the OBSERVER

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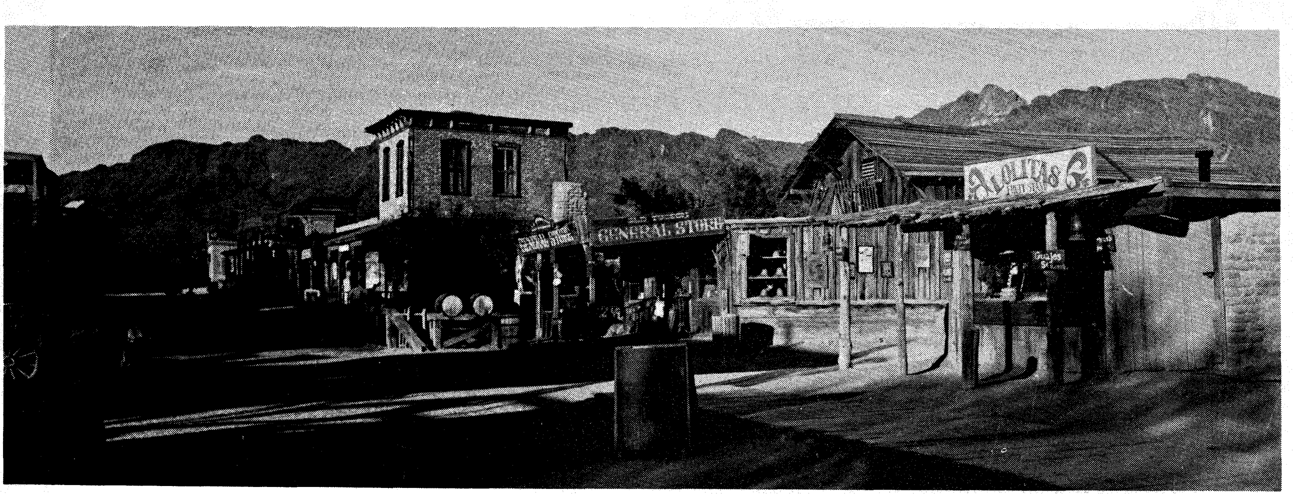

This Issue Comes To You From Tucson

The Cover

The Old West -- the cover picture was taken at "Old Tucson" by Mark Gordon. "Old Tucson", built in 1939 as a set for the movie "Arizona", depicts Tucson as it was in 1860.

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The *OBSERVER* is a quarterly publication of the National Radio Astronomy Observatory. Articles and comments should be sent to, P. O. Box 2, Green Bank, West Virginia 24944.

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One Site At A Time

The idea that each site should be featured once each year with most of the copy written by that site's employees has been proposed and kicked around for years. So, it wasn't any surprise that the idea surfaced again at our last editorial board meeting.

Bill Brundage suggested we offer Tucson the opportunity to have an issue about the 36-foot site to celebrate their ten years of operation.

Since Tucson responded so enthusiastically to the idea, we want to offer Charlottesville, the VLA, and Green Bank the same opportunity. Hopefully the March issue will feature one of these sites.

Thank you Tucson.

The Editors

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A special thanks to all the people who contributed articles and who helped with the *OBSERVER*.

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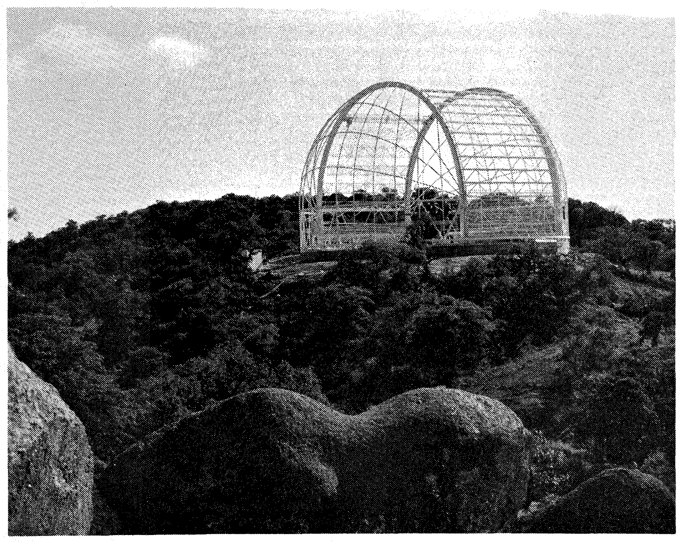
HISTORY OF THE 36-FOOT

Dewey E. Ross

The 36-foot had its beginning in the 60's at Green Bank. Frank Low and Peter Mezger, both NRAO astronomers with an interest in millimeter-wave astronomy, requested an instrument capable of coherent detection as well as the capability for use of optical-bolometer systems near a 1 mm wavelength.

John Findlay and the Rohr Corporation completed the design and work began in 1966. Hein Hvatum supervised the later stages of construction.

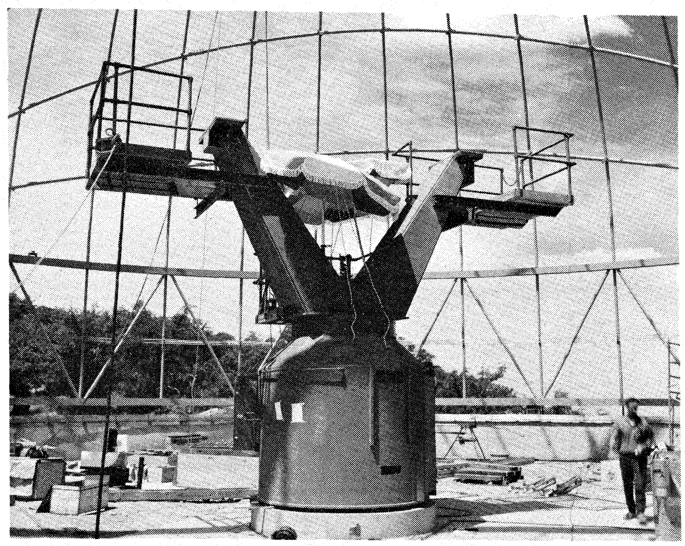


Kitt Peak Photo

Early construction - 36-foot dome

Omar Bowyer and Bill Vrable packed their belongings into a station wagon load of test equipment and supplies and headed west to spend a scorching summer in the desert testing the system as it was installed.

Stories began to filter back to Green Bank about flash floods (in the desert?) and rain storms in which city blocks had two feet of water standing. These stories were a bit strange to those of us who had never lived in the Southwest during the "monsoon" season but they were accurate.



Kitt Peak Photo

Testing the system

The NRAO base of operations and lab were housed in the Campbell Plaza Shopping Center in an area shared with Kitt Peak National Observatory's Space Sciences Division. The east wing of the KPNO building was completed in late 1967. The NRAO moved into a 1200 square-foot area in the basement.

The first permanent employees were Bill Terrel, Don Cardarella, George Grove and Ralph Burhans. Neil Albaugh and H. Donald Logan were frequent visitors to the site while preparing the cabling and receiver systems for the first observations which took place in October 1968.

The first observation, a temperature profile of the moon during an eclipse, was made using a 9.5 mm, Prime-Focus Continuum receiver and starred a cast of many. Among those present were Neil Albaugh, Don Cardarella, George Grove, Hein Hvatum, Emily Kitchen, Don Logan and Bill Terrell. The tasks included monitoring the pointing with a 12-inch optical telescope, driving the telescope, checking time with a stop watch and manually recording the time on a chart recorder. A chart recorder was the only means of taking data. Rumor has it that the first observation was similar to a Keystone Cops adventure. It was, however, the beginning of greater things to come.

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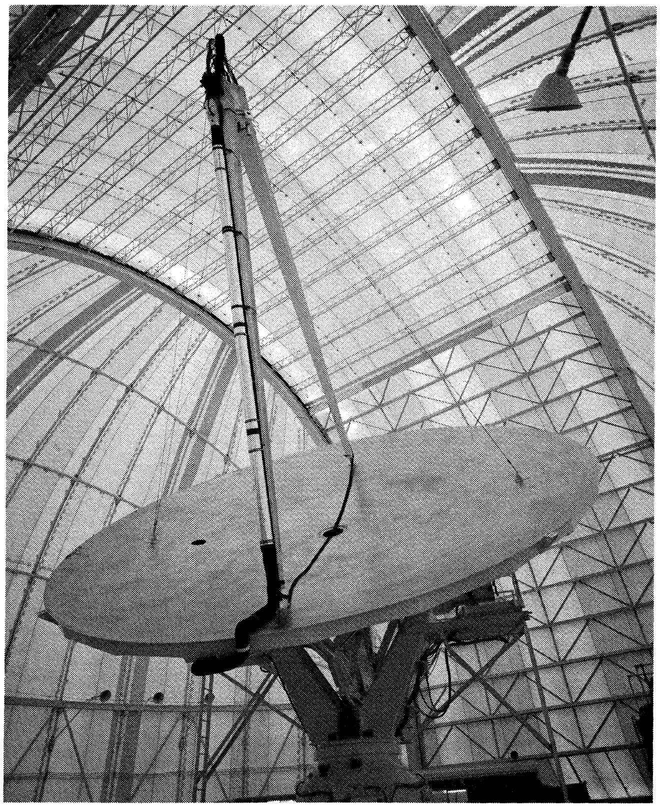


Kitt Peak Photo

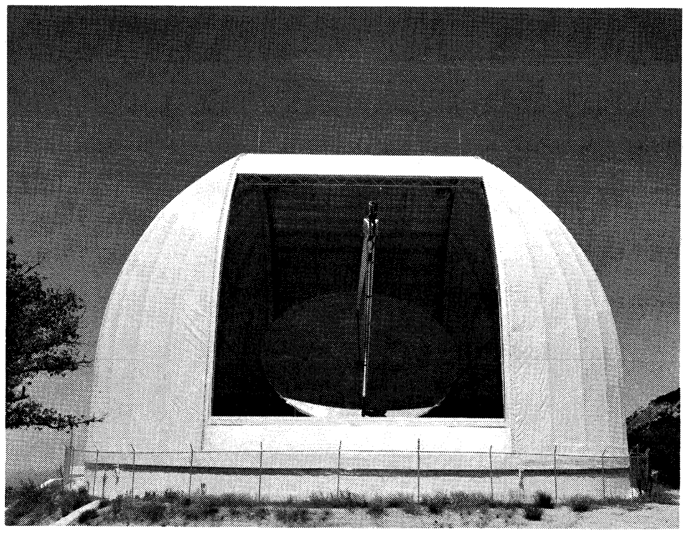
The 36-foot -- an inside view

The next few months were spent correcting problems and making improvements. The telescope was available for observing on a somewhat limited basis. Tests were conducted during the day and observing programs were run from sundown until dawn. Requests for observing periods of eight weeks were received and considered. Requests for as much as four weeks observing time were occasionally granted.

System upgrading continued and the first molecular-line receiver was used in the fall of 1969.

The permanent staff had grown to six by early 1970 and the first scheduled maintenance day for the 36-foot occurred on March 17, 1970. Molecular-line observations at 2.6 mm began about this time.

The decision to operate around the clock was made after many tests, modifications and an increase in observing requests. Full-time observations began in September 1970. The era of two-week observing runs had ended.



Kitt Peak Photo

The 36-foot -- an outside view

An electronics lab of 400 square feet was built inside the dome in 1971 in order that new equipment could be tested at the site rather than doing the work in Tucson and transporting it 55 miles to the mountain. As we grew we depended heavily on Carl Davis for our purchasing and on "Peck" McPherson for his dependability in shipping the supples to us.

During 1971 the trailer which was used to house visiting observers was moved from the top of the mountain to the 36-foot area near the dome. At the same time a second trailer was purchased and located in the same area.

The number of observing requests continued to increase and by 1973 there was more than a year's back-log.

The permanent staff continued to grow and the NRAO found that the original 1200 square feet of space plus two additional offices and an office trailer was insufficient. On May 9, 1974, we moved into 4800 square feet at our present location. In 1975, we annexed another 1623 square feet

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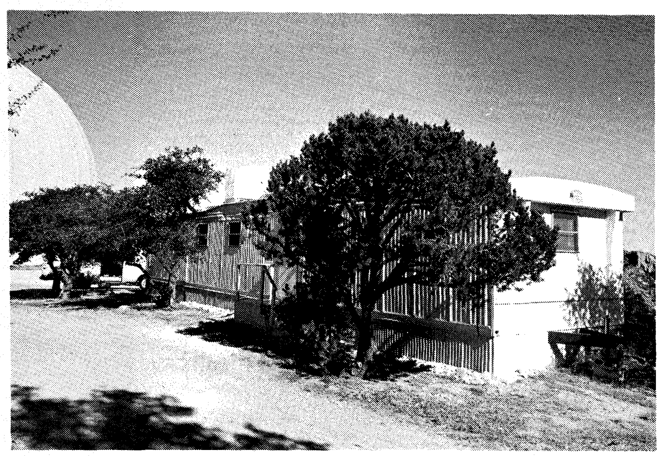
which now houses our storage area, screen room and computer room.

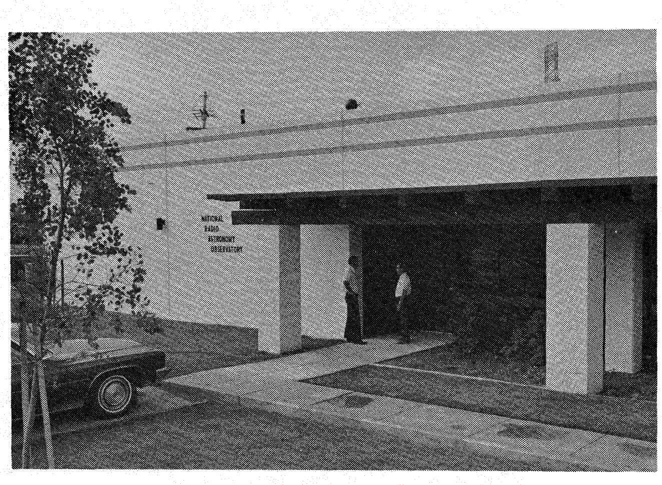
Growing pains continued and in 1976, a 2500 square foot electronics lab was built adjacent to the dome. Receiver systems are stored on rubber-tired carriages in the lab. Once a system has been prepared for installation, it is wheeled from the lab along the walkway to the dome. The dome is positioned so that a permanently mounted cherry picker/ crane can be used to lift the receiver into the dome and position it for mounting on the telescope. It takes an average of 15 minutes to disconnect the cryo-lines in the lab, wheel the receiver to the pick-up point, pick the receiver up and mount it and re-connect the cryo-lines.

Also during 1976, the operators' dorm was built so that our facilities would be in one general area. Prior to that, our operators who work seven-day shifts were housed in the KPNO dorm at the top of the mountain.

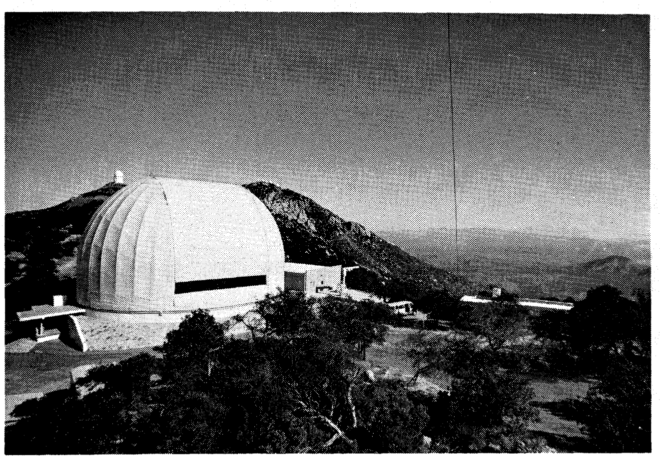
As we have grown so has the KPNO. What was once a barren mountain top is now a forest of telescopes.



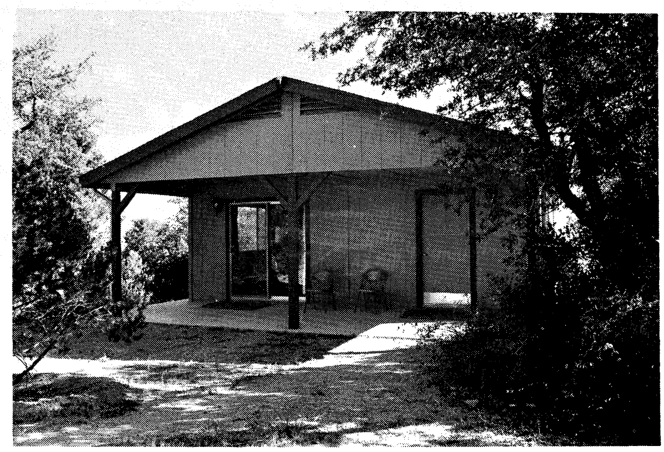
The observer's quarters



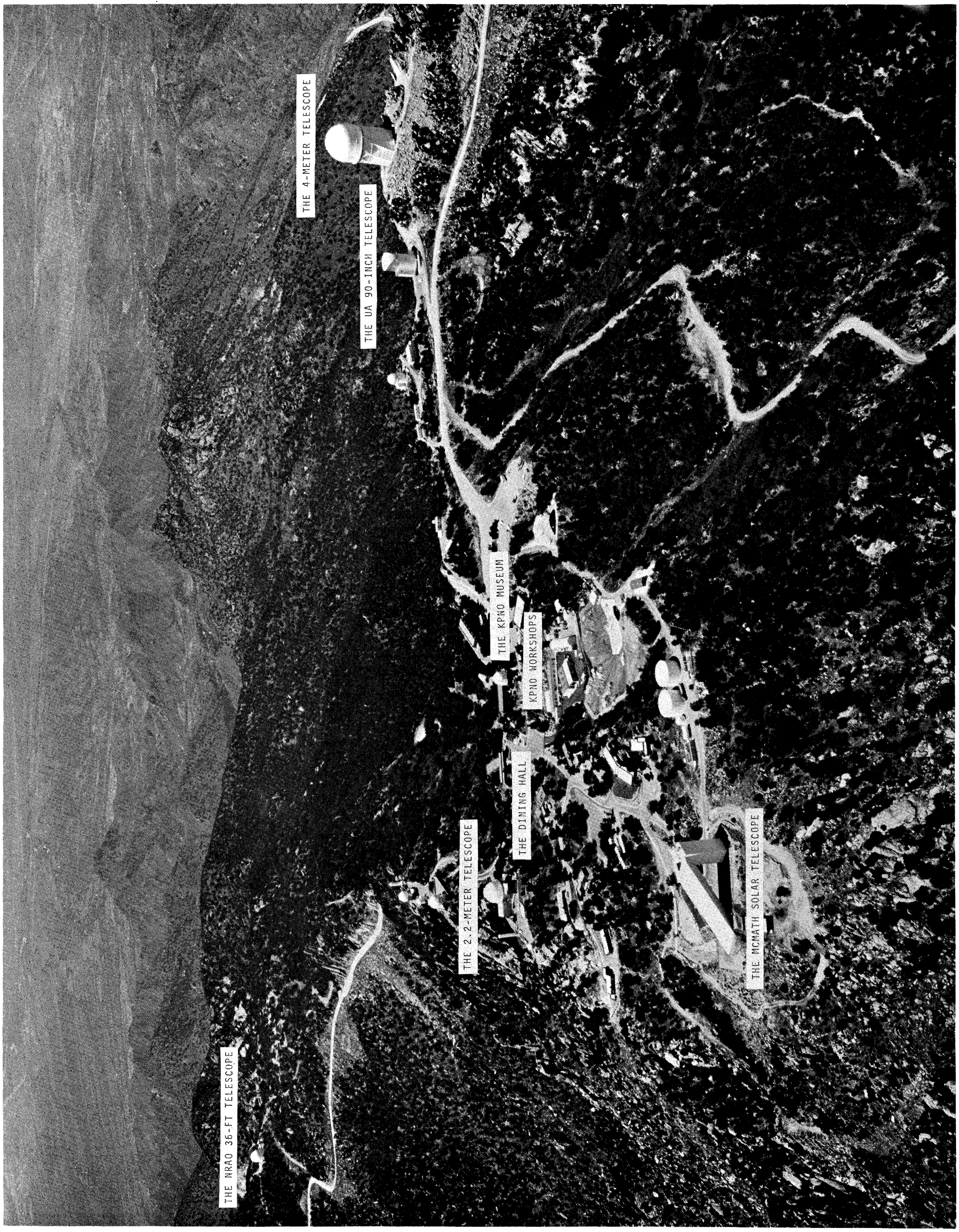
Tucson office and lab



The NRAO Complex



The operators' quarters



Kitt Peak Photo

An aerial view of the summit of Kitt Peak, looking southwest. The majority of buildings are Kitt Peak National Observatory. The 36-foot appears to the upper left. Since this photograph was taken, 2 new telescopes have been added. A UV vacuum telescope for KPNO, and McGraw Hill Observatory of the Dartmouth-Michigan-MIT consortium. The 4-meter is at an approximate altitude of 7600 feet; the 36-foot, at 6100 feet above sea level.

LIFE IN TUCSON

Dale Webb

Living in Tucson is much different than living in many other parts of the country. Not only is the weather generally nice year around, but also there is a sense of leisureliness that pervades the thoughts and the actions of people who live here. It is a relaxing way of life with the exception of those hours which one spends at work. Those hours are not very much different than working hours in most other cities. I think I can speak as somewhat of an expert on the area since I have been visiting Tucson since 1947, and first moved here in 1951.

To properly describe life in Tucson one needs first, to have a bit of "people" history. From about 300 A.D. to 1450 A.D. the Hohokum Indians lived in the valley now known as Tucson and the area surrounding Tucson. Sometime during the 1450's they mysteriously disappeared from this area. Later, the Pima Indians settled in these same fertile valleys and during the 1600's and early 1700's there was a large Papago Indian population in and around the area known as Tucson. These were mostly small settlements which were very loosely knit. The Spanish were in control of the land area at that time and were building, or had built missions in much of the southwest. Tucson has one of those historic missions named San Xavier Del Bac which was first built in the late 1600's by Father Eusebio Kino and is located just on the outskirts of the city of Tucson on what is now the Papago Indian Reservation.

The Papago Indians were a gentle, family oriented, farming people. In the same area however, there was an Indian tribe known as the Apaches who were warriors and hunters. The Apaches preyed on the Spanish and Papago populations. In order to protect the Spanish and the Indians, there were a series of forts built by the Spanish. One of these forts was known as Tubac which is to the south of Tucson, however that fort was difficult

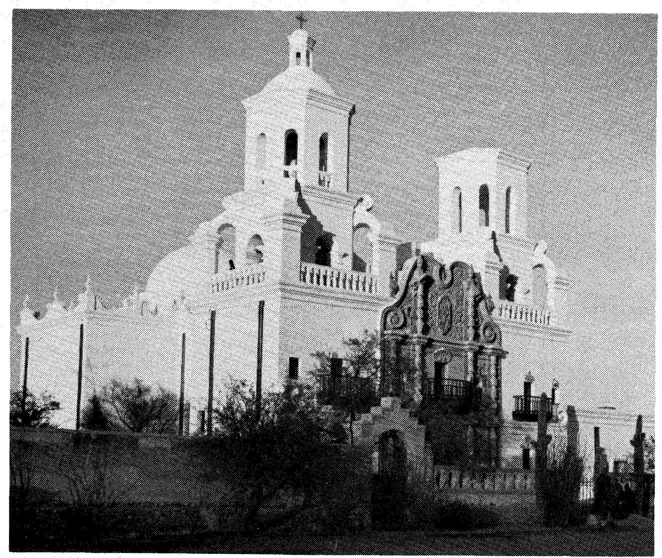


Figure 1. *San Xavier del Bac Mission was established in the late 1600's by Father Eusebio Francisco Kino. It has been known as the "white dove of the desert" and is still in use today as an Indian Mission.*

to defend. On August 20, 1775, Lieutenant Colonel Hugo O'Conor of the Royal Spanish Army selected the site for a new frontier presidio. This fort or "walled community" was on the site of present day downtown Tucson. Officially, Tucson considers itself a city that was founded in 1775.

