Kitt Peak Docent Training Manual 2008

KITT PEAK DOCENT

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MISSION AND REQUIREMENTS

Mission Statements

The Mission of NOAO is:

To provide leadership in the establishment and operation of premier ground based astronomical research facilities, to promote public understanding and support of science, and to advance all aspects of US ground based astronomical research.

To accomplish this mission, NOAO shall provide peer-reviewed access to state of the art observing facilities; develop and promote new astronomical initiatives in cooperation with other institutions, both domestic and foreign; maintain an active scientific staff that is engaged in both carrying out vigorous research programs and providing essential program leadership; develop and construct leading edge astronomical telescopes, instrumentation, and software; encourage public information and science education through an active outreach program; serve when appropriate as a coordinating agency for the dissemination of new technologies, data bases, and information about other astronomy related issues; and act as an advocate for US ground based astronomy.

The Mission of the KPNO Visitor Center is:

To inspire a sense of wonder and awe of the Universe through exhibits and programs To inform and educate public visitors *about basic and current themes in astronomy, the scientific process, and how KPNO/NOAO/NSF plays a major role in US astronomical research. .*

To carry out this Mission, the Visitor Center will provide safe, informative and entertaining displays, tours, and other programs that effectively communicate the above information, including recent astronomical events of significance. In addition, the Visitor Center will offer for sale carefully selected items that reflect the Visitor Center mission and that can further enhance astronomy and science education. Visitor Center personnel will be aware at all times of the importance of their interaction with visitors and will bear in mind the mission of the Visitor Center in their interactions with the public.

The Mission of the Kitt Peak Visitors Center Docent Program is:

To provide the public with well-trained docents who will represent NOAO and interpret the scientific mission and relevant local history of Kitt Peak. By educating the public about the value of astronomical research done on Kitt Peak, understanding of astronomy and science will be enhanced, thereby increasing popular support for these projects.

Docent Stations

A Kitt Peak docent is anyone who, after appropriate training, volunteers time to the organization for promotion of the NOAO and Kitt Peak missions. Primary duties involve interaction with the public to support and promote the goals of NOAO.

There are a few Docent stations:

Kitt Peak Visitor Center: Welcomes visitors and provides information as needed. All Kitt Peak Docents serve in this capacity.

Duties include:

- welcoming visitors as they arrive
- providing general information about Kitt Peak facilities and schedules.
- offering maps for self-guided tours.
- assisting with upkeep of Visitor Center
- assisting in Visitor Center Gift Shop
- assisting with exhibits
- performing science demonstrations

Kitt Peak Tour Guide

Presents a formal tour program, including visits to the telescopes. Tours are given three times daily, 10 AM, 11:30 AM and 1:30 PM, and last approximately 1 hour.

Duties include:

- welcoming group to Kitt Peak.
- giving basic introductory information about NOAO, Kitt Peak (see 'Sample Tour' in Section V of manual).
- stating tour objectives and cautionary information.
- giving tour of telescope, allowing questions as they arise.
- dismissing group and offering to answer questions to anyone who remains.
- collecting tour receipts and making sure guest have paid for the tours

School Group Guide

Duties include:

- Giving presentations and tours to school groups in cooperation with staff and other docents.

Requirements

Training: All docent candidates must satisfactorily complete the Kitt Peak docent-training program. The training program will cover policy, safety and technical topics. Training materials, along with one-on-one training by veteran docents, will provide additional information about Kitt Peak telescopes and their instrumentation, basic astronomy, the night sky, and Tohono O'odham culture. All tour guides and school group docents will be expected to have a working knowledge of these areas and be able to describe them to the public.

Successful completion of the training program is required prior to acceptance into the program. Review of the training materials is required of former docents returning to the docent program.

Time Commitment: Docents are required to donate a minimum of three 6-hour shifts per month. A shift runs from 10:00 AM to 4:00 PM at Kitt Peak. Travel time is approximately 1 hour and 15 minutes from the NOAO headquarters. Docent may schedule there days to suit their personal schedule. Time that is donated for special events or other outreach activities may be applied to the 18 hours.

Responsibilities

Primary Responsibilitie: The docent's primary responsibility is translating the scientific mission of Kitt Peak and promoting interest in the scientific research and technology. Such promotion consists of greeting visitors, conducting tours as needed, and interpreting exhibits. Active docents must satisfy the minimum time commitment.

Additional Docent Responsibilities

- Participate in regular docent meetings.
- Research and prepare specific programs upon the request of Public Outreach Program Coordinator.
- Promote the programs of Kitt Peak within the community.
- Conduct science demonstrations.

Organization

The docent program is administered by the Kitt Peak Visitor Center, which is overseen by the NOAO Public Outreach Department. The Public Outreach Program Coordinator manages the docent program.

Withdrawal from the Docent Program

Temporary Withdrawal from Active Service: If a docent is temporarily unable to fulfill the minimum monthly time requirement for any reason, he or she may choose to withdraw from active status. If inactive docents return to the program within one year, they may return to active status without having to repeat the Docent Training Program. Upon return to active service, returning docents will be paired with a docent to facilitate reorientation to the program.

Permanent Withdrawal from the Docent Program: If a docent wishes to end service to Kitt Peak, notification should be made to the Public Outreach Program Coordinator. All docent privileges will cease upon resignation. If an individual wishes to return to the program after withdrawal, they should contact the Public Outreach Program Coordinator.

Dismissal from the Docent Program

Missing Scheduled Shifts: If a docent must miss a shift, the Visitor Center must be notified immediately. Normally a docent who misses three scheduled shifts without notification will be dismissed from the docent program.

Failure to Present Accurate Information: Docents should feel free to approach another docent in private to ask for clarification of any information presented to the public. Should there be a question as to the accuracy of the information, the Public Outreach Program Coordinator or Visitor Center Manager should be consulted. NOTE – *it is the docent's responsibility to expand his or her knowledge of astronomy and of NOAO by attending the docent meetings, reading popular astronomy literature, joining the local astronomy club and doing whatever else is necessary to ensure sufficient familiarity with the subjects that the docent may respond knowledgeably to visitors' inquiries.*

Infraction of Policies: If a docent does not follow the policies as stated in this Manual, or disseminated at meetings or in writing, he/she will be dismissed from the docent program.

Attire and Appearance

While working at Kitt Peak, docents are expected to be easily identifiable as representatives of the Visitor Center. Docents on duty will wear pants, skirts, or modestly cut hiking shorts with a Kitt Peak shirt, or other prescribed uniform apparel. The Visitor Center will provide uniform clothing (e.g. Kitt Peak shirt) and name tags.

As docents are representatives of Kitt Peak and NOAO, we must expect that all such representatives are neat in appearance. Excessive jewelry, cut-offs, shorts shorter than 3" above the knee, tee-shirts with slogans, or any other clothing of questionable taste is considered inappropriate.

Unauthorized Programs

Unauthorized Off-Site Programs: Any public outreach program done by docents in the name of the Visitor Center, Kitt Peak National Observatory, National Optical Astronomy Observatory, or the Association of Universities for Research in Astronomy, Inc., must have prior approval of the Public Outreach Program Coordinator.

Unauthorized On-Site Programs: On-duty docents who wish to deviate from scheduled activities must first receive approval from the Visitor Center Supervisor. Off-duty docents wishing to conduct special programs or tours must request permission from either the Visitor Center Supervisor or the Public Outreach Program Coordinator.

Guests: Docents should, in general, not bring family members or guests with them when they are scheduled to give tours. Family or guests visiting Kitt Peak may not accompany docents to the cafeteria, administrative areas, or in company vehicles.

Docent Benefits

Transportation: A shuttle leaves daily from the NOAO parking lot at 8:30 AM. Docents wishing to ride the shuttle should call CFO at 318-8212 the day prior to your schedule shift and ask for their name to be added to the shuttle list. You must have a valid GSA driver's license to drive an NOAO shuttle. The buss leaves the mountain at 4:00 p.m. making stops along Ajo Way and returning to the NOAO parking lot at 5:15 p.m.

Food: Lunch is provided free of charge in the cafeteria between 11:30 a.m. 1:00 p.m. Docents typically conclude the 2-meter tour at 12:30 and go straight to lunch.

Gift Shop Discount: Gift shop items, excluding Tohono O'odham baskets, will be discounted 15% for docents.

Docent Uniforms: Docents shirts will be provided free of charge. You may purchase additional shirts at a 15% discount. Short and long-sleeve polo shirts will be issued upon completion of the training. Fleece jackets are available at cost. Docents must wear either the short or long sleeve shirt or fleece jacket while on duty.

Nightly Observing Program: All docents are invited to participate in the Nightly Observing Program at no cost. Docents must agree to assist staff with set up and clean up but otherwise may enjoy the evening. If a docents wish to bring guests to the program, the guests must have reservations but their fee will be reduced by 15% in addition to whatever other discount may apply. During the program, docents are expected to defer to paying customers if seats are in short supply.

Monthly Meetings: Docent meetings are held on the third Monday of every month except July and August from 6:00 to 8:00 pm in the main conference room downtown. The meetings are catered and feature a presentation by NOAO scientists, staff, or other individuals who have relevant knowledge to share. The meetings are one form of continuing education of which the docents should take advantage to increase their knowledge of NOAO and astronomy.

Dealing with the Press and Controversial Issues

If the a member of the media approaches a docent for comments or an interview, they should be referred to the Public Outreach Program Coordinator. Docents may not speak on behalf of the Visitor Center, KPNO, NOAO or AURA, Inc. to the media unless arrangements have been made through the Public Outreach Program Coordinator.

On-duty docents or docents serving as representatives of the Visitor Center, KPNO, NOAO or AURA, Inc. are asked to refrain from debating controversial issues and making comments of a political or religious nature. Representing NOAO should be taken seriously, and discussion of critical or controversial issues should be referred to Public Outreach or the Public Information Officer, depending on the issue. If you are in doubt about the appropriate way to handle delicate situations, contact the Visitor Center Supervisor, or the Public Outreach Program Coordinator.

Docents who hold religious convictions that might prevent them from discussing Kitt Peak science objectively should talk over the matter with the Program Coordinator before committing to the program.

Miscellaneous Regulations

Smoking and Eating: All NOAO/KPNO buildings and grounds are smoke free. Smoking is not allowed. Fire hazards are genuine and the threat to the observatory is substantial. Guests are welcome to bring food to the observatory and may eat at the picnic tables on the patio. It is appropriate to ask visitors to be careful with their trash and to deposit it in the black recepticals.

Wildlife and Pets: Docents are not allowed to bring their pets with them to Kitt Peak. Assistive animals are welcome. Contact with indigenous animals (coatimundi, mountain lions, all snakes, etc.) should be avoided. Feeding wildlife is prohibited.

Parking: Docents who use their own transportation to and from Kitt Peak may park in the Visitor Center parking lot. Those taking the shuttle will be able to park in the AURA parking lot at the corner of Martin Ave. and 1st St. A one-year parking pass will be issued to docents at the conclusion of training.

