule for the paleontologist: "Never publish on an important fossil locality that you have not seen yourself." Later I discovered how little time there would be to do research in Rampart Cave.

I did manage to make a field trip with Bernie Arms, our lab assistant, to Bat Cave below Quartermaster View just upstream from Rampart Cave. To mine the guano, the U.S. Guano Corporation built a million dollar tramway from the Hualapai Reservation to the cave across the Colorado River, packaging the guano for retail sale out of surplus buildings at the Kingman airport. We had learned of the project from an article in *Life Magazine* and from ads in local newspapers.

Bernie and I thought we might find interesting fossils, perhaps even more ground sloth dung in Bat Cave. We contacted Mr. Varley Compton of the U.S. Guano Corporation and were promised a chance to inspect their operation. In their cable car we swung off the rim of Quartermaster View and descended half a mile into the Canyon to find ourselves dangling above the Colorado River. From the far side landing tower a much smaller cable delivered the miners to the cavernous mouth of Bat Cave. Inside, all the deposits we saw looked like bat guano. Fresh guano reeks of ammonia and it is unlikely that large mammals such as ground sloths would inhabit the premises when guano was raining down.

The only fossil bones we saw were small, evidently those of *Tadarida*, the Mexican free-tailed bat of Carlsbad Caverns fame. I was disappointed when the guano yielded no fossil pollen, only wing scales of small moths and exoskeletal parts of beetles of no paleoclimatic significance. One guano sample was around 12,000 radiocarbon years old, old enough to be contemporary with the Rampart Cave ground sloths. We were in the right region and sampling the right time frame. Our breathtaking ride into the Grand Canyon by cable car entailed a means of transport that inflicted minimal damage on the land while providing ideal interpretive opportunities. Soon after our visit, an Air Force jet from Nevada buzzed the Inner Gorge and struck the cable with its tail. Somehow the jet survived, although the cable did not, and the system was abandoned. Tower parts are still in evidence. As far as I know, no other paleoecologists visited Bat Cave during the mining operation.

To showcase our program Ted started a Geochronology Colloquium, with tea, on Friday afternoons. A small and enthusiastic interdisciplinary mix of geologists, biologists and archaeologists could be expected. One day Ted told me that "Dr. D" wanted to attend our next colloquium and would I drive him out from the Tree-Ring Laboratory on the campus? I would. At 89, A.E. Douglass was a bit unsteady but quite alert and when we reached our gate at the foot of the Hill he wanted to make sure no traffic was coming down! Dr. D's last previous trip to Tumamoc, I learned, predated the construction of the present paved road, which is narrow enough to be sure, but not one-way like the one he remembered from the 1930s.

The Hill hummed with activity. In the pollen lab, totally rebuilt with NSF funds, Bernie Arms extracted alluvium from archaeological sites and a botany grad student, Jim Schoenwetter, helped count the pollen. At Matty Canyon in the Empire Valley southeast of Tucson, anthropologist Frank Eddy and geologist Spade Cooley were studying a beautifully stratified deposit. Over 5 meters of vertical exposure with buried organic lenses of ancient cienega deposits looked ideal for radiocarbon dating of our pollen profiles. The profiles accompanied archaeological remains, including pit houses.

Al Traverse, a Harvard-trained paleo-botanist then employed by the Houston Development Lab of Shell Oil Corporation offered us some free radiocarbon dates. With his classmate, Jane Gray, located on Tumamoc, Al decided to come for a visit. If not a rival of the Grand Canyon, Al assumed Matty Canyon must at least be scenically impressive or it would not be called a canyon. On our visit to the site Al discovered himself in the middle of a broad valley of mesquite grassland. He clambered down the banks of the arroyo, the entire section at most 25 feet deep and barely 3000 years old. Al kept his peace but I could see he thought Matty "Canyon" was a misnomer. He wondered if alluvial palynology was geologically old enough to take seriously.

While not old, the changes in the fossil pollen at Matty Canyon helped to initiate an alluvial chronology, one of our NSF research objectives. We were delighted to find some fossil pollen of maize (corn) in the older units, tangible evidence for prehistoric corn cultivation in Arizona. More maize (*Zea*) pollen appeared in a buried alluvial unit at Point of Pines where anthropologists Emil Haury and Ray Thompson ran the University of Arizona archaeological field school. Radiocarbon dates associated with the maize pollen ranged from 2300 to 4000 years old. With understandable pride, Jim Schoenwetter and I published our first paper in *Science* and caught some criticism from moss-backs for our breezy title: "Arizona's oldest cornfield." Years later, accelerator dates on corn cob fragments would solidly establish the age of *Zea* in the region. From the top of Tumamoc Hill itself, archaeologists Sue and Paul Fish have recently excavated bits of corn cobs of which the oldest was accelerator dated at around 2700 years ago. Bruce and Lisa Huckell also verified the idea that corn was being cultivated in southern Arizona before ceramics (pottery) came into use.

Archaeology aside, what I most wanted was a pollen record through sediments incorporating bones of extinct animals, ideally at a kill site such as the one at Lehner Ranch near Hereford on the San Pedro River. I wanted pollen evidence reflecting the environment experienced by the mammoths. For his Masters thesis archaeologist Lex Lindsay struggled with pollen extraction of samples from the Lehner Ranch, a mammoth kill site being excavated by the Arizona State Museum. I assured Lex that techniques I had learned in Ed Deevey's pollen lab at Yale incorporating hot concentrated hydrofluoric acid (HF) would do the trick. Admittedly, hot HF is not to be trifled with, and to handle it our centrifuge tubes had to be made of Nalgene, an acid- and a heat-

resistant plastic. The method yielded countable pollen extractions from San Simon, an Arizona cienega that University of Arizona botanist Eddy Kurtz kindly helped me core in the summer of 1956. Surely, the new technique would help recover pollen from the beds yielding the intriguing fossil mammoth-Clovis point association at the Lehner Ranch. I was wrong. The extracted residues were milky white, with pollen grains obscured by a siliceous colloid that resisted further treatment.

Eventually Peter J. Mehringer, Jr. (Pete) managed to dissolve most inorganic colloids with concentrated nitric acid. Even then, the Lehner pollen samples were miserable to count, and the results (including scarcity of tree pollen) seem discordant with what I think Cochise County should have looked like over 10,000 years ago.

In the spring of 1962 Pete and C. Vance Haynes enrolled in my pollen course. As part of the learning experience they were assigned projector duty at the First International Pollen Conference which attracted some 200 scientists to the University of Arizona campus during Easter week break. The conference was the brain child of Ted Smiley, ever the visionary. I assured Pete and Vance that they would hear and learn about the most recent research being attempted in this new field. It turned out that the projectors of those days were too noisy to allow the operator to hear anyone not shouting in his ear!

Field trips before and after the conference were planned, announced and filled. At the time biometrician Jim Mosimann was helping us with statistical interpretations of pollen from the Willcox Playa. Bill Byers was a grad student, investigating fossil pollen from Glen Canyon and Wetherill Mesa in Utah. Jim, Bill and I teamed up with Roger Morrison of the U.S. Geological Survey to guide a group of twenty palynologists and botanists on a visit to the Cloud Forest at Rancho del Cielo in southern Tamaulipas, México, 1500 miles southeast of Tucson. We had gone to all the trouble because we felt that anyone studying fossil pollen had to see "anomalous" mixtures of trees with good early Tertiary fossil records, in this case temperate *Liquidambar* (sweet gum), beech (*Fagus*), beech drops (*Epifagus*), ironwood (*Carpinus*) and fir (*Abies*) growing with tropical *Podocarpus*, *Meliosma*, *Eugenia* and tank bromeliads in a moist forest whose terrestrial fauna curiously lacks the Appalachian affinity seen in the plants. The field party, which included ecologists Pierre and Francoise Dansereau, Estella Leopold, Loren Potter, Matsuo Tsukada, Bill Watts and various European palynologists, was properly smitten with the Rancho del Cielo Cloud Forest and its guardian, Frank Harrison. It took us three days of demented driving through the Chihuahuan Desert of northern México to get back to Tucson in time for the conference.

Glowing with the perceived success of the cloud forest excursion, I imagined the post-conference field trip to playa lakes and alluvial outcrops in Arizona, New Mexico and west Texas would be routine. Our first stop was at Whitewater Draw near Double Adobe, the type site of early Holocene alluvium in the region. Several 8000-year-old radiocarbon dates and fossil pollen had come from sediments that had once disgorged bones of mammoth and other extinct fauna. I would interpret the record to Doug Byers, Ed Cushing, Frederick Johnson, Jock McAndrews, Gurdip Singh, Herb Wright and other luminaries, some old hands at alluvial geology. I had read the literature and had no doubt that I could read the pollen record in the outcrop, having collected and counted it myself. Pete Mehringer and Vance Haynes dutifully accepted the task of cleaning up the sections at Double Adobe for our field inspection.