In 1854, the Gadsden Purchase was ratified and the area known as Tucson then became officially a part of the United States. It then, of course, became the responsibility of the United States to protect its citizens in its newly acquired territory. As a result, in 1866, Camp Lowell was established near the edge of Tucson and the walled presidio. Between 1866 and 1873, they had approximately 200 troops stationed just outside the city of Tucson. This was a very large military organization at this time for this area. In March of 1873, the military announced that they were moving their fort from just outside the city limits to an area 7 miles east. This new fort was

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to be known as Fort Lowell. The reasons that they gave for moving were the evil influences of the city, dirty water, and the requirement for forage for their horses. The first requirement was apparently not solved by moving 7 miles east. One of the local historians told me that the major east-west street, now known as Speedway derived its name from the races which the military men would have on Friday night leaving the new Fort Lowell and heading for the bars and bordellos of Tucson. One record on microfilm states that a good horse could make it in 55 minutes.

The Indian wars were officially over in 1886 in this area, however Fort Lowell was not decommissioned until 1891 because the city fathers were afraid of the economic impact which the early closing of the fort might have on the city.

Figure 2. *This photo shows one of the original officer's quarters at Fort Lowell. The building was built in 1873. The original adobe bricks and the stucco finish are both apparent.*

Today, the Spanish and Indian cultures are still very obvious in much of Tucson life. The Indian culture has not been as predominate in present day Tucson life as the Spanish culture. The primary reason is that the Indian population today accounts for only 3 per cent of the total population, and many of the Indians live on reservations rather than mixing with the rest of the general population. However, there are five Indian reservations located in or around Tucson for three different Indian tribes. One of these Indian reservations is less than a mile from our downtown office on Forbes Boulevard.

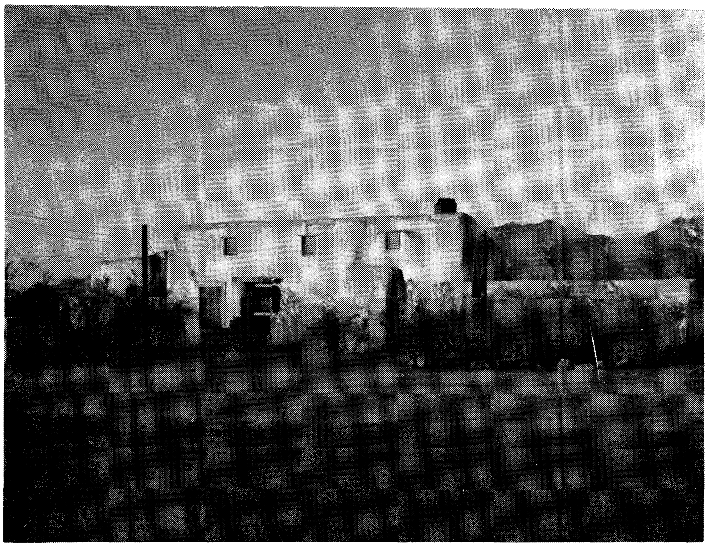

Figure 3. *This photo shows the Post Traders Building located at Fort Lowell. The building is now used as a residence, however at one time it was a general store complete with separate gambling rooms and bars for officers and enlisted men. The adobe does withstand the test of time.*

The Spanish influence in the Tucson area has been tremendous. People of Spanish heritage now make up nearly 25 per cent of the population. Our architecture, street names, customs, food, etc., have all been heavily influenced by the Spanish culture and traditions. A major portion of the homes in Tucson are built with the Spanish, territorial appearance. The original Spanish and Indian homes were built out of

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adobe which is made from straw and the dirt of the desert floor. The adobe mud solution is put into wood forms approximately 12 inches wide, 18 inches long, and 4 inches high. These forms are then left in the sun to dry into bricks. The adobe bricks are then layed with a mud packing and when complete, the outside is given a lime based stucco finish. Because the original homes were not air conditioned these thick adobe walls were used to keep out the heat in the summer and keep out the cold in the winter. The original homes and today's modern homes are normally built with a flat roof. Since there is no snow load a peaked roof is not necessary here.

With some of the "people" history in mind it is perhaps best to go on with some more current "people" information about Tucson. For many years Tucson has been known as a famous resort area and a large portion of the community is and has been employed directly or indirectly by tourism. The major employers here in the past thirty years and yet today have been the Federal Government, the University of Arizona, School District One, Davis-Monthan Air Force Base, and many service related businesses. There is also a fair amount of the population engaged in mining and agriculture, however they are small relative to the people in non-production industries.

Because of the large number of clear days and normally nice weather, the aircraft industry has been particularly important in the Tucson area. During the early 1940's a company called Consolidated Vultee employed 3,000 to 4,000 people in Tucson, building parts for bombers in World War II. After the war they were closed down, however the large hangers which they built were taken over by Grand Central Corporation during the early 50's to modify bombers for the Korean War. Their employment peaked at almost 4,000 people and when they went out of business those same hangers were used by Douglas Aircraft to employ approximately 1,500 people. In the past three years Lear Jet has moved to Tucson and is now modifying and will be building private jet aircraft for the commercial market. Until the late 1960's the only other major manufacturing employer in Tucson was Hughes Aircraft. They have employed up to 4 or 5,000 people at various times in the past 30 years. From 1957 until 1967 there was very little manufacturing being done in Tucson and the economy relied primarily on tourism and service industries. However during the 70's we have built up to the point where we have a much more balanced economy. As of June 1979, Tucson had an unemployment rate of 4.7 per cent and an employment by category as follows:

Manufacturing	18,700
Mining	6,800
Construction	13,400
Transportation and Public Utilities	8,800
Wholesale and Retail Trade	37,600
Finance, Real Estate	7,600
Services	35,100
Government	39,800

Now that we have explored the history and the economy as they relate to the people, I would like to describe some of the things to do in Tucson. Because Tucson has been a tourist area for many, many years there are numerous attractions, both natural and man-made, which are visited by thousands of tourists annually. Many of these places are favorite haunts of the local populace and to them, these attractions are a place to go on a nice weekend or weekday outing. I have been to all of the places that I will describe, and some of them I have visited many times.

If you are a history buff or like to learn about the past, Tucson has several excellent museums. They include an Anthropology Museum which is quite extensive in dealing with the geology and anthropology of the area; a Natural History Museum with extensive displays of the early Indian and Army battles and early settlement ways of life; a small Pharmacy Museum, and a large Geology Museum. There is a small museum at one of the early Army forts knows as Fort Lowell. You might be interested to know that all Tucson NRAO employees visited the Natural History Museum and Anthropology

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Museum as a company sponsored outing. On another occasion we had a steak, eggs and champagne breakfast at the Fort Lowell Museum and Park, complete with a guided tour and question and answer period on the old Fort Lowell.

If you are interested in botany or desert animals there is the Arizona-Sonora Desert Museum which has many of the living animals and plants of the Sonoran Desert. This is the only museum of its type in the world and it is a must for almost all visitors.

Many Tucsonans and visitors will tell you that Tucson is the Astronomy Capitol of the World. Indeed, astronomy buffs can have a field day in Tucson. Many of them begin their astronomy journey with a visit to the Tucson Flandrau Planetarium. Here they can enjoy a journey through time and space as they view the show on a 50-foot hemispheric dome, and listen to the sound effects on a 31-speaker system. They also have available a 16-inch public telescope which they can view through from dusk until 10:00 p.m.

Next they can visit the University of Arizona, and the Steward Observatory which is located on the University of Arizona campus. The Steward Observatory has three telescopes located on Kitt Peak, and four telescopes located on Mount Lemmon. In addition, they have telescopes located right on the University campus. The Kitt Peak National Observatory, which is a sister to NRAO, has not only their headquarters operating here, but they operate 12 telescopes on Kitt Peak, and have the AURA headquarters here as well. On Mount Hopkins, just south of Tucson, there is the new multiple mirror telescope operated by the Smithsonian Institute in conjunction with the University of Arizona. This is reported to be one of the major breakthroughs in optical astronomy,(in that they use six small mirrors simultaneously to equal the observing capability of a mirror approximately 176 inches in diameter). In addition, Smithsonian operates a Gamma Ray and three other telescopes on Mount Hopkins. San Diego and Minnesota jointly operate a telescope on Mount Lemmon. The Universtiy of Michigan, Dartmouth, and MIT operate a telescope on Kitt Peak. As you drive through the residential regions of Tucson you can even see telescopes with domes located in back yards. No, I didn't forget. There is another major telescope installation on Kitt Peak known as the 36-foot millimeter-wave telescope. I am told that this is also a world class instrument.

One of the favorite tourist attractions is Old Tucson. This is a 320-acre settlement which was originally created in 1939 by Columbia Pictures for the movie classic, "Arizona". Since then the town has grown considerably. It now boasts its own sound stages as well as a complete family-fun park. Stuntmen and actors stage gunfights on a daily basis and there are train rides and stage coach rides which provide a magnificent view of the territory. It is used for many modern-day movies and television series. Some of the more famous movies that have been filmed here are, "Death of a Gunfighter" with Clint Walker, "The Life and Times of Judge Roy Bean", "Heaven With a Gun", starring Glenn Ford, "Gunsmoke", starring James Arness, and the series known as "High Chaparral" used Old Tucson as its primary base. "Petrocelli", the lawyer series was filmed at or near Old Tucson as well as in the city proper. (See Figure 4.) "Little House on the Prairie", starring Michael Landon is frequently filmed at Old Tucson. Old Tucson is also a must for most visitors.

For a different experience we have, within 22 miles, Colossal Cave. It is possibly the largest dry cave in the world and maintains a temperature of 72^{o} year around. There is evidence that outlaws frequently hid themselves and their loot in the caverns. Cave explorers have never found the end of Colossal Cave and are still searching miles away from the entrance.

In my opinion, one of the most beautiful spots in this area is Sabino Canyon. It is a natural canyon in the Catalina Mountains which has a running stream most of the year. Tall trees of many varieties line the stream and many hundreds of types of vegetation and wildlife are protected

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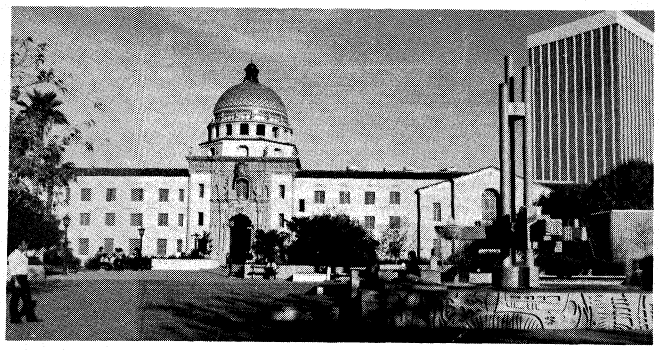

Figure 4. *Pima County Court House, built in 1929 in the Spanish Colonial Revival style. You may have seen this building on the TV series "Petrocelli".*

here. This is a favorite area for many Tucsonans to go picniking, hiking or to just relax and spend a leisurely day enjoying the sunshine. They now have an open-air tram which carries visitors through the most beautiful parts of the canyon.

Mt. Lemmon, which is 30 miles from Tucson via a very scenic route makes it possible for those persons who enjoy snow and tall pine trees to get away from the heat in town and drive a short distance to a beautiful area much like the mountains of northern Michigan, or West Virginia. This is a favorite spot for the skiers who can ski from January through April, the hikers who hike year around, as well as thousands of families who just enjoy getting away to the isolation of the tall trees. This 30-mile drive, which takes you from 3000 feet to 9175 feet elevation, also takes you through six separate vegetation zones. You can enjoy the beauty of cacti, many types of oak trees, manzanita trees, juniper trees, many types of pine trees, and fir and aspen trees.

One of our other major tourist attractions is the Davis-Monthan Air Force Base aircraft storage. Here over 4,000 airplanes and helicopters are stored on 3,000 acres making it the largest aircraft storage area in the United States. This site was picked because of the low humidity and mild temperatures.

There are other famous tourist attractions. La Fiesta de los Vaqueros Rodeo which is held the last week of February is well attended every year. A short distance from Tucson we have Tombstone which is a western city famous for its gun fights. There are many ghost towns within an easy day's drive, including some of the famous ones such as Jerome, Arizona. Jerome was once the fifth largest city in Arizona. It is now abandoned except for tourist attractions. Nearly a billion dollars in copper, gold and silver were mined out of one hill near this town. There are many Indian ruins including Montezuma's Castle, Montezuma's Well, Tuzigoot National Monument and others. Within a day one can also see one of the world's famous seven wonders, the Grand Canyon. Just south of that is another beautiful canyon known as Oak Creek Canyon.

In the paragraphs above I've given a little bit of "people" history, a description of things to do and the things to see for Tourists and local Tucsonans. However, there is much more to the Tucson way of life than just those items. Within the NRAO here in Tucson we have employees who are intensely interested in lapidary activities and rock hunting. We also have some who make pottery and some who make Indian jewelry. There are hunters, avid swimmers and several avid hikers. We do not have any spelunkers that I know of. However, that is also a favorite pastime in the area. For those who golf there are 15 golf courses. Tucson has 81 parks and 18 public swimming pools. For baseball fans we have our own baseball team known as the Tucson Toros and the opportunity to watch the Cleveland Indians baseball team during their spring training here in Tucson. For racing fans we have two dog racing tracks, and a thoroughbred quarter-horse race track. We also have a large circle track for hot-rod racing, and Tucson is the home of the Winter Nationals for the American Hot-Rod Association Drag Strip Racing. There are drag racing events each weekend throughout the summer. For hunters and fishermen there are many streams

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and hunting areas within three hours of Tucson. For those who like to go scubba diving we are within a few hours of the Pacific coast off Mexico.

High among the factors making Tucson an agreeable and invigorating community are the variety of cultural activities which are available. We have an outstanding symphony orchestra, a Saturday Morning Musical Club, the world famous Tucson Boy's Chorus, and the Tucson Pops Orchestra. The University of Arizona regularly presents many fine stage shows and musicals and the Sunday Evening Forum invites many outstanding representatives of government, education and entertainment to speak from the world over. We have several art galleries and a modern music hall and little theater in the Tucson Community Center complex. One of the things I like best about Tucson is the fact that there are many shopping areas spread out through the city. We have several malls, each of which covers many acres of land and have stores of every type from which you can purchase nearly anything you would want. Parking is free and convenient and there are no crowds of people pushing and shoving as one typically finds in the large cities back East.

Max Thomas, Bill Gust, and myself of the business office all agree that one of the things we like best about Tucson is the weather. All of us like temperatures 80° and above and dislike temperatures below 80°. All of us are normally early risers, and for early risers, there are beautiful sunrises over the mountains each morning. Many of the NRAO Tucson employees have swimming pools either at or near their homes, so swimming and outdoor exercise for many months of the year are a major form of recreation. My wife happens to be an antique car buff and for many Tucsonans that is a major hobby. Because of the nice weather year around, antique car buffs can work on and take their cars out for 12 months of the year. There are more than 10 antique or special interest car clubs in this area. Several of them have members with a total collection of cars exceeding 200.

If all this information on symphonies, boys' choruses, and so on, has led you to believe that Tucson is a kind of dry, sophisticated town, let me assure you it is not. Dewey Ross tells me that there are many observatory visitors and employees who have taken the tour known locally as the Dewey Ross Low Life Tour. The Low Life Tour might lead to such places as the Ranch House where you frequently see cowboys or motorcycle riders coming in and checking their guns at the bar and you might also see tattooed ladies dancing in the buff. For those who are not daring enough to go to the more rowdy cowboy hangouts, Dewey also has some reasonably entertaining night spots known as the Blue Note, the Cabaret, and the X House. If you want to hear some interesting stories, you might ask someone who has visited Tucson about the Dewey Ross tour. By the way, Dewey tells me that he has added a new attraction to the Low Life Tour for couples who visit Tucson. The new attraction is the Sweetwater Funtubs located southwest of town. Their advertisement reads: "Bring your favorite refreshment and a few close friends and enjoy an hour or two of fun, friendliness and relaxation in a redwood Hot Tub."

Tucson also has many country western night spots and frequent concerts by well-known country artists. For example, Merle Haggard, Dolly Parton, Waylon Jennings, Hoyt Axton, Bonnie Williams, Leona Williams, Kitty Wells, and Christy Lane have all been here within the past few months. For those who are into disco dancing we have disco establishments. We even pioneered the "anyone can do it in the barroom" boxing matches at one of the local nightclubs. While many towns have nightclubs which feature dancing ladies, Tucson has at least two nightclubs which feature dancing men. One of these nightclubs allows women to attend their Sunday night shows with no cover charge, however, they have a $500.00 cover charge for men who attend on Sunday night.

No folks, Tucson is not a stuffy town. Because Tucson is a "melting pot" in that

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its inhabitants are made up primarily of people who are not native, we have one of the most diverse cultural and social societies possible. We have every variety of restaurant from a five-star rated continental cuisine-type to the Der Weinerschnitzel Hot Dogs. In between there are many restaurants which feature many varieties of Oriental, Mexican, Italian and German food, as well as many traditional western steak houses.

Well, there you have one person's viewpoint of life in Tucson. Many would disagree with my opinion of how nice it is to live here. Some feel that the hot weather is unbearable, while others like myself won't take vacation until the thermometer hits 100°F. Many people miss having grass and tall trees. With water being scarce most people cannot afford, or do not feel morally right in having lawns, so their homes tend to have rocks in the front yard, or in many cases they have plain dirt and desert vegetation. The only rivers in town are normally dry. When they do have water in them, they are usually flooding and that means property damage and frustration to all who live nearby. (See Figures 5. and 6.) On the other hand, if you enjoy wide-open spaces, the ability to see for miles, enjoy mountains nearby, and an almost continuous or monotonous amount of sunshine, this is a beautiful place to live.

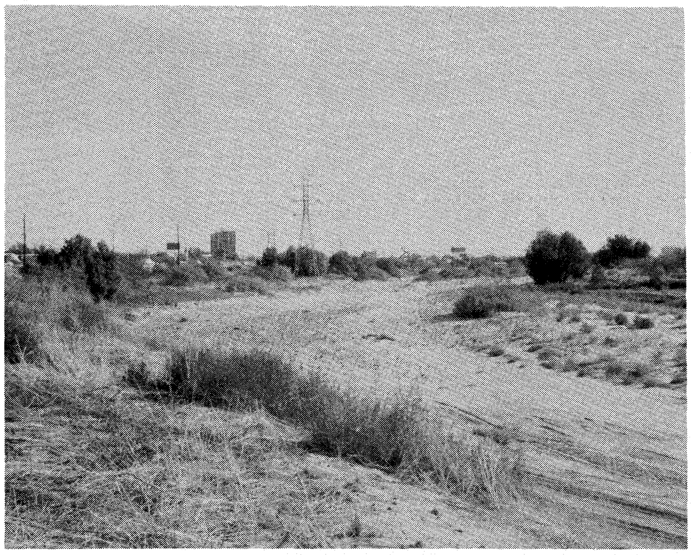

Figure 5. *The Santa Cruz River as it normally looks.*

Figure 6. *The Santa Cruz River in December, 1978. Just to the right of the floating log, the water is about 18 feet deep.*

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A BEAUTIFUL PLACE TO LIVE

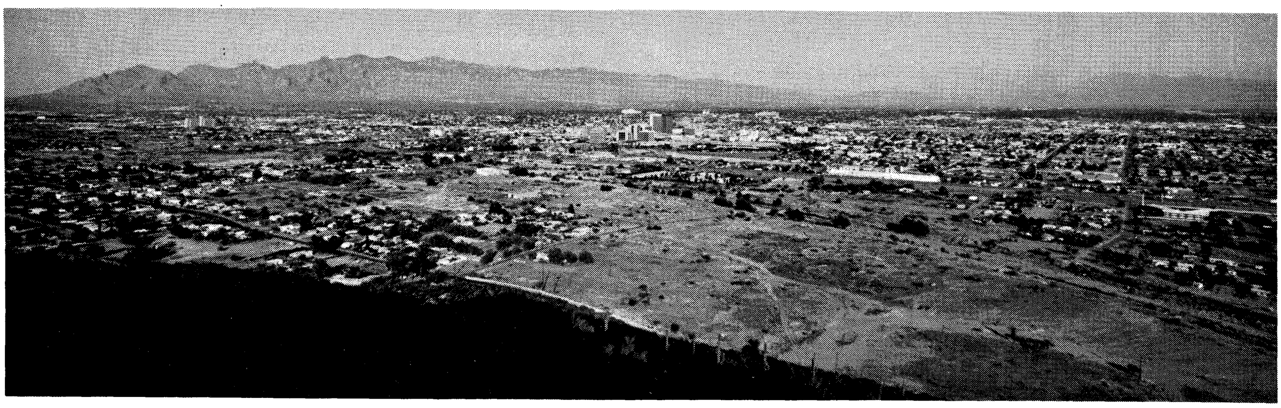

Figure 7a. *View from "A" Mountain looking northeast.*

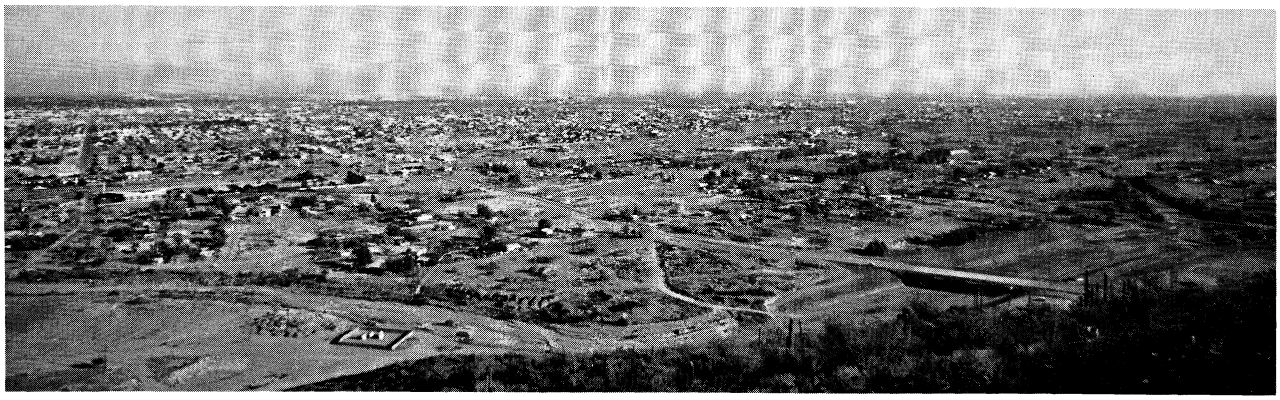

Figure 7b. *View from "A" Mountain looking south east.*

* * * * *

FUTURE MILLIMETER-WAVE OBSERVATIONS: THE 25-m TELESCOPE

Many of you may wonder what's happening to observatory plans to build a new telescope in Hawaii. Or, why we want to do this. Because this telescope is a result of what we've been doing in Tucson for over a decade, I thought it appropriate to include a summary which NRAO has prepared for the National Science Foundation regarding the Hawaii project.

The project has now been submitted by the NSF to the Office of Management and Budget. The preferred plan is the four-year one listed at the end of the summary. We have no way of knowing the likelihood that this project will be funded, but we are optimistic.

Within the NRAO, the project is planned by a Working Group. This includes John Findlay, Sebastian von Hoerner, Hein Hvatum, John Payne, Buck Peery, and Dale Webb. As Project Manager I chair this committee. Though not formally members of the Working Group, Lee King and Woon-Yin Wong perform the lions' share of engineering design. In addition to these people, who carry specific assignments related to the project, we depend heavily upon the advice of the NRAO scientific staff. In particular, Barry Turner who almost single-handedly got the project under way.

NATIONAL RADIO ASTRONOMY OBSERVATORY

THE 25-m MILLIMETER WAVELENGTH TELESCOPE
April 4, 1979

1. INTRODUCTION

The National Radio Astronomy Observatory proposes to build a radio telescope of diameter 25 meters, having a surface accuracy of 75 μm, to permit operation to wavelengths of 1.2 mm and shorter. The chosen site is the low-latitude, high-altitude Science Reserve on the summit of Mauna Kea, Hawaii.

This state-of-the-art instrument will allow astronomers to take full advantage of the millimeter-wavelength region of the electromagnetic spectrum. Specifically, it will help develop the new subject of astrochemistry, investigate star formation on galactic and extragalactic scales in regions otherwise inaccessible because of optical extinction, and attack the fundamental problem of the structure and evolution of galaxies by measuring the amount and composition of their gas content. It will be a powerful instrument for investigating activity in the nuclei of galaxies and quasars by permitting continuum observations in the wavelength region between the traditional optical and radio domains. It can also explore the atmospheres and surfaces of planets, satellites, and asteroids within our own solar system.

