

IV. Tektites and Meteorites

Tektites are high-silica glassy objects, ranging in size from microscopic to weighing a pound or more. Superficially, they can resemble corroded pebbles of obsidian (Photo 42). From the beginning of scientific work with tektites, they were found scattered about the surface of the Earth in many localities, with no apparent relationship to local geology. This fact led F. E. Suess in 1900 to conclude that tektites were a glassy variety of meteorite. Many other ideas followed, and some investigators changed their minds many times. Vexed by the tektite origin problem, well-known geochemist Henry Faul stated, "To anyone who has worked with them, tektites are probably the most frustrating stones ever found on earth."¹² Part of the frustration resulted from lack of data on the

¹²For a technical summary of the tektite problem see E. A. King, "The Origin of Tektites: A Brief Review," *American Scientist*, vol. 65, no. 2 (1977), 212-218; or S. R. Taylor, "Tektites: A Post-Apollo View," *Earth Science Review*, vol. 9 (1973), 101-123.

field occurrences of some of the tektites. A portion of my dissertation work sought to determine the field relationships of the tektites found on the Georgia Coastal Plain. Barnes, who visited some of the tektite localities in Georgia, had little success either in finding new specimens or narrowing down the stratigraphy of their occurrence. There was an apparent "age paradox" with the Georgia tektites. Analyses gave radiometric ages of about 34 million years, but tektites were thought to exist on a Miocene formation, which was considerably younger.

I contacted the Georgia State Geological Survey, and they agreed to furnish a truck for my work. A local gentleman, Will Sellers, had previously found a tektite near his home at Jay Bird Springs. I had to start somewhere, so I decided to visit him. He lived alone in an old weathered house on a small country road. He had little to do besides sit on his front porch. Needing some local contact to get me on private land and keep me out of trouble, I asked him if he would agree to act as my "field assistant" for the next month. He agreed to help but said I would have to pay him. When I asked what he thought a fair wage would be, he surprised me by saying, "Two

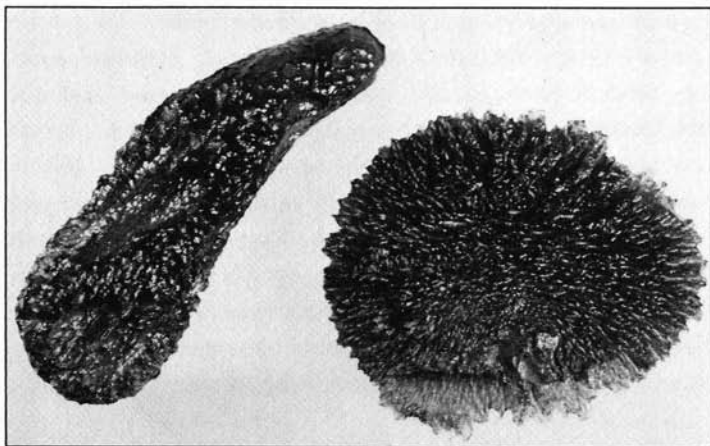


Photo 42. Transparent green tektites from Bohemia, Czechoslovakia. Length of drop-shaped piece is approximately five centimeters. (Photograph by the author)

dollars a day." Sellers proved to be invaluable because everyone in the county knew and liked him. During the course of the field work, we found two new tektite specimens, purchased two more, mapped the entire surficial geology of Dodge County, and managed to avoid a dozen portable propane-powered white-lightning stills. Although I obtained a lot of new information about the Georgia tektites and their occurrence, nothing I turned up seemed to bear on the important questions—how and where did the tektites originate?

By the time I arrived at NASA in late summer 1963, only three possible origins of tektites were seriously being considered: 1) origin from lunar volcanoes, 2) origin as melted ejecta from meteoroid impacts on the Moon, and 3) origin as melted ejecta from large meteoroid impacts on the Earth. The lunar volcanic origin theory fell by the wayside because it did not have a strong champion and it was generally believed that lunar volcanoes were not sufficiently energetic to accelerate volcanic melt to lunar escape velocity.¹³ Rejecting the lunar volcano idea left the two impact origin ideas, which were essentially the same except for the location of impact. O'Keefe had supported the idea of a lunar origin for tektites in a series of papers beginning as early as 1960, primarily on the basis of theoretical arguments. The supporters of a terrestrial origin for tektites were frustrated because their only strong argument lay in the chemical similarity of tektites to Earth materials—and the chemical composition of lunar rocks was unknown. Four occurrences of tektites were known at that time: two localities in Czechoslovakia and one each in the Ivory Coast, North America, and Australia and southeast Asia. The youngest group of tektites in Australia and southeast Asia contained specimens that clearly showed two melting periods—the original melting to make the bulk of the glass and a second period of partial melting on one side apparently caused by atmospheric ablation. A series of glass abla-