They also bore the brunt of the field interpretation when unexpected questions I could not answer were raised about the depositional gaps (breaks in the sequence) which I had not

noticed. The idea began to grow on me that there might be problems with the pollen record at Double Adobe. For one thing, it was not securely associated with the extinct fauna. For another, it suffered gaps of unknown duration. In any case, it was not a kill site and eventually Vance worked out that, contrary to expectations, radiocarbon dates on mammoth sites with cultural material were all around 11,000 years old. Much later when Mike Waters trenched the Double Adobe flood plain with a back hoe I would better appreciate the complexity of the cut-fill deposit.

On the recommendation of archaeologist Ted Sayles, who had collected a mammoth tooth at the spot, Jim Schoenwetter and I collected a Holocene pollen section near Fairbank on the San Pedro River. Exploring the same wash, Pete and Vance discovered the Murray Springs mammoth-Clovis site. Sayles had what was probably a mammoth molar redeposited from Murray Springs. Mammoths at Murray Springs proved to be 11,000 years old, verifying Vance Haynes' chronology elsewhere. To our dismay, the section lacked fossil pollen. Aside from Lehner we were having trouble finding fossil pollen and fossil mammoth bones *in situ*. Many of the older alluvial outcrops proved sterile or virtually so. Jane Gray also was experiencing difficulties with fossil pollen in outcrops of older (late Tertiary) sediments. My enthusiasm for arid land alluvial palynology began to cool. My impression of the abilities of Haynes and Mehringer soared, especially after they applied their skills to the excavation of the Tule Springs site outside Las Vegas, Nevada, using new protocols for pretreatment of radiocarbon samples. As a result, the alleged pre-Clovis age of the site collapsed.

For fossil pollen in arid land sediments the black muds cored from the floors of "dry lakes" such as the Willcox Playa in southeastern Arizona were more promising. For one thing, the reduced muds were rich in well preserved fossil pollen and fossil algae. For another, the basins were deep. Hundreds or even thousands of feet of lacustrine sediments could be expected in the arid west, a land of block-faulted basins and ranges. With luck and a hefty budget for core drilling, it might be possible to build a pollen chronology through the entire Pleistocene, the last 1.7 million years. So far we had the upper 140 feet from the Willcox Playa, an undated drill core with well preserved pollen in many levels.

My lab assistant Harrison (Harry) Yocum counted much of the fossil pollen from the Willcox Playa. One quiet afternoon he sensed he was being watched. From a small hole in the ceiling Harry detected a nose, two bright eyes, then a head and ears of a ring-tailed cat (*Bassariscus*). The animal returned on successive afternoons and grew more bold, perching on top of a cabinet. When Harry fed it by hand, matters got out of hand. At night the ring-tail began to explore the lab. It jumped onto Jane Gray's drafting table, urinating on and ruining the final copy of a painstakingly drafted pollen diagram. Perhaps it thought the scent of India ink was the territorial mark of a rival; I don't know. Other outrages followed, including destruction of an expensive new pair of field boots and the slaughter in its cage of a pet parakeet named "Shreve." Finally a new policy was implemented. Ring-tails would not be fed and all access holes would be plugged.

Our pollen successes attracted talent. In the mid 1960s Dave Adam arrived on the Hill ready to explore long cores from western basins. We decided to try to recruit the help of a new addition to the University's Botany Department from Chicago, Willard Van Asdall. We heard that Will was interested in the Chenopodiaceae, including the salt bushes. They favor alkaline soils on the shores of dry lakes such as the Willcox Playa. They were major contributors to the fossil pollen record. We decided to introduce Will to the Willcox Playa. We asked my pilot friend Alexander

"Ike" Russell, who was taking me into the mountains of Sonora to collect plants around remote airports, to fly us to Willcox in his Cessna. When we got to the playa, roughly eight miles wide, Ike decided it was dry enough to land, first testing his opinion with a touch-and-go to make sure the surface was dry and hard enough to be safe. From our impromptu airstrip we could walk to meter-high mounds, wind-blown teardrops perched on the floor of the dry lake. The mounds are formed of clay pellets accumulating in the lee of bushes of the shrubby chenopod *Suadea*. While Will was suitably impressed, he found better things to do than tackle the ecology of dry lake salt bushes. In coming years, through Will's guidance, a sizable and very talented group of ethnobiologists graduated from the University.

In 1962 Jane Gray left for a tenure-track position at the University of Oregon. She was succeeded on the Hill by G.O.W. (Gerhard) Kremp, formerly with the U.S. Geological Survey. One of his students, Al Gottesfeld, finished a master's thesis on the terrestrial paleoecology of the Triassic at Petrified Forest. Al loved the desert and camped out in it whenever he could. One night he called to tell me to come up to the lab with an ice chest. He had returned from Rocky Point on the Gulf. After witnessing a fabulous grunion run at the height of spring tide, Al had shoveled grunion and ice into the back of his truck and raced back to the Hill to share the fresh catch with all comers.

While the Geochronology experiment would soon be folded back into the Geology Department, I viewed the first years as very promising. We had established the potential of and some limitations of Quaternary palynology in arid regions and uncovered new evidence for glacial age cooling at low latitudes. Dave Adam and Jim Mosiman made pioneering contributions to the statistical treatment of pollen counts. To traditional arguments that the extinction of late Pleistocene megafauna was driven by climatic change, Pete and I had probed an interesting alternative, "overkill." Graduate students from various parts of the country found their way to the Hill, such as ethnobotanist Vorsila Bohrer, geologist Charles Schweger and entomologist John Mathews. Charlie and John were both interested in Beringian deep history. An Argentinean paleobotanist, Carlos Menendez, and a Mexican palynologist, Lauro Gonzalez, came on sabbatical leave visits. I was now eligible for one of those myself.

Sabbatical I. East Africa and Madagascar

Supported by a Guggenheim Fellowship, my first sabbatical which began in 1965 brought the opportunity to gain a wider view of both the Desert Lab, of arid land ecology, and of megafaunal extinction. I wanted to see the "living megafauna" in its African heartland and to visit some fossil sites, especially Olduvai Gorge being dug by Louis Leakey. My close friends, Ike and Jean Russell, decided to come along in their Cessna. We could visit more localities by air than on the ground. They would help with field and lab work. I was overjoyed.

Before we left I would participate in the International Quaternary Association Congress of ice age geologists from around the world gathering in Boulder, Colorado. From a symposium on "Pleistocene Extinctions" Herb Wright helped me edit a book which featured chapters by Ed Deevey, John Guilday, Vance Haynes, Art Jelinek, Estella Leopold, Ernie Lundelius, Pete Mehringer, Nikolai Vereshchagin and other friends of the Desert Laboratory. Led by Leo Heindl, there was a post-Congress field trip by bus through various parts of the Colorado Plateau. Most of the stops interpreted surficial geology. While scenic, many of the experts wanted more. They wanted to see a fresh exposure of an important site. At Lehner Ranch the conferees were delighted to see trenches exposing dated units and fossil pollen embracing the famous fossil mam-

moth-Clovis association, all carefully prepared by Pete Mehringer and Vance Haynes. Ed and Lynn Lehner, the genial and talented owners of the site, hosted the crowd and added the names of a variety of eminent out-of-state and foreign archaeologists and geologists to their guest book. The years would see many more such luminaries coming on pilgrimage to the Lehner Ranch on the Upper San Pedro Valley. Most tourists to the region are interested in Tombstone and the shootout at the O.K. Corral. The spear-out of mammoths by the first Americans has yet to find its public.

In October I left my family in Tucson and flew to Cairo via England. In Cambridge I gave a seminar on my favorite subject, Pleistocene extinction, to Harry Godwin's Subdepartment of Quaternary Research. On arrival in Cairo my BOAC jet flight was delayed a few minutes by traffic. The traffic, it turned out, was Ike's Cessna cleared to land ahead of us at the Cairo airport. Ike and Jean had shipped the Cessna by boat across the Atlantic and flown it from England through Spain to Egypt. For the flight to Nairobi we were joined by a friend of the Russells, Major William Swan, U.S. Army (Ret.). With the four of us (and lots of excess baggage), the Cessna was truly overloaded.