2. SCIENTIFIC NEED

Millimeter-wave astronomy, now approximately ten years old, includes the spectral region from roughly 1 mm to 1 cm, or 300 to 30 GHz. The peculiar advantage derived from the millimeter region of the spectrum is two-fold. First, it permits the astronomer to examine the dark, cold regions of the interstellar gas by means of the radiation from molecules which form there. Second, it permits astronomers to examine sources of continuum radiation at wavelengths midway between the traditional optical and radio spectral regions.

Observations in this spectral region have given new insight into the nature of the interstellar gases, the formation of stars, the evolution of galaxies, and the nature of explosive events in quasars and the nuclei of radio galaxies. They have also stimulated a new field of astronomical research now known as astrochemistry. These areas will be discussed in more detail below. Other research areas have also received large impetus with the advent of millimeter-wave observations. Among these are the study of planets and their atmospheres, comets, evolved stars and their interaction through mass loss with the interstellar gases, the evolution of planetary nebulae, the distribution

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of isotopes in our galaxy, and the distribution of molecules in external galaxies.

A. Molecular Clouds and Star Formation

Stars form from and disintegrate into the gas and dust known as the interstellar medium. The extinction of light by this medium allows only a limited study by optical techniques. The fundamental wavelengths emitted by the embedded molecules lie in the millimeter range. Through millimeter-wave astronomy, it is now known that approximately half of the mass of the interstellar medium is in the form of molecules, in clouds or cloud complexes which vary from about 3 to 300 light years in size and from 1 to 10^6 $M_\odot$ in mass. Stars form from these clouds. Except for hydrogen and some fraction of helium, the atoms in these clouds were formed in nucleosynthesis from stars long gone.

The distribution of the molecular clouds has been measured on an overall galactic scale. Several hundred thousand clouds are concentrated in the galactic nucleus and within an annulus between 12,000 and 25,000 light years from the galactic center. Within these regions the space-averaged abundance of the molecules exceed that of atoms by a factor of at least 5. This unexpected abundance of molecules has sharply changed our understanding of large-scale star formation within our galaxy. For a number of years it has been known that the space-averaged abundance of atoms decreases in the inner part of our galaxy. This decrease was presumed to be due to vigorous star formation in the galactic interior, such that the process of star formation depleted the interstellar gas. It is now clear that large amounts of gas do exist in the galactic interior, but in the form of molecules, thus providing the material from which a new generation of stars can form.

Many sites of star formation have been found by observations of molecular lines at millimeter wavelengths. In some cases these observations have been supplemented with observations of continuum emission in the millimeter and infrared regions. Typically, when densities within a cloud exceed 10^6 cm-3, intense maser emission occurs from several molecules. The most common molecular masers are OH and H_2O. In the same locale are usually found molecular lines having very broad wings. These broad wings indicate a rapid flow of mass as would be expected in the earliest stages of star formation. Often observations of millimeter continuum emission from the same regions show the presence of heated dust and compact sources of ionized gas characteristic of newly formed stars. In objects close to the sun, these ionized regions appear as parts of large molecular clouds. In the Northern Hemisphere the most spectacular example is the Orion Nebula, an example of a large cloud which is undergoing successive bursts of star formation.

All stages of this star formation process have been found by millimeter-wave astronomy. For the first time it is possible to investigate star formation on a quantitative basis. These data permit tests of, and refinement to, star formation theories developed over the last four decades.

The physical conditions within the clouds are also an important area of study. Observations of molecular emission lines show that cloud temperatures range from 6 K when there are no internal energy sources to 90 K when protostellar or stellar objects are embedded. Within the clouds, densities range from 10^3 atoms per cm^{-3} in diffuse clouds to as large as 10^8 cm^{-3} in highly compact regions within some giant complexes. Sometimes the distribution of velocities within the clouds suggest the clouds to be rotating. A few clouds appear to be collapsing, showing that their internal gravitational forces dominate over internal turbulence, centripetal forces, and magnetic and radiation pressure. The balance of these forces are fundamental to our understanding

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of how stars form, and to the energy balance and flow within the interstellar medium.

B. Interstellar Chemistry

The new subject of astrochemistry derives from the types and abundances of molecules within the clouds. It deals with the theories of molecular formation and destruction in the interstellar medium. At this time, more than 50 molecules have been observed. Adding the isotopically substituted species which have been seen, including ^{2}H, ^{13}C, ^{17}O, ^{18}O, ^{15}N, ^{33}S, ^{34}S, ^{29}Si, and ^{30}Si, increases this number to more than 100. Several molecular species were detected and identified by radio astronomers before they were even synthesized in terrestrial laboratories. The low temperatures of the molecular clouds have permitted the direct observation of hyperfine splitting in HNC and N_2H^+, which cannot be resolved in the laboratory. Furthermore, accurate microwave frequencies have been determined astronomically for several species inaccessible in the laboratory. These species include HCO^+, N_2H^+, HNC, CH, C_2H, and C_3N. These observations provide basic spectroscopic data required to understand the structure of these molecules and radicals.

The formation of astronomical molecules occurs generally under conditions quite unlike those on earth. The study of interstellar chemistry permits an investigation of chemical reactions not easily duplicated in the laboratory. Primarily because of millimeter-wave astronomy, the chemistry of ion-molecule gas reactions has experienced a major impetus in the last four years. Catalytic reactions on dust grains may also be important in the interstellar medium, and recent laboratory work has been devoted to this area.

C. Extragalactic and Cosmological Objects

Although to date millimeter-wave astronomy has had its greatest impact on galactic problems through observations of molecular clouds, millimeter-wave observations of continuum emissions have grown in importance. Cold regions have recently been detected in the isotropic cosmic radiation in the directions of several rich clusters of galaxies. One explanation is that the background radiation in these directions has been scattered by a tenuous hot gas comprising an intergalactic medium. For some years the existence of this gas has been predicted by astronomers on the basis of satellite observations of X-rays. The mm-wave observations tend to confirm the presence of the long-conjectured intergalactic gas.

The radiation from a number of extragalactic objects varies with wavelength in diverse ways which are poorly understood. Objects which are optically bright and variable usually exhibit a constant or increasing radiation intensity from centimeter to millimeter wavelengths. In at least one object, A0235+164, an intense outburst occurred simultaneously at optical and millimeter wavelengths, indicating a close relationship between the optical and radio variability. The polarization of another object, OJ287, has the same position angle observed at millimeter and near-IR wavelengths. Observations such as these may direct our analysis of the energetics and emission mechanisms of these cosmological objects.

Other important observations have been made of galaxies at millimeter wavelengths. The nuclei of the cores of several double radio galaxies have been observed to be strong emitters at millimeter wavelengths. The fact that several of these objects have also been detected as X-ray sources suggests that these objects may be cooling by means of the Compton effect.

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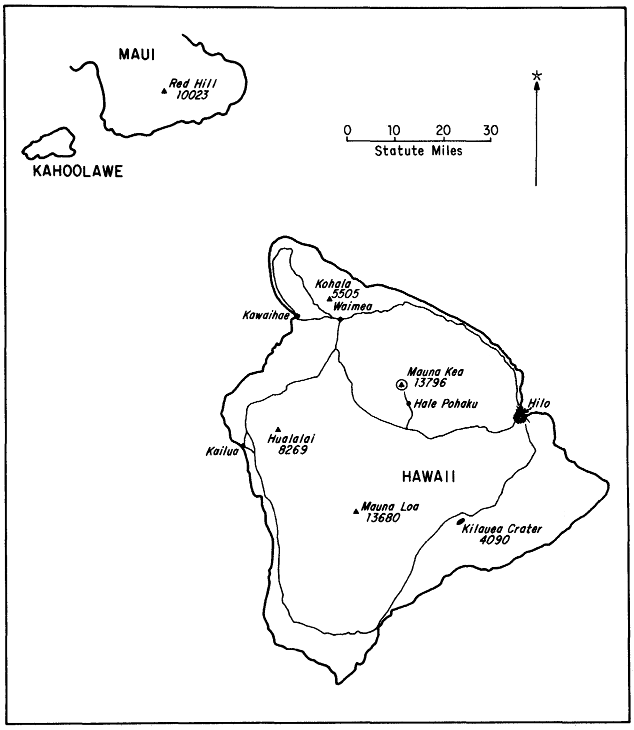

Figure 1. *Map of the Island of Hawaii*

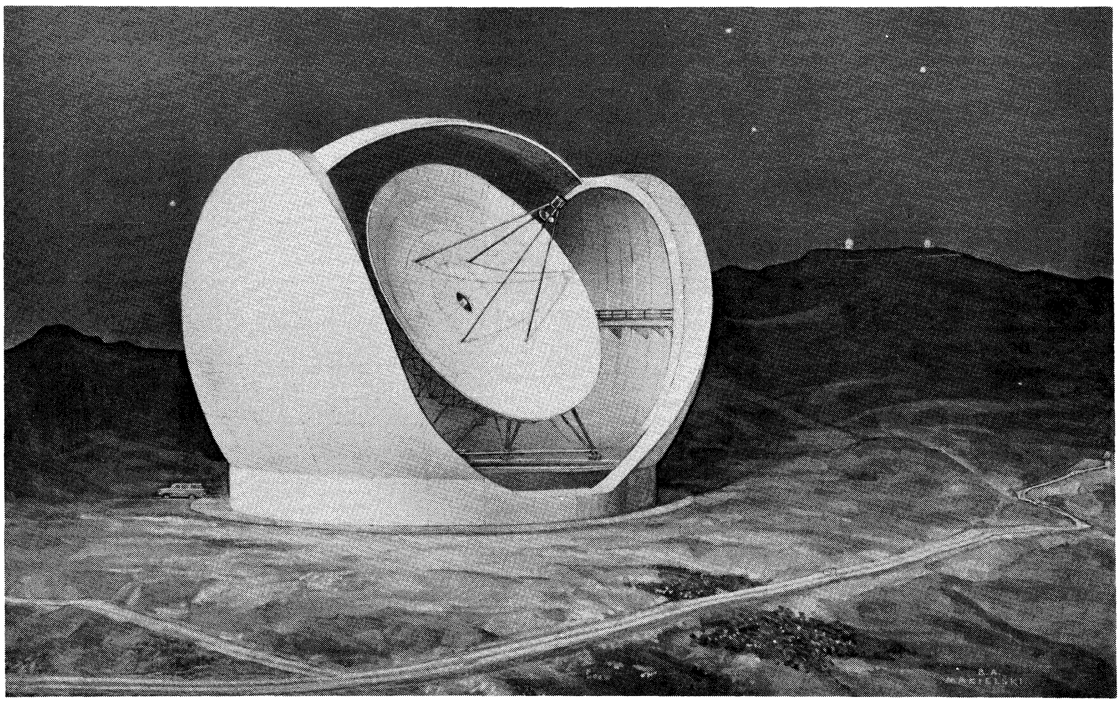

Figure 2. *Artist's conception of the 25-meter telescope.*

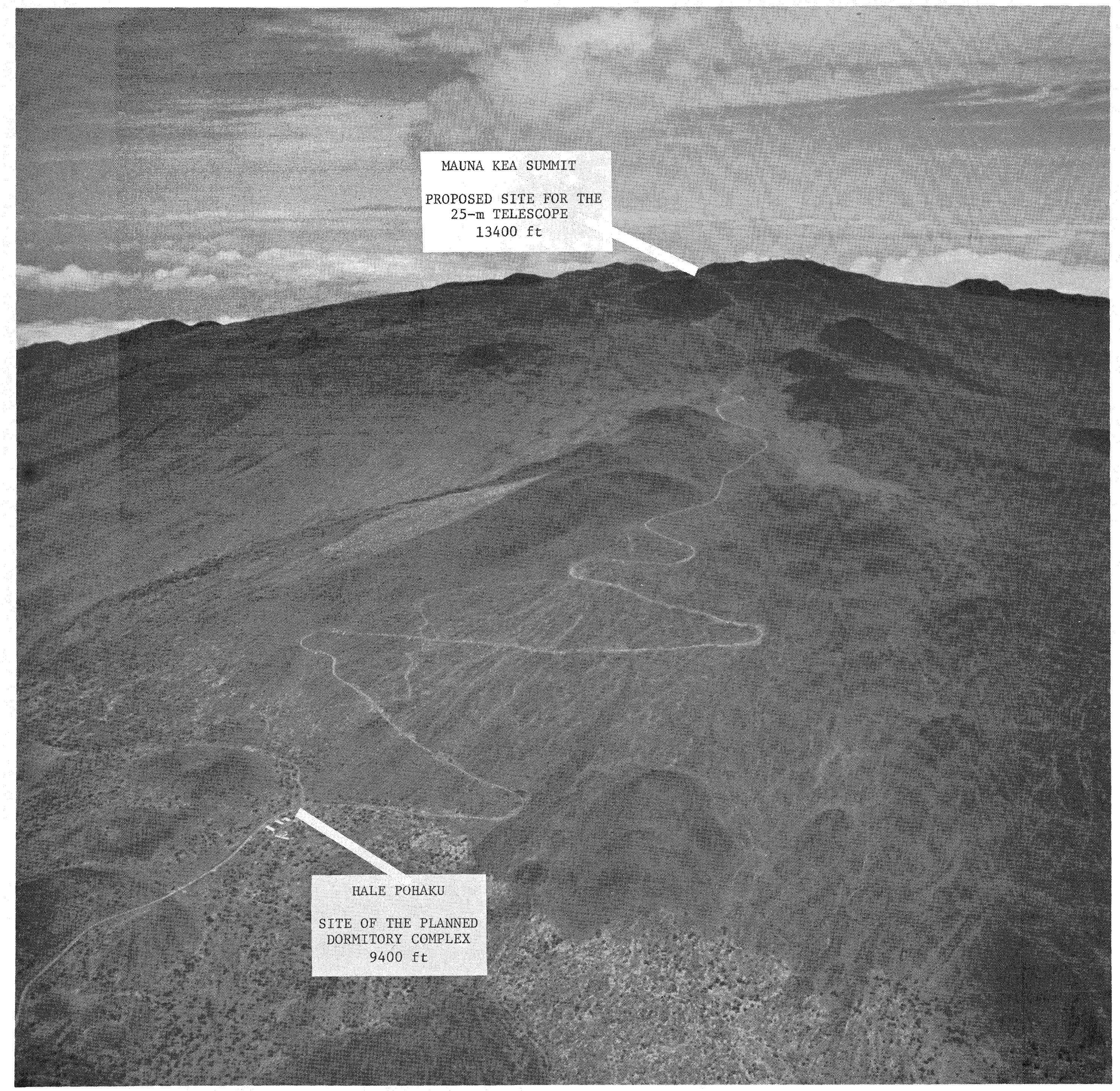

Figure 3. *The upper part of Mauna Kea*

3. IMPACT ON THE FIELD OF ASTRONOMY

Although the 36-ft telescope continues to be in heavy demand, an increasing fraction of the important research proposals are being limited by the restrictions of angular resolution, sensitivity, and wavelength range which are intrinsic to this telescope. It has a smaller collecting area than is needed and cannot operate well at wavelengths shorter than 2.4 mm. While recent advances in radiometer technology offer an improvement in sensitivity, the limitations on resolution and wavelength range can only be removed by the construction of a larger telescope with a more precise surface. Certain research areas, involving sources with high surface brightness and small-scale angular structure, will require a millimeter-wave interferometer. However, the wide range of astronomical problems which can be addressed by millimeter-wave observations needs not only the higher angular resolution but also the sensitivity and frequency flexibility provided by a large, filled aperture.

The proposed 25-m telescope offers a 5-fold increase in collecting area at wavelengths now covered by the 36-ft telescope. It extends the frequency range of the 36-ft by more than 1 octave. And, the high altitude and low latitude of the Mauna Kea site minimizes the fundamental limitation of atmospheric absorption.

4. STATUS OF THE TELESCOPE DESIGN

The 25-m telescope is based upon a homologous design, a principle developed at the NRAO over the past ten years by S. von Hoerner. A millimeter-wave telescope requires an extremely precise surface. In this case the design calls for a paraboloid surface with rms deviations less than 75 μm. Conventionally designed telescopes usually involve a truss structure supporting surface panels and feed, movable in both elevation and azimuth. Gravitational deformation of these structures occurs by a sagging of the surface panels between the hard support points, and by an overall deterioration of the entire surface from a paraboloid. While this deformation can never be avoided, careful design renders it harmless in terms of radiometric performance. First, the surface is supported by many points close together, resulting in equal softness of the truss structure. Second, the truss structure is designed so that it always deforms into a parabolic surface, albeit of differing focal length. The use of a truss structure which is insensitive to gravitational deformation by means of controlled flexure, is called a homologous design.

It is important to emphasize that, while the design of the telescope utilizes advanced concepts, the analysis of the design is performed by standardized structural programs such as NASTRAN or STRUDL. The NRAO design program has been developed and used for many years to produce designs for 100-m, 65-m, and 25-m telescopes. Analysis of the 25-m telescope design by conventional structural programs predicts excellent performance. To investigate further the effects of manufacturing irregularities in the steel tubing, a variational analysis has been developed. The performance figures given in the NRAO proposal use this "worst case" estimate.

One homologous telescope, the 100-m radio telescope of the Max-Planck-Institut at Effelsburg, West Germany is in operation. Its performance is as predicted by the designers, thereby proving the effectiveness of a homology design. The United Kingdom is also using a homology design for its proposed millimeter-wave telescope.

Volumes I and II of the proposal outlining the requirements for, performance of and estimated cost of this radio telescope have been submitted. Every design goal of the 25-m telescope has now been met by a specific concept, proven either by actual experiment or by computer analysis. Considerable research and development has been done to accom-

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plish this. Prototype surface plates have been manufactured, a prototype of the surface adjustment device has been made, and surface measurement equipment has been developed which can meet the specifications. A computer analysis has been made of the conceptual design. A computer analysis has been made of the conceptual astrodome design. An exact location for the telescope on Mauna Kea, Hawaii has been chosen. A conceptual site plan at this location has been made. A conceptual plan for a building at the telescope has been made. Contacts or informal agreements, have been established with other research groups and the University of Hawaii, operating on Mauna Kea, to keep abreast of problems and special requirements in operating research equipment at this site. This experience is incorporated into our final design and construction plans, where applicable.

The major steps in this project, from the site choice to the telescope design, have been taken. The procurement and construction sequence have been identified and ordered by the management program PERT (project evaluation and review technique). The NRAO is now ready to proceed with the detailed design and construction of this telescope.

5. SIZE OF SCIENTIFIC COMMUNITY INVOLVED: MILLIMETER-WAVELENGTH

The 36-ft telescope has been attracting both radio astronomers and chemists. Last year 48 institutions used the telescope, including 104 visitors, 14 graduate students, 2 postdoctoral students, and 12 members of the NRAO permanent staff. The NRAO list of staff and visitor publications for 1978 include theoretical, observational, and engineering articles. Fifty-three publications approximately 25 percent of the total number, involved observations made with the 36-ft telescope. An example of the interdisciplinary nature of the astrochemistry is the cover story, a 13-page special report, featured in the October 2, 1978 issue of Chemical and Engineering News, a widely read journal of the American Chemical Society. This article "Chemistry of Interstellar Space" presents an excellent and up-to-date summary of this subject.

6. DETAILED DESCRIPTION OF THE PROJECT

A. Cost Estimate

For the purposes of planning costs, the NRAO has divided the project into non-recurring and recurring costs. The non-recurring costs include detailed design, construction of astrodome and telescope, construction of the buildings on the summit and the base support building in Kamuela. The recurring costs begin when the telescope goes into operation. They do not include the cost of radio receivers, which are included in the overall operations budget of the NRAO.

To obtain the current estimate of cost, we have started from the estimates listed in Volume II of the Proposal, which were based on actual bidding experience. To adjust these costs from the 1976 base of the proposal to an effective date of December 31, 1978, we have used the construction index for high-rise buildings in Honolulu, which we believe is the index most appropriate for our project. This index has experienced an annual increase of 10 percent. The forward projections assume a continued inflation rate of 10 percent per year.

For non-recurring costs, the NRAO has prepared three funding plans. Plan A, the Optimum Plan, assumes $4.4M in 1981 and the balance in 1982. Even though the project will not be completed until March 30, 1984, Plan A gives the most favorable price, $22,850k. Plan B assumes $4.4M in 1981 and two subsequent years of funding. Construction will be complete on May 22, 1984. The cost is $25,390k. Finally, Plan C assumes $4.4M in 1981, followed by three years of funding. Here construction will not be complete until May 24, 1985. The cost is $27,080k.

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B. Project Management

The NRAO plans to act as prime contractor for this project. Through our project office the detailed design of telescope, astrodome, and buildings will be prepared. When the detailed design is completed, contracts will be sought for the construction of the telescope, the astrodome, the summit buildings, and the buildings in Kamuela. The latter are called the base support facility. Appendix 2 describes the project management in more detail.

C. Annual Operating Costs

Recurring costs have been calculated on the basis of our operating experience in Tucson and on Kitt Peak, and on the actual 1979 operating budget of the Canada-France-Hawaii telescope corporation now operating in Hawaii. Because of our planned close working relationship with CFH and with the United Kingdom infrared telescope, we plan a salary schedule and personnel benefits parallel to what they are now using. The anticipated costs have been estimated in current dollars. The costs projected to 1985 assume an inflation rate of 7 percent.

D. Associated Equipment

Based on our experience in Green Bank and on Kitt Peak, we plan to install a computer system at the summit which is adequate for astronomers to take and reduce data. In principle an astronomer will leave the mountain after his telescope run with his data in a reduced form. No extensive computer facilities are planned for the base support facility except those required for engineering and business use.

The method of preparing receivers will also parallel that now in use at Kitt Peak. At NRAO headquarters, a high-level engineering group will develop and refine critical elements of a receiver system. When completed, these elements will be shipped to Hawaii where the on-site engineering staff will incorporate them into receivers for use on the mountain. Because of its distance from the mainland, the technical group of the base support facility will require a number of senior engineers.

NRAO is currently engaged in the development of receivers for frequencies to 300 GHz. Of particular interest for the 25-m telescope are mixers, Josephson effect devices and bolometers. For example, NRAO is presently constructing a bolometer system which will work at 3 mm, 2 mm, and 1 mm wavelength. Further development is, of course, planned as technology permits.

E. Implied Grant Support

So far as we are able, the NRAO plans to continue its program of travel support for astronomers using the Mauna Kea telescope. In this way any geographic penalty due to travel may be minimized.

F. Lifetime of the Facility

The useful lifetime of the telescope will be at least 20 years. It is, of course, impossible to estimate the life expectancy as a forefront instrument, but this expectation seems reasonable, on the basis of our experience with the NRAO 140-ft and 300-ft telescopes.

7. PROJECT MILESTONES

Three different construction schedules have been developed, corresponding to the three funding schedules. The construction schedules have been planned using PERT.

A. Two-Year Funding

1981 - Design telescope, astrodome, buildings and site development.

- Begin procurement of surface plates.

1982 - Begin procurement of telescope, astrodome, and buildings.

- Complete foundations of telescope and astrodome.

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1982 - Install telescope tower.
- Complete site utilities.
1983 - Complete telescope, astrodome and buildings.
1984 - Complete test of telescope.

B. Three-Year Funding
1981 - Design telescope, astrodome, buildings and site development.
- Begin procurement of surface plates.
1982 - Begin procurement of telescope and astrodome.
- Complete foundations of telescope and astrodome.
- Install telescope tower.
- Complete site utilities.
1983 - Complete the astrodome.
- Complete the telescope, except for the installation and setting of the plates.
- Complete the site buildings
1984 - Complete the telescope, and the tests of the telescope.

C. Four-Year Funding (The Most Probable)
1981 - Design telescope, astrodome, buildings, and site development.
- Begin procurement of surface plates.
1982 - Complete the foundations for the telescope and astrodome.
- Begin construction of the astrodome.
- Complete the site utilities.
1983 - Begin construction of the telescope, completing the installation of the tower.
- Complete the main construction phase of the astrodome.
1984 - Complete the astrodome and telescope.
- Start and complete the site buildings.
1985 - Complete the site development and test the telescope.

* * * * *

TUCSON'S PEOPLE

From left to right: Dale Webb, Max Thomas, Paul Rhodes, Betty Stobie, Dan Bass, Jackie Cochran, Mark Gordon, Stan Sullivan.

Although we are a small group, it is very difficult to have everyone assembled for a group picture. Now that we have a captive audience we will include pictures of our staff so that maybe the "voice" on the other end of the telephone will have some identity.