Entering Administrative, Observatories, Control Rooms, Restricted or Departmental Work Areas: Docents may not go into any departmental work areas, observatories, control rooms or restricted areas without authorization. Kitt Peak is a working research facility and extreme care must be taken not to disturb scientific researchers.

While conducting authorized tours, docents may take groups to the 2.1-meter, 4-meter and Solar telescope viewing galleries.

Visiting the Mountain After Hours: The road to Kitt Peak closes to the public and to docents at 4:00 p.m. Nightly Observing Program participants or docents working in an after-hours officially sponsored program, may drive around the gate and proceed to the summit.

Mentor Program

At the conclusion of training, trainees will be assigned to mentors for thirty days before assuming the regular docent responsibilities. The mentor program helps trainees make a smooth transition from the classroom to the mountain. Trainees will schedule their shifts in accordance with their mentors and initially follow the tours conducted by the mentors. When the trainee is ready to take the lead, the mentor will follow the tour and provide support and feedback to the trainee. At the end of the thirty days, the mentors will complete written evaluations of the trainees and the trainees will complete self evaluations. The mentor's evaluations will be placed in the trainees' files and the self evaluations will serve as personal references for the new docents. Assignments will be made at the conclusion of the eight-week training session.

Section II
Docent Office/Administrative Procedures

The Shift

A shift is defined as the six hours from 10:00 a.m. to 4:00 p.m. Travel time to and from the mountain is not included. Docents taking the NOAO shuttle must be at CFO downtown no later than 8:30. The bus departs Kitt Peak at 4:00 and arrives downtown by 5:15.

Tours must begin at the advertised times of 10:00, 11:30, and 1:30 so please keep an eye on the clock. Docents who are not conducting tours are to work the floor of the visitor center and interact with guests who come in between tours. Make yourself available for questions and assistance with the exhibits.

Between 12:30 and 1:30 whenever two or more docents are working, one of those docents will conduct the demonstrations at the demonstration station located by the mirror display between the spectroscopy and infrared exhibits. The docent who is to conduct the demos should eat lunch at 11:30 while the other docent conducts the 11:30 tour. All the demonstration materials are lock inside the station. The key is available in the gift shop.

When conducting the 1:30 tour of the 4-meter telescope, try to have your guests back in the visitor center by 3:15 to allow time for shopping and for the staff to close up and leave by 3:45. The bus departs the mountain promptly at 4:00. This means keeping your introduction to about fifteen minutes, which is a good rule of thumb for all the tours. Then get the guests up and out. If you leave the visitor center by 1:45 or so you can have them at the telescope by 2:15 and out of the telescope by 3:00. Remind your guests that if they wish to do any last minute shopping that they must go directly back to the gift shop because it closes at 3:45.

If you are riding the bus down, you may board it at one of two locations, either in the maintenance yard or in front of the administration building.

Scheduling and Communicating

The Kitt Peak Docent Forum on Yahoo groups is the scheduling and communication hub for the docent program. Each trainee will be signed up on the forum during training and will use the forum to communicate with the other docents and to schedule shifts. The URL for the forum is –

http://groups.yahoo.com/group/docentforum/

A feature of the docent forum is the calendar, which the members of the group can access. This calendar is for use in scheduling docent shifts, special tourist groups, and events. To put yourself on the calendar, follow these steps:

- Sign in to the docent forum.
- From the menu on the left, click on "Calendar."
- Once at the calendar, click "Add" on the day you plan to work.
- Then type your name in the "Title" field.
- Ignore "Event Type" and "Date."
- For "Time" select "all day event."
- Ignore "Location," "Notes," and "Repeating."
- At "Reminders" select "Do not send a reminder."
- Now click "Save" at the bottom of the screen and your name will appear on the calendar for that date.

Email: To send email to any member of the docent forum, find that person's email address under "Members." If you click on the email address, a message window will open and your email will be posted as a message to the forum. If you wish to communicate privately with another docent, you may highlight and copy that person's email address and paste it into a regular email header.

Forum's Purpose: The forum serves as a way for docents and staff to communicate ideas, ask questions, and share information that is relevant to astronomy or Kitt Peak. Members may also add links, upload photos, and post files to the forum providing that whatever is placed on the forum falls within the bounds of the forum's purpose as described on the home page.

Departmental Communication

Feedback from our docents is paramount to the success of our program. Therefore the Public Outreach Program Coordinator is available for discussion with docents on matters of policy, questions on astronomy or research, or suggestions for improvements. All problems, questions or points of confusion should be brought to the Public Outreach Program Coordinator without hesitation.

Section III

Working with Visitors

Lost and Found: Any found property should be turned in to the Visitor Center. Documentation should be given as to where the item was located, a description of the article, and the date. Any visitor reporting a lost object should be directed to the Visitor Center cashier.

Restrooms: Public restrooms are located to the west of the main visitor parking lot. There are also facilities on the ground floor of the 2.1-meter and 4-meter telescopes. A wheelchair accessible restroom is located in the Visitor Center which docents may use.

Handicapped, Disabled and Elderly Visitors: In the event that a guest is physically unable to do the walking portion of a tour, the Visitor Center Staff may grant permission for the visitor to drive to the 4-meter telescope. Individuals requiring assistance to participate on the tour may use the wheelchair in the Visitor Center.

Pets: Occasionally visitors will bring their pets with them while visiting Kitt Peak. We strongly discourage this practice. Should animals be traveling with visitors, the following rules are to be observed:

- Pets are not allowed in any building on the mountain.
- While on the grounds they must be kept on a leash.
- Owners must clean up after their animals.

Picnicking: Picnic grounds are available for visitor’s use. The picnic area is just above mile post ten. It is open daily and may be reserved for special events. Requests to reserve the picnic area may be directed to Kitt Peak Administration. Tables are located on the patio behind the visitor center and in the median of the parking lot and may be used by visitors who wish to eat food that they brought.

Food: A modest refreshment hut with cold drinks and chips is located beside the Visitor Center and a small food concession is operated during special events by tribe members. Otherwise the only food available to visitors is the snack food sold in the visitor center gift shop.

Alcoholic Beverages: Kitt Peak National Observatory is on the Tohono O’odham Reservation. Alcoholic beverages are strictly prohibited on this reservation. Any visitor observed with alcohol should be reported immediately to the Visitor Center.

Vehicle Problems: If a guest reports problems with his or her vehicle, Kitt Peak staff will assist, if possible. Gasoline may be purchased in Sells, 32 miles west, or the Coyote Convenience Store, 15 miles east of Kitt Peak. Should a visitor not be able to reach either of these locations, a small amount of gasoline (about 2 gallons) may be purchased from Kitt Peak.

Dealing with Questions: During a docent’s tenure on Kitt Peak, it is likely that he or she will be faced with questions that can’t readily be answered. If you are unsure of an answer to a question, do not hesitate to say, “I don’t know.” Several staff astronomers have offered to serve as resources for the Visitor Center. Working with the experts, we will help you research the answer. If the visitor leaves name and address, or email address, every effort will be made to respond. Tough questions and their answers may be posted on the docent forum for the benefit of all docents.

Receiving Feedback from Visitors: We welcome and encourage feedback, both positive and negative, from our visitors and we expect the docents to relay this information to staff. Thank them for their concern and get pertinent details. If you are unable to satisfy a visitor's complaint, refer them to the Visitor Center Supervisor or the Public Outreach Program Coordinator.

Visitors and High Altitude Warning: When directing visitors to a self-guided tour or when leading groups around the mountain, always remind visitors that Kitt Peak is at 7,000 feet above sea-level. Individuals with cardiac or respiratory problems should be cautioned to take extreme care. In the event of medical emergency, follow the guidelines outlined in Section IV, Emergency Procedures, of this booklet.

Section IV
Emergency Procedures

Emergency Situations

An emergency situation is any event in which the lack of prompt attention could result in injury, death or major property damage. These include, but are not limited to:

Medical emergencies:
- signs and symptoms of heart attack
- difficulty breathing/choking
- major bleeding
- fractures or major trauma
- heat stroke
- loss of consciousness

Security emergencies:
- weapons on observatory grounds
- visitor assault/harassment
- theft

Fires

Employee, docent or visitor in trouble

Using radios for Emergency Communication

Critical to our fire and safety procedures is immediate radio contact with trained emergency personnel. Therefore, all docents must carry a radio at all times when working on the mountain. The radio must be kept on, and the volume may be turned down to an audible but non-interruptive level while giving a tour.

If you are first on the scene of an emergency situation you should radio for help immediately. Always use channel 1 on the radio while on Kitt Peak.

Accident or Illness: To contact medical personnel on the mountain, call as follows: "Request medical assistance at..." and state your location. Use the word <u>emergency</u> only if it is a true emergency as defined above. Be specific about your location; for example, if you are in the 4-meter state whether you are in the viewing gallery, on the observation deck, at the visitor entrance, etc. Do not call for specific individuals. It is imperative that radio communications be clear and brief. After making the call, stay with the injured person until assistance arrives but do not forget about the other visitors.

Given our remote mountain location, Kitt Peak has trained personnel for medical emergencies. KPNO rescue services will respond to all medical emergencies anywhere on the observatory site - the observatory's privately leased property, private roads, sub-leased properties, and picnic area - and anywhere along State Highway 386, subject to the availability of trained staff.

The observatory owns and maintains two vehicles for use in medical emergencies and is a member of the statewide Emergency Medical Services Communications Network.

Fire: If you discover a fire in a building, pull the nearest fire alarm pull station to alert and evacuate everyone in the building. If the fire can be contained or extinguished without endangering yourself, use the nearest fire extinguisher. If you are not able to control the fire, leave and close the door behind you.

Contact the rest of the mountain employees by radio to report the location and the size of the fire. If unable to make radio contact, dial 444. Trained fire brigade members will report to the Fire Barn.

Police: Contact mountain staff by radio as follows: "Emergency at...requiring immediate assistance" and state your location. Mountain personnel will respond and evaluate the emergency situation. Police should be called at x 444 or 9-911 **only if** mountain personnel are unable to respond or assist.

Non-emergency Situations

General: Situations that require assistance but are not emergencies should be handled through the Visitor Center. Radio contact, if required, should be brief and clear describing the nature of the problem. Visitor Center staff will refer the call to the appropriate party.

Encountering Wildlife

Snakes: Kitt Peak is home to a variety of snakes, most of which are non-venomous and beneficial to us. If you encounter a snake on the grounds, or in a building, radio the Visitor Center. There are two species of venomous snake that could be encountered, the black-tailed rattlesnake and the coral snake (rarely seen). Tribal Game and Fish Regulations prohibit killing or collecting of wildlife on the Tohono O'odham reservation. If a snake is encountered, follow these procedures:

- Do not attempt to handle the snake.
- Do not harass, injure or attempt to move the snake.
- Keep yourself and visitors at a safe distance.
- Radio the Visitor Center.

Identify, if possible, the type, size and number of snake(s).