¹³It is interesting to note that this idea was resurrected years later by O'Keefe when it became apparent that tektites did not come from the lunar surface. See J. O'Keefe, *Tektites and Their Origin* (New York: Elsevier Scientific Publishing Co., 1976).

tion experiments conducted at the NASA Ames Research Center by Dean Chapman and Howard Larson¹⁴ reproduced the shapes of the ablated tektites almost exactly. Chapman and Larson argued that the tektites had to originate from the Moon; otherwise, the detailed shape of the ablated layer and the geometry of the ring-waves formed on the ablation-melted surface would be different. The experiments provided powerful support for the lunar hypothesis, which was forcefully presented by Chapman. The arguments raged. Barnes and Urey were firmly committed to a terrestrial origin. Adding to the excitement was the anticipation everyone felt in knowing a final answer was only a few years away.

A junior colleague of O'Keefe's at the Goddard Spaceflight Center found the very high pressure silica mineral coesite in tektites.¹⁵ This discovery further supported the impact origin because coesite is known to form on the Earth's surface only in impact craters. Of course, it might also form in cratering events on the Moon's surface.

It was gradually realized that the Czechoslovakian tektites came from Ries Crater, a large impact crater in southern Germany. Radiometric age dating showed that the Ries Crater and the Czechoslovakian tektites were both 15 million years old. Likewise, the Ivory Coast tektites were found near the Bosumtwi Crater in Ghana, and both the crater and the tektites were dated at 1.3 million years. This connection furnished strong evidence to most impartial observers that the impacts that formed craters in the Earth also formed tektites.

My personal research with tektites continued from time to time, and I contributed to a better understanding of the physical properties, inclusions, and field occurrences. However, I was unsuccessful

¹⁴D. R. Chapman and H. K. Larson, "The Lunar Origin of Tektites," NASA Technical Note D-1556 (Feb 1963), 66 pp. Also, D. R. Chapman and H. K. Larson, "On the Lunar Origin of Tektites," *Journal of Geophysical Research*, vol. 68 (1963), 4305-4358.

¹⁵L. W. Walter, "Coesite Discovered in Tektites," *Science*, vol. 147 (1965), 1029-1032.

in obtaining data that uniquely pointed to either a terrestrial or a lunar origin.

Charlie Schnetzler finished his Ph.D. work at MIT and was hired at the NASA Goddard Space Flight Center, where Walter and O'Keefe were his colleagues. Schnetzler continued to work with his graduate school professors, Drs. Bill Pinson and Pat Hurley, who were strong supporters of a lunar origin for tektites. In 1966 they investigated the strontium/rubidium age and isotope systematics of the Ivory Coast tektites along with rock materials from the nearby Bosumtwi Crater in Ghana. They found that not only did the tektites and crater rocks lie on the same isochron and their isotope systematics were virtually identical, but that the isotopic ratios were very unusual. They concluded that "the evidence available at present suggests that the Ivory Coast tektites are most probably the fusion products of meteoritic impact at the Bosumtwi crater site"—a dramatic change of opinion for this research group. The evidence and arguments that they presented were quite convincing.¹⁶ Schnetzler's work was proof of a terrestrial origin. His ideas were accepted by almost everyone except, curiously, his own colleague, O'Keefe, who continued to cling to the lunar origin idea.

At the time, I was working with a Czech researcher to determine the cause of color variations in an unusual Czechoslovakian tektite we had borrowed from the Prague Museum. We believed it was appropriate for us to present our results at the International Geological Congress to be held in Prague in August 1968. My wife and I arrived in Prague a week early, met my Czech colleague, and travelled to southern Bohemia to investigate the field occurrences of some of the Czechoslovakian tektites. We stayed in small towns and quaint hotels while spending several beautiful days in the field. We visited several tektite localities in gravel pits and farm fields and collected a number of fine specimens. We returned to Prague one day before the congress and behaved like tourists. The people of

¹⁶C. C. Schnetzler, W. H. Pinson, and P. M. Hurley, "Rubidium-Strontium Age of the Bosumtwi Crater Area, Ghana, Compared with the Age of the Ivory Coast Tektites," *Science*, vol. 151 (1966), 817-819.