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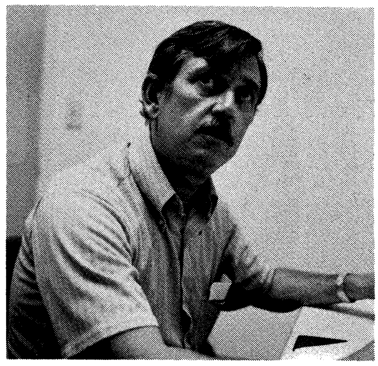
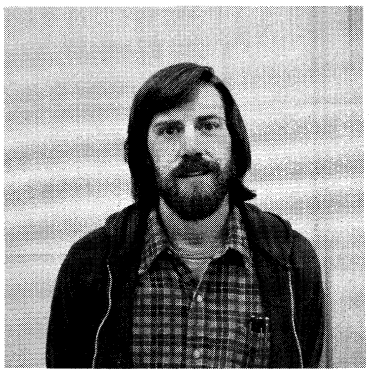
TUCSON'S PEOPLE (Continued)

Don Cardarella

Delia Figueroa



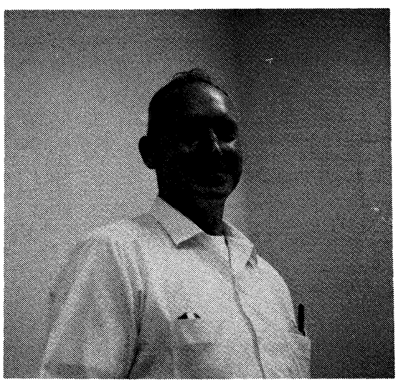
Bill Gust



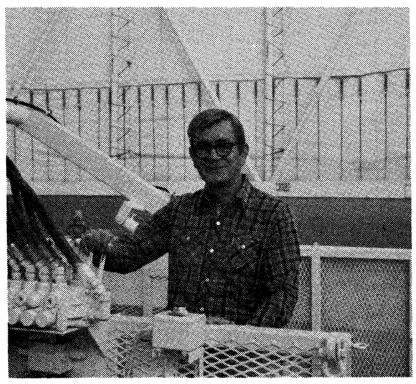
Rick Howard

Dave Myers

Werner Scharlach



Cal Sparks



John Weaver

THE TUCSON ELECTRONICS GROUP

John Payne

From left to right: Ruben "Bud" Hill, Ron Silver, Bob Freund, John Payne, Terry White, Mike Route, Jesse Davis, Dewey Ross.

Despite appearances to the contrary, the group in the picture is not on a day outing from the Arizona State Prison. No - it's the Tucson Electronics Group ready and willing to investigate and remedy the subtle and mysterious problems that seem to beset the 36-foot radio telescope. At the most inconvenient times any of this dedicated group will leap out of a warm bed in the middle of the night, drive 65 miles to the telescope and cheerfully tweak the equipment to satisfy the visiting astronomers' slightest whim.

Due to the small size of Tucson Operations, we have to operate quite differently from the Electronics Group in Green Bank, for instance. If the cryogenic system fails, for example we can't call on Troy Henderson or Dave Williams to fix the problem, we have to do it ourselves. If the dome servo or the telescope drive fails, again -- no calling on Fred Crews -- we fix it ourselves. We don't have a machine shop, just a small shop with a lathe and a mill, so for our major machining jobs we depend on the shops in Green Bank and Charlottesville. Over the years we have gotten really first-rate service out of both these shops. We also have very close ties with Sandy Weinreb's development group in Charlottesville. In conjunction with the University of Virginia this group supplies us with the very sensitive microwave mixers that are essential for our millimeter wave receivers.

In looking back over the past five years it's quite surprising the progress that has been made in millimeter wave receivers. The graph on page 26 indicates how the noise temperatures of receivers at 100 GHz has dropped over the years. Our dual-channel 70-115 GHz receiver now has a noise temperature of 285^{o} KSSB at its best frequency. This means than an observation that took 63 hours in 1974 now takes one hour. A big improvement!

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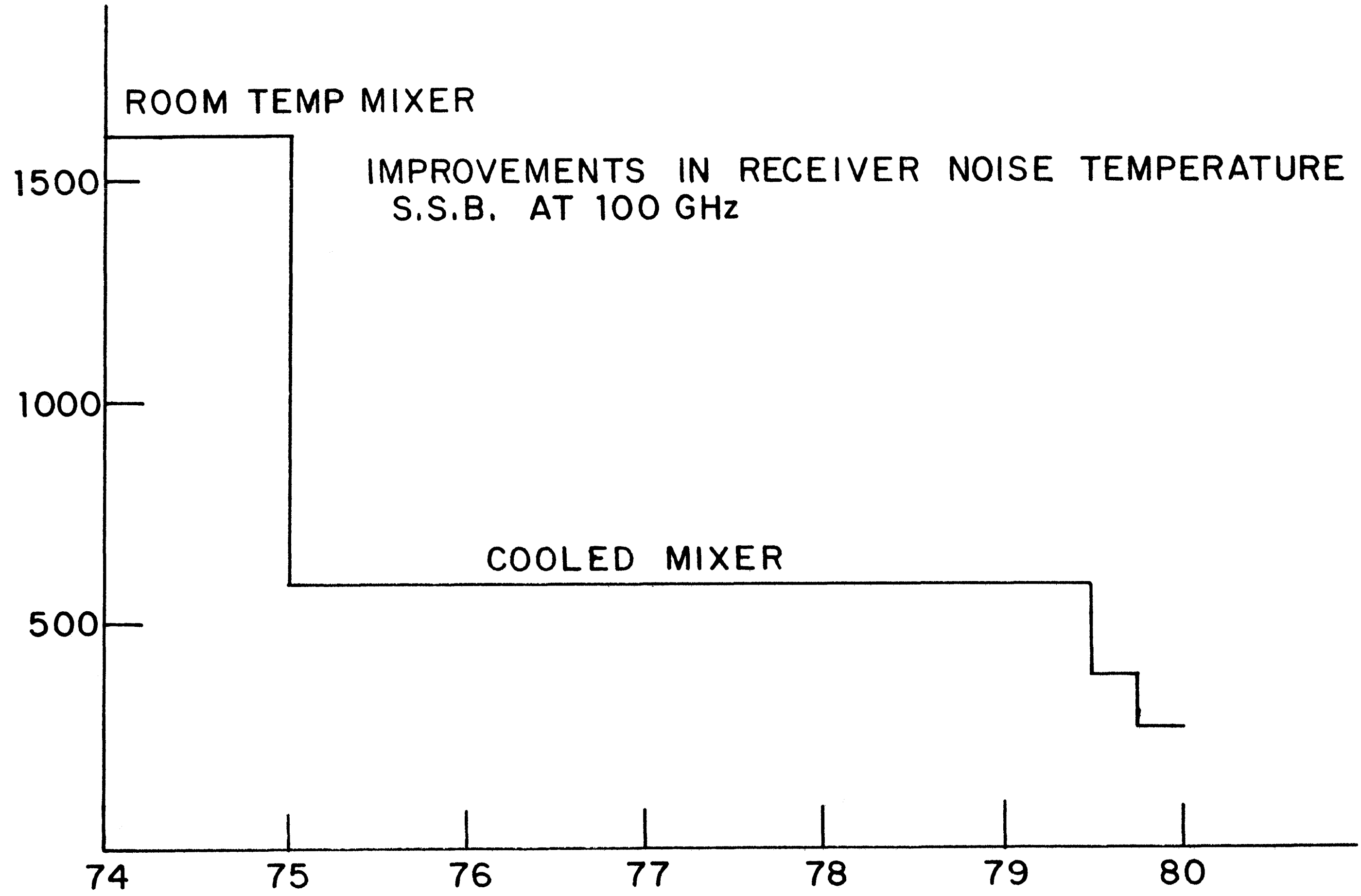

Although reducing the noise temperature of receivers will always be important, some of the more interesting developments have been in other areas of millimeter wave instrumentation. It's probably fair to say that in the early days of millimeter wave receivers the design methods used were an extension of the methods used at lower frequencies. The problem is that the higher the frequency the smaller the waveguide becomes. At a frequency of 150 GHz, for instance, the waveguide we usually use measures only 0.051 x 0.0255 inches and the problem of machining inside waveguide of this size is pretty obvious. So, a few years ago people in the millimeter wave business started looking at techniques that are used at higher frequencies and scaling them down. The diagrams on page 27 provide a good example.

On the left-hand side is shown the heart of a millimeter wave mixer receiver. Two orthogonal polarizations are received (this gives a factor of two in observing time) and the two polarizations are split using a conventional waveguide orthomode transducer. The two signals are then converted to an intermediate frequency and amplified. All these components are held at 15°K by a closed-cycle helium refrigerator. When we wanted to build a broadband (70-115 GHz) receiver the orthomode transducer presented a problem. The only

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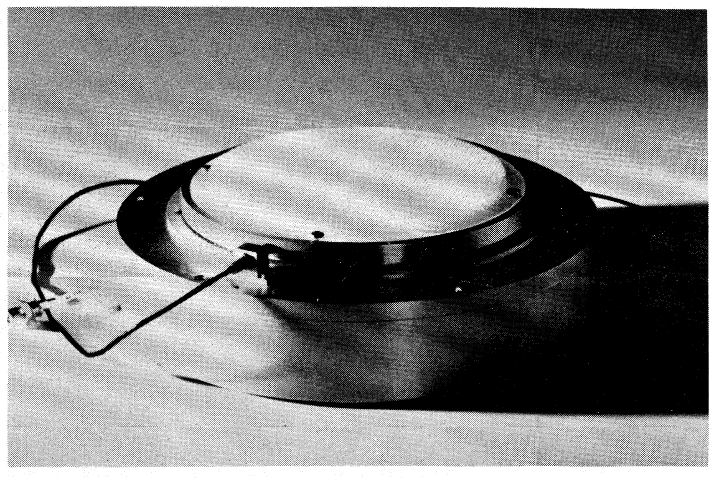
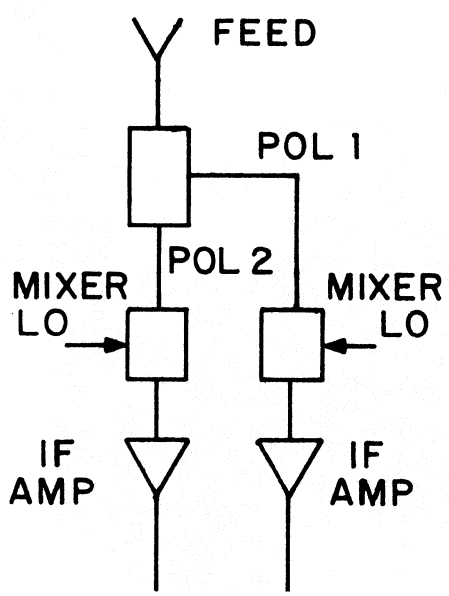
manufacturer who would bid on it was asking $70,000 and would give no guarantee of any specifications! The diagram below shows a simple answer borrowed from the infrared experimenters -- cost of the wire grids about $15.00 and virtually perfect performance over a huge range of frequencies. We now use this technique in all our receivers.

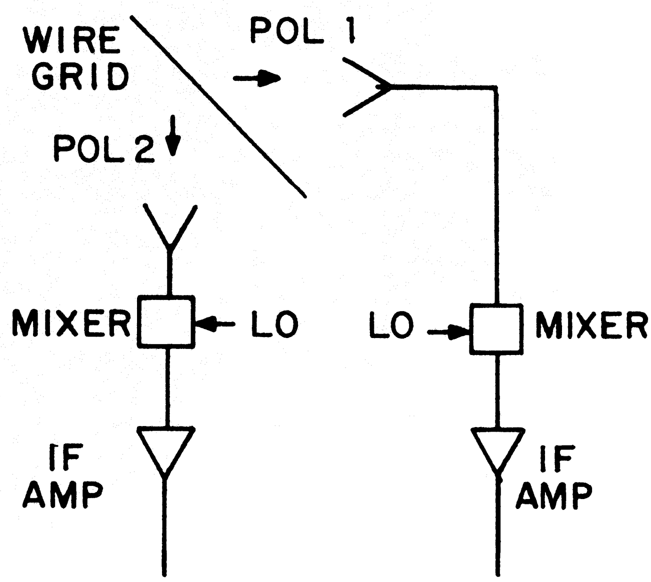
Soon after this development radio astronomers expressed an interest in determining whether millimeter sources had any components that were polarized. This called for the development of a quarter wave plate suitable for use at 100 GHz. This had not been done before and Bob Freund came up with a good solution shown in the photograph at the right. It is a slab of rexolite carefully machined with very narrow grooves. This creates what is known in optics as a quarter wave plate. By placing this plate over the feed system of a millimeter wave receiver one may make the two receiver channels sensitive to right-hand circular polarization and left-hand circular polarization and by switching the plate



rapidly back and forth by 90° it is possible to separate polarized components of a radio source. This instrument has already produced interesting astronomical results both in spectral line and continuum.

Three years ago we first started work on higher frequency receivers. The next





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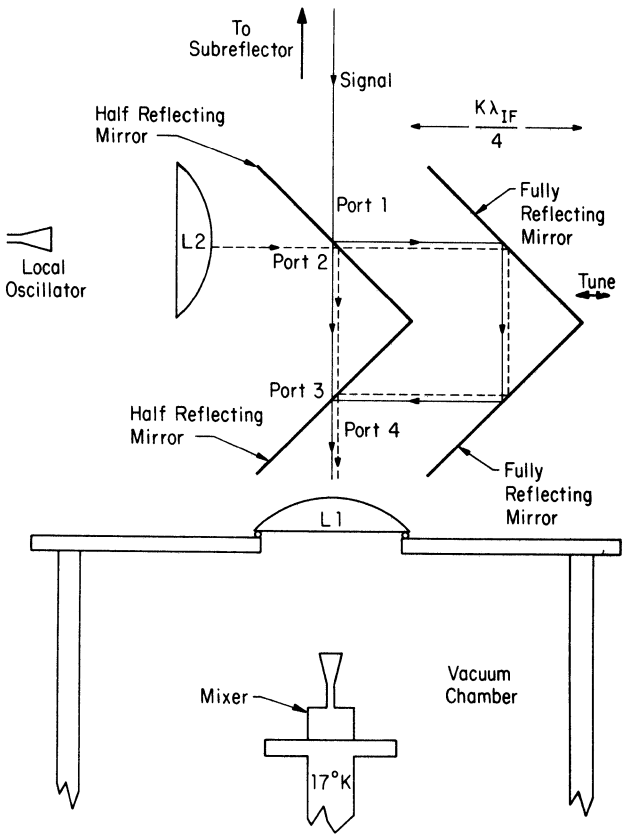
atmospheric window from the 70-120 GHz is 130-170 GHz. The problem is that as one goes higher in frequency, waveguide gets smaller, losses get larger and local oscillator sources become very expensive and very unreliable. A klystron at 150 GHz cost $12,000, has a warranty of 150 hours and quite often doesn't work when you get it. This makes the support of receivers at these frequencies quite difficult.

The high waveguide loss and low power availability from klystrons forced us to change completely from the ideas used in existing millimeter receivers. The basic problem in a millimeter-cooled mixer receiver is to inject the upper signal sideband, the lower signal sideband and the local oscillator into the mixer with low loss. It's also nice if the device rejects noise on the local oscillator at the signal frequency and has no moving parts at 15^{o}K.

The device shown below does all these things and is really a folded version of a



Michelson Interferometer straight out of dusty old physics books of 60 years ago.

The beam splitters are wire grids made out of two-mil wire and wound 32 threads per inch. Garnet Taylor wound these and not to be outdone he recently wound one out of one-mil wire for use at 230 GHz. Teflon makes good, low-loss lenses at millimeter wavelengths and a good anti-reflection layer for the lenses may be produced simply by machining grooves in the surface.

We first produced a room temperature version of a receiver using these principles two years ago. Just recently we have observed using a cooled version of the receiver and we have noise temperatures of 800^{o}K SSB over the range 140-170 GHz. Jack Cochran and Mike Routt built this receiver and as far as we know it is the best in the world.

John Payne and Bobby Ulich have done a lot of work on standing waves over the past year or so. Standing waves, the bane of spectroscopists' lives, result from the interference between two (or several) signals. In the case of a receiver mounted on a Cassegrain telescope the two signals result from noise radiated out of the receiver and returning via two paths, the first by reflections from a local mismatch in the receiver, the second by scattering from the subreflector. These two signals then recombine in the receiver to give the horrible result known as standing waves. If one could modulate the path length of one of these signals by many wavelengths during an integration period the standing waves would get smeared out and pretty much disappear.

The device on page 29 does this in a way that's pretty obvious. It was built by Lucky and Company in Charlottesville and seems to work very well. The graphs on page 29 show what happens to standing waves when the "corner cube" is switched on. It's only fair to say that we deliberately set up things to make the standing waves as bad as we could in this experiment and things aren't usually as bad as this.

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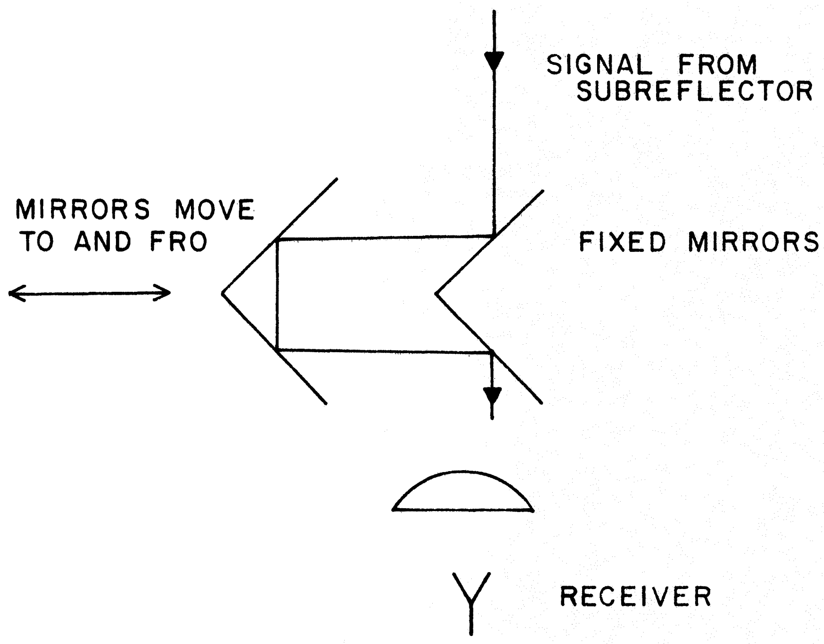
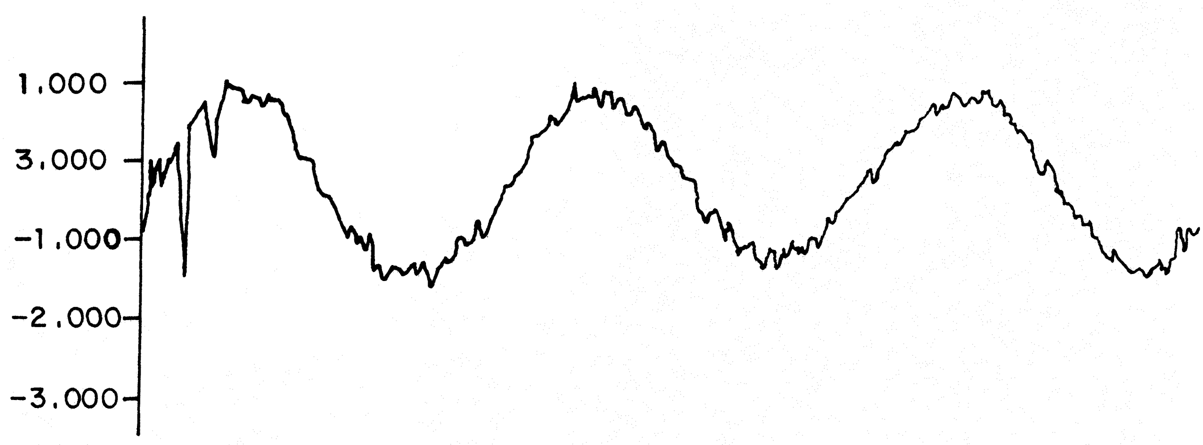
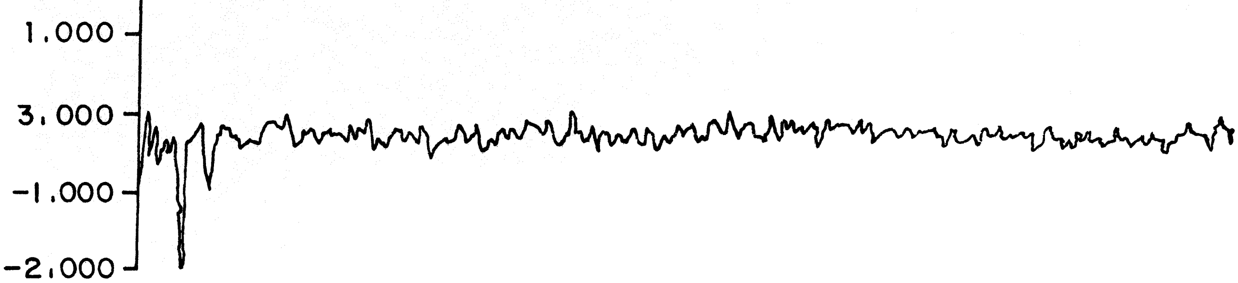


SPECTRUM WITH CORNER CUBE OFF



SPECTRUM WITH CORNER CUBE ON



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Over the past few years frequency switching with the Cassegrain system has been impossible owing to difficulties with standing waves. Using the path length modulator frequency switching is again possible although only over fairly small excursions. This means a factor of two in observing time for some observations.

On to more exotic receivers! As everyone appreciates, as far as receivers go, generally speaking the colder the better. For continuum observations the optimum receiver will have the lowest noise temperature and the largest bandwidth. Our telescope sort of works in the 200-300 GHz atmospheric window (with about 12% efficiency) so about nine months ago we decided to build the most sensitive continuum receiver that was possible in this frequency range. The lowest temperature we felt that we could reasonably expect to achieve for the way we operate our telescope was 0.3°K.

This temperature is achievable by using an isotope of helium called ^3H_e. This isotope used to be very expensive but as it appears as a byproduct of hydrogen bombs lying in storage its price has come down dramatically in recent year . The simplified block diagram below shows how the ^3H_e refrigerator works.

The heart of the receiver is a doped germanium bolometer that is held at a temperature of 0.3°K. The signal from the subreflector is first filtered by a quasi optical filter and then is focused onto the bolometer by a teflon lens. The signal is modulated by the action of the nutating secondary and this results in a modulation of the bolometer resistance. A bias battery and bias resistor convert this to a small voltage (on the nanovolt level) which then may be amplified and fed to the computer via a synchronous detector.