Coatimundi: The Quinlin mountain range is the northern most extension of the coatimundi. This typically central/south American animal does not pose a threat to humans. It is, however, a wild animal and should not be handled.

Mountain Lions, Bobcats, Bears: Large predators are present on Kitt Peak though rarely seen. If one is sighted on the main observatory grounds, immediately radio this information along with the precise location of the animal to mountain staff.

- Do not harass the animal.
- Move to a safe distance.
- If possible, keep the animal in sight until staff arrives.
- Do Not Feed.

When encountering any animal, keep it in sight, if possible, until appropriate personnel arrive. If unable to do so, note the location.

Sexual Harassment: NOAO takes sexual harassment in any form seriously. It is illegal and against the policies of NOAO for any volunteer or staff person, male or female, to harass another volunteer or staff member by making unwelcome sexual advances or requests for sexual favors or other verbal or physical conduct of a sexual nature. **Any volunteer who believes he or she has been the subject of sexual harassment should report all the facts and circumstances immediately to the Docent Coordinator or Public Outreach Manager.** No volunteer or staff person will be subject to any form of retaliation or discipline for pursuing a sexual harassment complaint. Reports of harassment will be investigated promptly and steps will be taken to resolve the situation appropriately.

Docent Volunteer Job Description

Title: Kitt Peak Docent

Reports To: Public Outreach Program Coordinator, Visitor Center Supervisor.

Volunteer Description: Docents teach and interpret the history and mission of Kitt Peak National Observatory. Docents interpret exhibits, and telescopes to general public and school groups. They present and discuss general astronomy and related science information to the general public. They conduct school outreach programs off site. Docents also assist with Visitor Center special events. Docents must enjoy speaking with the public and they must be comfortable imparting information in an informal group setting. Docents must also be dependable.

Qualifications:

Minimum of 18 years of age

Ability to communicate with the general public

Have an interest in astronomy and related sciences

Possess a desire to enhance or develop public speaking skills

Requirements:

Successful completion of a 7-week training course

Actively participate for at least one year after training is completed

Volunteer for a minimum of twelve hours per month (three six-hour shifts)

Be enthustic and dependable

Enjoy meeting and speaking with people of all age groups

Help out in the gift shop when needed

Attend monthly docent general meetings

Conduct science demonstration in the VC

CHAPTER 2
General Astronomy

Coordinates

To find one's way around, it is useful to have a system for locating points. A city for example might be laid out on a grid. The intersections of streets running N-S and E-W become references for locating places. On earth we use latitude and longitude to locate points on the globe. These coordinates are measured in degrees and minutes. The major lines in this system are the equator and the prime meridian.

If we expand the lines of longitude and latitude out to the celestial sphere, we create a system of equatorial coordinates with right ascension corresponding to longitude and declination corresponding to latitude. Just as longitude and latitude are fixed on the earth and turn with it, lines of right ascension and declination are fixed on the celestial sphere and turn with it. Actually, they remain stationary and the earth turns inside the celestial sphere, but the perception is that the stars are moving.

Right ascension is measured in hours, minutes, and seconds. Declination is measured in degrees and minutes, either plus or minus depending on whether the object is above or below the celestial equator, which is simply an expansion of the earth's equator out to the celestial sphere.

The two coordinates are always given together when specifying an objects location; for example, the coordinates for the globular cluster M22 are RA 18h 36.400m and Dec. -23° 54.000m. Just as in a day, a complete rotation of right ascension takes twenty-four hours, each hour corresponding to fifteen degrees (15 x 24 = 360). Declination goes from zero at the celestial equator to ninety degrees at the zenith and in negitive degrees to the horizon. The 0h line of RA is the equivalent of the Greenwich Meridian on earth

Another means of locating objects on the celestial sphere is by the altazimuth system. This method uses degrees to locate something with respect to north; e.g. east is ninety degrees and south is one hundred eighty degrees of azimuth. Altitude is measured from the horizon to the zenith. Because one cannot look below the horizon, altitude is always positive and is indicated as 10 degrees, twenty-five degrees, etc. You will frequently hear of this system used in reference to telescope mounts. The WIYN telescope, for example, is on an altazimuth mount. You will probably never hear coordinates given in this manner. RA and Dec are the most common.

Constellations

There are currently eighty-eight constellations that divide the sky. These were adopted in 1922 by the International Astronomical Union. In 1933 they adopted official boundaries for the constellations. These constellations are based upon the forty-eight Greek names listed by Ptolmy in the 2nd century. The remaining forty were added subsequently by a variety of persons. When you hear that something is in a particular constellation, it simply means that the object is in the part of the sky that bears the name of that constellation. It is a means of narrowing an object's location. To pinpoint the object would require the use of its equatorial coordinates.

The Changing Stars

As you watch the stars at night, you will see that they appear to move across the sky. In reality it is the earth rotation that you are seeing. Yet we refer to this movement of the stars as the diurnal (daily) motion of the stars. The stars seem to set, but the earth has just turned you away from those stars that are visible at night. You will also notice that the stars that are visible at night change with the seasons. It is not that the stars change but that the earth has moved in its orbit around the sun and so gradually points you toward different stars as it turns you away from the sun. If you were to view the day-time sky during a total eclipse, you would see the stars that you cannot see at night.

Sidereal vs. Solar Day

You might also hear an astronomer speak of a sidereal day. We usually think of a day in terms of the sun and the time required for the earth to make one rotation with respect to the sun. A sidereal day, on the other hand, involves the earth's rotation with respect to the stars. As the earth rotates, it also revolves around the sun. When the earth has completed one rotation, its orbit has carried it to a location different from the one that it occupied when it began its rotation. Therefore, it again faces the stars it faced when it began its rotation but it must now turn just a bit farther to come back into line with the sun. The difference is about four minutes.

The Solar System

Most of us know the major components of the solar system. Therefore, a few facts about the planets and sun will suffice.

Interesting facts

Venus was once thought to be lush because of its thick cloud cover. In reality, Venus is very inhospitable. The atmospheric pressure on the surface is ninety times that of Earth's. Because of the thick clouds, the temperature on the surface is hot enough to melt lead (about 900 degrees F). And those clouds that we used to think provided water for the lush vegetation turned out to be composed mainly of sulfuric acid.

Jupiter's equatorial bands are the result of differential rotation; Jupiter rotates slightly faster at the poles than at the equator. And it rotates rapidly. The jovian day is only about ten hours long. This differential rotation creates turbulence in the atmosphere, which we see as the equatorial belts.

Pluto remains a controversial object. Some astronomers classify it as a planet while others classify it as a Kuiper Belt object. The reason for this is due largely to the differences between Pluto and the other superior planets. Pluto is terrestrial, closer in composition to the inferior planets; the others are gas. Pluto's orbit is eccentric, inclined seventeen degrees from the ecliptic and at times carrying the planet inside the orbit of Neptune. On the other hand, Pluto is spherical and has a moon, characteristics associated with planets. A case can be made either way.

There are additional elements in the solar system that are not as well known as the planets. The asteroid belt is one such element. Containing close to a million asteroids, the asteroid belt extends from 2.15 to 3.3 AU from the sun, between Mars and Jupiter. Asteroids are probably left over from the formation of the solar system, when small particles began to accrete but failed to reach planetary proportions because of the gravitational influence of Jupiter. Programs such as Space Watch are designed specifically to monitor asteroids because some asteroids cross earth's orbit and pose a grave threat to civilization if they collide with it.

The Oort Cloud and Kuiper Belt are parts of our solar system and are believed to be the sources of comet nuclei. The Oort Cloud (proposed in 1950 by Jan Oort) is thought to exist well beyond the outermost reaches of the solar system, up to a light year from the sun, and contain countless comet nuclei whose orbits get disrupted occasionally. When that happens, some of these comets drift toward the solar system and establish orbits that take them around the sun and back to the Oort Cloud. These comets are called long-period comets because their orbits require more than two hundred years to bring them back through the solar system. Other comets, though, require less time to complete their orbits and return. This class of comet is called short-period, and its origin is believed to lie in the Kuiper Belt (theorized by Gerard Kuiper in the 1951), a flattened inner extension of the Oort Cloud, extending from 30 AU to about 1000 AU.

Finally, the Zodiacal Light is a phenomenon that can be seen with the unaided eye, in the spring about ninety minutes after sunset and in the autumn about ninety minutes before sunrise. It is the reflection of sunlight off the zodiacal dust, cometary and asteroidal particles lying along the ecliptic out to about 5 AU.

The Ecliptic and Our Perspective

The ecliptic just referred to is the plane along which most of the planets travel in their orbits. It is also the path the sun follows across the sky. Of course the sun does not travel across the sky – that is just our perspective. Close observation reveals that the sun not only moves from east to west daily but also north to south during the course of the year. This north-south shift relates to the change of seasons. Notice that the sun shifts to the north during the spring and summer and to the south during the fall and winter. The reason is that the earth is tilted 23 ½ degrees from the ecliptic. As the earth orbits the sun, its northern hemisphere is tilted toward the sun for part of the year. This causes the sun's rays to shine directly on that part of the earth, causing summer. The southern hemisphere is tilted away from the sun so the rays shine obliquely on that part of the earth, causing winter. The times when the sun is at its northern and southern most points are called the summer and winter solstice respectively. Those times of the year in the spring and fall when the sun shines equally on both hemispheres are called the vernal and autumnal equinox respectively.

If you watch one of the superior planets move across the sky over many nights, you will notice that it moves eastward. At some point, though, the planet appears to cease its eastward movement and for a brief time appears to move westward with respect to the background stars. This backward movement is called retrograde.

Like many other apparent motions that we see in the night sky, retrograde is a matter of perspective. In reality, retrograde is a celestial version of what you witness when your car overtakes another car on the highway. When viewed against the background landscape, the car in front appears to be going the same direction as your car with respect to the background. As you overtake the car, though, its forward motion seems to slow until, as you pull along side and then pass, its motion with respect to the background appears to be going in the opposite direction. The same is true of the planets. The inner planets move faster in their orbits than the outer planets and so overtake the outer planets. As the earth overtakes and then passes an outer planet, we see that planet slow and change direction briefly. It is all a matter of relative motion.

The moon goes through phases during its orbital period. Many people believe that the dark portion of the moon is in the shadow of the earth. Actually, the portion of the moon that is dark is the portion that is not illuminated by the sun. If the earth's shadow passed over the moon, we would call it a lunar eclipse. The moon's phases are eight in number and are labeled as follows: new moon, waxing crescent, first quarter, waxing gibbous, full moon, waning gibbous, third quarter, and waning crescent. The new moon occurs when the moon is between the earth and the sun, at which time the sun's glare obscures the moon during the day and during the night we are facing away from it. As the moon moves eastward in its orbit, a fraction of the moon's surface becomes illuminated. And because the moon has moved to the east, we now see a waxing crescent in the western sky. The moon continues on its eastward journey, moving farther from the sun and thus becoming more fully illuminated. At the point where it is opposite the sun, we have a full moon. The cycle continues until the moon is again obscured by the sun's glare.