Departing from our airway instrument flight plan to Aswan, we flew "by sight" up the Nile. Landing at twilight at Luxor we unloaded, tied down, and then, to the astonishment of airport guards, proceeded to unroll our sleeping bags and to set up camp under the wing of the Cessna in a corner of the field, as was the pilot's custom. There were military planes around and this wasn't a lonely strip in the Sierra Madre of Chihuahua. "Didn't we intend to spend the night in one of the tourist hotels in town?" We did not. The airport guards finally offered a compromise. We could sleep out at the base of the tower next to a barracks under mercury vapor lights, which we reluctantly did. The mosquitoes were very bad and so was the idea of camping out at Luxor Airport.

At Aswan Ike discovered he had burned out his left wheel brake. There was no chance for repairs. We left for the Sudan and flew across Nubia, a vast desert wilderness worthy of the name with no trees or shrubs or ground cover of any type except along the Nile. This was the hyperarid region, as different from the Sonoran "Desert" as Antarctica is from Patagonian steppe. The Carnegie desert lab scientists Godfrey Sykes and D. T. McDougal had done research here.

On take off at Malakal two maintenance workers cutting grass suddenly loomed up unexpectedly out of a ditch next to us as we roared down the strip. Fearing that he might hit them, Ike jammed on the brakes and cut power. While the bad brake did not work, the good one did, all to well, throwing us into a ground loop which crumpled the wing tip and tail tip and collapsed a wheel. In a week Ike somehow managed to repair the damage well enough to ferry the Cessna on to Nairobi with Jean while I flew ahead on Sudan Airways and Major Swan returned to New York.

The Cessna spent three months in the shop at Nairobi undergoing repairs while we visited game parks and attempted some fossil pollen extractions at William Isaac's botany laboratory in the University College of Nairobi. Prof. Isaac and his wife were genial marine algologists, and parents of the famous archaeologist Glen Isaac. Bill Bishop of the Kenya Geological Survey directed us to outcrops around Lake Magadi which yielded vast numbers of fish bones trapped by an ash fall along with some fossil pollen.

Africa had much to offer. Now the television is awash with nature shows on African big game. In the 1960s, it was all much more remote. For reference material we collected megafaunal manures. We sampled thorns on fever trees, detecting reduction in thorn number with height. We visited Lake Turkana,

Serengeti Park and near Uaso Nyiro we met George and Joy Adamson.

Louis Leakey invited me to ride with him on trips to Olduvai Gorge from Nairobi. I tried and failed to persuade him that early Pleistocene extinctions of carnivores, giant pigs and giant baboons might be triggered by competition with or even predation by early hominids. I was impressed with Leakey's success at exhibiting early man-extinct megafaunal sites at both Olduvai, Olorgesaille, and Kariandusi. Although the Hot Springs, South Dakota, display is superior to anything of its kind in commemorating America's extinct mammoths, there still are no Clovis-mammoth associations on public exhibit in the United States to match what Kenya offers. Our Eurocentric approach to New World patrimony glosses over the significance of Clovis colonization. Where is the heritage memorial to honor the first Americans themselves?

Topping off the trip was a month spent in southwestern Madagascar. The Cessna was now repaired and ready to go. We met anatomist Alan Walker in Kampala, Uganda, persuaded him to join us, and flew for two hours through solid overcast east from Nampula across the Mozambique Channel to Majunga, where much to our relief the clouds parted. We could see red flood waters coloring the ocean and then the Madagascar coast itself. Near Tulear in southwestern Madagascar, we visited beaches littered with shells, not of clams but broken egg shells of the elephant bird, *Aepyornis*. We visited fossil deposits in Holocene alluvium, similar to arroyo banks to be found in Cochise County and throughout the west. The difference was that in Madagascar the deposits might harbor bones of extinct animals, including hippo and giant tortoise. The extinct fauna disappeared very late, only a thousand years ago or so, coincidental with human colonization, although butchering sites of the elephant bird and other extinct animals are curiously scarce.

The Africa-Madagascar experience was worth a follow-up. I returned with my family in the summer of 1966 to revisit Tsavo and to spend another month in Madagascar with Tucson botanists Richard Felger and Pierre Fischer at the famous French Government Marine Field Station at Tulear. We collected fossils of extinct hippo for the Smithsonian Museum and more egg shells of *Aepyornis* which turned out to be ideal for radiocarbon dating.

Fossil rat middens: "Gold in them thar hills"

Back at Tumamoc Pete Mehringer was teaching the pollen course and had joined the Geochronology faculty. We both were impressed with Phil Wells and Clive Jorgensen's success at chronology building in the Mojave Desert using fossil rat middens. We knew Rampart Cave harbored similar material. What about other parts of Arizona and the Southwest? In a new course "Paleoecology and Man" I found an opportunity to coax graduate students shopping for a thesis to join the treasure hunt, the search for ancient middens. The glacial age pollen record which Dave Adam, Anne Bent, Kathryn Clisby, Ulf Hafsten, Dick Hevly, Estella Leopold, Pete Mehringer, Paul Sears, Herb Wright and others had pioneered in this region suggested important change in glacial times. Desert grassland appeared to have been overrun by pine forest during the full glacial, if we read the fossil record right. But no one knew what went on in the low elevation deserts, the sort of record that the Carnegie botanists would have wanted. Wells and Jorgensen said there had been a juniper invasion in California's deserts and we had that twig of juniper from Rampart Cave in Arizona's segment of the Mohave Desert. What happened to the saguaro?

Geochemist Paul Damon tried his hand at prospecting. To our astonishment he brought in remains of a fossil midden with juniper (and lacking saguaro) that he had collected from a

small rock shelter near Picture Rocks Pass in the Tucson Mountains, not far from the Desert Laboratory. Saguaro, not juniper, grows in those mountains today. This was the imprint of the ice age changes we had been seeking, and here it was right in our back yard!

The Great Fossil Rat Midden Hunt now began. A "Corps of Discovery" spearheaded by Tom Van Devender and including Martha Ames, Jim King, Paul Leskinen, Pete Mehringer, Kevin Moodie, Art Phillips, Geof Spaulding, and Jeff Zauderer were joined sooner or later by Julio Betancourt, Ken Cole, Pat Fall, Lisa Graumlich, Cynthia Lindquist, Jim Mead, Bob Thompson, Larry Toolin, and Bob Webb, among others. While the Tucson Mountains were not a rich source, lots of fossil midden sites were found in western Arizona, eastern California, Nevada, southern Utah, New Mexico, west Texas and northern México. It became apparent that in addition to juniper the southwest deserts had been invaded by scrub oak, pinyon, sagebrush, yucca and shadscale. At higher elevations there was another shuffle, verifying what we found in the fossil pollen record. Montane conifers such as limber pine, Douglas fir, white fir, dwarf juniper, and occasionally spruce or bristlecone pine occupied today's woodlands of pinyon-juniper or oak-juniper. Clearly, the biota of the arid west had been profoundly affected by climatic conditions over the last 40,000 years and in their papers in *Science*, *Nature* and other professional journals the grad students at the Desert Laboratory led the way to new finds in paleoecology. Whenever a student had a worthy manuscript on fossil middens and needed some extra financial help to see it into publication, support could usually be found in an administrative office.

I think it was December of 1968 when Robert MacArthur, perhaps the best of the new breed of American ecologists of the time, came to Tucson to spend part of his sabbatical at Tumamoc Hill. Pleistocene extinctions had begun to attract media attention, including a piece in the December 7th issue of *Time*. Robert helped contribute to an advanced ecology seminar on extinctions which I ran jointly with faculty from the Biology Department.

Around then Dave Adam left us for the U.S. Geological Survey in Menlo Park, a great research opportunity for him given Dave's interest in the fossil records of drill cores from western lakes and playas. Pete Mehringer left for the University of Utah and eventually became Professor of Anthropology at Washington State University in Pullman.

Pete's final contribution before departing was the Missouri mastodon project. Not since the time of A.C. Koch (in the 1840s) had there been such excitement about mastodons in Missouri, an unlikely source for such fossils. They are more often found in Michigan and Florida. It all began when serendipity lent a hand.

On a summer contract Pete had tried and failed to recover fossil pollen from Rogers Shelter in the flood zone of the soon-to-be-constructed Harry S. Truman Reservoir. Seeking something to show for his bid, Pete turned to an adjacent spring-fed marsh on the terrace of the Pomme de Terre River, a place called Boney Spring. The cores he recovered looked very promising for fossil pollen. Then Pete noticed they contained bone and tusk fragments. "That's from my cow. She bogged down here years ago," commented the skeptical owner of the spring, a Missouri dairy farmer who was watching the coring operation.