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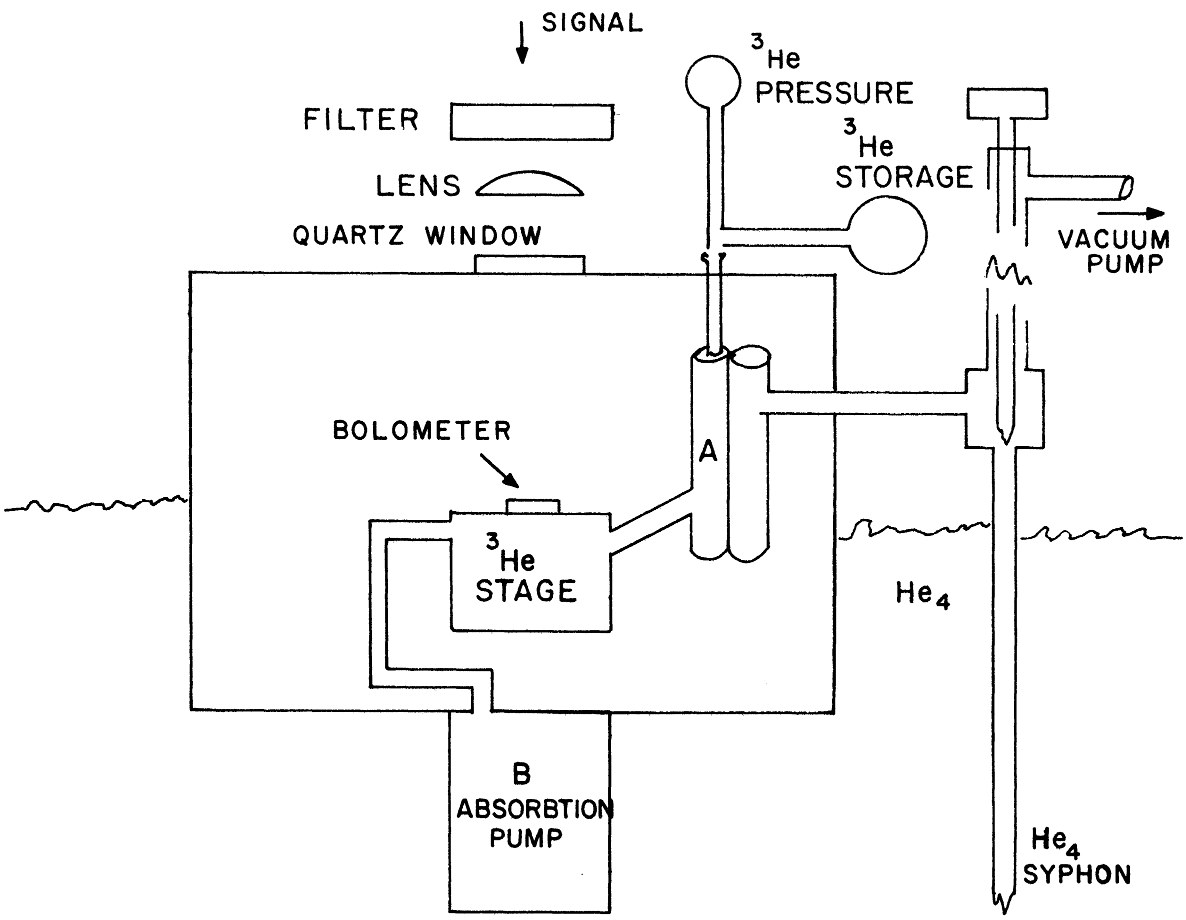

^3He condenses at 1.3°K and boils at 0.3°K and in the refrigerator it cycles between these two states (just like the freon in a domestic refrigerator). The ^3He refrigerator is completely immersed in a bath of ^4He contained within a commercial dewar. The basic sequency of operations is as follows. The ^3He is a gaseous form within the enclosure marked "A". ^4He is syphoned from the main bath into a chamber thermally coupled to chamber "A". Using an external vacuum pump the ^4He has the pressure reduced above it and it boils at 1.2°K thus condensing the ^3He. The vacuum pump is disconnected and the absorption pump "B" is thermally connected to the main bath (by means of exchange gas in the walls of the absorption enclosure). The absorption pump now reduces the pressure above the ^3He and the 0.3°K temperature is reached. It takes about 30 hours for all the ^3He to boil off and at that point the activated charcoal in the absorption pump is heated slightly, the ^3He is released and the cycle may start again.

A really critical part of this receiver is the band pass filter in front of the lens. It must work with all polarizations, must have low loss and very good rejection. Jesse Davis has come up with a good solution and we how have good filters for the 1mm, 2mm, and 3mm atmospheric windows. The 1mm filter has a transmissivity of 0.7 and the others are even better.

Many people have contributed to the project. A group from the University of Oregon has built the refrigerator; Peter Ade, at Queen Mary College in London has built the detector; Omar Bowyer has designed a fast-switching subreflector and the Green Bank and Charlottesville shops have done their usual excellent job of supporting us. It all has to come together yet and we are due to test it on the telescope early next year. Some bugs are bound to emerge but if the receiver is anything like as sensitive as we hope, it should have a lot of use.

Lots more exciting projects are on the horizon. We hope to have a 190-230 GHz receiver working soon. We'd like to work on new methods for measuring components up to very high frequencies (1000 GHz). We hope to start work on an acoustic spectrometer to replace our filter banks. There are many more but these can be the subject of a future *Observer* article!

* * * * *

ARIZONA WILDLIFE AND HUNTING

Jackie Cochran

Arizona ranks among the top three states in the diversity offered in big game hunting. Most serious Arizona hunters aspire to the exclusive "Big Ten" society whose membership is limited to those hunters that have bagged one or more of all of Arizona's big game animals. Nine of Arizona's big game animals are officially listed as big game. These include the mule deer and whitetail deer, elk, antelope, javelina, bear, buffalo, wild turkey and bighorn sheep. The tenth animal is the mountain lion, which is officially listed as a predator, but most hunters consider it a top trophy animal. All of these animals are available within the immediate Tucson area with the exception of the elk and buffalo. Except for the buffalo, permits are available to non-residents of Arizona.

Considering many of our readers are West Virginians and that I spent many a season hunting deer there, I'll draw a few comparisons. As far as whitetails go there is very little difference. Their range is the forest covered mountains much like those of West Virginia. Mulies on the other hand offer an opportunity for adjustment. Habitat generally includes the desert floor and the foothills of the mountain areas (keep in mind that the Arizona foothills are 2000-4000 feet in elevation). Temperatures during the hunt

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range from 65^{o}-85^{o}F and there is little or no water available. However, anyone familiar with the Boone and Crockett World Record Book would soon take note of the many Arizona deer listed there.

Small game hunting is also a popular Arizona sport with mourning doves, whitewings and quail abundant in the Tucson area. The cottontail rabbit is the only animal classed as game that has no closed season, but predators and non-game species provide targets for the year-round hunter and sportsman.

Scopes and glasses are a real must with targets frequently in the 200-400 yard range. Hunting from horseback is also a common practice and does offer many advantages in transporting water, equipment and game to base camp. There are many areas to be considered by a newcomer to Arizona before his first hunt. A guide or a friend who is familiar with laws, game and hunt areas would be will worth seeking.

For information write:

Arizona Game and Fish Department
P. O. Box 9099
Phoenix, Arizona 85068

Telephone: (602) 942-3000

* * * * *

MINEROLOGY

Werner Scharlach

There are rocks around here!

This part of the country grows rocks and cacti. Anything else is imported, usually to the detriment of the local ecology. Both cacti and rocks take on a seemingly endless variety of forms, so its no great wonderment that there are many groups of people interested in one or the other, or both.

Ruth and I got into the rock business while still in California, after seeing what friends of ours were doing. And once in Arizona, Ruth wanted to have something to do, and a rock hobby seemed appropriate. The hobby is now a small business, and has given us a lot of satisfaction, albeit a lot of work.

We started off slowly, because of a miniscule budget, and some equipment can be expensive. The first setup had a rock saw, a double arbor for sanding wheels, and a vertical polishing wheel. The kind of equipment one needs depends on the kind of rock work one intends to do. We have emphasized flat work, partly because from the first, we realized there are hundreds of millions of cabochons in the world, and our adding another 100,000 would not make much impression. Or so it seemed.

As it has turned out, our line of products has something special: the degree of polish. We have in common with other lapidarists several items, such as bookends, desk sets, sliced geodes, but the way we make our pendants is different. Everyone likes to have something unique, for that gives one an edge on the competitors.

The types of rock available in Arizona include petrified wood, jaspers and agate and a combination called jasp-agate. There's also a little petrified palm and petrified dinosaur bone. Right now we have Mexican Crazy Lace, Botswana agate, Brazilian agate, and other agates from California, Australia, and elsewhere besides the Arizona types, also several types of geodes.

We have gone on a few digs for rock, but a combination of little time, almost no equipment, and the fact that the surface has been largely picked over by rockhounds (even out here where the amount of rocks seems endless), has decided us against any more trips. When we are away on vacation, or just visiting someplace close by, we keep an eye open for rock shops. This way we have come across unusual sources of supply in out of the way places. Our largest amounts of rocks come from professional importers. From them we get the material in the rough and then work it up into the finished products.

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What kind of people are rockhounds? We have found them to be rather fine folks. We have known a few characters out of the story books, like a former dealer in New Mexico. He claimed he had made his second million in wholesaleing rock. His first million was from being an industrialist in Illinois. He was a little guy, and his wife looked tough enough to bite off a piece of rock and hit a lizard with it -- no hands!

Once a year the Tucson Gem and Mineral Society sponsors their show which pulls in people from around the world. There are about half a dozen such shows in the country like that. The Smithsonian Institute usually sends some fantastic specimen for display. Dealers are here by the dozens and it takes several days to look at everything just once. This is the time when we do most of our rock buying, and we gradually have come to know people. It's nice to compare with them what has happened since last year.

To avoid sitting behind a counter in a store, we operate out of our home, going to crafts fairs and displaying in a museum and somebody else's store. Occasionally we display at the University Hospital in conjunction with their gift shop. Our house is small, and the shed cannot hold all the equipment, so what would have been the den is the saw room. The storage area for rough rock is the backyard, and the cut portions are everywhere. So far we have kept them out of the bedroom, but there are no guarantees!

As I Said, we have had a lot of satisfaction from rock work. In fact, I'm more convinced now that some "talk" to us. (Maybe I'm flipping my wig.) But one thing is for sure, if you don't mind getting dirty, this may be for you. Otherwise I'd suggest you pick something else.

* * * * *

A SLIGHTLY BELATED CHRISTMAS POEM

W. D. "Bill" Gust

'Twas the week before Christmas,
And all through the lab:
The excitement was mounting,
Even though it was cold and drab.

The receivers and electronics,
Were tuned to a pitch;
In the hopes the observers would have
Nary a complaint nor a hitch.

The engineers were all snuggled neatly
In their offices with care;
In the hopes the chief would be looking,
Not for hide, nor for hair.

Two of the Techs were huddled over
their oscilloscopes,
Soldering and wiring, and so
full of hope
That the lathe and the mill would
dutifully break,
So that only electronic's projects
could they make.
The other Techs as usual were soldering and wiring,
Which to me looks like fun,
But they claim it is tiring.

The computer was programmed for the
coming year;
And the one who had done it
Was such a dear.

The operators were operating
Oh, what a sight!
Pulling, pushing and twisting
With all of their might.

The support was doing what they
Normally do best;
Sitting on their duffs
With their feet on the desk.

* * * * *

MORE THAN YOU WANTED TO KNOW ABOUT SOUTHERN ARIZONA

M. A. Gordon

Now that the cold winter winds are whistling through the cracks of your doors and windows, and the heating oil cost are rising, many of you may think about the warm southwestern desert. What's it like out here? Are people moving here just to keep warm? What about the summers, and the rattlesnakes, spiders, and scorpions? And, the history! Is the Old West still alive? Or, was it ever alive?

I've now lived in Tucson for six years. For a New England boy who came to love the Virginia Piedmont, it was one helluva shock. Butler Burton once bet me one can of beer for every house without wheels that we could count between the Tucson Airport and Kitt Peak! The skies are deep blue, the sun is blindingly harsh, and there isn't much shade. In many ways, it reminds me of the moon; both depend upon artificial systems for living -- water, food, and air-conditioning. The city is new, having grown from 60,000 in 1950 to nearly 500,000 today. There aren't many two-story buildings. In short, it sprawls. You're either married to a car, or you stay at home!

The politics are unbelievably complex. The emphasis is on individuality. We have politicians as diverse as Mo Udall and Barry Goldwater, but sharing an intense love for Arizona. One recent candidate for the United States Senate (who had been a Congressman for many years) shot his neighbor's horse because it wandered onto his property. Our newest Senator, Dennis DeConcini, made news as a freshman senator when he hamstrung the Panama Canal turnover. Arizona is the only state without Medicaid, and its treasury continues to have an annual surplus -- even with taxes which are ridiculously low by New England standards. Even the place-names are peculiarly individual, like Phoenix for a city which materialized out of nothing, and Show Low where two arguing ranchers decided who'd stay and who'd leave by cutting a deck of cards.

But, I want to tell you about the southwestern desert. And the place to begin is with its climate.

Its Climate. Water. It's the key to understanding the desert. It is scarce and precious. The large-scale wind circulation pattern flows from the northwest during most of the year, causing the wet Pacific air to dry as it blows to the southwest. First, as the air lifts up over the Pacific Coastal range, it cools and the water condenses. The same process occurs again as the air flows over the next mountain range to the east, the Sierra Nevadas. And the next ranges to the east, the Inyo Range and the scattered mountain peaks in western Nevada. When the air reaches Tucson, it has been through the adiabatic wringer a number of times. The average long-term annual rainfall is 11 inches, with a 50% variation from one year to the next. And, that comes in a very small number of storms with rainfall so heavy that the ground cannot absorb it. The recharge rate for the natural underground aquifers is less than 15% of water falling on the desert floor. The water table has dropped from 20 to 600 feet below the surface in 50 years because of high consumption by agriculture and mining operations.

In late summer the pattern changes. (The large-scale wind pattern above the United States is generally fixed with respect to the sun.) As the sun moves northward in summer, the prevailing winds over southern Arizona blow from the southeast and the Gulf of Mexico. There aren't as many mountain ranges along this route, the hotter summer air can hold more moisture, and the Tucson air becomes humid -- humid for the desert, that is. The day's heat convects the moist air upward. Puffy clouds appear by noon, thunderstorms often by 5:00 p.m. Dramatic enormous, land thunderstorms which can be seen for miles because of the dearth of heavy foliage. And, because moisture absorbs millimeter radio waves, the 36-foot telescope's usefulness decreases during this season, and we schedule maintenance.

Every desert region is unique. Southern Arizona's desert, Texas's Balcones Desert, Llano Estacado, and southern New Mexico's

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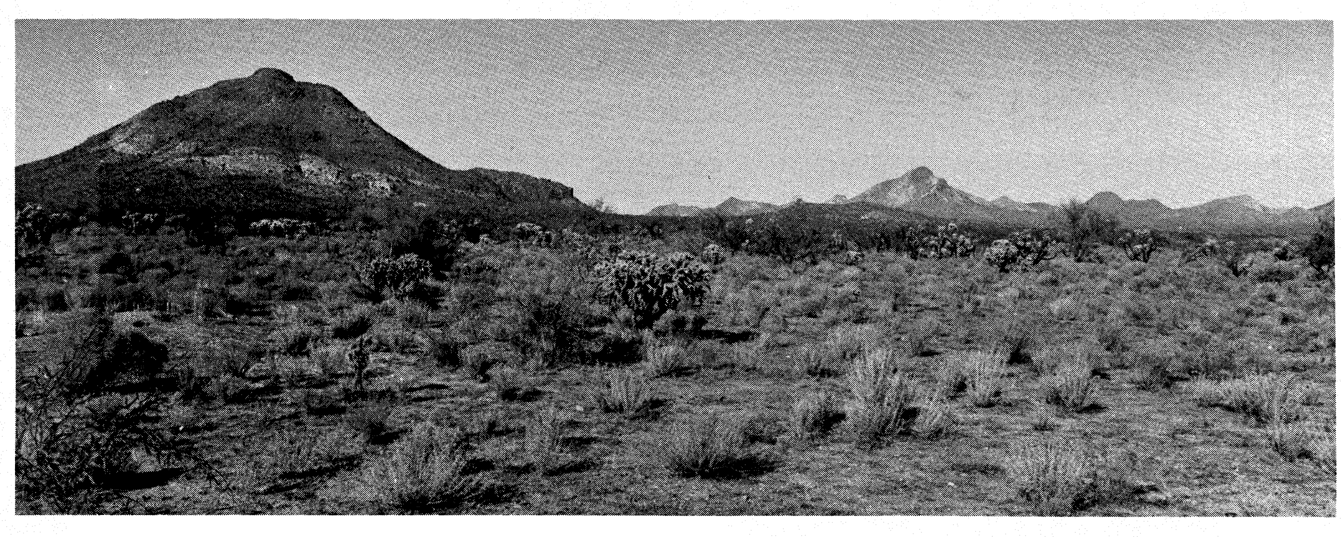

Figure 1. *A panoramic view to the north along the highway between Tucson and Kitt Peak. This typical desert scene in the Avra Valley would be characteristic of the Creosote Bush botanical family were it not for overgrazing. The visual impression is still of that family, but the plants are slightly different. 2500 feet. The tree-like Jumping Cholla (opuntia fulgiea) are scattered among clumps of invading Burro Weeds (Haplopappus tenuisectus) which have survived because of their unpalatibility for cattle. The trees are Mesquite (Prosapis juliflora) and Foothills Palo Verde (Cercidium microphyllum). The background mountains reach to 5000 feet and are typical of eroded volcanic mountains. At left is Bell Mountain, known to the Papago Indians by a more anatomical name.*

All photographs by M. A. Gordon

Chihuahuan Desert, may all look alike to the newcomer, but closer inspection will reveal dramatic differences in landscape and in foliage. All because of slight variations in rainfall patterns and in air temperatures.

In the Sonoran Desert (southern Arizona and the State of Sonora in Mexico), most of the year is dry. Rain comes always in late July and August, and in some years lesser amounts in late December and early January. The dryness of the air lets infrared radiation move freely in and out of the atmosphere, allowing large variations in surface air temperature during the day. The cold, dense air which rolls down the mountains to the valley floors at night accentuates this effect. In winter, the air usually ranges from 65°F at night to 105°F or more during a single day. But, during the wet season in August, you just have to sweat and bear it. The air temperatures tend to stay in the upper 90's, and the smart Tucsonan will leave.

The Botany. The Sonoran Desert really looks like a moonscape, at least on a large scale. Old eroded volcanic mountains stick up through the desert floor, forming bare mountain ranges with desolate stretches in between. (See Figure 1.) But, look more closely. There are plants. Amazingly enough, some plants survive this parched climate. They tend to be low to the ground and remain unobtrusive by not obstructing your view of the landscape. Except for those giant cacti, growing 40-feet tall.

This botany is sophisticated and highly evolved to withstand the long droughts. I'm not a botanist, and those of you who are will, hopefully, not mention it to me. But here's how I see it.

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The Sonoran Desert is more or less split into two botanical communities. One, the "Creosote Bush", occurs in the flat open spaces and is characterized by low bushes and dwarf shrubs. (See Figure 1.) Trees are generally absent, except on the edges of drainageways. The other botanical community is known as the "Palo Verde-Saquaro" type. Here we find trees and larger cacti. This community is usually located on slopes in the foothills. (See Figure 2.)

The desert plants have to evolve to meet two criteria to survive: protection against being eaten, and survival with little water. Most of the desert plants are thorny, perhaps to discourage hungry predators. Almost all of them can be classified as either "planners ahead" or "quick-change artists".

With little water, intense sunlight, and high air temperatures, the plants must cut down their surface area to minimize water loss by evaporation. Thus, the plants tend to be low to the ground, have few leaves, and coat their leaves with a heavy wax. Some of them drop their leaves and grow a new set every time it rains. Their root systems are enormous, often

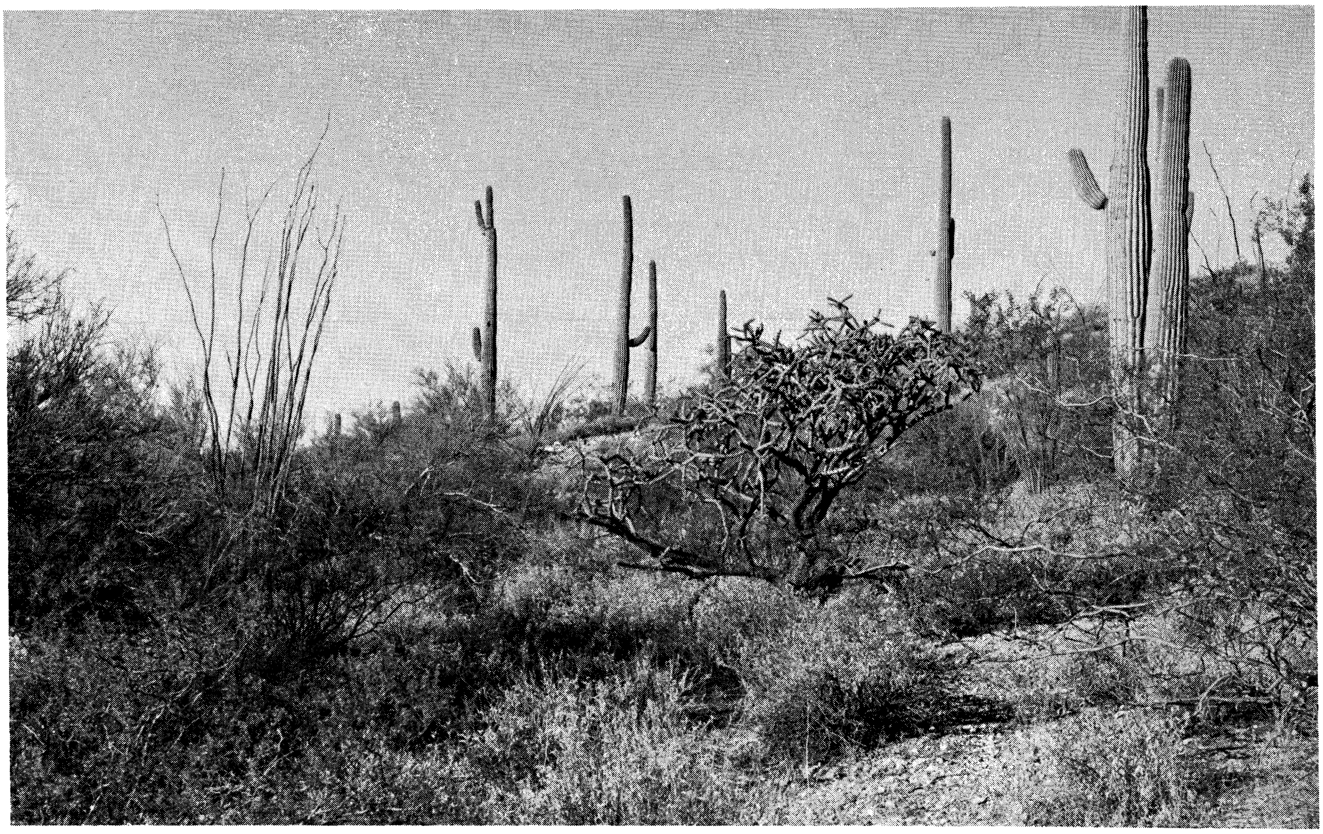

Figure 2. *A typical example of the Palo Verde-Saguaro community common to the foothills. 3000 feet. The large Saguaros (Cornegiea gigantea) are about 50-feet tall and 100 years old. On the left is an Ocotillo (Fouqueria splendens). The branches of a Foothills Palo Verde (Cercidium microphyllum) can be seen on the extreme left. In the center is a Stoghorn Cholla (Opuntia versicolor). The ground cover is mainly Brittlebush (Encelia farinosa). On the extreme right protrude the denuded branches of a Creosote bush (Larrea divaricata) about 7-feet high.*

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having several times the volume of the plant above ground.

With rainfall so sparce, pollination is a problem. Pollination by means of windblown material would be ridiculously ineffective, because of the low density of vegetation. So, most plants pollinate by attracting birds and bees. That's why the desert was thought to be good for people with allergies -- little pollen in the air.

Don't pack your bags on this point. Tucson is horrible for allergic people. The people who've settle here have planted fast-growing, non-native plants. Some of them, like the Mulberry tree and Bermuda grass give off enormous amounts of pollen. Because there is little rain to wash the air, the pollen content of the air over Tucson is extremely high. Also, there's dust in the air, blown from the denuded areas of new construction and agriculture. To top it off, there's Valley Fever. That's the innocuous name given to a vicious lung disease started by spores living in the desert soil. One of my friends, a lung pathologist, came here for research at the University Hospital because Tucson has the greatest range of lung and respiratory problems of any place in the country; indeed, a bonanza for a young medical researcher.

Back to botany. The quick-changers are the leafy plants that grow leaves on short notice. Chief among these is the Ocotillo (oh-koh-TEE-yo), *Fouquieria splendens*. (See Figure 4.) Each plant is a spray of stalks jutting upwards from the ground, each stalk about 10-20 feet long. Most of the time it looks dead. Following a rain, the clusters of thorns along the sticks grow clusters of leaves within 48 hours. The plant then photosynthesizes like mad, for a week until the ground begins to dry out. The leaves then dry up, fall off, leaving their stems as new thorns. The stalks make excellent fences, very often taking root and continuing to bloom. When it is time to pollinate, Ocotillo develops brilliant red flowers at its tips to attract humming birds. Another quick-changer is the Palo Verde (Green Stick or genus *Cercidium*), named because of its green bark. (See Figure 3.) These look like 20-30 foot trees with no leaves (and giving little shade). After a rain, the twigs grow leaves which are quickly shed when everything dries up. Meanwhile this clever plant uses its bark for photosynthesis (if you have to have bark, why not use it)! There are several kinds of Palo Verde, commonly known by their color: green, blue, and yellow. Most common here is the green or Foothills (*Cercidium microphyllum*). The blue (*Cercidium floridium*) actually a bluish-green, are riparian, and are found by arroyos (washes) because they've been cursed with a hard seed. It takes tumbling down a rocky wash after a rain to crack these seeds to permit germination. The yellow or Mexican Palo Verde (*Cercidium incantrememba*) is common in landscaped areas because it grows more quickly than the others. In April or May, the Palo Verde bloom is a panorama of lacy lemon-yellow, produced by millions of tiny flowers.