Velocities

Few people give much thought to the velocities at which we travel on our journey around the solar system or around in circles as the earth rotates. When they find out they are usually astounded because it is difficult to imagine that we could be traveling that fast and not be able to feel it. The speed at which the earth carries someone around its axis depends on where on earth that person is. The closer to the equator, the faster one travels. At the equator, the earth rotates at 1650 km/hr (1031 mph). At the poles, of course, the speed drops to zero. If you think that is fast, the earth in its orbit around the sun is traveling in excess of 100,000 km/hr (60,000 mph). The solar system also has an orbital velocity because the galaxy is turning (picture a pinwheel spinning on a very large scale). The orbital velocity of the galaxy at our point in it is about 1,000,000 km/hr (625,000 mph). To offer a sense of proportion, though, even at that incredible speed it takes us about 230 million years to complete one revolution.

Distances

Because the universe is unimaginably vast, astronomers have had to develop units of measure that are suitable for such distances. Imagine trying to measure the distance to the nearest spiral galaxy in miles after considering that it is 2.2 million light years away and that a light year contains 6 trillion miles. You would spend the rest of you life writing zeros. The smallest astronomical unit of measure, then, is an astronomical unit, which equals the average distance from the sun to the earth: 148,800,000 km or 93 million miles. This is usually written as AU. From there the scale expands to a light year. A light year, written as ly, is a measure of distance not time. It is the distance that light travels in one year through a medium such as interstellar space. A parsec (pc) is 3.26 light years. That figure represents the distance at which one AU subtends one second of arc. A kiloparsec (kpc) is 3.26×10^3 and a megaparsec (mpc) is 3.26×10^6. Megaparsecs are generally used in calculations of large-scale structures and their movements or evolutions on a universal scale

Our Galaxy

The Milky Way is the name that we have given to our own galaxy. Even though we cannot see our galaxy completely, we infer some of its characteristics from the portion that we can see and by comparing that to other galaxies. We know that the Milky Way is a spiral galaxy. It has a nucleus from which radiate four arms composed of gas, dust, stars, and a smattering of planets. The stars number in the hundreds of billions. The Milky Way is approximately 80 thousand light years across. Our solar system lies about two-thirds of the way from the center on the outer edge of one of those spiral arms. A device for remembering the names of the arms is to think of COPS: Cygnus, Orion, Perseus, Sagittarius. Galaxies are classified according to their shapes. The broad classifications are spiral, lenticular, elliptical, and irregular.

Stars

The stars of which galaxies are composed form from clouds of hydrogen gas. These stellar nurseries give birth to groups of stars, called clusters, of which there are two types: open clusters and globular clusters. Open clusters are found in the disks of our galaxy and usually consist of younger stars. The number of stars in an open cluster can range from a few dozen to hundreds of stars. Globular clusters occupy the halo of our galaxy and contain stars that are as old as the galaxy itself. A fine example of a globular cluster is M13 in Hercules. This cluster contains something between 300 thousand and half a million stars, an inspirational sight in a telescope.

Star Birth

Stars develop from clouds of molecular-hydrogen gas, they evolve over millions or billions of years, and they die. A star is born when some of the gas in the cloud begins to collapse in on itself. This event could be triggered by a variety of things such as irregularities in the density of the cloud or the shock wave from a nearby supernova. As the gas collapses, it gains mass and temperature. With mass comes gravity and with an increase in gravity comes an increase in mass as the forming star accretes more of the surrounding gas. As gravity pulls inward on the gas, the temperature at the core of this gas ball rises. This thermal energy is radiated away until gravity compacts enough gas to make the core of the protostar opaque.

When the thermal energy can no longer be radiated away, the temperature at the core increases significantly. If the temperature exceeds 10 million Kelvin, hydrogen fusion begins and the resulting core pressure halts the gravitational collapse of the gas and gravitational equilibrium is achieved. The ball of gas is now a hydrogen-burning, main-sequence star.

Star Death

A star similar to our sun will live, fusing hydrogen into helium at its core, for about 10 billion years. At the end of its life, a star exhausts its hydrogen fuel, which causes the thermal pressure at the core to decrease. This in turn allows gravity to regain the upper hand and collapse the core, which now consists of helium ash. But there is also a hydrogen shell around the shrinking core. The shell is also being compressed by gravity, and it finally reaches a temperature at which hydrogen fusion begins again. The hydrogen burning in the shell adds more helium ash to the core and causes the outer layers of the star to expand. It will not overcome gravity, though. The star’s core continues to shrink until the temperature reaches 100 million K. Now the helium in the core begins to fuse, but it cannot resist gravity. Instead it dumps carbon, the byproduct of helium fusion, in the core. The core continues to heat as a result of the helium fusion and finally it becomes hot enough to cause the fusion rate to increase rapidly in what is called a helium flash. The flash does produce enough thermal energy to halt the collapse, but it also causes the hydrogen-burning shell to expand, which lowers the thermal energy pushing outward on the outer layers of the star. The outer layers contract. When all the core helium has been fused into carbon, all that is left are a hydrogen-burning shell and a helium-burning shell. Both shells contract along with the inert carbon core that is being crushed by gravity. Eventually, the star will eject its outer layers into space, leaving behind the burned-out carbon core that will glow brightly as a white dwarf. The remnants of its shell will be viewed by astronomers as a planetary nebula.

Large stars undergo a similar fate in that they have layers of shells fusing a variety of elements. Their demise is more cataclysmic, though. Massive stars die in an event known as a supernova. When the cores of these stars can no longer resist the crush of gravity, they collapse violently and eject their outer layers far into space. The energy released in a supernova can rival the combined energy of all the stars in the host galaxy. If the star was between 1.4 solar masses and 3 solar masses, it will leave behind a neutron star. As the core collapses, it squeezes the electrons into the nuclei of their atoms, creating neutrons. The energy of these neutrons counteracts the force of gravity to halt the collapse of the core. A neutron star is incredibly dense and typically only about ten kilometers across; yet a paperclip make of neutron star material would weigh more than Mount Everest. If the star exceeds three solar masses, its death will likely result in a black hole. This phenomenon occurs when even neutron degeneracy pressure is insufficient to halt the collapse of the star's core and it is reduced to infinite density, what scientists call a singularity. Black holes were predicted by the general theory of relativity and can be understood only by analyzing their affects on surrounding matter. Black holes exert such gravitational force that not even light can escape them; hence the name.

Nebulae

Nebulae are gaseous clouds and quite often serve as stellar spawning grounds. But this is not true in all cases. As was indicated above, some nebulae are the remnants of dying stars. These are called planetary nebulae because of their spherical shape. The best example of a planetary nebula is M57, the Ring Nebula, which is all that is left of a solar-mass star. Other nebulae, such as M1, the Crab Nebula, are supernova remnants. These are not planetary nebulae strictly speaking because they are not spherical. The two remaining types of nebulae are clouds of hydrogen gas primarily. Emission nebulae, also called ionization nebulae, glow because ultraviolet light from nearby hot stars excites and ionizes the atoms in the gas, causing them to emit light. Reflection nebulae, conversely, shine only with the light that they reflect from other stars. The reflection nebulae are usually bluer in color than emission nebulae.

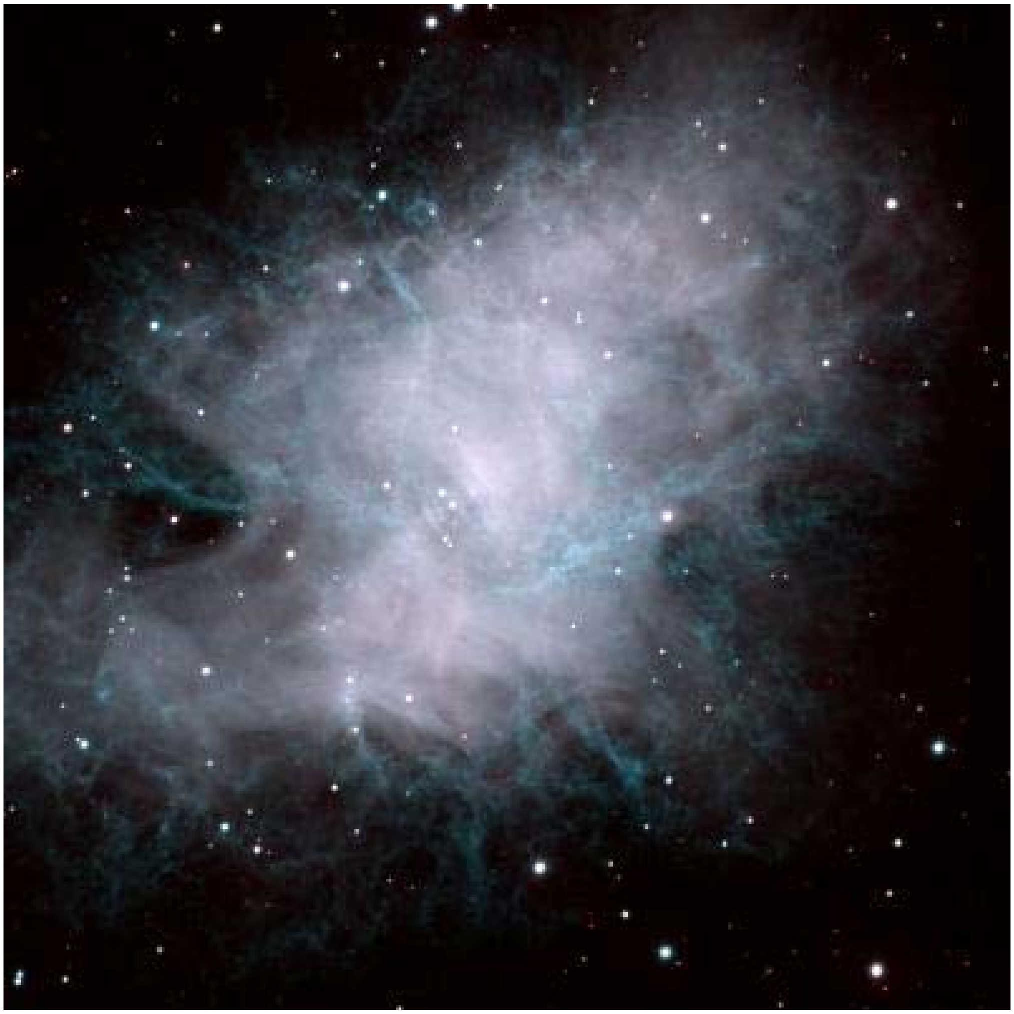
The Local Group and Local Supercluster

All of the afore mentioned objects can be found in our own galaxy, which is one of thirty galaxies known as the Local Group. The Local Group exists on the edge of the Local Supercluster, which comprises other groups such as the Virgo and Coma clusters. The Local Supercluster is one on many that indicate that matter in the universe is not evenly distributed but has an evolving structure. This structure evolved from the original expansion of the universe, called The Big Bang, when irregularities in the density of matter caused it to clump instead of spreading evenly. The result that we see today is in the form of vast gaps of seemingly empty space between filamentary strings of superclusters spreading web-like across the universe.