Prague were excited about their recent political successes. The Russian yoke was lighter than it had been only months before. The names "Dubcek" and "Svoboda" were on everyone's lips. The mood was almost jubilant.

The opening of the congress was uneventful. Our paper was scheduled for later in the week. On the second day, we heard many low flying jets in the evening and early morning hours, but we slept anyway. On the morning of August 21, we knew something was wrong. We dressed in a hurry and went to the hotel dining room. The staff were in tears. Looking through the large dining room windows, we saw a man excitedly handing out newspapers to the people on the street outside. Then, at the end of the street, appeared the lead tank of a Russian armored column, coming toward us at a deliberate pace. Young soldiers with submachine guns were lying on their backs on both sides of the tank and watching the rooftops and windows for possible gasoline bombs. We moved away from the windows.

The telephones didn't work for two days, and we could not contact the American Embassy. When I finally got an operating line, a very tired voice told me that an American diplomatic representative would lead a convoy of Americans out of Czechoslovakia the next morning. The convoy would form at a little village called Rudna. We didn't have a car, but I remembered that my old professor, Bullard, and his wife were staying in our hotel. I found Bullard, told him of the embassy plan, and asked if he had a car. He did! It was a little VW beetle, but the four of us and our luggage, which I was prepared to abandon, fit into it nicely. Our biggest strategic problem was that we were on the wrong side of the Vltava River. We had to cross a bridge, but all of the bridges were heavily guarded by tanks, gun emplacements, and young soldiers with assault rifles. Except for military vehicles, the traffic was not crossing. Nothing ventured, nothing gained. We drove to one guard position and asked, in our best mixture of Russian, English, and sign language, if we could cross. The soldier on the driver's side of the car, after pointing his weapon at us and eyeing the passengers,

disinterestedly waved us through. The soldier on the other side of the beetle seemed to disagree. We decided to go ahead and leave the soldiers to "talk it out." It was an anxious moment, but we drove across the bridge and never looked back. The soldiers on the far end of the bridge thought that if it was okay to let us on the bridge, it was certainly okay to let us off. We drove through the guard position at a modest speed, looking for street signs to point us on our way to Rudna. There were none. The Czechs had removed most of the street signs and highway signs to cause problems for the Russians.

Actually we found the right road to Rudna with little difficulty just by counting blocks on our city map. We were making good progress when we encountered a 10-car traffic jam. Two tanks were blocking the road, and a tank commander was motioning for the cars to turn around and go back. He was not allowing anyone to pass. We didn't know what to do. We were off of our map, but we had noticed a side road a mile back and decided to try taking it in hopes of going around the roadblock. Since the road didn't go very far, we had to turn around. Then we noticed a Czech on a motorcycle beside the road. He gestured for us to cross a cultivated field. We followed the tracks in the field. At one point we almost got stuck, but finally we came out of the woods onto the road to Rudna about a half mile beyond the roadblock.

When we arrived at Rudna, only five cars were there, all Americans and Brits. The diplomatic representative had not yet arrived. I purchased some candy bars and food at a small store in case we were stranded in the countryside for a long time. The embassy staff member arrived, accompanied by a truck carrying a load of full five-gallon gasoline cans. We gassed up all the cars, which by then numbered around 50, and drove toward West Germany via Pilzen. We occupied ourselves by counting tanks and armored vehicles, which in this sector were mostly East German. We crossed the border without incident. Fortunately for us, the invaders were anxious to have all foreigners leave the country. Warner, who was attending the same congress with his wife, was staying in another hotel

across town and left Czechoslovakia on a special train to Vienna. It was my first, last, and only trip to visit the Czechoslovakian tektites.

Although tektites do not come from the Moon, some meteorites should. There didn't seem to be anything wrong with the meteorite impact mechanism for providing lunar ejecta that would fall on the Earth. Clearly, tektites were not that ejecta, but pieces of the Moon could be expected to show up somewhere in the meteorite collections. Because the bulk density of the Moon is so low, only 3.34 grams per cubic centimeter, it cannot contain much very dense material, such as metallic nickel-iron. So, it seemed logical that the place to look for lunar fragments was among the less dense stony meteorites. Using NASA-MSK press releases to make people aware of the potential importance of previously unrecognized meteorites, I invited the public to send pieces of suspected meteorites to me for identification.¹⁷