Another group of quick-changers is the desert grasses and flowering plants. Every few years the desert gets spring rains. The seeds lying dormant for those drought years quickly germinate, grow and bloom. The desert floor and slopes burst into a carpet of flowers which then fade, drop their seeds and again begin the dormant years.

The cacti are the planners-ahead. They don't change very fast. But, after a rain, the succulent tissue between their hard corset-like ribs swells, storing water for six months to a year. The girth of cacti shrinks during drought, like that of a patron of Main Chance. During the dry spells, the cacti use the stored water. They can store enough for about one year, truly the squirrels of the desert plants.

The giants of the cacti are the Saquaro (Sah-WAH-ro), *Carnegaeia gigantea*. (See Figure 4.) These 40-50 foot single cacti are the hallmark of the Sonoran Desert. They are not seen elsewhere possibly because they require rainy seasons twice a year, a phenomenon which does not occur in the other U. S. deserts. These are the oldest plants in the Sonoran desert, often living to 150 years or more. At 10 years, they may be only eight inches tall. Arms don't form until about 70 years. They grow in "forests",

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Figure 3. *A Foothills Palo Verde, about 20-feet high. Photosynthesis occurs in its green bark.*

covering thousands of acres and only on hillsides, presumably because the cold air of winter nights can roll right down by them to settle elsewhere on the valley floors. A full-grown Saguaro weighs about 15 tons in the wet season, and is almost all water. Birds, especially the woodpeckers, bore out holes in the stem for nesting. There is evidently little damage to the Saguaro, which coats the hole with a leather-like material. This cactus blooms only at night, during the cool desert nights of May. The wooden ribs of its internal skeleton, together with Ocotillo stalks, have been used for centuries to support the mud roofs of adobe buildings in the Sonoran Desert.

Another prominant cactus is the Cholla (CHOY-ya), genus *Opuntia* which comes in many types and shapes. They look like cucumbers wired end-to-end, and are covered with spines (See Fig. 5). These you should avoid. The spines have barbed tips. When an unsuspecting animal or man brushes against the cucumber-like segment, the barbed spines embed themselves in the flesh. Moving on, the wounded mammal takes along a broken segment (and a pain) which will drop off elsewhere and germinate a new plant. In this family, common names have been chosen to describe the appearance of the segments: Buckhorn, Teddybear, Pencil, Staghorn, Cane, etc. Jumping Cholla, though, is the name of the plant in which the segments break off most easily. People swear that this cactus jumps into them!

In addition to these plants, the Sonoran Desert contains other heavy and thorny plants or trees like Acacia, Mesquite (Mes-SKEET) and Ironwood. Mesquite (*Prosapis juliflora*) is a hardy 20-foot tree found near washes. Its dense wood makes

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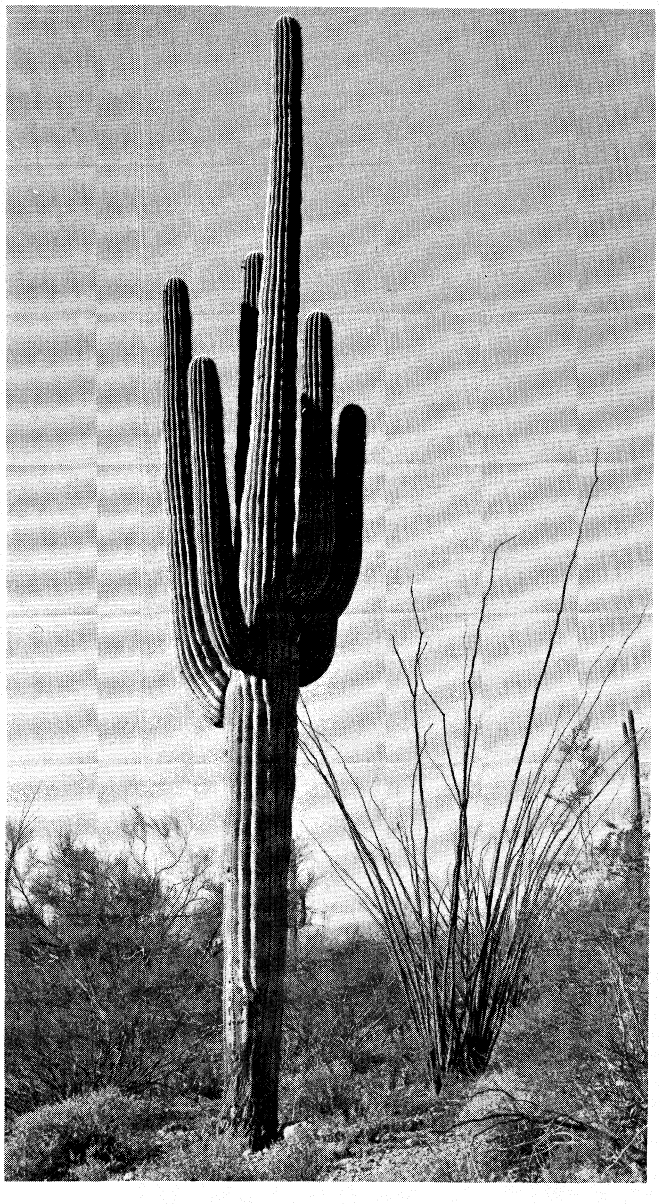
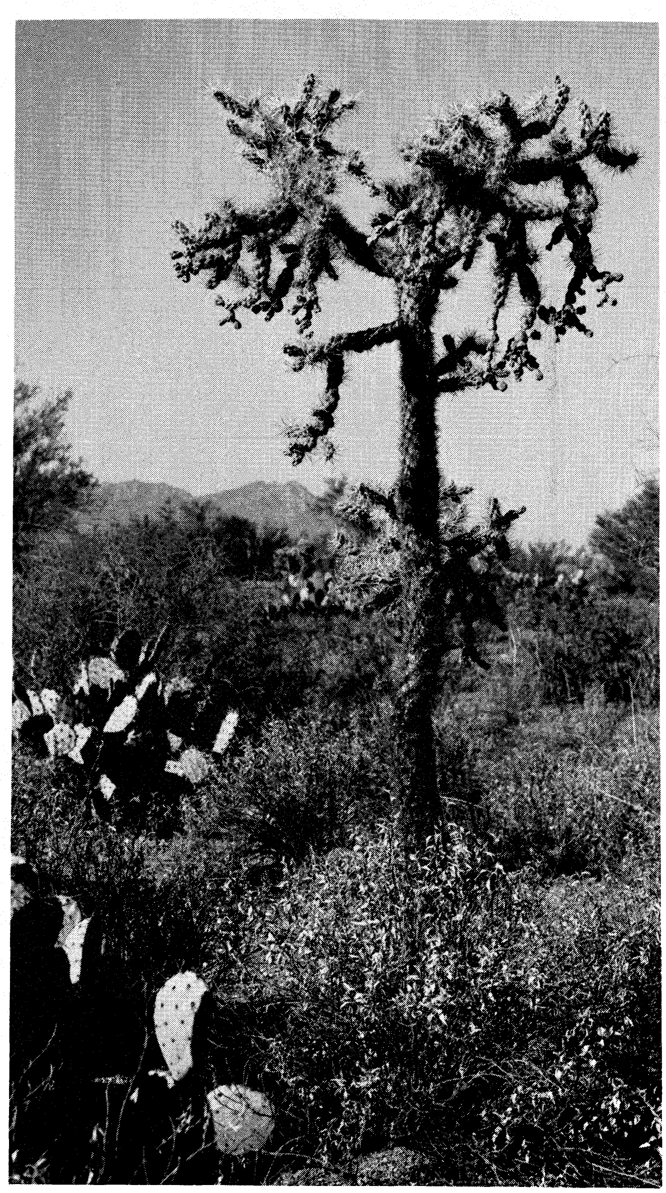


Figure 4. *This many-armed Saguaro is about 50-feet high, weighs about 15 tons, and is about 150 years old. The diameter of its trunk is about 15 inches. To the right is an Ocotillo.*

Figure 5. *A close-up of the Jumping Cholla. Don't touch, it is very painful to have an embedded quill and to pull it out with pliers. This cactus is the same as in Figure 1 and is about 6-feet high. In the foreground is Brittlebush. To the left are Englemann Prickly Pear Cacti (Opuntia phaeacantha discata). Many Tusconans make Prickly Pear jelly from their purple fruit, known as Tunas.*



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an excellent firewood -- if you can get it started, giving off a pungent odor which is a favorite for steak-grillers. Ironwood, (*Olneya tesota*) which looks like Mesquite, is so dense that it doesn't float, hence the name. Ironwood is easy to identify in winter, because it always has leaves. All of these desert trees have tiny tree rings, because they grow so slowly.

A third category is the Desert Lilies. The Sotol (SOH-tol), and the Century Plant or Mescal or Agave (Ah-GAV-ee), and Yucca are broad-leafed plants which grow close to the ground. There are many different varieties, but a common trait is the giant bloom which occurs once a year for the Sotol and the Yucca and once in a lifetime for the Agave. The Yucca (genus *Yucca*) fruits are invaded by worms, which eventually hatch into moths, which fly to another Yucca and lay their eggs on new fruit, the migration thereby pollinating the plant. Symbiosis of the first rank! Its roots make excellent soap, and have been used as such by Indians. The Agave (genus *Agave*) is now becoming better known to the world, because tequila is distilled from its sap. Once in its 75-year lifetime, it sends up a bloom stalk. The stalk grows a foot a day, and extends to 30 feet above the two-foot high Agave. Growing the bloom stalk takes all the plant's sap, and afterwards the plant shrivels and dies. The bloom stalk then falls over, and the seeds land about 15-30 feet away to begin new plants. Sotol, (*Dasylirion wheeleri*) a Yucca-like plant shown in Figure 6, has an enormous annoual bloom stalk. Mexicans make a potent whiskey from its roots, also called Sotol.

The final category I should mention is the brush which lies close to the ground, within five feet of the surface. The Sagebrush, the Tumbleweed, the Creosote Bush, the Bursage, the Brittlebush, and the Desert Broom.

All of these plants cover the desert floor extensively. The leaves and shoots are heavily covered with wax or resin to minimize water loss. Some plants can drop their leaves during drought.

Figure 6. *One of the desert lilies described in the text, this Sotol (Dasylirion wheeleri) is found between 4000 and 6000 feet. The 20-foot bloom stalk is an annual occurence, just like that of the Yucca. Mexicans make a potent whiskey from its sugary sap. Its dried leaves are the spoon-like ingredients to floral arrangements sold across the United States.*

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The exact mix of cacti, trees and brush depends sensitively upon annual rainfall and temperature and so also upon altitude. What I've described is the botany of the Sonoran Desert from 2,000 to 4,000 feet, essentially the covering of the desert floor. (Tucson's altitude is 2,500 feet above sea level.) As one goes up into the mountains, the botany changes from this open desert into chaparral into western woodlands, with evergreens, oaks and other deciduous trees. (Chaparral is familiar to Tucson dwellers, as the Scrub Oak, Buckthorn and Manzanita thickets just above the desert floor. The cowboy's word chaps refers to what he must wear to protect himself from the thorny brush of the chaparral. (See Figure 7.)

The Aura. Walking in the desert gives me a different feeling than walking in the east. Aside from bumping into thorny plants, you can feel and hear the difference if you just shut your eyes. First, the sun. It beats down with a blinding intensity during 260 cloud-free days a year. No shade, no diffusing clouds. Just intense, contrasty light. You can feel it through

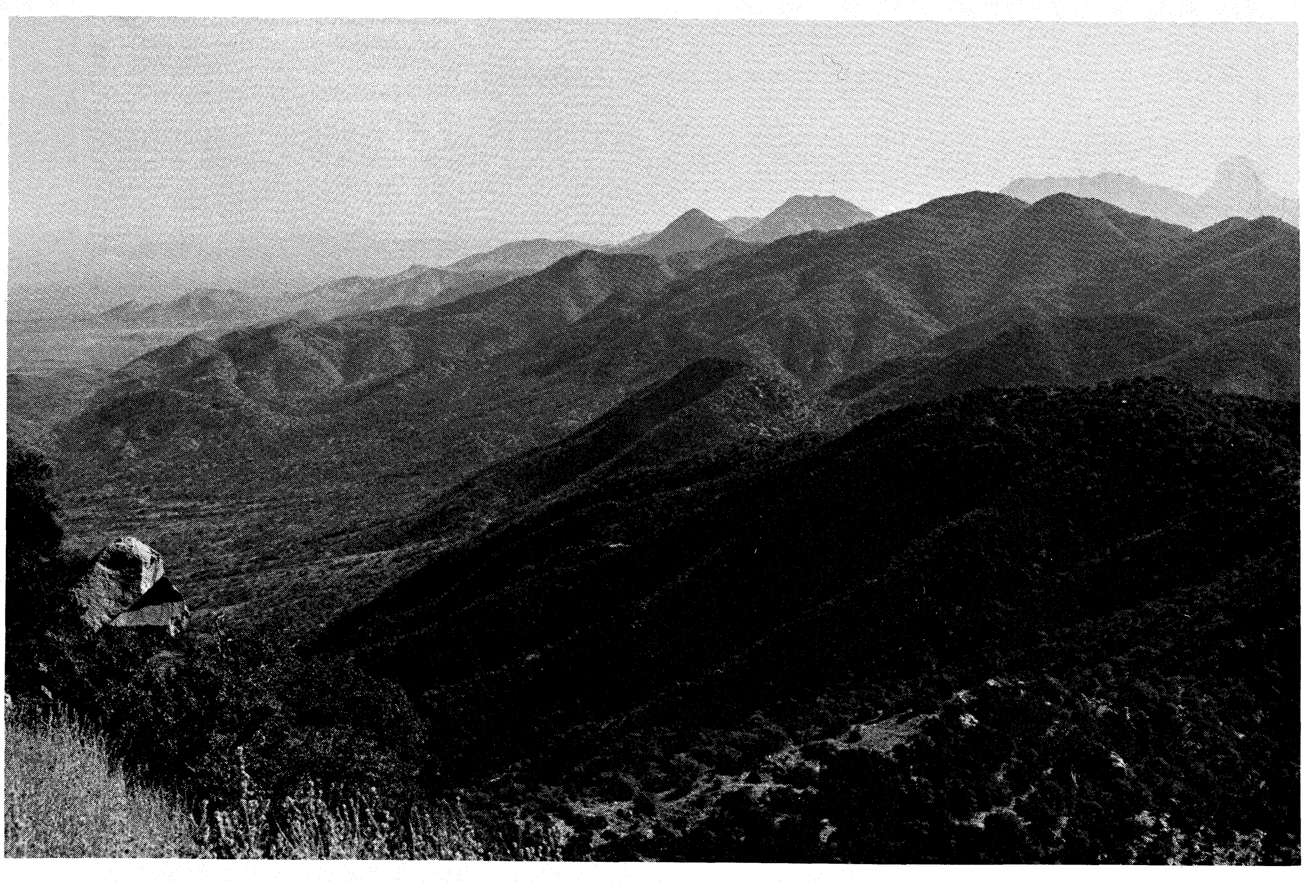

Figure 7. *A view to the southeast from Kitt Peak, taken from the near vicinity of the 36-foot telescope. Typical mountain view in the Tucson area. The closer foothills are at 5000 feet and covered with Scrub Oak (Quercus turbinella) as is characteristic of chaparral. The background mountains are the Baboquivari Range, with the knob at the extreme right believed by the Papagos to be the home of their god. The haze is predominatly caused by sulfur dioxide, a product of the nearby copper smelters.*

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closed eyelids; extremely dark glasses are nearly a necessity. Even when it's hot, your skin feels dry. In this low humidity, sweat disappears as if it were never there.

The sounds are somewhat eerie. The wind blows a lot, with no tall trees to break the force, reminding me of the ocean. Sound carries amazingly far, also like the ocean. The sounds of birds -- and there are an amazingly large number of species in southern Arizona -- can be heard for a long way. At night, the baying of coyotes is commonly heard.

There are strange visual sensations. Away from the city, the lack of foliage exposes your senses to the enormous scale of the landscape. You can see for miles. There's a sense of being alone and unprotected from the elements: no trees to run to, no bushes to hide in. I keep telling Hein Hvatum that bicycle riding is no fun because you can see the scenery for miles ahead. There are no visual surprises.

In the city, it is also a little odd visually. The lack of dense foliage allows you to see into every back yard, home or commercial building alike. The trash, the garbage cans, the laundry, the odds and ends of spare parts and lumber are clearly exposed to the visitor. Everything looks a littly grubby and half-finished. In fact, the most exclusive residential subdivisions have deed restrictions preventing you from exposing your trash cans, your laundry, your air conditioner, or your wood pile. All of this must be hidden from your neighbors' view.

When it rains, your sense of smell becomes suddenly turned on. Evidently, either the propagation or detection of odor requires moisture in the air. After a rain you smell the musty odor of the wax coating of the Creosote Bushes, the scents from the desert blooms, and even the dust in the air. The contrast in odor before and after a rainstorm is astonishing; it's like being transported to a different place.

And the dust. It follows you everywhere. It permeates every crack and crevice of your house, it gets into your clothes, and it makes your skin itch after a while. I'm not writing about the kind of experience reported for dust storms, just everyday living. I can even feel it in my eyes as a kind of tiredness at the end of a day. Those who wear contact lenses are frequently miserable on a windy day.

<u>The Wildlife</u>. Yes, Virginia, there are poisonous creatures in the desert. Lots of snakes, spiders, scorpions and some lizards and toads. First, the snakes. We have rattlesnakes of many types, all pit vipers who sense the size and proximity of their target by pit-like infrared sensors in their skulls. They are everywhere in spring, summer and fall. But, I've only seen one in the six years I've been backpacking, and I've never known anyone who has been bitten. In short, they stay out of man's way. We also have coral snakes. These are very deadly although fortunately rare. Black Widows are extremely common, every house has scores of them. Also Brown Recluse spiders, although much rarer. Tarantulas are everywhere. They seldom bite, are extremely fragile, and are kept as pets by many children. Scorpions are also extremely abundant. Of the three common types, the littlest one is the most dangerous. The last one of those I saw was under Max Thomas's desk at the office! And, we have toads with poisonous skins. There's also the Gila (HEE-la) Monster, a 15-inch lizard with a poisonous bite.

But, for all of these, there is a much larger number of non-poisonous creatures who depend upon speed to avoid a predator. We have wild pigs (Javelinas), rabbits and mice, coyotes and all manner of wild cats. The desert teems with wildlife. Most are highly adapted for survival in an arid climate. There's even a kangaroo rat which never drinks, getting all moisture from seeds and recycling water from bladder to digestive tract. And deer and bighorn sheep in the mountains.

Birds are seen everywhere in the morning and in the evening. Quail and roadrunners are found on the ground. Cardinals, doves, finches, flickers, flycatchers, owls, sparrows, wrens and woodpeckers in the brush and trees. Hawks, eagles and buzzards in the air. People come here from all over

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the United States to observe and record the birds. Over 200 species have been found in one canyon alone, Madera Canyon just south of Tucson. Over 430 species have been found in Arizona.

There is humanoid wildlife as well, but Dale Webb is the expert on that. Some of it is very dangerous and could also be classified as pit vipers.

The History. Southern Arizona's is long and complex at least for the New World. To sketch it, I'll divide it into three periods: pre-Coronado (before 1540), Spanish-Mexican (1540-1853) and United States (1854 to present).

Southern Arizona was the home of a number of distinct Indian tribes, some of which have descendants living here now. The earliest tribe is called Paleo-Indian, big-game hunters who were here between 30,000 and 10,000 B.C. The reason for their disappearance is unknown, perhaps a change of climate. The Desert Culture followed, covering the years 9,000 B.C. to 200 B.C. These gatherers and hunters learned to use grinding stones and evolved into primitive farmers.

You should note that until the 1920's, rivers flowed year-round through the Tucson area. The water table was about 20 feet below the surface then, decreasing only recently to its 600-foot depth because of pumping for agricultural irrigation. Beavers were common along these desert streams.

The largest of the Arizona Indian groups was the Hohokam, flourishing in the desert regions from 200 B.C. to 1400 A.D. They numbered as many as 50,000 during peak years. They engineered networks of canals to irrigate their fields, in which they grew maize, cotton, beans, squash and tobacco. These canals enable them to live in areas away from the river, extending their influence over a large geographic area. In the later years, this culture built large pueblo-type dwellings. The most famous of these is the Casa Grande (Big House) which has survived and is located about 50 miles north of Tucson. It was four stories high and had 16 rooms. But, this culture burned rather than buried their dead, and we have little knowledge of these enigmatic people. Sometime around 1400 A.D. they disappeared. One theory is that the soil fertility declined. We may never know, but some believe the modern-day Pima culture to be their survivors.

The tribes living here today came into the region toward the end of the Pre-Coronado period. The Apache went to the mount ns, the Pima settled near the northern desert rivers and the Papago settled near the southern desert rivers. These cultures are very different. Ethnologists divide the Arizona Indian languages into Ute-Aztecan (Pima, Papago and Hopi) and Athapascan (Apache and Navajo).

The Apache are a gathering and hunting people, organized into small bands rather than a single nation. Their allegiances were primarily to family rather than to tribe. Chiefs were elected and not hereditary. They were fierce fighters, plundering the more docile river Indians and, later, Spanish and Mexican settlers. Family structure was important, and democracy was an integral practice to Apache living.

The Pima live along the valleys of the Salt and Gila Rivers, calling themselves the "river people". When the Spanish first tried to interrogate them, the natives kept answering "Pim", which means "no", or "don't understand". Hence, the name Pima. Their traditional enemies were the Apache, and many Pima later served as scouts for Spanish, Mexican and American armies fighting the Apache. Their society was commune-line, with a hereditary chief and a council. Marriage was not necessarily a lifelong commitment, with each spouse free to break it off at anytime. Pima Indians are highly skilled in pottery and basket-making.

The Papago, cousins to the Pima, live around Tucson. Kitt Peak is part of their eight million acre reservation. They call themselves "the desert people". Unlike the Pima, this people practiced agriculture by "flash-flood farming". They also harvested the beans of the Mesquite tree, and the fruit of the giant Saguaro. During the winter, they moved to higher elevations where water is more plentiful.

Enter the Europeans. Following erroneous reports of the seven golden cities of

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Cibola, Coronado mounted an expedition from Mexico City in 1540. It moved through the Arizona desert in July in full armor, and also into New Mexico, Colorado, Kansas and Texas. No gold was found, and these negative reports discouraged further European encroachments into southern Arizona for the next 100 years. Coronado did provide maps, however.

In 1687, things changed for southern Arizona. Father Eusebio Francisco Kino, a Jesuit missionary, was ordered into the Primeria Alta, or the high country of the Pimas, as southern Arizona was then called. Father Kino was born in Italy and educated in Germany. During his college years, he became deathly ill and vowed to dedicate his life to God if he survived. He subsequently joined the Jesuits and became an expert in animal husbandry. He had hoped to be assigned to the Orient, but he spent the first six years in Baja California; from 1681 to 1687. His entry into southern Arizona would forever change the character of that part of the desert. He lived in extreme humility and poverty, moving from tribal center to tribal center, offering advice to the Papagos on how to plant and harvest and how to care for livestock. A chain of missions were established in the Primeria Alta, from what is now Sonora, Mexico to Casa Grande, Arizona. Some were small, known as visitas, and some were the sites of mission churches such as Magdalena, Tumacacori and San Zavier del Bac near Tucson. The relationship between Kino and the Indians was generally excellent because he gave only sound advice. It has been estimated that in his 24 years of wandering, he traveled nearly 75,000 miles on foot or on horseback. While the Indians hated the few Spanish settlers who sought silver in the mines of the Pimeria Alta, Kino was loved and respected. He died in 1711 in Magdalena, Mexico, while dedicating a new mission. He founded 29 missions and 73 visitas. But, most importantly, he improved the quality of life for the native inhabitants.

After his death, the situation went downhill. The best farm lands were being taken over by the Spaniards, angering the Indians. The distinction shrank between the humanitarian Jesuit missionaries and the opportunistic servants of the Spanish king. The Apaches refused to have anything to do with either, and they sacked the missions as often as they could. In 1751, all the Indians revolted against the Europeans, plundered the missions and chased the white men out of the Pimeria Alta Kino's benevolent work was overturned.