It was not a cow at all; it was bone from not one but what eventually turned out to be 31 individual mastodons in a bone bed of 731 bones between 13,600 and 16,200 years old. It was grist for two dissertations, one by Jim King and the other by Jeff Saunders, and field experience for many University of Arizona students. Among other finds the Missouri mastodon team laid to rest A.C. Koch's 150-year-old claim that Missouri mastodons had been hunted by prehistoric people. The mastodon

bones were much older than the artifacts, although some artifacts were sufficiently close to the fossil bones that it was easy to see how they might mislead the unwary. Unfortunately, the fossil mastodon bone bed could not be permanently exhibited *in situ*.

By 1969 a new palynologist, Al Solomon, had arrived on Tumamoc to initiate modern (airborne) pollen sampling and to join the new scanning electron microscope (SEM) group. Our SEM opportunity came when a friend brought Charlie Drew to Tumamoc Hill. Charlie was a chemist working as a research scientist at the Navy's Michelson Laboratory located at China Lake, California. Charlie had recently acquired one of the first scanning electron microscopes, a vast improvement over the light microscope in examining surfaces. He had heard that pollen was an ideal subject for SEM study and he was right. SEM photomicrographs were stunning and soon appeared on covers of all sorts of scientific journals. With the help of Al Solomon and Jim King, Charlie and I published an atlas of southwestern pollen types. Promising as it was, the method was too cumbersome, at least in our hands, to apply to routine fossil analysis and hoped-for breakthroughs in paleoecology were not forthcoming. Much better use of the SEM was made by Donna Howell who photomicrographed the brush-like tongue of a long-nosed bat, showing how it was able to mop up pollen from its face and head as well as from its favorite flowers, those of agave and columnar cacti. When she was studying their diet, Donna briefly kept an experimental bat colony in the attic above the main lab. If Tumamoc lacked a belfry, at least for a short while we had the bats.

In 1969, guided by Doug Evans of the National Park Service, Austin Long and I finally got around to investigating the ground sloth caves in the Grand Canyon, beginning with Rampart and Muav. That summer we also accepted Bob Euler's invitation to join in the excavation of Stanton's Cave. There was ample material for research on fossil pack rat middens, diet of extinct animals, and the chronology of megafaunal extinction. 1969 also saw our first Grand Canyon Colorado River trip sponsored by the Arizona Academy of Science. Near Shinumo, Jim Mead, then a high school student, discovered fossil pack rat middens (with displaced juniper) in the Inner Gorge, the first fossil juniper from the Canyon since Dick Shutler's collection from Rampart Cave. Midden collections from Stanton's Cave yielded ample juniper, twig figurines and occasional fossil birds including vulture bones. Our river trips anticipated things to come. Lounging comfortably on rubber rafts while floating downstream, we gazed up at inaccessible holes far above us in the Redwall Limestone, idly speculating that some should have been the nesting sites of the extinct California condor. It turned out that we were right, as Steve Emslie and Jim Mead discovered later after investigating some of the "inaccessible" caves.

Grand Canyon research appealed to Jim King, Jim Mead, Art Phillips, Wayne Sigleo, Geof Spaulding and Tom Van Devender. In an extraordinary bout of field work in the roughest and most physically demanding parts of the Grand Canyon, Ken Cole took advantage of his skills as a gymnast to recover suites of midden samples that revealed significant change in all the common tree and shrub species from the Canyon rim to the sandstone cliffs just above the Colorado River. Someone told Ken his new data was good enough to publish in *Science*; he submitted a paper and *Science* published it. Ken's discoveries included dung and bone deposits of the extinct goat, *Oreamnos harringtoni*, material that helped Jim Mead with his dissertation on that animal.

In the Sheep Range of southern Nevada Geof Spaulding elegantly displayed the shuffle of montane conifers moving to higher elevations and being joined by extralocal species in the Holocene, a biotic enrichment as the cli-

mate warmed. In the Great Basin Bob Thompson combined fossil pollen with midden analysis to show that while the vegetation of the last ice age supported arid adapted limber and bristlecone pines down to the elevation of Lake Lahonton, the trees were scattered among shrubs and probably did not constitute a forest. Even the last 1000 years showed slight but significant translocations from black brush to creosote bush in the Mojave Desert where Bob Webb investigated desert plant recovery on abandoned and cleared sites of 100-year-old ghost towns. Julio Betancourt found major changes in vegetation of the Four Corners area. Last but not least, Tom Van Devender ransacked desert mountains from Coahuila and west Texas to eastern California and Sonora discovering a rich late Quaternary record of previously unknown woodlands occupying what are now treeless desert mountains. Tom noted a number of distributional overlaps, species of southwestern plants coexisting in middens and presumably in nature that no longer associate as far as botanists are aware. Some truly incredible associations were put to the test by AMS dating and found to be the result of sample contamination. Still, the record of anomalies seems valid and was supported by direct dating in at least a few cases, as Tom and the "Corps of Discovery" showed in a paper in *Nature*.

In 1972 Dick Harington, an expert on *Oreamnos*, came down from Ottawa to see the fresh-looking dry pellets and other fossils of extinct goats in place at Rampart Cave. Two globetrotting Australians, palynologist Geof Hope and paleontologist Jeanette Hope, inspected Rampart on one of our trips; later Geof returned to Tumamoc on a sabbatical. Both would help me visit key fossil sites in Australia. Fran Bartos undertook pollen analysis of deer pellets and deer diet on Tumamoc Hill. Eleanora (Norrie) Iberall finished a thesis on diet of Harrington's extinct mountain goat based on the wealth of fecal pellets that Bob Euler had excavated from Stanton's Cave. In her literature search she discovered the materials analysis lab of Dick Hansen of Colorado State University. Dick visited the Hill, taught us more about how to "know your shit," and completed a study concluding that globe mallow, Mormon tea and salt bush were the main forage of extinct ground sloths. The sloth dung was so well preserved that it matched the carbon and nitrogen ratios of modern cow manure.

Gerald Kelso took fecal palynology to its nadir with a dissertation on the distribution of ingested pollen in human excreta, both fossil and fresh. Some found reason to protest the outrage when Gerald dried his odoriferous research samples in the lab's stove, previously devoted to warming casseroles at potlucks.

Austin Long, Dick Hansen and I published our new data from the Grand Canyon ground sloth caves, including radiocarbon dates that faded away around 11,000 years ago, coincidentally, we noted, with the age of the Clovis culture and extinct mammoth. Caves with ground sloth dung were also known in South America. When did the South American ground sloths vanish? More to the point, when did the last dung drop on the floor of those caves? That question was enough for Austin and me to begin planning field work in Chile and Argentina.

Sabbatical II. South America

In the fall of 1972, I was once again eligible for a leave. I had recovered from the terrors of the over-water flight to Madagascar and the ground loop in Malakal and proposed another grand tour of fossil sites of another continent, this time South America. Ike and Jean had flown from Tucson to Tierra del Fuego in their Cessna once before and they were ready to go again. Along the way, we narrowly escaped the Managua, Nicaragua, earthquake of October 1972 after just making it into Tapachula, on the México-Guatemala border,

having glided into the field dead stick with empty gas tanks. Ike disliked the trouble of gassing up unnecessarily.

In Perú we visited Pichimachai Cave excavated by MacNeish and the famous Talara tar pits, with extinct animal bones exposed in fresh diggings, considerably more impressive than what one can see in California at Rancho La Brea. In Brazil we examined mastodon fossils at the Araxa Hot Springs, and in northern Venezuela some mastodon sites in spring deposits allegedly with cultural material. Nevertheless, the main object was the inspection of two caves known to harbor ground sloth dung. One was the famous Mylodon or Eberhardt's Cave in Chile, the other the recently discovered Gruta del Indio in Argentina, being investigated by Humberto (Tito) LaGiglia of San Rafael.

San Rafael is a beautiful small city in the wine district of Mendoza province. The surrounding desert looks very much like the eastern Mohave of California and Nevada. There are various desert shrubs that made us feel at home, especially creosote bush which unlike creosote bush in North America comes in more than one species.

Hector d'Antoni, a palynologist from Museo de la Plata, brought his family to San Rafael and joined us in the field. He was working on a pollen diagram from the dung in Gruta del Indio. Unfortunately, we could never be sure what type of ground sloth was involved. There were many extinct ground sloths in the fossil record of South America. Teeth of ground sloths of two different families were found in the cave. The "bonegas" (lumps of dung) were smaller than any Austin and I had seen in the U.S. and much smaller than the specimens collected at the Mylodon Cave in Chile. Their source remains a mystery. Whatever the species, the last dung we could find to date was around 10,000 years old.