Recent findings indicate that the universe is not only expanding but that the expansion is accelerating. Scientists gauge the movement of objects in the universe, other galaxies for example, by measuring the redshift of the object. Redshift occurs as an object moves away from us and the light waves that it emits get stretched out, making them appear more red. Red is at the long wave-length end of the spectrum. If the object is far enough away, its light will be shifted into the infrared. Much of the exploration of the large-scale structure of the universe is conducted in the infrared.

Seeing

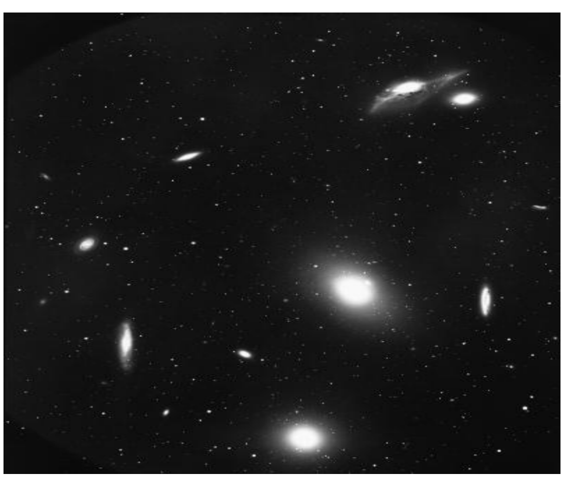
Seeing is the term astronomers use to describe the stability of the atmosphere and thus the quality of an image. The more turbulent the atmosphere, the poorer the quality of the image. Seeing is not to be confused with transparency. The latter term refers to the clarity of the sky. It is possible for the sky to be quite clear but the seeing to be poor. It is also possible for the transparency to be poor but the seeing steady. Poor atmospheric seeing is thought to be caused by undulations between separate layers of air. Air refracts, or bends, the light that passes through it. The most recognizable effect of this refraction is the twinkling of the stars. But when objects are being observed through a telescope, the twinkling only serves to blur the image. For large, research telescopes, the problem can be acute because light from distant objects must be focused as precisely as possible in order for the instrument that is analyzing the light to function efficiently or for high resolution to be achieved in the case of imaging. To counteract atmospheric effects, scientists have developed adaptive optics, devices that measure constantly the amount of distortion to an image and make corrections to the telescopes optics in response to that distortion and thus eliminate it.

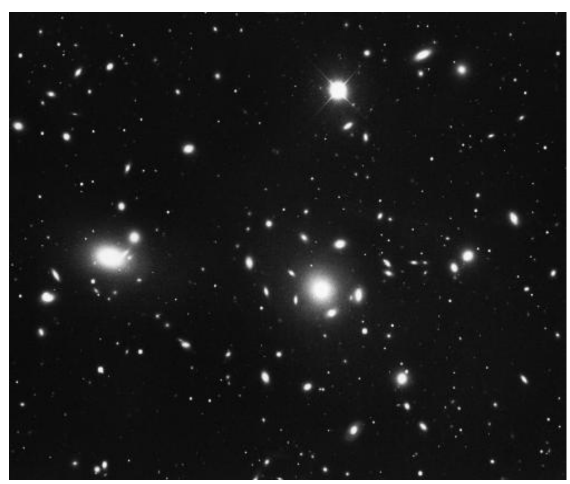


Crab Nebula M1
A supernova remnant

M110

Andromeda Galaxy M31





Virgo Cluster

Coma Cluster

Abell 39

Dumbbell Nebula M27

Horsehead Nebula IC434

Lagoon Nebula M8

Trifid Nebula M20

CHAPTER 3
HISTORICAL PERSPECTIVE: *REALM OF THE LONG EYES*

August 31, 1953

35 astronomers met at Lowell to discuss the creation of a jointly funded and operated telescope for photoelectric research. Telescope time was very difficult to get and many astronomers lacked access. Dr. Leo Goldberg proposed a national observatory. Astronomers recommend that a committee be formed to study the problem of a national observatory.

January 1954

NSF Advisory Panel for Astronomy endorsed the idea of a national observatory. A special advisory panel formed, including Dr. Goldberg and Dr. McMath. Research and education were considered equally important for facility to encourage new astronomers. The panel recommended that NSF support construction of a national observatory including a 36 in. and an 80 in. stellar telescope and the world's largest solar telescope.

1955

Site survey began. Thousands of miles were covered in an effort to locate the ideal site for the observatory. The search was finally narrowed to 150 sites.

1956

After strict evaluation of the 150 sites, the search was narrowed to five sites: Chevalon Butte near Winslow, AZ; Summit Mountain near Williams, AZ; Hualapai Mountain near Kingman, AZ; Kitt Peak; and Junipero Serra Peak near Monterey, CA. Hualapai Mountain and Kitt Peak were deemed the two best possible locations.

March 1958

Results showed Kitt Peak to be the best location. It was rated superior on the following eleven criteria:

- Good seeing (refers to stability of the atmosphere)
- Low wind velocity
- Temperature stability
- Microthermal stability
- Upper air trajectories
- Absence of airplane vapor trails
- Developable area on top
- Southerly latitude
- Fewer city lights
- General support facilities
- Proximity to academic institution

1958

The lease is negotiated with the (then) Papago tribe and passed into law by the 85th Congress of the United States.

Telescope Fact Sheets and Drawings

On the following pages you will find drawings and fact sheets for the 2.1-meter, 4-meter, Solar, and WIYN telescopes. While the public is not allowed to tour the WIYN, the information is a good comparison of technology to the 4-meter.

NAME:	**2.1 -meter (84") TELESCOPE**
SIZE:	2.1 meters (84")
TYPE:	CASSEGRAIN
FIRST LIGHT:	September 15, 1964
FOCAL RATIO:	f/2.63
MOUNTING:	Equatorial - Axis at 32 degrees Fork Mount - Requires a hydraulic floor to move sideways or up/down when fork is rotated at large angles. Inside fork length is 9 feet. 2 sets of bearings: north support for polar axis - oil pad bearings; South support for polar axis - standard bearings
STRUCTURE:	BUILDING - 92' high.

MIRROR: **PRIMARY**

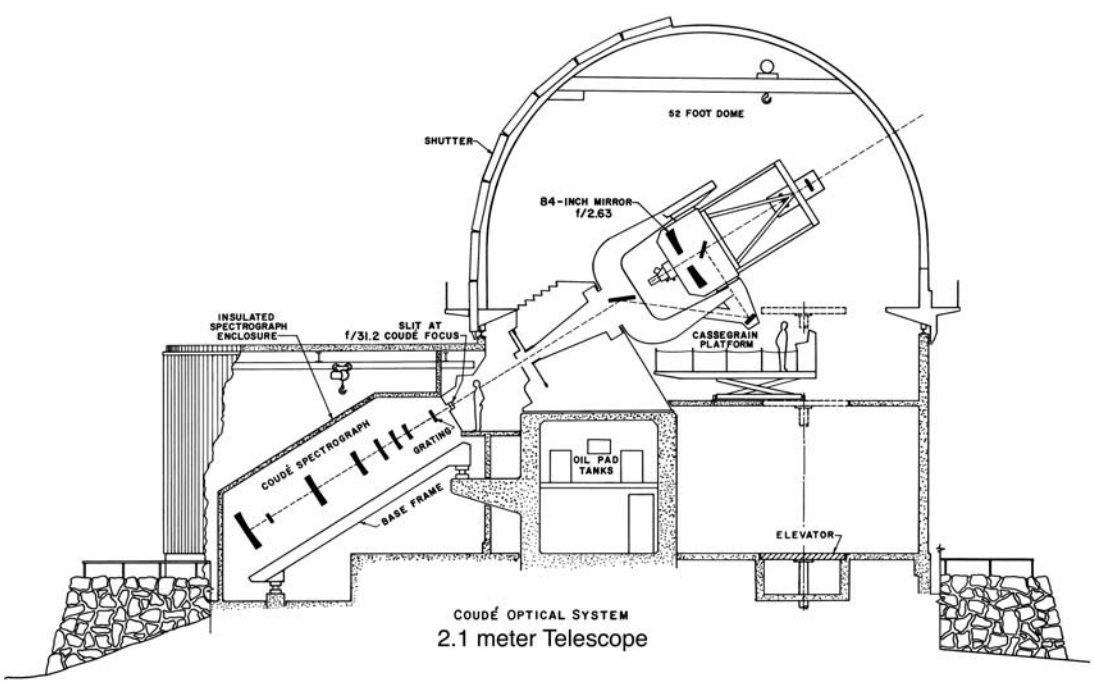
Diameter:	2.1 Meters (84")
Weight:	3000 lbs.
Material:	Pyrex Glass

Polished to 4/millionth's of an inch and coated with reflective aluminum at thickness of /1000th of a human hair

Originally the light path for the Coude' system to the spectrograph started with the light striking the primary mirror and reflecting to the secondary, and from the secondary to the Coude' reflecting mirror, again reflected off the mirror that directs it through the slit to the spectrograph. Later the Coude' system used the tower as a reflecting surface for the light to be routed to the spectrograph.

Mirror constructed by Corning Glass Works using a new procedure at the time called "sagging." Large chunks of Pyrex Glass were placed in a mold and melted to fill the mold. The disk was also honeycombed and ribbed in its' construction. The mold was constructed, the glass placed in the mold and the kiln heated to 2300 degrees F. The glass melted and was kept at a temperature of 1040 degrees F. for two months and then allowed to cool. The disk spent 7 months cooling down.

The mirror was transported by rail to Tucson and then trucked to Kitt Peak where the opticians ground and polished the surface over the next 15 months.



COUDÉ OPTICAL SYSTEM

2.1 meter Telescope

Script for 2.1-m Audio Tour
September 2006

STATION 1
Looking at the observatory structure from the north entrance.

The 2.1-meter telescope was the first large stellar telescope installed at Kitt Peak. It opened to visiting astronomers on September 15th, 1964 when Dr. G. Van Biesbroeck of the University of Arizona used it to make measurements of close double stars. On that day the Kitt Peak 2.1 meter became the largest telescope generally available on a competitive basis to American astronomers, breaking the monopoly on large telescopes held by private and state universities. Many competent researchers who would otherwise not have had access to a telescope of this caliber could now apply to the national observatory for time on this state-of-the-art research instrument. The structure housing the telescope initially served double duty. The public's interest in the new national observatory brought many curious visitors to the mountain top. Because the official Kitt Peak visitor center was not completed until November 1964, the annex on the left of the observatory served as a temporary location for distributing brochures and selling postcards and native crafts. The second floor held a temporary museum room containing models, transparencies, audio-visual aids, pictorial material, and general astronomical information. When the Kitt Peak Visitor Center opened to the public a few months later, the brochure counter was removed and the museum room was converted to a work space. The observatory structure then remained solely an enclosure and support structure for a world class research telescope.