The next year, the Spaniards returned in force and established garrisons (presidios) at key locations. No more attempts at handholding with the natives! An uneasy truce was maintained for some years, a balance between Spain's military muscle and the humanitarian assistance of the Jesuits and the resentment of the Indians.

In 1767, another change. Carlos III of Spain believed that the Jesuits had been undermining his influence in the New World and expelled them from all Spanish territories. They were replaced by brown-robed Franciscans, who had a different philosophy of the appropriate relationship between missionaries and pagan natives. In spite of this, they were preferable to the Spanish army. Some, like Father Junipero Serra of California, were regarded as almost as successful as Father Kino. The Indians loved him. Between 1768 and 1776, the Sonoran missions were largely rebuilt.

In 1774, another event was taking place 30 miles to the south of Tucson. An American-born Spanish soldier, Captain Juan Bautista de Anza received permission to find a route to the California missions. Off he went, through Yuma to San Gabriel, a mission near present-day Los Angeles. A year later, Spain was interested in establishing a land route from Mexico City to the San Francisco Bay. Knowing the route to San Gabriel, Captain de Anza went along. The expedition settled the town of Yerba Buena in California in 1776, whose name was eventually changed to San Francisco. The previous year, 1775, de Anza's Arizona presidio was moved northward by his Irish-immigrant commander, Lt. Colonel O'Conor, to a place more easily defended. The new location was called Tucson, after the nearby Papago village of Chuk Son. The

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same group, within a year, founded both Tucson and San Francisco. For the next 150 years, Tucson would be Arizona's largest city.

The Spanish influence in New Spain was waning. It could not afford the level of support necessary to colonize. Mistreatment of Indians became more flagrant as governmental neglect deepened. In 1781, the Indians again revolted. Almost every male European in the Pimeria Alta was killed. Women and children were spared -- an unexpected courtesy, showing that the Europeans had made some impact upon the Indian sense of values.

In 1785, New Spain received a new viceroy. Bernardo de Galvez devised a plan to keep the tribes fighting each other, by supplying them with liquor and arms. Amazingly, it worked. De Galvez had accomplished what sword and cross could not. The Pimeria Alta was no longer a Spanish problem for the next 25 years.

The situation changed dramatically in 1821. The Spanish colonists revolted, and Mexico was born. It could not afford to supply even the meager support to the Indians that Spain had been giving. Also, the instability of the new country brought neglect to the Pimeria Alta. There were 17 changes in government between 1821 and 1846. During this period, restless Americans were merrily settling in Mexican territory. Either Mexico felt any western colonists might hold the land for them or they were too involved with their internal governmental problems to care.

The American colonists in the Texas part of Mexico eventually revolted and set up their own republic in 1836. In 1845, Texas was annexed into the United States. When Mexico protested that the United States was legitimizing an illegal seizure of their land, President Tyler told them to go to war if they didn't like it. Mexico promptly declared war on the United States.

Mexico was in no position to wage war. Within a short time, American troops were in Mexico City. The war ended in February 1848, with the Treaty of Guadalupe. Mexico lost nearly half of her territory to the United States. What is now California, Nevada, Utah, New Mexico, parts of Colorado and Wyoming, and Arizona north of the Gila River. Tucson remained as part of Mexico. The land to the north of the Gila, roughly north of 34 N including what is now Phoenix, became U. S. territory.

If you look at a map, you can see that the lack of U. S. territory in southern Arizona made it awkward for travelers going from El Paso, Texas to San Diego, California. There was also the problem of the right of way for a railroad. Accordingly, James Gadsden of South Carolina was appointed American Minister to Mexico to solve this problem. At the time Mexico was nearly bankrupt, its treasury depleted by war and corruption. Gadsden talked Mexico into selling a large parcel south of the Gila, an extremely reluctant decision for a country which had just lost half its territory to the buyer. Gadsden reported back to Congress in 1853, which then debated the wisdom of this purchase of sagebrush and sand. Gadsden was instructed to cut the offered price in half, which enraged the Mexican government. Nonetheless, Mexico needed money badly and in 1854, the deal was closed and ratified by Congress. Tucson, the largest city in Arizona and New Mexico (next to Santa Fe), became part of the United States. This act is known as the Gadsden Purchase.

American colonists streamed into the new territory, and Tucson became a wild town, supplying guns, women and booze for the new arrivals. (It has changed little over the years!) The Butterfield Stage Line was set up in 1858 to carry mail and passengers from St. Louis to San Francisco in three weeks. Butterfield placed stations at 18-mile intervals over the 2800-mile route. Fifteen hundred horses and mules were purchased. The cost was $200 plus meals. It was one hell of a trip, with as many as nine people in a single coach. You could sleep only with difficulty; there were no baths or shock absorbers. There were recorded cases of people going insane on the trip. But, travelwise, Tucson was now in weekly contact with the rest of the United States.

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The outbreak of the Civil War cut stagecoach travel. There were no soldiers available to protect the West, and Cochise had discovered raiding locally was much easier than his earlier habit of raiding in Mexico and then slipping back into his Arizona home for rest and recreation. The ranchers gave up their ranches, and moved into Tucson to avail themselves of gambling, women and booze -- which Tucson excelled in providing. During the war, Confederate soldiers opened a garrison in Tucson, as part of Jefferson Davis's plan to link the southern states with the Pacific. The citizens ignored the politics, they were otherwise occupied.

In 1860, Arizona became a U. S. Territory separate from New Mexico. While Tucson, as the largest city was the likely choice for a capital, it had the presumed disadvantage of having been under the Confederate flag, and its citizens spoke Spanish to boot. The prevailing politics were Union and Anglo. Until 1867, the capital was a two-room log cabin near Prescott. Then Tucson became the capital for ten years. Prescott won it back in 1877. Finally, the tiny agricultural community of Phoenix -- presumed to have no political history -- became the capital. Tucson was given the university as a consolation prize. (From what I've seen, Phoenix was the real loser.)

The combination of poor roads, continued Indian unrest, rustlers and corrupt politics kept Arizona from becoming a state until 1912. Statehood has not ended these problems. Arizona remains first in land fraud and first choice as a retirement home for metropolitan mobsters. Joe Bonanno, a neighbor of astronomer Bart Bok, is now being tried on the basis of his captured autobiography. Barry Goldwater is seen as a politician of moderate views by the majority of Arizona's citizens, certainly not as a conservative. Agribusiness uses 97% of the state's underground water, producing less that 2% of its gross state product. The water table in Tucson has dropped from 20 feet to 600 feet below the surface in 50 years. Carefully prepared longterm zoning plans are breached at the drop of a buck by any interested developer. By statute, the maximum welfare levels are fixed to 60% of the federal minimum. In spite of a Supreme Court ruling, the state legislature held up the furnishings for a newly completed University library for one year, until the University Hospital stopped performing non-therapeutic abortions. The ERA is almost a four-letter word. Automobile emission control, an essential to preserve the clear air of the LA-like Tucson basin, is viewed by state legislators as an "economic hardship" on Arizona citizens. (Meanwhile, Phoenix has an enormous smog problem.) Automobile safety standards? Hah! The Central Arizona Project, billed as a way to bring Colorado River water to parched Tucson, is a concrete canal to nowhere. All of the river water has been previously committed to California. Arizona is the only state not to administer the federal Medicaid program. But, we do have London Bridge, legal prostitution in some counties and marvelous Mexican food. And that scenery still undefiled by man is magnificent!

It is still wild and woolly out here. Perhaps in the long run chaos is more beneficial to society than governmental regulations and order. Whatever your preference, Arizona is indeed a Calvin Coolidge state.

A marvelous book of anecdotal Arizona history is Arizona, by Marshall Trimble, published in 1977, by Doubleday. ISBN 0-385-14064-9.

The standard botanical reference book is Arizona Flora, by T. H. Kearney and R. H. Peebles, published in 1964, by the University of California Press.

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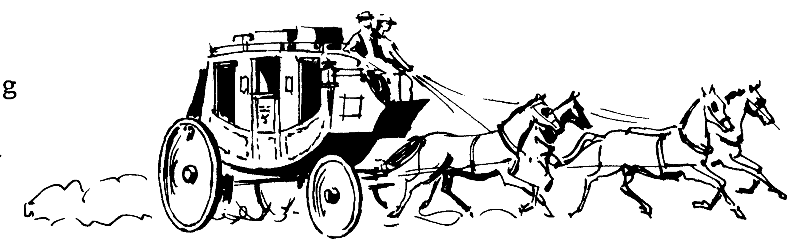

A TYPICAL OBSERVING RUN

Paul Rhodes

There is nothing typical about an observing run at the 36-foot telescope, but this was my assignment from the Lou Grant of Tucson. I guess a brief description of what is supposed to happen might be helpful to the uninformed. A typical observer might be Dr. Charfman.

After Dr. Charfman arrives at Tucson International he finds he must take a taxi 15 miles to the opposite end of town. There he tries to find where Bill Gust has hidden his luxury model GSA vehicle. Then he mutters an oath hoping the gas tank is full or he can find a gas station open at 11 o'clock at night.

Fifty-four miles and an hour southwest of Tucson, Dr. Charfman finally arrives at the telescope site. Then he finds that the only room left for him is the one with the "skunks". After eight hours of restful sleep he awakes to the arrival of the engineers and technicians who will help him get started. He also meets the telescope operator who will help him gather the data for his next publication.

Hopefully, the following hours of his run will be typical and uneventful.

Normally, to keep things from being dull, these are some of the untypical things that can and have happened. Disco Don, our resident grey-beard, relates the story about one of our jogging lady astronomers. Going jogging before dinner she asked if it was okay to "just wear jogging shorts to dinner". Don replied that it would be nice if she wore a top as well.

You've all probably heard the story of John Weaver and the rattlesnake. Bob Brown still says he doesn't know if John can jump the 15 feet from the top of the stairs to the dome door. But when Bob returned from dinner John was outside and the snake was inside. The snake's demise came shortly.

Werner Scharlach, our astronomer/operator who does some optical observations at KPNO, has the honor of shortening my life by a few years. I was awakened by the phone about 2:00 a.m. Groggily answering, I hear Werner say, "There is a fire in the MG room!" Then silence. By the time he returned to the phone I was at the window looking for flames on Kitt Peak. As it turned out only the insulation had burned on the generator for the telescope azimuth motor! We, thankfully, have a spare generator.

Cal Sparks, another of our operators, must have been named after Calvin Coolidge, because Cal is Mr. Cool. The only person known to have perturbed Cal was our ex-programmer, Mike Hollis, who had a reputation for making people lose their cool. Cal came very close recently, though, when asked to baby-sit while operating the telescope. It seems visitors had brought their six-month old son on the observing run with them and asked Cal to baby-sit while they went to midnight lunch. All Cal could manage to say was, "NO!"

Dave Myers is the only operator to actually take part in, and survive, all telescope operators' nightmare. It seems that the 36-foot telescope was not designed to work in moderate winds and this is a severe handicap at 6300 feet on Kitt Peak. Dave was trying to observe a very important source, (they're all important) even though the wind was kicking up in that direction. Simultaneously, three things happened. The wind over-powered the azimuth drive, the azimuth drive breaker opened allowing the telescope to run free. As Dave saw the telescope start to swing he applied the brakes. Nothing happened! As we determined later, a fifty-cent check valve had failed. All Dave could do was watch as the telescope revolved three times around the azimuth axis. Twelve hours later the telescope was running again. It seems Dr. Snyder was timing the repair crew. Back to Dr. Charfman's run.

If Dr. Charfman avoids these and other

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typical problems he might be able to have a smooth run until his last night of observing. Then, as I call it, "Lastnightitis" occurs and there is no hope. There was one occasion where a normally intelligent operator, who shall remain nameless, tried to help astronomers push a fifty-ton dome to get that last hour on the source.

I guess I didn't really write about a typical observing run, but I never claimed to be a Rossi. Sorry about that Lou.

* * * * *

ODDS AND ENDS

M. A. Gordon

There are some things you never forget. Among my collection are a few NRAO - Tucson stories which may also amuse you.

Soon after John Payne and I arrived here in 1973, we got a frantic call from the telescope late one afternoon. The azimuth brakes had failed, and the telescope had been blown two and one half turns past the azimuth limit. All the cables had been ripped from their connectors!

Panic! Disappointment! The two of us had just arrived from Charlottesville and were not interested in beginning our administrative jobs with a disaster. We called around and dispatched every technician and engineer to the mountain. And fretted.

First, we needed some food to calm our nerves and to give sustenance for what was surely going to be a long night. Spaghetti and a martini each, as I recall. Then we drove to the mountain.

When we arrived, there was Lew Snyder, Jr. and colleagues. He had listed every employee's name on the black board and was marking down their time of arrival. The scoundrel! Even though the telescope had been rewired and put back into operation in 12 hours, in a forthcoming paper Lew thanked all of us in order of time of arrival. John and I were listed dead last.

Then there was the surplus-property problem. Tucson Operations had expanded faster than the space available, and our limited warehouse area was crammed with excess government property. We had tried and tried to get rid of this through proper NRAO channels, but nothing happened fast enough. John Payne's crew were replacing old electronics at a great rate; we were becoming choked with surplus property. One morning, in desperation, I decided to ship it all to Green Bank. Our property officer was there, and they had storage facilities. So, Mayflower trucked all this stuff to Green Bank, to Richard Fleming personally. And, of course, without advance warning. I didn't want them to say, no!

Pandemonium. Anger. What did Tucson think they were doing? Bill Howard called me and read the riot act. When he finished, he burst into laughter and told me he wished he had thought of something like that.

And then there's the AUI Trustees' visit. A couple of years after I arrived, Dave Heeschen informed me that the full board of AUI Trustees and their wives would visit Tucson and the 36-foot telescope in conjunction with their January meeting at the VLA. Well, I wanted this rare visit to be absolutely unforgettable. Dale Webb and I hired a sight-seeing bus for the trip to Kitt Peak. We spent weeks learning everything we could about the southwest and about Tucson, so that we could perform as tour guides during the long trip to and from Kitt Peak.

Quality lodging was also an objective of ours, and we inspected about 25 inns and guest ranches before we chose the Arizona Inn. This Inn is a truly posh place. Built in 1930 by a charismatic Arizona woman, it has been awarded honor after honor for its atmosphere, its food, and the unique quality of its rooms and furnishings. Its gardens are gorgeous, and its architecture reflects the Old West-territorial style peculiar to Tucson.

The Trustees' visit went well, as far as we can tell. The tour talks up and

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down the mountain seemed to be appreciated, and our guests enjoyed the Inn. They were happy to be away from the frigid Northeastern winter. Except for one thing. Evidently, this four-star Inn had been having trouble with a deranged employee and had discharged him earlier that week. Late one night, during the AUI visit, this man drove down the street and emptied a revolver into the front door of the Inn. I often wonder how many of the AUI Trustees now believe that gunfire is still an everyday occurrence in Tucson! The Inn management is still shocked at any mention of this incident, and AUI has never returned.

Then there was the expedition of Dewey Ross and me to White Mountain in California. NRAO was considering White Mountain as a potential site for the 25-meter telescope. Access up this rugged mountain was a problem, and Dewey and I were going to explore solutions.

I had visited this mountain several times before and knew that the trip by commercial carrier was arduous. So this time we would drive -- and camp along the way. Gutsy Dewey was eager to come, but he really didn't know me very well at the time. Camping meant camping; no motels! Off we went, spending the first night in Death Valley after erecting a tent in a 30 mile per hour windstorm. Food was cooked on our Coleman stove, including lunch breaks. Even after we arrived in Bishop, we slept in cold unheated buildings owned by the University of California. During all of this time, Dewey's spirits remained high. Although he clearly believed that he was traveling with a fanatic, he did not point this out to me.

But the last straw came on the way home. We had pitched the tent at 7000 feet on the eastern side of a desolate mountain range in Nevada. The temperature fell to well below freezing. Dewey froze (I had been fortunate enough to borrow a down-filled sleeping bag, but the one Dewey borrowed was intended for summer camping). Even I was cold. The next morning we crawled shivering from our tent. I cooked what I thought was a nourishing breakfast of coffee, eggs, bacon, and boiled potatoes. In a few minutes I caught Dewey surreptiously scraping the potatoes into the garbage pit. He had suffered everything else, but he was darned if he would succumb to the disgusting New England habit of having boiled potatoes for breakfast. We ate in restaurants for the rest of the way home, and he's never volunteered to accompany me on another trip!

Finally, there was the mainland Chinese delegation to learn about U. S. radio astronomy. Owing to a great recommendation from MIT's C.C. Lin, the delegation spent several days with NRAO in Tucson, learning everything they could about how to do millimeter-wave astronomy. We spent a great deal of time with them, giving them all of our knowhow and very much enjoying their company. When it came time to part, they presented me with a beautiful scroll. The only thing I could think of was a gift appropriate for their prodigious note-taking: U. S. Government ballpoint pens.

Within five minutes of their departure, Neil Albaugh came into my office. He asked me whether I'd ever opened up one of those pens. I opened his, only to find the label "made in Taiwan" stamped on the cartridge. What a diplomatic blunder! Frantically, I went to the stockroom and checked every pen we had in stock, only to find that this was an Albaugh hoax. I could have strangled him, but the crime would have been known instantly. The entire staff had been told of this ahead of time and giggled for days afterward.

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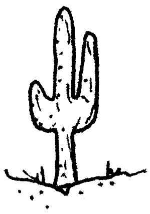
SOME GOOD THINGS MADE AND EATEN IN THE OLE SOUTHWEST

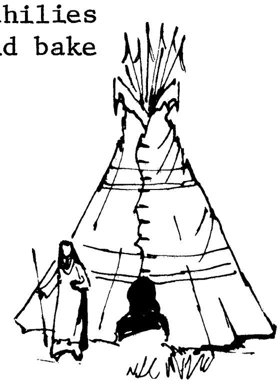


MEXICAN CORN BREAD

"Max" Thomas

1 c. corn meal
1/2 tsp. salt
1 c. cream style corn
2 eggs
1 small can green chili peppers
2/3 c. buttermilk
1/2 tsp. soda
1/3 c. shortening
1 c. grated sharp cheese

Drain and chop chilies, mix other ingredients except cheese, and pour 1/2 of the mixture into a hot ceramic or iron skillet. Sprinkle cheese and green chilies over it. Pour the rest on top and bake in 375° oven for 30-40 minutes.



INDIAN FRY BREAD

Kay Ross

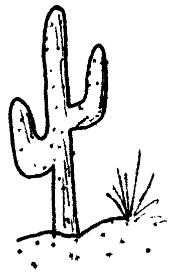
2 c. flour
1/2 tsp. salt
2 tsp. baking powder
1/2 cup powdered milk

Mix all ingredients and add warm water to form dough. Knead until dough is soft, but not sticky. Cover with a cloth and allow to stand for 2 hours. Shape into balls, about 2 inches across, then flatten by patting or using a rolling pin to about 8 inches in diameter. Have about 1/2 inch of heated shortening in a large frying pan and fry bread on one side until brown and then turn and brown other side.

CHEESE TOSTADA

Kay Ross

Butter tortilla. Grate sharp cheddar cheese, chop peppers, add meat (hot sausage), and salsa and spread on tortilla. Place in oven under broiler until cheese is melted.



TORTILLAS

Kay Ross

2 c. all purpose flour
2 tsp. baking powder
1 tsp. salt
1/3 c. lard
6 oz. cold water

Mix well. Knead until rubbery. Shape into size of golf balls. Roll out very thin (6 to 8 inches in diameter). Heat through on very hot griddle. Turn frequently until dark brown.

CHIMICHANGAS

Dale Webb

4-5 lbs. chuck roast
1 can stewed tomatoes
1 small can chopped green chili peppers
2 small cans chopped ripe olives
1 medium onion, chopped
1/2 c. catsup
Hot sauce to taste
1/4 tsp. garlic salt
1/4 tsp. pepper
Salt to taste
*2 dz. flour tortillas, long horn cheese

Salt and pepper roast and cook overnight at 200° about 10 hours making sure roast is covered. Keep covered until ready to shred. Shred meat and put it into frying pan, add remaining ingredients, cover and simmer about 12 minutes. If tortillas have been refrigerated, steam heat to soften. Spoon meat mixture onto tortillas and roll into a log, tucking corners in as you go. Fry at medium-high heat in small amount of Crisco oil until brown. Sprinkle on grated longhorn cheese and serve. Makes 2 dozen. Suggested toppings: Sour cream or guacamole or salsa and shredded lettuce.

**Use Kay Ross's tortilla recipe for flour tortillas*

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GOOD THINGS (Continued)

HOT MEXICAN TOMATO SAUCE

Don Cardarella

1 - 2# can solid pack tomato
1 onion, finely chopped
10 green chili peppers, chopped
1 tsp. oregano
2 T. wine vinegar
1 T. oil
1/2 tsp. chili powder
1/4 tsp. comino (cumin)
Salt and pepper to taste.

RATTLESNAKE HORS D'OEUVRES

Alice Gilmer

After skinning and cleaning snake, cut into lengths that fit easily into a Dutch oven or similar vessel. Submerge the pieces of snake in a solution of 3/4 water, 1/4 vinegar, and 1 cup of your favorite barbecue sauce.

Boil slowly until meat can be pulled off easily with a fork from backbone and remove all bones from the meat.

If hors d'oeuvres are not to be used the same day, place the meat in waxed paper or plastic bags and put in the freezer. (A little bit of snake meat goes a long way.)

If hors d'oeuvres are to be used the same day, keep the prepared snake meat in the refrigerator and immediately before serving, prepare as follows: Spread a thin layer of the cold meat on crackers or whole wheat wafers and cover with a thin smear of thick barbecue sauce.

BAKED BEANS

Judy Webb

First dice 1/2 lb. of bacon and cook in large saucepan until nearly crisp. Next dice 3/4 of a large white sweet onion into 1/4 inch or smaller size and put in with bacon and saute, drain most bacon grease (leave one tablespoon). Pour 2 cans #3 size of pork and beans (we prefer Hunt's) into the pan and stir well. Put in 3 heaping teaspoons of horseradish (or to taste), put in 3-4 tablespoons of yellow prepared mustard. Put in 1/4 cup catsup. Pour dark molasses until bean sauce begins to turn dark and you can taste the molasses. This should be approximately 1/2 cup. Note: you could also use about two handfuls of dark brown sugar. Turn on low or simmer heat and stir occasionally. Cook for a minimum of 2 hours (we prefer 3-4 hours). Do not let it stick to the bottom of the pan.

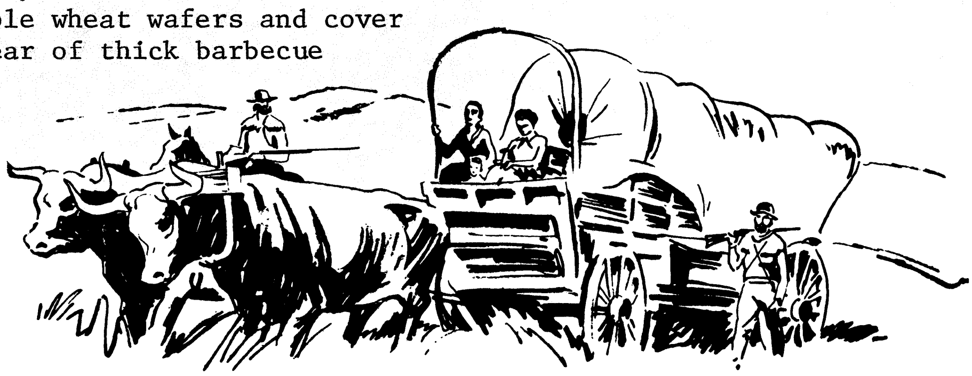
This baked bean recipe has been used on several of our NRAO picnics.

TEQUILA SUNRISE

Dewey Ross

1 shot tequila
4 oz. orange juice
1 tsp. grenadine syrup

Pour over 6 ounce glass of crushed ice and stir. Enjoy!