Ike, Jean and I persuaded Tito to fly with us to Puerto Natales in Chile to collect samples in the Mylodon Cave, a huge cavern with a sizable deposit of manure looking out on glaciers of the Southern Andes across Ultima Esperanza Sound. The cave was made famous around 100 years ago. The hide and fresh-looking dung of the extinct mylodon triggered a futile search for living ground sloths. Recently cryptozoologist David Orim has resumed the search based on reports of a small ground sloth in the Upper Amazon. I wish him well. I cannot find evidence of ground sloths after 8000 BC. I think Orim started his search ten thousand years too late.

On one of our flights from the Natales airstrip to Punta Arenas, the overcast turned squally and Ike decided it might be wise to land. Besides, we were hungry and it was past lunch time. He spotted a sheep ranch at the end of a narrow dirt road straight enough to serve as an emergency strip. The wind was right and we tried it. Unfortunately, none of us had seen a line of small homemade telephone poles which converged on the road just ahead of us. Braking hard, Ike still could not stop the Cessna in time. Fortunately, the wood in the pole we struck was rotted and on impact the pole flew into pieces, leaving no more than a cup-shaped dent in the leading edge of our wing. By the time all had been explained to a troop of curious sheepherders from the station, we were truly hungry and accepted their hospitality, a steaming bowl of hearty mutton soup and mounds of tasty fresh baked bread. That afternoon the weather improved and after negotiating cost of damages to the phone line we flew on our way.

From Tierra del Fuego and its flocks of guanacos we flew toward the ice fields of the Darwin Channel until the weather turned foul, then north up the east coast. At La Plata Hector and Suzanna d'Antoni showed us Ameghino's world-famous circular museum. After helping collect a sample of Mylodon hide for ^{14}C dating, Tito LaGiglia returned to San Rafael. In Brazil Jean insisted we take time off to ex-

perience carnival in Rio where we were joined by my wife, Marian, who flew down from Tucson. On walking through narrow streets packed with wildly celebrating revelers en route to the main pavilion, Ike had his pocket picked. He saw it happen and could do nothing. In the mad carnival crush his arms were pinned to his sides.

Back at the Desert Lab in Tucson, Al Solomon had invited the genial Rutgers ecologist Murray Buell, recently retired, to teach a semester of my field ecology course. Murray and his wife loved students and hosted ice cream parties in their home. The parties became potlucks and, with Al Solomon's guidance, an eclectic self-sustaining student-run seminar, dubbed the "Mescal, Marching and Menudo Society" was born. Beer was consumed much more often than mescal, once or twice menudo (soup of tripe) was actually served, and plenty of marching back and forth was the fate of seminar speakers who were often obliged to run a gauntlet of sharp questions, rather like a cross examination in court. Many grad students would discover that their dissertation defense was a simple matter compared to their trial by fire as a guest speaker of the Menudo Society.

One visit to Argentina deserved another. In 1974, I went back with Tom Van Devender and my son Tom Martin to search (without success) for more ground sloth caves in Mendoza Province. Tito LaGiglia did show us organic deposits that looked like pack rat middens or the South American equivalent. Austin Long came down on his sabbatical and clarified the dating relationship between sloth extinction and earliest cultural activity (in the form of charcoal) at Gruta del Indio. In Argentina, as in North America, the overlap between first hunters and last ground sloths was very brief. Fossil middens and fossil pollen records showed change, not necessarily for the worse, during the time of extinction. The ground sloths must have been highly vulnerable to human predation whenever humans were on the scene. The year of 1974 was memorable, although I did not realize it at the time, for the discovery in Hot Springs, South Dakota, of the first bones of the Mammoth Site and the beginning of a unique, precious collaboration between the town of Hot Springs and a group of geologists led by Larry Agenbroad of Northern Arizona University.

Spirit of 76

In 1976, in response to archaeologists who seemed to believe nothing important could happen rapidly, Jim Mosiman and I modeled a maximum rate of impact by Clovis foragers which we called "blitzkrieg." It blitzed through the media with great success, topped off by a *Reader's Digest* article on our Rampart Cave research by James Michener. Nevertheless, many archaeologists rejected blitzkrieg. They expected to find people in the New World well before Clovis time 11,000 years ago and refused to accept the possibility that all megafaunal extinctions occurred together, as our model required. They certainly did not buy the idea that extinctions could happen in only a few hundred years. I was amused at the subsequent popularity of the asteroid (bolide) model for dinosaur extinction which doomed large animals in a much shorter interval of time, perhaps less than a year. Well, we had our human bolide timed with mammoth extinction: one good catastrophe deserved another.

On a hot July evening, as so many are in Tucson, the "Menudo Society" was enjoying a seminar around the swimming pool at Betty and Bill Fink's comfortable condominium. Betty was our superbly talented secretary and coordinator on the Hill. The potluck dishes, many vegetarian, were excellent. The speaker, Donna J. Howell, had an impressive command of her subject, the adaptations of pollinating bats, and her audience was unusually quiet and attentive. I was not happy to be called away to

the telephone.

It was Mary Kay O'Rourke with an urgent message. My friends, Bob Euler and R. Roy Johnson, both researchers at Grand Canyon National Park, were trying to reach me. Then the blow fell, something about a report of smoke coming out of the mouth of Rampart Cave.

The slow combustion, hardly a "fire," lasted months, enduring all best efforts of Park Service crews and other firefighters to extinguish it. The Bullhead City Department volunteered to a man. The Tucson Fire Department conducted experiments on how to smother slow combustion. I learned about brattice cloth, employed to seal off the air. At one point, Park Service fire fighters in gas masks working inside the cave almost had it out. Then a rockfall threatened their safety and underground efforts ended. An exhaust system was attempted, pumping exhaust gas into the cave. Although the rate of combustion could be greatly reduced by oxygen depletion, the heat of combustion was retained in the dung blanket. When eventually fresh air leaked back into the cave, as eventually it did, combustion resumed.

All agreed the fire could be stopped by flooding. Since most of the fossils would be ruined in the process, I did not want that. Finally, six months after the fire was discovered, the Mine Safety group of the U.S. Bureau of Mines brought it under control. While a part of the deposit on the west (right) side of the cave had survived, the whole experience was a nightmare. In addition, I was dismayed (although not surprised) by snotty publicity. Here was a fossil deposit that revealed in magnificent detail the life history of several extinct animals otherwise only known by their bones, animals native to the Grand Canyon and to the Southwest to disappear forever not long ago, as geologists view the world. Nevertheless, some columnists could not resist the opportunity to trash the federal agencies for spending tax dollars in fighting a fire in "sloth dung." "What will they do next?" Well, I had livened up lectures with one-liners and now the columnists had their turn. I compared the loss of Rampart to the burning of the ancient library in Alexandria, with scant effect. During the Denver meetings of the American Association for the Advancement of Science that fall, when science was in the news, I was interviewed on CBS Television. CBS played the story straight for the most part, but could not resist an exit comment by Walter Cronkite, something about bringing their viewers the latest news on "endangered feces."

Not all was sackcloth and ashes. That year (1976) I learned that Ray Turner was looking for a new berth for his ecohydrology project in the U.S. Geological Survey. Ray had long demonstrated a genius at desert monitoring, including the interpretation of repeat photographs (Hastings and Turner 1965), the study of permanent photos established by Carnegie botanists and others on Tumamoc Hill (Goldberg and Turner 1986), saguaro demography, began by Volney Spalding, and the detailed mapping of the range of Sonoran Desert trees and shrubs soon to be published. He more than anyone belonged on Tumamoc Hill. Now that Clark Martin was leaving the Hill and the Santa Rita Range Experiment Station along with range research was being terminated by the USDA, the ghosts of the Carnegie botanists would have given me no peace if Ray had not been urged to occupy space now available. Eventually a memorandum of agreement was drawn up between the University and the USGS and Ray arrived with his team. Since Ray's recent retirement, the unit is led by Julio Betancourt and Bob Webb with other desert scientists involved including Betsy Pierson who continues the saguaro monitoring. Another inspired member of the group is Jan Bowers, who writes books on her own time. Besides a biography on Forrest Shreve, and the ecological controversies of his day, Jan has introduced her readers to a biogeography of desert mountains (*The*

Mountains Next Door), the stark beauty of desert dunes (*Seasons of the Wind*) and my favorite on her creative approach to gardening in Tucson with its wonderful slant on Jan's own changing views: *A Full Life in a Small Place*. The arrival of the USGS group also on the Hill ensured some new work on fossil middens. In addition, Bob Webb and Alex McCord innovated the dating of floods by tree-ring dating of scars on riparian trees. Bob undertook the repeat photographic analysis of Stanton's 100-year-old views of Inner Gorge vegetation in the Grand Canyon, detecting expansion of frost sensitive plants. Poor Bob! We all pitied his fate, to have to conduct research within the Inner Gorge of the Grand Canyon on innumerable river trips.