To view the 2.1-meter telescope, please pause this recording and proceed to the interior visitor gallery through the door of the annex and up the stairs.

STATION 2
The Telescope

One inspiration for the Kitt Peak 2.1-meter telescope was the world's largest telescope at the time – the giant 200-inch (or 5-meter) telescope at Mount Palomar in California. The design of the 2.1-meter incorporates many of the same principles of the Palomar 200-inch, as well as some new technological advances in mirror making for its era.

The primary mirror, made by Corning, was fabricated from Pyrex glass using a method called sagging, in which large chunks of glass were placed in a mould and melted at 2300 degrees Fahrenheit. The common process at that time involved ladling molten glass into a mold. This was expensive and resulted in greater imperfections in the mirror blank. Sagging, on the other hand, cost less and produced fewer imperfections. The 2.1-meter was not only the largest mirror of its time produced using this new method; it was also the first ribbed mirror to undergo this type of production. The back of the mirror is honeycombed to reduce the weight. This required precise placement of ceramic bricks in the mold, spaced at critical intervals. The glass flowed between the bricks to produce the ribs. An additional seven months of controlled cooling were required to complete the 2,980-pound blank. The bricks were then removed from the mirror blank leaving the honeycomb pattern. It then took another fifteen months for opticians to grind and polish the mirror's surface to an accuracy of 4-millionths of and inch.

The telescope's mount is of the equatorial type, which means that the large blue fork arms supporting the telescope point north and are aligned with the Earth's rotational axis. The fork pivots east-west, allowing the telescope to follow objects accurately across the sky during long exposures or observations. The telescope itself moves north-south by pivoting on its attachment points at the form arms. Once the telescope is pointed at an object, tracking occurs as the fork arms pivot toward the west at the sidereal rate, the rate at which the stars move across the sky.

This telescope remains in demand despite its age. Current instrumentation ensures that the telescope is able to support the research requirements of modern astronomers. In the decades since Dr. Van Biesbroeck's visit, the 2.1-meter has been used to make significant contributions to the body of astronomical knowledge and thus expand our understanding of the universe. These contributions include the discovery of the first pulsating white dwarf – a type of variable star, discovery of the Lyman-alpha Forest – a series of hydrogen lines in the light from very distant objects that provide clues to the cosmic environment of the early universe, and the first observation of gravitational lensing – a phenomenon predicted by Einstein's theory of general relativity in which the gravity of a galaxy or galaxy cluster redirects the light from a more distant object much as light is redirected by a lens, allowing astronomers to see the distant object.

Please pause the recording and exit down the stairs and through the door on your left to see the Coude tower.

STATION 3
Coudé Feed Telescope

The tower to the south of the 2.1-m observatory contains part of the Coudé Feed Telescope that supplies light to the Coudé spectrograph housed in the observatory structure directly across the road from the tower. The spectrograph is the size of a large room and therefore immobile. Originally the 2.1-meter telescope was equipped with a series of auxiliary mirrors arranged in such a way that light could be reflected into the spectrograph regardless of where the telescope was pointing. The word Coudé comes from the French word for elbow. In early 1970 construction began on the Coudé feed optical system, which would allow use of the Coudé spectrograph independently of the telescope. Thus both the main telescope and the Coudé Feed could be in operation simultaneously. On top of the structure housing the spectrograph is a rectangular enclosure, which covers the tracking mirror. Light from that mirror is reflected to the image-forming mirror at the top of the tower, which then reflects it through a baffle tube and onto a third mirror located at the rear of the 2.1-meter support. That mirror reflects the light into the spectrograph. The Coudé Feed Telescope has been employed by staff and visitors since September 1973 to study spectroscopy of stars including spectral classification, stellar abundances, radial velocity curves of binary and variable stars, and spectrophotometric studies of variable stars. Today, the Coude Feed is often the home for new instrument built by the University of Florida that helps astronomers search for extrasolar planets – planets outside of our solar system. Known as the Exoplanet Tracker, or ET, this instrument holds the promise of discovering dozens of new planets in the years ahead.

This concludes the tour of the 2.1-meter telescope. To return to the visitor center, please follow the road down hill and to the right.

NAME: **McMath-Pierce Solar Telescope Facility**

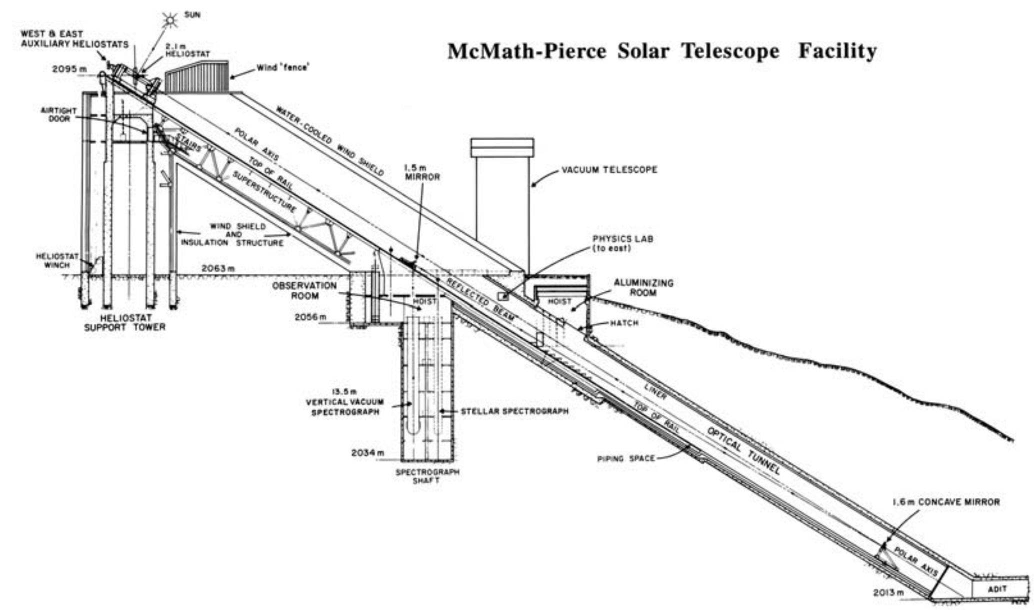
SIZE: 1.6-m main, 0.9-m east aux., 0.9-m west aux.
At 1.6-m aperture, the world's largest solar telescope.
All-reflective optics with no windows, lenses or central obscuration.

PRIMARY USES: High-precision solar spectroscopy and polarimetry.
Infrared spectroscopy and imaging (1-20 micrometers).
Solar-stellar spectroscopy.
Laboratory spectroscopy.
Planetary and cometary spectroscopy.
Terrestrial atmospheric spectroscopy and monitoring (including ozone and CFCs).

TELESCOPES: 3-mirror heliostat design
Main - 1.61 m - f/54
East Auxiliary - 0.91 m - f/50
West Auxiliary - 0.91 m - f/44

CURRENTLY AVAILABLE INSTRUMENTS: 13.7-m Czerny-Turner solar spectrograph with wavelength scanning, double=pass capability, and CCD or IR camera.
1-m Fourier Transform Spectrometer covers 0.22-18 micrometers with resolving power up to 3,000,000. Stokes polarimetry and telescope polarization compensation available.
4.6-m Czerny-Turner stellar spectrograph with UV-enhanced TI 800x800 CCD and TV Guider.

CURRENT PROJECTS: Near-Infrared Magnetographs 1 and 2.
Upgrade stellar spectrograph with cross dispersion and 1024x3072 CCD.
Upgrade telescope control system to modern hardware and software.
Adaptive optics


McMath-Pierce Solar Telescope Facility
SUN
WEST & EAST AUXILIARY HELIOSTATS
2.1 m HELIOSTAT
Wind 'fence'
2095 m
AIRTIGHT DOOR
WATER-COOLED WIND SHIELD
POLAR AXIS
STAIRS
TOP OF RAIL
SUPERSTRUCTURE
1.5 m MIRROR
VACUUM TELESCOPE
WIND SHIELD AND INSULATION STRUCTURE
HELIOSTAT WINCH
2063 m
HELIOSTAT SUPPORT TOWER
OBSERVATION ROOM
HOIST
2056 m
REFLECTED BEAM
PHYSICS LAB (to east)
ALUMINIZING ROOM
HOIST
HATCH
13.5 m VERTICAL VACUUM SPECTROGRAPH
STELLAR SPECTROGRAPH
LINER
TOP OF RAIL
OPTICAL TUNNEL
2034 m
SPECTROGRAPH SHAFT
PIPING SPACE
1.6 m CONCAVE MIRROR
POLAR AXIS
2013 m
ADIT

Script for McMath-Pierce Audio Tour

STATION 1:
Standing to the west of the telescope, upper level

Commissioned in 1962, the McMath-Pierce Solar Telescope Facility is the world's largest solar telescope. It bears the names of the persons largely responsible for its existence. Dr. Robert McMath was an industrialist, trained in civil engineering, who developed a passion for astronomy while working on ways to apply motion picture technology to science and education. Eventually McMath's interest turned toward solar physics and he was later appointed head of the NSF's advisory committee on the National Astronomical Observatory. It was at his recommendation that the NSF funded construction of the world's largest solar telescope. Dr. Keith Pierce, a staff astronomer at the McMath-Hulbert observatory at the University of Michigan, was hired by Dr. McMath to assist in the design and development of the solar telescope to be constructed at the new national observatory. Dr. Pierce eventually became the associate director of the observatory and spent the remainder of his career researching the Sun at the McMath solar telescope, rededicated in 1992 as the McMath-Pierce solar telescope facility.

Its unusual design stems from the need for a very long focal length. The objective of the telescope is to produce an image of the Sun about .9 meters, or 36 inches, in diameter. The focal length required to produce an image of that size was 90 meters. While that focal length could be achieved with a more traditional design, the problems inherent in that design, namely heat build up at the secondary mirror and diffraction caused by the secondary mirror, prompted astronomers to explore other design options. They settled on a design that employs flat mirrors called heliostats to track the Sun and reflect light into the telescope. The heliostats are mounted atop the 100-foot vertical tower at the north end of the telescope. Their use will be discussed further in the visitor gallery.

STATION 2:
Inside the visitor gallery

Looking to your right at the top of the diagonal, you see the apparatus that houses the heliostats. The center mirror is a 2-meter flat that reflects a beam of sunlight 500 feet to the 1.6-meter mirror at the bottom of the diagonal. This is the mirror that gives the telescope its aperture. The 1.6-m mirror is curved and reflects the focused beam back up the tunnel to the 60-in. flat mirror in front of you, which in turn reflects the light into the observing room. On either side of the main heliostat are the .9-meter auxiliary heliostats. Their corresponding mirrors may be seen on either side of the diagonal.