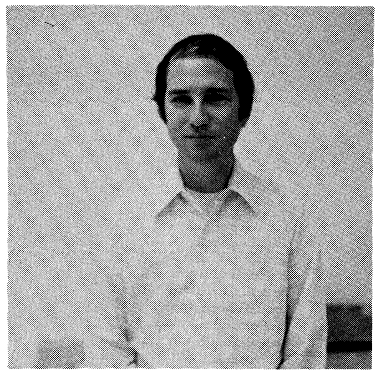


PERSONNEL UPDATE

New Employees

Roger D. Blandford
Visiting Scientist
Basic Research - CV

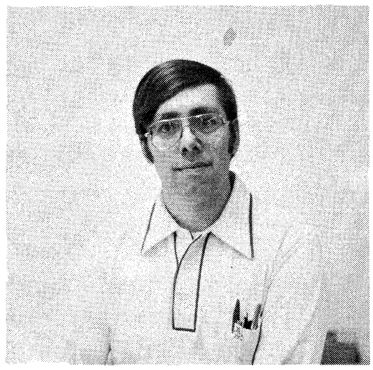
John M. Dickey
Assistant Scientist
Basic Research - CV



Gary A. Fickling
Scientific Programming Analyst II
Computer Division - CV

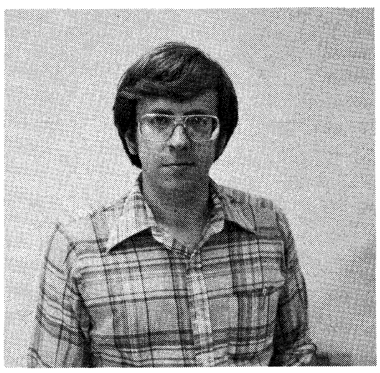
Galen R. Gisler
Assistant Scientist
Basic Research - CV

Jerrold I. Kaplan
Scientific Programmer I
VLA Computer - NM



George E. Martin
Scientific Programmer I
Computer Division - CV

Nadine V. Owens
Technical Trainee I
VLA Construction - CV



Jeffery J. Puschell
Research Associate
Basic Research - CV

R. Craig Walker
Assistant Scientist
Basic Research - CV

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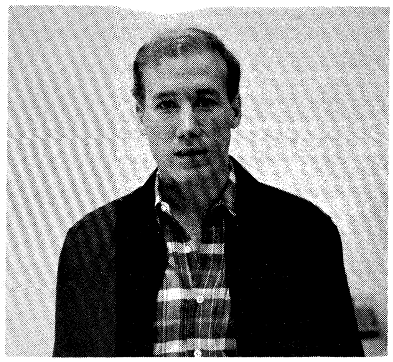
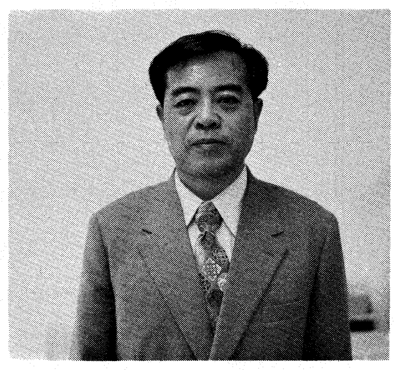
NEW EMPLOYEES (Continued)



Thomas D. Worrel
Technical Trainee I
Computer Division - CV

De-lin Xiang
Visiting Scientist
Basic Research - CV

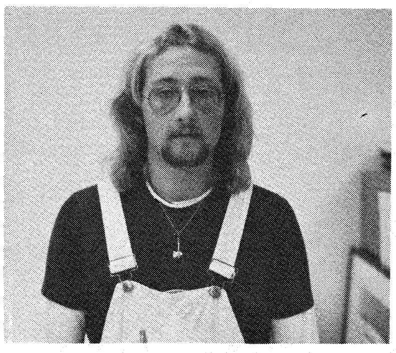


Qifeng Yin
Visiting Scientist
Basic Research - CV

OTHER NEW EMPLOYEES - PHOTOS NOT AVAILABLE

Frederick A. Bandle	Maintenance Trainee	VLA Project Management - NM
Pat Chavez	Telescope Mechanic	VLA Antenna - NM
Rosalie A. Ewald	Technical Trainee I	VLA Electronics - NM
Richard A. Hagen	Accountant	VLA Array Operations - NM
Martin Lopez	Telescope Mechanic	VLA Antenna - NM
Hazel M. McQuain	Janitor	Maintenance Division - GB
Ben G. Ross	Technical Specialist II	VLA Array Operations - NM
Richard R. Timney	Intermediate Technician	VLA Electronics - NM
Gary W. Towner	Intermediate Technician	VLA Electronics - NM

REHIRE



John C. Bishop
Advanced Computer Operator
Computer Division - CV

TRANSFERS

Larry D'Addario to Electronics - CV
Elizabeth B. Stobie to Tucson Operations

TERMINATIONS

Beverly L. Bibb
Eugene G. Binford
Carole A. Black
Charles E. Jarrett, Jr.
Wanda Y. Lewis
Benjie Montoya
Samuel E. Okoye
Jake F. Sanchez, Jr.
Malcolm W. Sinclair
B. L. Ulich

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HOW TO HAVE A GOOD GARDEN IN TUCSON THE YEAR AROUND!

Albert Webb

For the past five years our Editor has been asking for an article on gardening in Tucson. I have had a good garden for many years, however my gardening conditions are not normal for Tucson because I live about a quarter of a mile from a now normally dry river bed and the soil in my yard is fairly rich and nearly rock-free.

A more interesting and normal Tucson gardening experience can be best described by my father. When I asked him if he would write about his garden he handed me a draft of a letter that he was planning to submit to the local newspaper. My father's article follows. *Dale Webb*

Yes, it's possible to pick garden-fresh vegetables the year around in Tucson but you have to plan it that way. You should be able to raise from two to four crops per year if you do it right because here the weather is right to grow a garden nearly all year. (That's about the only thing right about growing a garden in Tucson.)

In Michigan, Ohio, Pennsylvania and nearly all the states that Tucson people come from, everything is right: good soil, long growing season, and plenty of water. There's no problem growing a good garden with these conditions.

On the other hand the experts say Tucson has a short growing season, a lousy granite-type soil, expensive water, and everything else you could think of that would prevent growing a good garden. However, if you want a good garden you can have one.

The things I am going to tell you won't be found in any garden book or in any other garden column in this paper. Why? The reason is that the experts who write the books and columns assume, (1) a good soil that requires many years to build up, and (2) general information from books is applicable if everything is right. Except for the weather in Tucson nothing is right and general information is rarely applicable to gardening in the Tucson area.

Five years ago we moved here from Detroit, Michigan and bought a house on 33rd and Harrison Road. I soon found out there was no way I could dig or rototill my soil because it was not only hard but it was also loaded with rocks and caliche (crust of calcium carbonate). The first thing I did was dam up about a 10 x 10 plot and run water on it for two days until it was soft enough to dig up and take out the rocks, some as large as 6 inches across. It took me nearly all summer to clean them out. I used these rocks to build borders for five garden plots with paths in between and connecting them. (See Figure 1.)

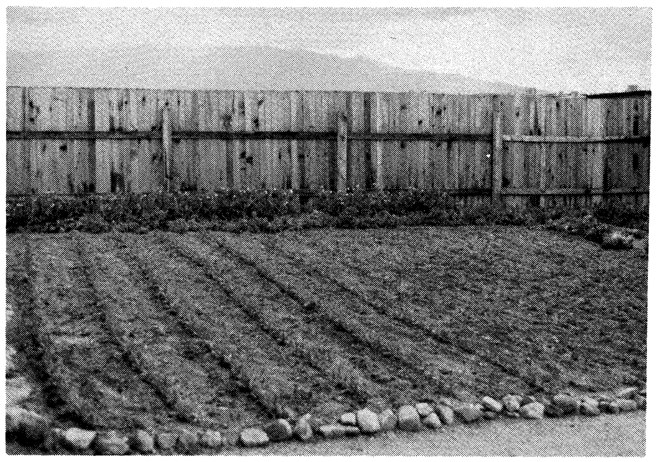

Figure 1.

I decided, because the ground was so hard to spend $50.00 on top soil for one plot to see if it would help. After adding the top soil, I put in some bush beans and I want you to know they were so happy there -- so much so that they never came up After a month, not a single bean sprouted.

A soil test at the University of Arizona cost me $4.00 and a two month wait for this reply: "You have a problem soil."

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Nothing was said about what to do for it.

Forest Magic, soil conditioner, was selling for $.90 - $1.20 per bag and I bought about $60-$70 worth and mixed it in. It worked okay but my beans cost me about 10¢ each. Of course in three months the Forest Magic was all gone and I was back where I started from. Later I'll tell you about a soil conditioner that is cheaper and better.

Next, I decided to get a trailer. I made a deal with a local riding stable to pick up 15 loads (about 30 cubic yards) of fresh horse manure. I put six inches of manure all over my five garden plots. Now I could see I was beginning to go the right way so I rented a rototiller for, what I thought, a couple hours work. When I started the tiller up, lo and behold, it jumped right off the ground. I got out my old lasso, tied it to the furrow maker on the rear of the machine, looped it around my hips and leaned back. This made the machine dig a little. We went all over that garden an inch at a time. It took me 16 hours. The next summer I put in 15 more loads of manure so now I can pick my soil up by the handful and work it easily with a hoe. During this one year I also mixed in 500 lbs. of 10-6-4 fertilizer. I use 10-6-4 because if you use 16-20 you will burn up your beans, corn, etc. It does a good job. Now I fertilize every crop I put in.

This is probably a good place to tell you why I now use fresh horse manure instead of dried out, bleached-out steer manure the experts say to use. The number one reason is it's cheap and it's easy to obtain. Second, Tucson's alkaline soil needs the acid that's in horse manure. This helps to bring the soil in balance.

It will take six - seven months for manure to break down and mix with the soil. I put my first manure on in June and planted my garden in September. The garden was only fair. However, the next spring I had a good one and they have been good ever since. Remember, you have to manure well and add a generous supply of fertilizer before you even think about planting. Manure is necessary only if you have the kind of soil most of Tucson has. Down near the river, for example, the soil is good and manure isn't needed -- just fertilize.

Once you have built up a good soil, you need to work it up. A rototiller is nice for this purpose but you really don't need one if your soil is in good shape. All you need is a good hoe with a hard-steel blade. Unfortunately most hoes have blades which are too deep. I cut a 4-inch deep blade half way from the bottom with a hack saw or a grinder. If using a grinding wheel, go across the blade until you can break off the lower half. Afterwards, sharpen the two ends and bottom of the blade. I now have a hoe 5 inches across, a usual width, and 2 inches deep to do all my gardening with. If you use the hoe edge and draw it through the soil, it will stir the soil 3 inches deep which is all you need. Your hoe is all that's needed to stir the ground and to make your rows.

In addition to a good soil and a hoe, you need a good watering device. Here's how I made the one that works so well for me. Buy a plastic bucket about a foot across and 6-8 inches high (costs about $1), a 5/8 inch female hose end, a steel washer to fit over the hose nipple, and a screw clamp. About 2 inches from the bottom of the bucket, make a 1/2 or 5/8 hole and shove the hose nipple through. Then put on the washer and clamp to keep the nipple from tearing out of the bucket. Attach your hose to the bucket, set it where you want to water well, turn on the water and presto, you have an inexpensive irrigation system.

Two days before we plant anything, we take our bucket watering device and deep-water whatever area we are going to plant. We run the water slowly so that it soaks down at least 8 inches to a foot over the whole area we intend to use. A typical hose watering after your seeds are in, generally wets down only a couple of inches. The sun in Tucson will quickly dry that up and your plants won't have enough moisture. On the other hand if you deep-water, the sun pulls the moisture up to the seed and it germinates and grows.

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All plants with long roots like corn, beets, carrots, squash, potatoes and cucumbers must be deep-watered once a week to grow and produce well. We also sprinkle everything for about an hour every night. Let's be a little more emphatic. If you don't deep-water corn and potatoes for example, you won't get either. We learned this the hard way. The first time we put in corn out here we only sprinkled and the corn got 3 feet high, tassled out and that was it. I called the experts at the University of Arizona who took two days to call me back and tell me there were a lot of reasons why my corn didn't grow tall. I don't have to ask anyone now. I might be repeating myself but, I'm telling you that if you don't deepwater at least once a week you won't get any corn.

With a good soil, a proper tool to work it, and an effective watering system, you are ready to produce a lot of good, fresh vegetables.

You might want to ponder this point: if you are putting in a garden only to save a lot of money, don't. Most articles glorify the savings but neglect to mention the expenses. For example in Tucson, you can spend $150 to $200 per year for water, 70¢ a pack for seeds, and quite a few dollars on fertilizer. Besides these expenses you might use a $400 freezer that costs $50-$75 per year to operate. Only people who live where there is adequate rain or get a 50% discount on fertilizer and seed can save on gardening.

No, my friends, there are only three benefits you will get from growing your own produce:

(1) Really good, fresh vegetables;
(2) the pleasure of growing your own vegetables; and
(3) the exercise.

From here on I'm going to tell you how we grow each of the dozen vegetables we use and I'm sure if you use common sense and follow the instructions on every package, you can do well with any others you like. If beans, corn, etc. aren't up within a week, replant because even if they do come up later they won't be worth a nickel. Yank late germinations out. Seed is cheap compared to the cost of wasting water on vegetables not worth picking. You should know that every vegetable has a time to develop and a time to die so make sure your garden vegetables grow as rapidly as possible. Corn, for example, is supposed to tassel out in 60 days and it will tassel in 60 days even if it's only 3 feet tall, but is supposed to be 7.

Green Beans: Let's start with green beans. They seem easy to grow and produce a lot for the space used. I always figure two months for beans even though some are ready in 45 days. We start beans about March 15 and continue planting every three or four days until April 10, and only 2-3 rows so our harvest will be spaced out over maybe three weeks. This gets our crop off by June 1st. If seeded much beyond June 1, the blossoms drop because of the heat and there won't be any beans. This gives us just enough to eat but not for freezing. Fall planting starts around August 15 and we plant every week until October 5. By December 7-8, you can depend on a frost so figure to have them off by then. The fall crop produces enough for freezing. Two years ago we froze and ate 168 quarts. This year we have a good crop again. We have found the Northrup King Greencrop, which are flat and 5-8 inches long, to be the best producer here. Our second choice is Ferry Morse Tenderbest. We planted both this fall.

We make our not so straight rows about 15-18 inches apart, one inch deep and place the beans about 4 inches apart. Notice I said about. I drop my beans from a standing position so they aren't exactly 4 inches apart. Really, though, if you just get them in the ground they grow providing you have done your ground and water work. (See Figure 2.)

Garden books say to cover and tamp. I don't, I cover with my hoe by just drawing it along the top of the row of soil I piled up when I made the row. It topples back into the row and watering afterwards settles the earth neatly around the seed. It helps to hoe through the rows once in a while to stir up the ground.

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Figure 2.

A nightly sprinkling will keep your beans growing fine. We have had no trouble with bugs on beans.

Peas: We put in peas about January 1-5 in rows about 18 inches apart and 4 inches between seeds. We like early perfection sold by Northrup King. This spring we picked 50 quarts from our patch. As for the beans, we put in 3-4 rows at a time so the harvest is stretched out. Bugs don't bother peas. We don't plant peas in the fall because we're heavy on beans then. Instead we go heavy on peas in the spring. They're early and you can get them off and put corn right afterward. One of our plots this year had peas all harvested by April 17. Corn followed immediately and was picked by July 4. July 5, we replanted corn in the same plot and it was through by September 15. Beans followed the corn and were planted September 21. This year we will get four crops from the same garden plot. Usually we get 2-3 crops but it depends on what we have in.

Corn: Corn follows peas as soon as I cut the pea vines down with a lawn mower. They make a fine mulch like grass clippings. I plant corn in rows 25-30 inches apart. Larger ears are produced if you space rows 30 inches apart. Although the books specify 36 inches, I've had good luck with 30 (with the price of water I don't believe I would benefit much at 36 inches). We plant three kernels every 12 inches and thin to two plants. If you plant at regular intervals like we did you can have fresh corn for six weeks. When the corn is 6 inches high, we deep-water once a week and sprinkle every night until the silks begin to form. This is the time to start weekly applications of Sevin on the silks to stop the corn borers. Be sure to treat new silks as they appear. Thereafter, we deep-water every 4-5 days until the crop is picked. This is very important. Check your ground to make sure you have plenty of moisture -- your corn will be sweeter and have larger ears.

We planted two kinds of corn -- Ferry Morse Sugar Dot, has yellow and white kernels and is the sweetest corn we have ever had. We grew two crops on the same plot this year. The first crop produced 135 ears of Sugar Dot and a second planting of Style Pak Hybrid Ferry Morse, 105 ears. Style Pak has 8 inch ears and 16-20 rows of kernels per cob but isn't as sweet as Sugar Dot. We froze some of the Sugar Dot but ate all the Style Pak in about two weeks. I don't know if planting corn in succession reduces production or not. I'm not in

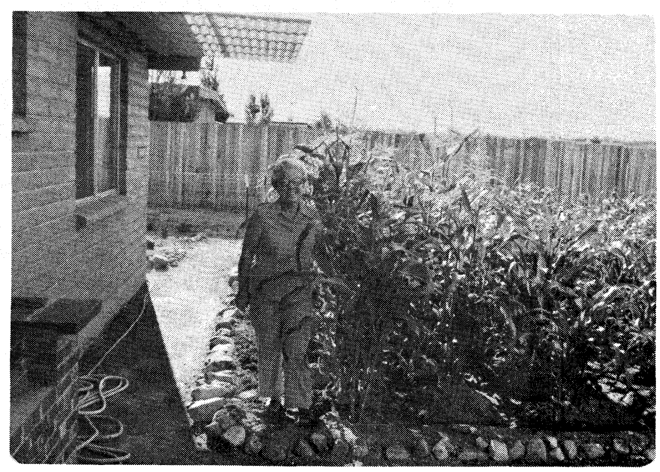

Figure 3. *Mary Webb and corn.*

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favor of running corn on top of corn but, would rather follow corn with beans or something else. My rows the first planting were only about 24-25 inches apart which may have given me an extra 30 ears. (See Figure 3.)

Corn stalks are put back onto the soil. every time my wife picks corn (8-10 ears each night), I cut the stalks up into pieces 2-4 inches long and drop them on the ground. Shortly after the corn is harvested the stalks are all cut up. The corn stubble is dug up and sliced into small pieces with a shovel. When I get ready to plant beans, I bare a 5 foot swath, make a row with the edge of my hoe and put in the beans. I leave the corn lying between the rows. After watering and a couple of hoeings, the corn stalks are on their way to being mulch. After three months the corn is nearly all gone and I have a large amount of mulch to stir into my soil.

Squash: We plant in round hills about one foot across and 4 feet apart. After brushing the top off with your hands, put in 6-8 seeds and brush the dirt back on, about 1/4 to 1/2 inch deep, and water. They should be up within a week but replant if they aren't. If they do come up later, they'll likely be puny. When large enough to deep water, dust with Sevin and stop sprinkling.

Radishes: Radishes are the bane of most people but they needn't be. The secret is to draw a row 1/2 inch deep, plant seed by hand one inch apart, cover lightly, and water. They should be up in one week and be the size of small golf balls in three weeks to 25 days. Don't let them get too big or they will get hot and coarse. I generally sprinkle radishes night and morning because they need to be damp. Early Scarlet Globe and Crimson Great are our preference.

Head Lettuce: Make a 1/2 inch deep row and lightly sprinkle seeds from the package (better too little than too much). When they are three inches high, thin by pulling out some plants and transplanting. For nice heads, the plants should be 6 inches apart and watered regularly. I put radishes and lettuce near each other because both need plenty of water. You can raise head lettuce all winter. Last year we had lettuce from October to June by planting at intervals. By June head lettuce gets buggy and wilts quickly from the heat. Towards the end of September you can plant again. We like Great Lakes head lettuce.

Carrots: These will grow all year around. Plant 1/2 inch deep in rows 15 inches apart. Shake seed out of package very carefully so seeds aren't too close together. Make several plantings per year and plant only enough to eat before they get too large. They need deep watering after they are several inches long. No bugs bother carrots. We like Hybrid Danvers by Northrup King.

Beets: Put in like radishes. Plant seed 2 inches apart by hand and cover lightly. Since they can be grown all year, don't let them get too big, and plant only what you can use. A daily sprinkling keeps them growing. Detroit Dark Red is the kind we raise.

Onions: We like the large Spanish sweet onion so we plant either Ferry Morse or Northrup King. The only time we don't plant sweet onions is during the hottest part of the summer. Plant seeds by hand, one inch apart. If given plenty of water, they'll grow 4-5 inches across. They are sweet, not hot like cooking onions. Regular cooking onion sets are planted and watered well.

Tomatoes and Peppers: We set our plants and some years they turn out well, and some years not so good. This year, for example we had a lot but the tomatoes were small (we made a lot of chili sauce). The peppers in contrast were large and good.

Potatoes: I don't plant potatoes the standard way anymore. (Dig a hole, put in the potato and dig potatoes out in fall.) This is the way I do it now: I slice the seed potatoes lengthwise, making sure there are eyes in each half. I lay the cut side down and cover with soil. Water normally until six inches high and then deep-water every week. This method will grow potatoes but deep-water is a must.

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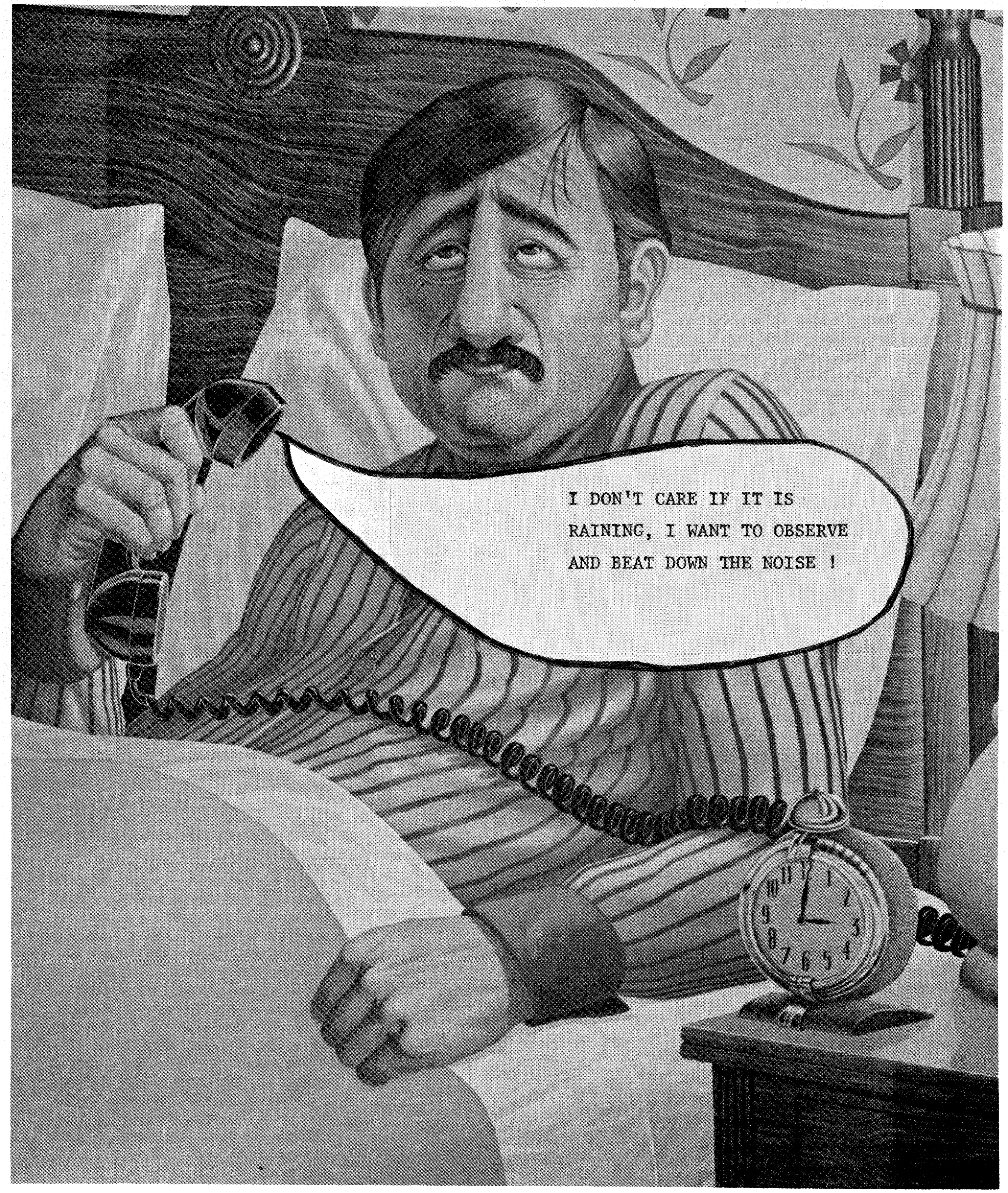
I DON'T CARE IF IT IS
RAINING, I WANT TO OBSERVE
AND BEAT DOWN THE NOISE !