Besides mischievous ring tails, the grounds of the Desert Laboratory feature interesting animals such as native mule deer, a herd or two of resident javelina (collared peccary), foxes, cottontails, and an occasional bobcat. In season, the Gila monster and three species of rattlesnakes may be expected on or near walkways, to the delight of ophidiophiles and the horror of ophidiophobes. Occasionally a rattler slips indoors, including the day I reached for my telephone, carelessly left on the floor, and discovered a hatchling rattlesnake coiled in the finger well. A photograph of the rattler in the telephone appeared above the masthead of the August 23, 1977, issue of the *Arizona Daily Star*.

Perhaps the most unusual animal on the grounds is an icon, a life-size model of a Shasta ground sloth made of welded wire, and known to all comers on the Hill as "Weldon." Being only an outline, not a fully embodied replica, Weldon is inconspicuous, as seems appropriate for an extinct beast. Weldon haunts a space between our cardon cactus and the South American creosote bush planted in the patio cactus garden years ago by ecologist Tien Wei Yang.

In the summer of 1977 Weldon was fleshed out with papier-mâché, covered with brown "fur" and given a lead part in a bit of Tumamoc theater. It began when I received a copy of a one-act play, *Range Wars*, recently scripted by the Bay Area poet, Michael McClure. This was soon after Dick Felger brought Michael up to the Hill for a visit, and I gave him some reprints. One hardly hopes for such a dramatic response to reprints. From *Science* Michael had incorporated my account of what happened to ground sloths (and other Late Pleistocene megafauna) into an anachronistic scramble of Lincoln County, New Mexico, characters including Billy the Kid and his girl friend, and three half-naked prehistoric ground sloth hunters. Weldon would be speared and doused with ketchup in our version of the play. The dramatis personae included Marty Eberhardt, Gary Nabhan, Karen Reichardt, Sandra Turner and Sandra's tenant at the time whose name was Billy. Naturally he was type cast as "the Kid."

Lacking a stage, we held forth in the open between buildings, the actors appearing in a spotlight in front of the audience on chairs in the parking lot. Mahina Drees, assisted by Tony Burgess and Steve McGlaughlin, directed the world premier (so Michael McClure assured us) to a packed parking lot, two nights running. All members of the troupe, except Billy, who was a real estate appraiser in real life, went on to distinguish themselves in ethnobiology, ecology, botany, or all of the above. A Thespian talent may not be necessary for professional success but I suspect it helps. Weldon is again disembodied in his own private *Walden*, waiting for another chance to go public.

In the mid 1970s, Al Solomon left for Oak Ridge National Laboratories to be replaced by palynologist Vera Markgraf. Vera and her students, including Ben Brown, Faith Duncan, Pat Fall, Bonnie Fine, Sue Fish, Pacifico Payawal and Bob Thompson developed research projects from the Great Basin, México, South America, and the Philippines and were joined

by Hector d'Antoni who had won a Guggenheim Fellowship to work at the Desert Lab. Louis Scott of Bloomfontein in South Africa and Gurdip Singh of the Australian National University arrived on sabbatical leaves. Pat Fall published some research which illuminated a serious limitation of alluvial palynology, the tendency for pine pollen to be overrepresented in fine-grained sediments.

In 1978 Dave Steadman came to the Desert Lab with ambitious plans for investigating the prehistoric fossil record on oceanic islands. He expected to find (and did) many avian extinctions, not only in Pacific Islands but also in the Lesser Antilles, far more than were known or predicted at the time. In September on South Cottonwood Lane, the home of Ike and Jean Russell, Mary Kay O'Rourke and I were married surrounded by a small group of friends. Another sabbatical leave could be requested soon (they are not automatic). The obvious place to go would be Australia and parts of the Pacific. While Australia would be an ideal place to explore by Cessna, Ike's flying days were over and Jean needed to stay home to care for him in the little time he had left.

Sabbatical III. Australia and the South Pacific

Like other good things, sabbaticals do not come free. No matter how good one's teaching in the six years between eligibility, administrators do not want to grant a leave with pay to some deadbeat to waste on the golf course. I had learned that they especially like to be promised a book. Since I already had one in mind, the promise was easy. Now out-of-date and out-of-print *Pleistocene Extinctions* (1967) was due to be revised. More than that, it needed to be redone with better coverage of a crucial part of the globe where the chronology and pattern of prehistoric extinctions invited close comparisons with America and the Old World.

A menagerie of "giant" marsupials, most larger than the largest living one, the red kangaroo, vanished from Australia in the late Pleistocene. Then much later, within the last 1000 years or so, a dozen giant flightless birds, the moas, disappeared from New Zealand. Other extinct birds such as flightless geese and flightless ibis were being described in Hawaii. Virtually everyone agreed that the moa extinction and all other extinctions on oceanic islands were triggered by the side effects of human colonization. The arguments for climatic change focused on Australia itself, with various Australian paleontologists and archaeologists probing all possible causes for the phenomenon. It was especially challenging since nothing like it had been unearthed in older Australian faunas.

I wanted to learn more about the Australian extinction chronology. Although Geof Hope and Jeanette Hope had not encouraged the idea, I wondered if the Australian caves might not harbor dung deposits or at least collagen-rich bones of extinct animals that would be ideal for direct radiocarbon dates. While Jeanette had found a carcass of an extralocal Tasmanian wolf in a cave, in radiocarbon age it was much too young to represent the time of extinction of diprotodon and other Australian megafauna.

When Lucy Cranwell Smith learned that I planned to visit her native land, New Zealand, she helped me get in touch with the experts. These included archaeologists Roger Green, Roger Duff and Atholl Anderson. Through Lucy and Watson Smith, I had already met the Australian palynologists Donald Walker and A.R.H. (Tony) Martin.

Then without warning a renown Australian anthropologist, Richard Wright, and his family showed up at the Desert Lab. He was returning home from a sabbatical in England via the United States. He wanted us to hear the latest results of excavations at a newly discov-

ered incredibly rich bone bed of extinct giant macropod kangaroos at Lancefield in New South Wales. Like the Boney Springs and other mastodon deposits in Missouri, there was archaeological material in uncertain association.

In the fall of 1979, Mary Kay and I flew to Sydney. Richard and his wife Sonia helped us recover from jet lag in their historic home on Sydney Harbor. They sent us on to Canberra where Jeanette Hope was about to start a field excursion to sites I had long heard about and longed to see. These included Lake Mungo with what were then the oldest direct radiocarbon dates on prehistoric Australians, over twice the age of the Clovis culture in the New World, and lunettes of the Willandra Lakes including Jeanette's "Frog Kill Site" where cultural remains over 20,000 years old were associated with bones of mostly small vertebrates.

By the time I was ready to leave Australia and New Zealand four months later I had promises of chapters for a new extinction book from outstanding Australian and New Zealand scientists dealing broadly with the problem of extinctions. And Jeanette Hope was right, there were no cave coprolites or soft tissues to match the fossil organic boluses so common in favorable caves in the Grand Canyon. Ernie Lundelius and others had found *Sarcophilus* coprolite, masses of chewed bone in limestone caves in the Nullarbor Plain. These were not organic. The best Australian dates come from samples of egg shell, on carbon locked into calcite or aragonite in the eggs of extinct birds (bigger than an emu) called *Genyornis*. It was intriguing to note that in paleontological deposits rich in extinct fauna there was no archaeological material in an unquestionable association. Conversely, in well dated stratified archaeological deposits, such as the recently discovered caves of the Franklin River in Tasmania, there were bones of living large mammals. Of course, there was nothing to match a Clovis site. Otherwise the parallels to North America were striking. None of this affected my long-time friend Ernie Lundelius of the University of Texas and his students (now eminent paleontologists themselves), Russ Graham and Holmes Semken, who believed that climate drove the extinctions.