The curved mirror that receives light from the main heliostat is tilted slightly off axis to allow the beam from the heliostats to pass above the flat mirror in the center. Thus the light entering the telescope is not diffracted by that mirror and the image retains maximum contrast. The tilting of the curved mirror introduces only a negligible aberration that has no appreciable affect on the image.

The carriage on which the 60-inch mirror is mounted allows for repositioning of the optic over various instruments in the observing room directly below. The McMath-Pierce provides a versatile platform for both solar observations and daytime study of the planet Mercury and nighttime research on bright objects such as the moons of Jupiter and comet Temple-1 during the Deep Impact mission of July 2005. Additionally, because of the telescope's all reflecting and open optical path, researchers study the Sun in far-infrared wavelengths, a region of the electromagnetic spectrum closed to solar telescopes that employ large vertical vacuum tanks to house their optics. These vacuum tanks are sealed at either end with transparent material that is opaque to infrared wavelengths longer than about 2.2 microns. For more information about current research and a view of the observing room, please visit the lower level of the telescope.

STATION 3
The Observing Room

The circular platform is the optical bench. On it may be mounted a variety of instruments in numerous configurations. The bench is positioned below the opening for the 60-inch flat mirror. Below the bench resides the main spectrograph, housed vertically in a 21-meter-long steel cylinder 1.8-meters in diameter. The cylinder sits on bearings that allow it to rotate at a rate matching that of the Sun's image. The image's rotation is typical of optical systems employing heliostats and occurs because the Sun changes its orientation with respect to the heliostat as the day progresses. Across the room to the south is the Solar-Stellar Spectrograph. It has been used to take spectra of stars as faint as twelfth magnitude, or about 250 times as faint as the unaided eye can detect. That program has since been discontinued and the instrument is now used primarily for observing planets.

The McMath-Pierce telescope has additional instruments that are not visible from this viewing location. There are numerous ports through which the telescope can direct its beam to reach these instruments and much science that may be done. Scientific programs that have been undertaken at the McMath-Pierce include studies of the distribution of sodium emissions from the planet Mercury and identification of molecular absorption lines in the regions above sunspots, including lines from the molecule H_2O. New instrumentation is under development and the McMath-Pierce Solar Telescope will continue as the premiere facility for infrared study of the Sun until such time as its role is eclipsed by the Advanced Technology Solar Telescope, a 4-m aperture instrument currently under design to replace both this and the Dunn Solar Telescope at Sacramento Peak in New Mexico. The ATST may see first light in 2014 from Haleakala, Hawaii.

NAME:	**NICHOLAS U. MAYALL TELESCOPE**
SIZE:	4 meter (158")
TYPE:	CASSEGRAIN
FIRST LIGHT:	February 27, 1973
FOCAL RATIO:	f/2.7 (Prime)

MOUNTING:

Equatorial - Axis at 32 degrees
Yoke Mount is approximately 41' d.
2 Sets of Main Bearings;
"Horseshoe" bearing - RIGHT ASCENSION - Parallel to Earth's Axis (Longitude in Sky)
Perpendicular bearing - DECLINATION - (Latitude in sky)
Rotates East to West tracking the Earth's Rotation at a compensated speed.
Moving parts weigh 300 tons
Turns on a thin film of oil - 0.004 " thick on 8 hydrostatic bearings

STRUCTURE:

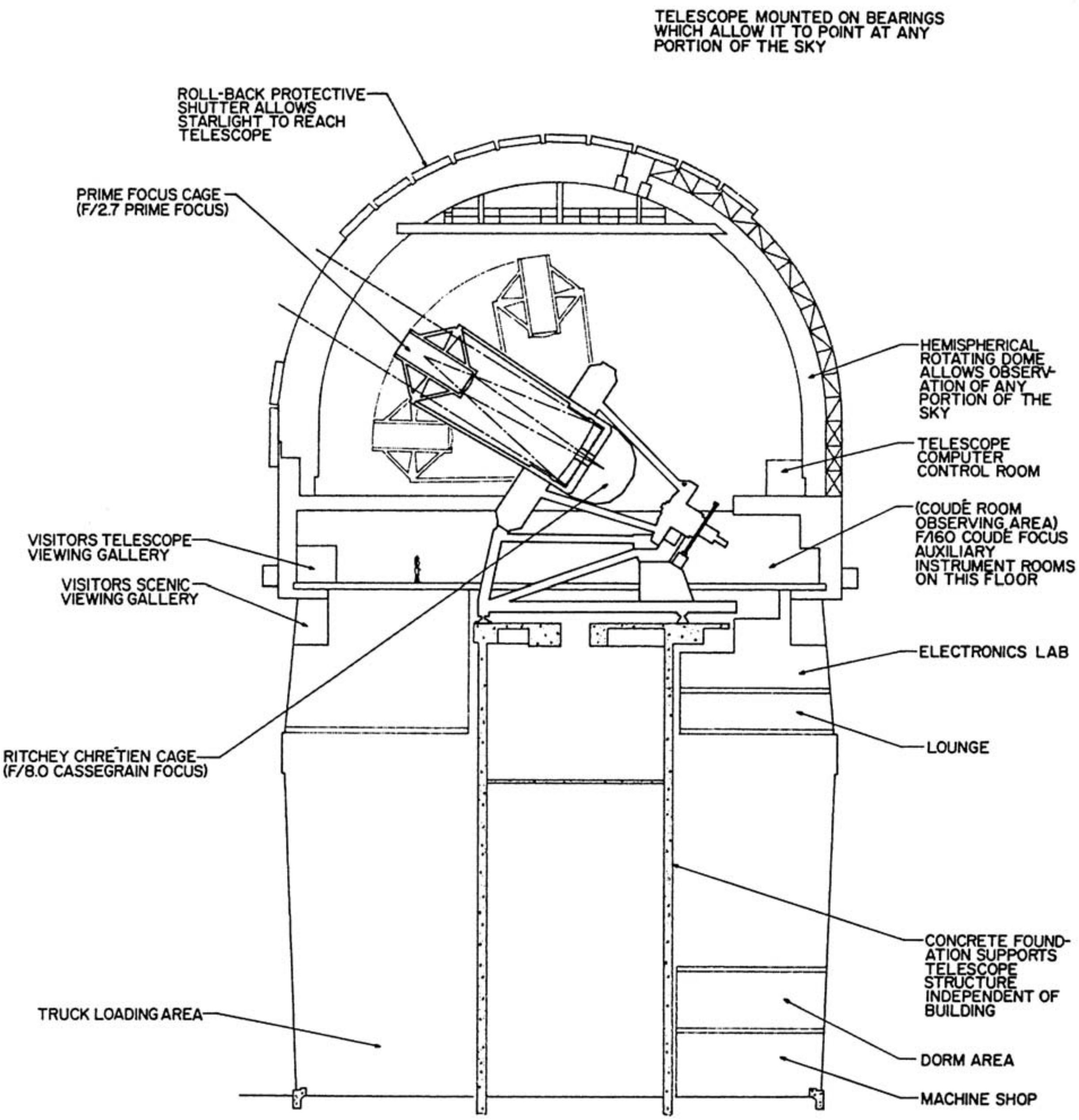
BUILDING
Supported by 10 hexahedrons
Each: 96' Tall - 33' Wide - 35 tons
Building - 187' high.
30,000 sq. ft. floor space

PIER
Telescope mounted on a cement pier that is completely separate from the building and the dome.
Pier 92' above ground
Poured cement - walls 18" thick
37' diameter hollow cylinder

DOME
Constructed of 1/4" steel plate in a double shell structure
OD 108' - ID 102'
Louvers added in 1997 for air circulation and temperature control
Dome weighs nearly 500 tons
Dome moves with the telescope
Rotates on 32 trucks in 5 ½ minutes
Shutter a 27' slit opens in 2 ½ minutes
Observing floor at base of dome is 100' above ground
Dome built to withstand winds of 120 mph
Inside of dome covered aluminum insulating panels

MIRROR:

PRIMARY
Diameter 4 Meter/158"
Weight 15 Tons
MaterialFused Quartz, polished to 1/millionth of an inch
Coated with reflective aluminum at a thickness of 1/1000th of a human hair.
Back of mirror is supported by 9 computer controlled pneumatic pads.
Mirror edge is supported by 24 counter balanced push-pull levers.


TELESCOPE MOUNTED ON BEARINGS WHICH ALLOW IT TO POINT AT ANY PORTION OF THE SKY
ROLL-BACK PROTECTIVE SHUTTER ALLOWS STARLIGHT TO REACH TELESCOPE
PRIME FOCUS CAGE (F/2.7 PRIME FOCUS)
HEMISPHERICAL ROTATING DOME ALLOWS OBSERV-ATION OF ANY PORTION OF THE SKY
TELESCOPE COMPUTER CONTROL ROOM
(COUDÊ ROOM OBSERVING AREA) F/160 COUDÊ FOCUS AUXILIARY INSTRUMENT ROOMS ON THIS FLOOR
VISITORS TELESCOPE VIEWING GALLERY
VISITORS SCENIC VIEWING GALLERY
ELECTRONICS LAB
LOUNGE
RITCHEY CHRÊTIEN CAGE (F/8.0 CASSEGRAIN FOCUS)
CONCRETE FOUND-ATION SUPPORTS TELESCOPE STRUCTURE INDEPENDENT OF BUILDING
TRUCK LOADING AREA
DORM AREA
MACHINE SHOP

Script for 4-m Audio Tour
September 2006

STATION 1
At the top of the road, facing the structure.

An icon of Kitt Peak National Observatory, the 4-m telescope structure punctuates the view of Kitt Peak from miles around. Beneath its cavernous dome rests the crown jewel of the observatory – the Mayall 4-meter telescope. Known as the 158-in when it achieved first light in 1973, it was the second largest optical telescope in the world.

The telescope bears the name of Nicholas U. Mayall, the director of Kitt Peak for the decade from 1960 to 1970. Mayall's vision for the future of astronomy and Kitt Peak's role in the field began with the idea that the mountain needed a large telescope. The 4-m was a product of that idea; its light-gathering ability would allow it to study faint objects beyond our galaxy and beyond the reach of smaller telescopes, a key to understanding the exciting concept of the expanding Universe.

The monolithic building rises 187 feet to elevate the telescope above the turbulent air flow over the summit of the mountain. Supporting the massive instrument within is a hollow concrete pier that stands 92-feet tall, spans 37 feet in diameter, and has walls 18-inches thick. Creating the pier required a round-the-clock effort involving a circular slip form that was hoisted from the bedrock as is was filled with concrete. A convoy of trucks carried concrete to the site 24 hours a day for three consecutive days. The ten geometrical frames, called hexahedrons, to which the exterior panels are attached stand 96 feet tall, are 33 feet wide, and weigh 35 tons each. They were fabricated in Phoenix, transported to Kitt Peak intact, and installed at a rate of one per day. They are not attached to the pier, thus isolating it from the rest of the structure to prevent vibrations from being transmitted to the telescope.