It wasn't long before I received a fragment of a common type of stony meteorite from an area near Sweetwater, Texas. Recovering a previously unknown stony meteorite was a real thrill. When writing to a colleague at the Smithsonian Institution about another matter, I mentioned I had identified a new chondrite in West Texas and that I would send a slab for the Smithsonian collection after the specimen was cut. I received a terse reply ordering me to send the whole piece immediately. Folks at the Smithsonian were jealously guarding their turf as keepers of all government meteorite samples. Their orders led to an exchange of letters between the head of the Smithsonian and the NASA administrator. Ultimately a compromise enabled us to send whatever meteorite samples we had that were government property to the Smithsonian, but only after we completed our research with them. Thereafter, I was careful to acquire specimens privately whenever it was feasible or desirable.

After a classroom lecture on meteorites, Clanton, Foss, and I

¹⁷The invitation stands. Please send me a walnut-sized sample of any suspected meteorite you come across, and I will identify it and return it to you. Send to Bert King, Department of Geosciences, University of Houston, Houston, Texas 77204-5503.

were talking with astronaut Rusty Schweickart and mentioned we were going to New York for a technical meeting. Schweickart, who had been selected for the crew of Apollo 9, checked his pocket calendar and noted he would be on Long Island at Grumman to check out his Lunar Module (LM) at about the same time. He gave us a number where we could reach him at Grumman and invited us to stop by if we had the chance.

The meeting ran late. We ate a hamburger for dinner and called Schweickart, hoping he might be working late. We located him through Grumman's paging system, and he gave us directions to the facility. He notified plant security we were coming, and we met him at the entrance to a large hangar-like building. Within the large, clean area were several fledgling LMs in various states of fabrication. I felt as if I had stumbled into the nesting place of the Valkyries! Schweickart explained the LM electrical systems and other LM systems. After an hour, we left him to more serious work. As we walked out into the parking lot, the huge, yellow, nearly full Moon illuminated the night sky. The Moon appeared close enough to touch, but I knew it was more than a quarter million miles away. I couldn't imagine landing on the Moon in one of the tiny spacecraft I had just seen. But that was exactly what we would soon attempt.

I continued to work with meteorites. I chased fireballs and recent falls, which was sometimes frustrating and sometimes fun, but rarely resulted in a recovery.

A group of meteorites called "basaltic achondrites" appeared to be the best candidates for lunar meteorites derived from the lunar maria.¹⁸ These are rare meteorites with igneous volcanic textures similar to terrestrial basalts.

In December 1968, Apollo 8 took Borman, Lovell, and Anders away from the Earth, around the Moon, and back again by Christmas. Other missions were soon to follow.

¹⁸This idea, which was originally suggested by Cal Tech graduate student Mike Duke and his professor, Dr. Lee Silver, proved to be incorrect. Lunar meteorites were recognized in the meteorite collections from the Antarctic ice, but only years after the Apollo missions were over.

While unsuccessfully searching for a meteorite fall close to Crosby, Texas, I heard on the car radio about a very bright fireball witnessed in southern New Mexico, Texas, and northern Mexico. I returned to my office and asked my secretary, who was fluent in Spanish, to place some phone calls for me. I first contacted a newspaper editor in Chihuahua City. We had a lengthy conversation about the phenomena accompanying the meteorite fall but no specimens had fallen near Chihuahua City. Finally, I asked him the right question: "Do you know anyone who has any pieces of the meteorite?" "Oh yes," he said, and suggested that I call the newspaper editor in Hidalgo del Parral, much further to the south. My secretary located Sr. Ruben Rocha Chavez, editor of *Correo del Parral*. He recounted how a brilliant fireball had broken apart with a loud explosion in the middle of the night and had showered fragments over a large area near Parral. Chavez had several pieces of the meteorite on his desk and described them to me. There was no doubt—he had fragments of a freshly fallen stony meteorite! He invited me to visit Parral to see his pieces and to collect specimens. I thanked him for the information and his invitation and told him I would be there as soon as possible.