The answer, I felt, would come from oceanic islands. Dave Steadman took Mary Kay O'Rourke and me to see his lava tube excavations in the Galapagos. Unlike Hawaii, New Zealand, the islands of the West Indies and most of those in the Pacific, the Galapagos escaped late prehistoric extinction of native land birds, reptiles and land mammals. Dave's detailed sampling of many rich cave faunas on the Galapagos yielded numbers of bones of virtually all known species of land vertebrates from the islands, including Darwin's finches. With one possible exception, a giant rat not seen historically, all local extinctions known from the Galapagos occurred in the last 200 years. The rate of historic losses is two orders of magnitude greater than anything Dave could find prehistorically. Radiocarbon dates revealed that the giant rat also survived into historic time. No one knows its fate; an indirect effect of human contact is strongly suspected.

Then Dave and I were invited to visit Storrs Olson and Helen James and a cave they were excavating in Maui. Tom Stafford conducted radiocarbon dating on extinct flightless ibis and flightless geese that vanished close to the time of first human colonization over 1000 years ago, significantly older than extinctions in the Galapagos where prehistoric settlement did not occur and prehistoric extinctions are unknown.

Recently Tom and Dave invited me to a cave they were excavating on Eua in the Kingdom of Tonga. Human arrival was marked in their excavation by sudden appearance of charcoal, around 2500 years ago, earlier than prehistoric invasion of New Zealand and Hawaii. Prehistoric voyagers got to Tonga first.

Best of all, the cave on Eua had a fairly rich record of extinct rails, doves, pigeons, parrots and other land birds, back to an Uranium-

Thorium date on limestone of around 65,000 years ago. In all that interval there were no extinctions or obvious faunal turnovers. If climatic change had an affect at all on island bird extinction, it was not to be seen in this record. A similar lack of extinction until humans arrived is now evident in the case of New Zealand's extinct moas. Without human colonization, oceanic islands, large and small, escape intense extinction.

Before leaving Tonga for Tucson, Dave asked if Tom and I might want to see a colony of fruit bats. We did and Dave drove us to a mango orchard next to a few houses. The trees were alive with "flying foxes."

"What's going on, Dave? I thought you said all the islanders love to eat bats. What spares these guys?"

"Tonga has a king," Dave reminded us. "These are the king's bats. They are taboo. Only he or his agents may kill them."

I could only wish the King of Tonga had been around when the island was first colonized. Royal edict might have saved some of the extinct land birds.

Back in Tucson, Tom Van Devender had been teaching my paleoecology course with his unquenchable enthusiasm. By 1984 Quaternary Extinctions was released, winning glowing reviews. That year Jim Mead, Larry Agenbroad, Owen Davis and I also published on the remarkable new Utah cave, Bechan, with its amazing deposit of mammoth and other megaherbivore manures. This was an excellent deposit for determining mammoth diet—mostly grass.

In 1985 with the help of the University's Centennial Fund we held a one-day symposium in Tucson on Quaternary extinction and brought all the participants up to the Desert Lab for an open house. It would be the last time I would see Ed Deevey whose interest in biogeography, geochemistry and radiocarbon dating and pollen analysis inspired my career.

I had one more sabbatical ahead, and one more life to live, as it were, this one to be uncomplicated by the search for fossils. I wanted to collect plants from the Río Mayo in northern México, on the trail of one of the Carnegie Botanical Laboratory last remaining investigators, Howard Scott Gentry.

Sabbatical IV. Plants of the Río Mayo

Thirty years had passed since I had come to Tucson with the intention of taking field trips into northern México. To be sure, there was the excursion to Rancho del Cielo in 1962 and another in 1978. With field classes I had driven the Durango highway in Durango and Sinaloa, crossed the Sierra Madre from Yécora, Sonora, to La Junta, Chihuahua, long before construction of Highway 16 began. In his day Ike Russell flew many of us into tiny airstrips in the Sierra Madre. All his passengers tell stories about busy flying with Ike, one story more hair-raising than the next. The flights into the Sierra became less appealing when hostilities between the "mafioso" (drug dealers) and the Mexican army precluded innocent botanical excursions in light aircraft. We had visited Basaseachic Falls and crossed the Gulf into Baja California to see boojum habitat and whales. Ike piloted Geof Spaulding, Fred Wiseman and me to La Junta, Chihuahua, to find the Chihuahuan species of spruce (*Picea*) endemic to the Sierra Madre Occidental. Fred had organized ambitious trips down into west coast México and developed detailed road logs of the dominant desert plants. Jody Lee Duek, Charlie Drew and I had driven to San Luis Potosi to visit Eric Mellink to see his research plots demonstrating an increase in diversity of native rodents around small scale agricultural plots in the Central Plateau.

All of these trips and many others with scheduled classes to the Sonoran coast, the Yaqui River, or the Magdalena palm canyon were educational. Mexican jaunts were wonderful, romantic, and therapeutic. Anyone who

appreciates Richard Shelton's "Mexico" in his book of poetry *The Bus to Veracruz* will understand what I mean.

Mexico is remarkably rich in species. It features far more kinds of rattlesnakes, fence lizards, deer mice, pack rats, pines, oaks, leguminous trees, agaves, and cacti, to name a few groups, than the rest of North America. The daunting diversity fascinates biogeographers and demands an explanation. The ice age fossil record explored by the midden hunters from the Desert Laboratory suggests that México no less than the western U.S. experienced climatic changes and an intrusion of northern species during glacial times. But its richness cannot be explained by climatic change alone. Biogeographers may invest many years, even lifetimes, in studying the biota of México with little to show for by way of theory. Nevertheless, I felt the need for some sort of project beyond class trips or vacation jaunts, wonderful as they were.

Plant explorer Howard Gentry spent many years in the field in México. He viewed the country as a cornucopia, spilling species into other parts of the continent. Arizona gets its fair share, especially in our sky island mountains, which may harbor upwards of 1000 species in one mountain island. Most of the dominant species of plants in the Sonoran Desert and desert grassland of southern Arizona can be traced deep into northern México. There they grow in remarkable combinations with a variety of related species unknown north of the border. Palms are found with pines, fir trees with tank bromeliads, and tropical figs with sugar maples, to name a few.

In the Great Depression Howard Gentry somehow supported himself through sale of natural history specimens while undertaking a botanical inventory of one drainage, the Río Mayo of southern Sonora and western Chihuahua located between Ciudad Obregon and Ciudad Chihuahua. The region was virtually unknown botanically when he began his field work. The local names, uses, and legends of plant species native to the region had not been investigated. Tropical dry forest which Howard called "short tree forest" hugs the base of the Sierra Madre and spills into the lower portion of the barrancas. Except for local removal of mine timber, it was all uncut. The pine forest of the Sierra Madre was virgin timber. As Howard found, the native Americans speaking their own languages could reveal much of their unique ecological knowledge to the interested botanist.

Howard Gentry's book, *Río Mayo Plants*, written while he operated out of the Desert Laboratory on Tumamoc Hill, was a powerful inducement. In the early 80s, I found myself drawn increasingly to the Río Mayo country with students or friends collecting plants. The ones we found were not always included in Howard Gentry's monograph of 1200 vascular species (trees, shrubs, forbs, grasses and ferns). New 1:50,000 scale topographic maps helped us tremendously.

By rights I suppose my fourth sabbatical should have been aimed at the extinctions known to occur on the one continent I had not visited, Asia. I could go to Siberia where new Russian radiocarbon dates suggested a gradual decline of woolly mammoths and other megafauna rather than sudden (catastrophic) extinction seen in America. The difference is fascinating. However, I had come to the University of Arizona to be close to México and apart from class trips into Sonora to introduce students to the edge of the tropics I had not attempted any real research in México for many years. Now time was running out. The Río Mayo in southern Sonora was only a day's drive from Tucson. For no more than the promise of adventure itself I could tempt my friends, many of them students or former students, to join a week-long foray into parts of the Río Mayo region which Howard Gentry had not visited. Even if he had, the seasonal changes were so great that we were sure to find some

plants in flower that he would have missed. We made eight trips in 1986 alone and over 20 in the next five years.

Members of the field party were invited to collect what attracted their interest, which is what I did. Since uninteresting or drab species like grasses would be neglected, we would spend a few hours collecting nothing but grasses if the season was right. Gentry listed 50 grass species; we now have over 200 from the same region. Some collaborators found special interests. Cathy (Kik) Moore saved big-leaved oaks and worked out their relationships to hydrothermal alteration (acid barrens). Chris Eastoe specialized in a group rich in species in the headwaters of the Río Mayo, the ground orchids. George Ferguson had a sharp eye for pines when he was not discovering new ferns. Jody Lee Duek, Matts Myhrman and Janet Miller filled plastic bags with hard-to-reach specimens at the bottom of Basaseachic Falls. Mike Rourke took coverage data on the woods along Highway 16, the only paved road into the Sierra in our region. Phil Jenkins, Renee Rondeau, Jim Malusa, Guy Clothier and Wayne Van Voorhies returned from an exploration of the Río Mayo west of Moris where I am sure no collectors have been before or since. Dr. Georgie Boyer took on the assignment of collecting every weed species in a mountain bean field. Dick Barber and I joined Prof. Richard Spellenberg from New Mexico State University to help him collect oaks. While driving full tilt along lumber truck roads in the Sierra, Rich can spot rare oak hybrids. With his students, Prof. Andy Sanders of the University of California at Riverside has collected the foothills and coastal plain at the Río Mayo . They keep adding records to the region. Tom Van Devender does the same along the Río Cuchujaqui, and in the Sierra de Alamos. Angelina (Gela) Martinez video taped the uncut forest of the Upper Río Cuchujaqui threatened by buffel grass clearings. Dave Yetman has found that the ethnobotanical lore of the Mayo and other Indian groups is much richer than even Howard Gentry reported. Some Quaternary experts, archaeologists Dennis and Peggy Stanford, paleontologist Elaine Anderson and anthropologist Don Grayson along with Charlie Drew were lured into a week-long collecting foray ending at a lumber mill in the well-named, rarely-visited Sierra Oscura. Charlie's small station wagon was the first vehicle of its class to get over the miserably rough bouldery track into the Sierra. The indefatigable Howard Gentry had been there 55 years earlier. Deep incisions of the Sierra Oscura remain tierra incognita, at least to plant collectors, if not to the Serranos, the mountain ranchers and Indian inhabitants who frequent paradise.

If there were few fossils of extinct animals in the Rio Mayo country, there were surrogates. Livestock allowed to graze in the woods in natural habitat reveal how plants protected themselves from the extinct natives. These would have included native American species of bison, horse, camel (*Camelops*), mammoth and glyptodonts which once served to disperse the fruits of some of the native trees. Ecologist Dan Janzen and I even managed to publish on some of this in *Science*.

Resurrection

The years 1986 and 1987 saw the beginning of a resurrection at the Desert Lab. The buildings were painted inside and out and new flooring installed. Joe McAuliff served as a one-year replacement to teach my courses and to initiate some very important studies on desert perennials and desert soils, an aspect of geobotany that could only be accomplished when a skilled desert ecologist such as Joe is enmeshed in a department strong in geomorphology such as mine.

Even more valuable to us, Joe contacted unit heads in Ecology, Tree-Ring and Arid Lands and initiated a Desert Laboratory scien-

tific advisory committee to begin to find a suitable niche for us within the University. Long-term research about the desert was our claim to fame. The Arizona-Sonora Desert Museum helped by employing Tom Van Devender as a research scientist and Bob Webb and Julio Betancourt attained positions of leadership with the U.S. Geological Survey on Tumamoc Hill.

Finally, in part stimulated by Larry Agenbroad's success at initiating private fund raising for the Mammoth Site, I decided the Desert Laboratory might try the same approach. There were friends of the Carnegie Botanical Laboratory from years ago still living in Tucson who thrilled to the idea of a rejuvenation. There were others who endorsed the geochronology initiative and the concept of an off-campus "beacon-on-the-hill." Friends and supporters may not know or care about all the details of current research, but they can appreciate the desert itself and the mystery of its comings and goings over the eons. The Laboratory could add value, historically and spiritually as well as analytically to the understanding of what deserts are all about. We only had to invite some of our friends to support us in whatever way they chose. We did and they came forward.

In 1987 we formed an Advisory Committee chaired by Dr. Bud Simons, a recently retired surgeon. We issued a case statement and within a year raised our first $100,000. After many years of dedicated part-time service, Betty Fink who had served all sorts of roles on the Hill, from administrative assistant to secretary, had to leave us for a full-time job, a wrenching loss. Joe McAuliff left for a faculty position at the University of Nevada, Las Vegas. The momentum of his efforts kept us on the track. I retired from the University in 1989, kept my wonderful office on the Hill (with windows onto the desert on three sides) and devoted as much energy as I could to the campaign.

A brilliant geochemist with strong biological interests in dry lands and their origin, Jay Quade, was hired to replace me. Jay set up his lab on the Hill, took on the daunting task of leading the Desert Lab Scientific Advisory Committee for the Faculty of Science. We redesigned our half-time position to "Program Coordinator" and hired Dianne Boyer (great granddaughter of Godfrey Sykes) and later Tony Burgess. Through their efforts and especially that of Jean Russell and other members of the Advisory Committee we campaigned for a fellowship in the name of "Ike" Russell. Through Ray Turner we won support of the Animas Foundation for a new and especially appropriate research position aimed at sustainability of grassland and grazers.

I view the post Carnegie research effort, the last forty years, with considerable satisfaction. At the Desert Lab deep history is more than either long-term field studies or short-term paleontology. Armed with radiocarbon dating the researchers on the Hill showed that the dry lands of western United States and northern México experienced a major displacement of their "life zones" in glacial times. With further study we noticed that glacial times were the norm and the interglacial era in which we live now is abnormal or atypical. Saguaros, palo verdes, pinyon, limber pine, ponderosa pine and spruce, most if not all of our trees and shrubs, are now displaced northward or to higher elevations than the places they occupied over most of the last 40,000 years, our window of chronological detail. This simple discovery will, I predict, take decades to sink in. The details can be found in a new book on packrat middens edited by Julio Betancourt, Tom Van Devender and me.

Mammoth, ground sloth, and saber-tooth cat and other extinctions stripped the continent of its most magnificent animals. No plants were lost to our knowledge. This all happened around 11,000 radiocarbon years ago (about 13,000 calendar years ago) without benefit of an asteroid hit or other cosmic accident. Pre-

historic human colonists called Clovis hunters are uniquely seen in the fossil record around that time. There is no solid evidence for *Homo sapiens* in America before 12,000 radiocarbon years ago and the circumstance may actually be the explanation. Whether or not it is, the extinctions of mammoth and ground sloths were so important in altering the ecology of the region, not to mention the hemisphere, that they deserve attention in teaching our children about the history of our country.

America was discovered long before Columbus by colonists so well adapted to the land on which they lived that they could survive in late glacial climates of the subarctic tundras of northern Siberia and Alaska. The mammoth and other megafauna they found when they spread south in America resembled in diversity the game plains of Africa. Vegetation and climate were changing when this all happened. Prehistoric people reached southern Arizona before saguaros and palo verde came to occupy our Sonoran Desert. Important as they are (and the investigators at the Desert Lab are just a tiny fraction of the small army of paleoecologists studying ice age paleoclimate), there is no strong evidence that the climatic changes 11,000 years ago were either unique or even less favorable for mammoths and ground sloths than those they and other large beasts soon to go extinct had endured earlier in the Quaternary. Whether or not the extinctions were a cosmic or a cultural accident, or both, we may sell America short if we fail to recognize the potential of the land to support much greater diversity of large carnivores and herbivores than have won usufruct to date.

Other Desert Lab devotees would find other themes than these to illustrate the accomplishments of the program. Some are aware of the vast potential for studies devoted to explaining differences in the structure and pattern of desert vegetation formed by substrate (soil and rock type), a pattern best seen from low flying aircraft. With carefully crafted experiments some show how the exclusion of certain small mammals powerfully affects the life of certain plants within experimental plots. Control plots themselves can change far more than most field naturalists would guess. The research of University of Arizona ecologist Larry Venable and his students show this in their studies of the seed bank of desert annuals on grounds of the Desert Laboratory. The very latest paper in *Science* on middens is by Pete Van de Water, Steve Leavitt and Julio Betancourt. It shows, through changes both in stomatal density and in stable isotope composition of glacial age limber pine, that the glacial atmosphere was depleted in carbon dioxide. Just possibly glacial age plant communities were inhibited by carbon dioxide depletion with trees less dense and woodlands more open than they are now.

So it seems clear to me that there is much more to look forward to. Years ago Robert MacArthur called field stations the "ecologist's telescope." He was on sabbatical on Tumamoc Hill at the time. The University of Arizona once claimed fame as "The Lamp of the Desert," before it was suspected that some might think of "desert" as pejorative. That is certainly not true of those who study deserts. We think they harbor phenomena more mysterious than the stars. And if graduate education in ecology faces a dilemma, as Robert MacArthur once suggested, I think a place like the Desert Laboratory provides a solution, for reasons of scale as well as site and tradition. The importance of the Desert Laboratory is being rediscovered.

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