A quick check of airline schedules showed it was not going to be easy to get to Parral. I could fly to El Paso, but that was still more than three hundred miles north of Parral. It was the fastest way, however. My secretary promised to cover me with paperwork. I stopped by my house for a few clothes and headed for the airport. The plane took off on time, but, as luck would have it, a faulty landing gear indicator light grounded us in San Antonio for five hours while it was replaced. By the time I arrived in El Paso it was already dark. I picked up a rental car, cleared through customs, and drove south. It was important to recover pieces of the meteorite right away in order to measure their short half-life radioactivities. This would be great practice for the Radiation Counting Laboratory of the LRL. The Mexican highways were difficult to negotiate in the dark. The best technique was to follow a hundred yards behind a car with Mexican license plates. Some of the drivers were going 80

miles per hour, and when I saw brake lights or a cloud of dust, I knew the driver had spotted a burro on the highway. I arrived in Parral just after dawn. I checked into a hotel, washed up, drank some strong coffee, ate eggs and tortillas, and went to look for the newspaper office. I was waiting when the editor arrived.

I was astonished when I saw the two big meteorite pieces on the editor's desk. One weighed more than 30 pounds. The greatest surprise was the meteorite type—a rare carbonaceous chondrite. Chondrites are stony meteorites that contain chondrules, small spheres of silicate of disputed origin. Carbonaceous chondrites are chondrites that contain abundant carbon and organic compounds. While I was standing in Chavez' office, the telephone rang. The editor handed the receiver to me. It was a colleague from the Smithsonian who wanted information about the meteorite. He had called my Houston office, where my secretary gave him the number of the newspaper office. I told him what little I knew. I asked the editor about his plans for the two specimens on his desk. He said they were reserved for the National Museum. I agreed this was perfectly appropriate, but I was eager to recover some additional specimens.

The editor said I must visit the local municipal president or mayor. I was going to be treated as an official NASA representative. The mayor, Sr. Carlos Franco, was extremely gracious, and though my Spanish was meager and he spoke little English, we had an amiable meeting. I explained, through the editor as translator, how scientifically important meteorites are in general and that this particular one was a very rare type. Sr. Franco was eager to help me, and he assigned me one of his policemen and an official car for as long as I needed them.

We drove to places where specimens had been found. Recovering additional specimens proved to be easy. Everyone had small pieces of the meteorite, but I wanted some larger ones. I purchased these from the local people, with the policeman acting as interpreter and handling the negotiations. We documented several sites where specimens had been found. The stones had showered over a large area. One large stone had missed the post office in Pueblito de

Allende by only 30 feet. Meteorites normally are named after the nearest post office. This one almost named itself. We listened to many tales of the fireball, its direction of travel, the loud claps of thunder, stones falling everywhere, and people running to the church in the middle of the night. I picked up 13 pieces of the meteorite (Photos 43–44), including two large ones—enough samples for the time being.

By late afternoon, the day began to seem very long. I had not slept in 30 hours, and I still had to drive back to El Paso. We stopped at a little cantina, and I bought drinks for the meteorite party—the policeman, a local engineer who had been very helpful, and the Mexican reporters who had followed us all day. I bid them *adios* and hoped to make it to El Paso before nightfall. I pinched my arms and bit the back of my hand to stay awake. I arrived in El Paso after dark and entered U.S. Customs. I was met by a young customs agent who had taken a course in geology and wanted to know about the rocks I had. I finally reached the airport, turned in the

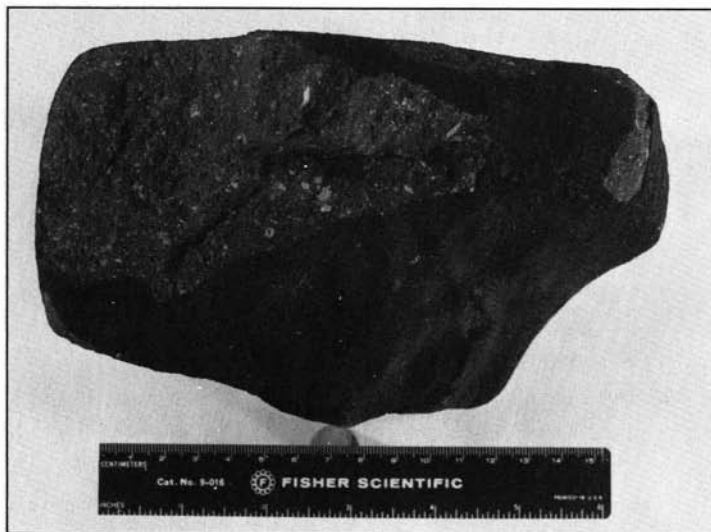


Photo 43. A piece of the Allende meteorite showing typical thin black fusion crust (ablation skin) and a broken surface. (Photograph by the author)

rental car, and inquired if anyone from Washington had made car reservations. Two of my Smithsonian friends had reserved cars, so I left them a long note telling them who to see and where to go to recover additional meteorites. I called Houston and told them to get the lab ready. I dozed for several hours in the airport until boarding time and then slept all the way to Houston.

One hundred and one hours after the fall we were gathering

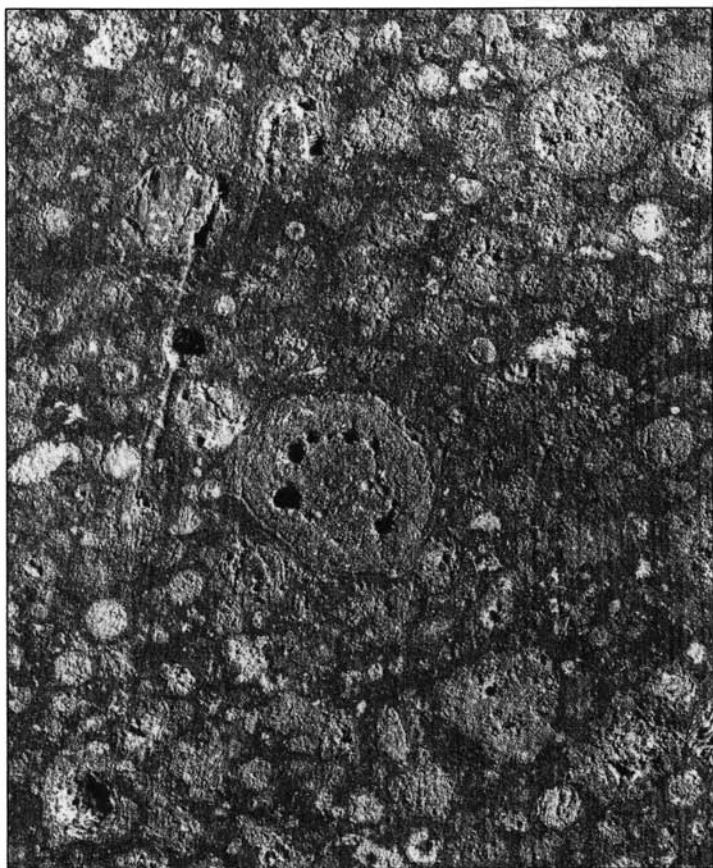


Photo 44. Sawed slab of the Allende meteorite showing sections through numerous chondrules. Length of field of view approximately four centimeters. (Photograph by the author)

data on a piece of the Allende meteorite in the LRL low-background gamma-ray counter.¹⁹ The Allende meteorite proved to be a “gold mine” of meteoritical science. We distributed many pieces to various investigators, using the procedure as a dress rehearsal for the lunar sample analyses. My own work with Allende would have to wait. It was too close to arrival time of the first lunar sample, and a lot of work remained to be done at the LRL. Allende became the best known and most studied meteorite in history.

In March 1969, the Apollo 9 crew—McDivitt, Scott, and Schweickart—flew a mission in Earth orbit. Schweickart didn't get to take his LM to the Moon, but the mission provided invaluable engineering data.

I was unexpectedly given a two-hour time slot with the Apollo 11 crew for a refresher in rocks, minerals, and meteorites. I borrowed some rare specimens for the session from Dr. Carleton Moore of the Center for Meteorite Studies at Arizona State University. The Apollo 11 crew wanted to know about tektites. Was there any possibility the tektites came from the Moon? I answered “no,” then gave them a brief explanation and history of the topic.

The crew also wanted practical advice on sample collecting. Was it better to get one extremely well-documented sample or several undocumented samples? For the first landing, no one would complain if the astronauts collected several samples with minimal documentation. Rock scientists would be particularly pleased if the crew brought samples of different rock types. Collecting rocks that looked different from each other was important, if possible.

Apollo 10 carried out most of the mission to the Moon except for the actual landing. The crew of Stafford, Young, and Cernan were launched in mid-May and enjoyed an extremely successful flight. Apollo 11 was next!

¹⁹E. A. King, E. Schonfeld, K. A. Richardson, and J. S. Eldridge, “Meteorite Fall at Pueblito de Allende, Chihuahua, Mexico: Preliminary Information,” *Science*, vol. 163 (1969), 928–929. See also, E. A. King, Jr., “The Largest Stony Meteorite,” *Pacific Discovery*, vol. 25, no. 1 (1972), 12–14.