Situated on the 30,000 sq. feet of floor space inside the towering edifice are offices, darkrooms, living quarters, a machine shop, and an aluminizing chamber for recoating telescope mirrors.

While the Mayall 4-m was under construction at Kitt Peak, its sister telescope, the Victor M. Blanco 4-m was undergoing installation on Cerro-Telolo in Chile with help from funding from the Ford Foundation. The Cerro Telolo Inter-American Observatory, operated by NOAO in the southern hemisphere, affords astronomers access to the southern celestial sphere. The two telescopes are identical.

Please proceed to the visitor entrance on the (south?) side of the building. Take the elevator up, climb the flight of stairs to your right when you exit the elevator, and turn right at the top of the stairs to enter the viewing gallery. Please pause this recording.

STATION 2
The viewing gallery:

As you stroll around the viewing gallery, you will enjoy a bird's-eye view of the observatory. Look to the left of the facility to see the majestic McMath-Pierce solar telescope with its diagonal structure pointing toward the north celestial pole. In the foreground of the solar telescope is the 3-acre basin for collecting rain and snow melt, the primary source of water for the observatory.
Follow the ridge toward the right and you find the 2.1-m telescope with its white dome on a silver building. The 2.1-m opened in 1964 and afforded American astronomers access to a world-class research telescope. Farther along the ridge

toward the right sits an observatory topped by a silver hexagonal dome. Inside is the WIYN 3.5-m telescope, the newest and most optically refined telescope on Kitt Peak. Completed in 1994 and operated by a consortium comprising Wisconsin, Indiana, Yale, and NOAO, the 3.5-m telescope served as the prototype for the new generation of large telescopes and marked a radical departure from the telescope designs of the previous era as exemplified by the 4-m.

Let your gaze slide down the ridge to the right and stop at the small gray structure. You have arrived at the Calypso Telescope, a 1.2-m reflector and the only privately funded observatory on Kitt Peak. Financing for Calypso comes from Edgar O. Smith. A wealthy business man with a passion for astronomy, Smith indulged his passion by taking a degree at Columbia University and then collaborating with a group of Hubble engineers to create the Calypso. Its 1.2-m aperture derives from the atmospheric cell size above Kitt Peak so the telescope is maximized for imaging from this location.

Now shift your gaze right again over to the southwest ridge and you will see the two radio telescopes. In the foreground is the 25-m VLBA radio telescope. It is one of ten such units composing the Very Long Baseline Array that stretches from Hawaii to the Virgin Islands. By accurately timing and recording observations from each telescope and then integrating them at Socorro, New Mexico – headquarters for the National Radio Astronomy Observatory – the individual telescopes achieve the resolution of one huge telescope. The white dome behind the VLBA telescope contains the 12-m radio telescope operated by the Arizona Radio Observatory.

Directly in front of you with its cylindrical dome stands the University of Arizona's observatory containing the 2.3-m Bok reflector. It is named for astronomer Bart Bok who directed the university's Steward Observatory (when?). So respected was Dr. Bok that he set out to obtain funding for a 60-in telescope and returned with funding for a 90-in or 2.3-m telescope, which is very similar in design to the Kitt Peak 2.1-m. The oddly shaped dome resulted from the need to minimize construction costs.

Finally behind the 2.3-m are two smaller observatories belonging to Spacewatch, a group operating within the Lunar and Planetary Laboratory at the University of Arizona. Spacewatch monitors Earth-crossing asteroids and other solar system bodies that could pose an impact hazard to Earth. This concludes a partial tour of the telescopes at Kitt Peak.

Please enjoy the remainder of your walk around the viewing gallery and pause before exiting to peruse the striking images on the wall near the exit to the foyer. All the images were taken by the Mayall and Blanco 4-m telescopes. Once in the foyer, ascend the stairs to see the 4-m telescope. You may pause the recording.

STATION 3:
The Telescope

Welcome to the Mayall 4-m telescope, the largest telescope on Kitt Peak.

The telescope and mount bear a resemblance to the 200-in or 5-m telescope at Palomar Observatory in California and to a lesser degree the Mt. Hamilton 120-inch or 3-m. To limit design costs and reduce the time spent on experimental engineering for the 4-m, designers decided to simply update existing telescope designs The 4-m mount grew out of a concept developed by W.W. Baustian, chief engineer for Kitt Peak at the time. The most obvious difference between the 4-m mount and the Palomar mount is the positioning of the horseshoe. At Palomar it sits in front of the telescope, which is supported between the struts.

Supported by eight hydrostatic bearings and sliding on a thin film of oil the moving parts of the mount weigh a staggering 300 tons, yet so precisely balanced is the whole arrangement that the telescope is driven east and west by the turning of a one-half horsepower electric motor. Because this is an equatorial mount, typical of the era, it is aligned with the north celestial pole, the horseshoe supporting the north end. The telescope achieves it north-south motion by pivoting on bearings at its attachment points in the horseshoe. Once the telescope is pointed at an object in the sky, the mount turns opposite the direction of the Earth's rotation at the same rate the stars travel toward the west.

The observatory dome and the telescope are synchronized. As the telescope tracks, the five hundred-ton dome repositions itself automatically to provide the telescope a clear view through the twenty-seven-foot-wide slit opened when the thirty thousand pound shutter retracts. The inside of the dome is covered with 26,600 square feet of embossed aluminum insulating panels. Its diameter is 102 feet, and it rotates completely in about five and a half minutes.

In December of 1964, General Electric began work on the 4-m mirror. Mirror-making processes developed in the 1930s allow quartz to be fused into mirror blanks. Quartz was desirable because of its lower sensitivity to temperature changes. General Electric pioneered a process of fusing quartz ingots to produce a mirror of the desired size. The ingots were created by fusing very pure silica sand in a vacuum oven at 3300 degrees. Those ingots were then fitted together and fused in another furnace. Four fusions were required to join the three layers of ingots composing the final mirror. Because the mirror is solid glass it weighs an incredible 33,000 pounds.

Since its construction, the Mayall has enabled many important accomplishments in the field of astronomy, one of which is the discovery of dark matter in the universe through observations of the rotation speeds of spiral galaxies. Some of the first major infrared observations in astronomy were done with the Mayall. Astronomers have examined elliptical galaxies such as M87 and M49 to understand the dynamic structure of these objects. Astronomers have also used the telescope to help determine the distance scale and large-scale structure of the Universe. In recent years, the Mayall has been able to take large color pictures of astronomical objects with the use of the Mosaic imager, and it has fostered nearly two dozen major sky surveys, including one that has discovered more than half the known Kuiper Belt Objects beyond Pluto.

Kitt Peak and the Mayall telescope were among the first to use CCD detectors such as Mosaic instead of photographic plates, both for direct imaging and spectroscopy. The FTS spectrograph instrument was a landmark in very high-resolution spectroscopy. More recently, FLAMINGOS was the first on the sky with a 2K x 2K infrared detector array. Supporting all of this research was user-friendly software developed by KPNO/NOAO so that the data taken by the instruments and the visiting astronomers could be calibrated and reduced efficiently, leading to excellent scientific productivity – the real measure of an observatory's success.

The 4-m remains the most requested NOAO telescope on Kitt Peak. New instrumentation and continued refinements keep it current with leading-edge astronomy research. The wide-field infrared imager NEWFIRM is the latest development and an example of why NOAO remains the center for U.S. ground-based astronomy.

NAME: WIYN - (Wisconsin, Indiana, Yale, NOAO)
SIZE: 3.5 meters (138")
TYPE: Modified CASSEGRAIN
FIRST LIGHT: 1994
FOCAL RATIO: f/1.75 – Prime
Telescope has wide field imaging and uses fiber optics technology
MOUNTING: Altitude-Azimuth19" minimum viewing angle
Total moving weight - 35 tons

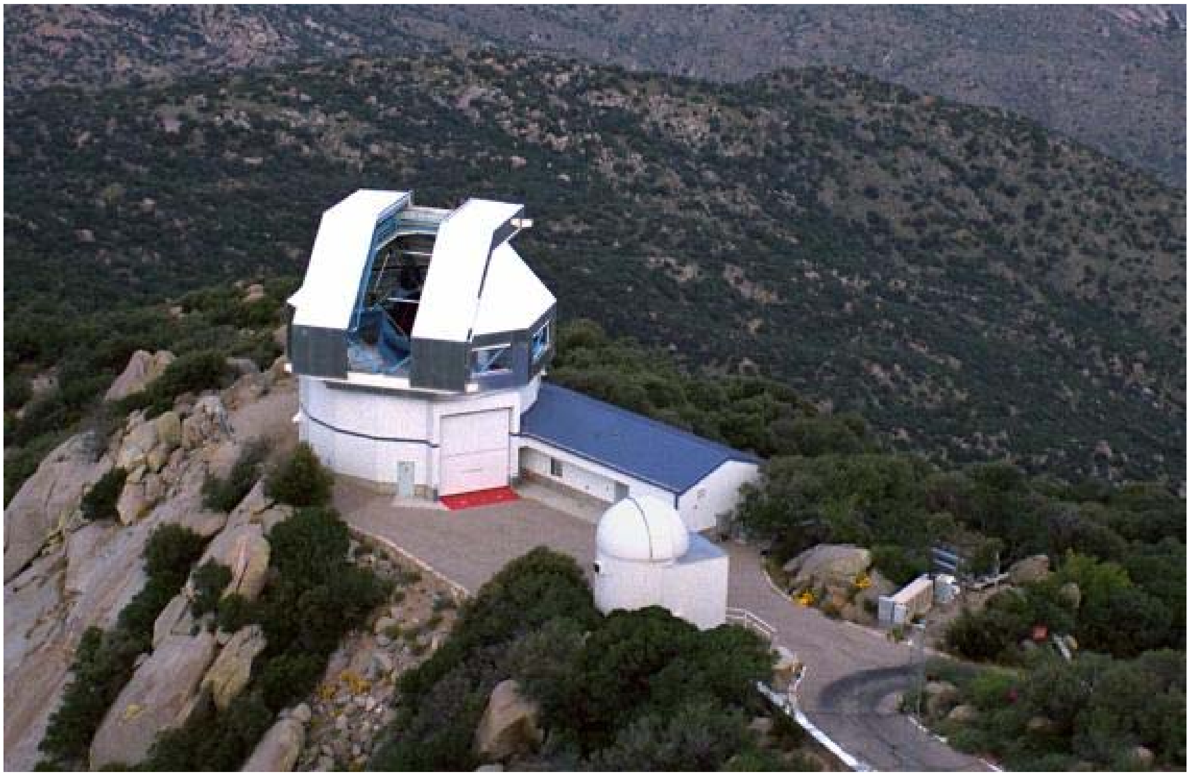
STRUCTURE: **DOME**
Truncated rhombi-cube octahedron
Moving weight - 40 tons
Very efficient use of space
8 overhead doors to open and adjust and stabilize temperature/air flow
Slit 4.2 meters

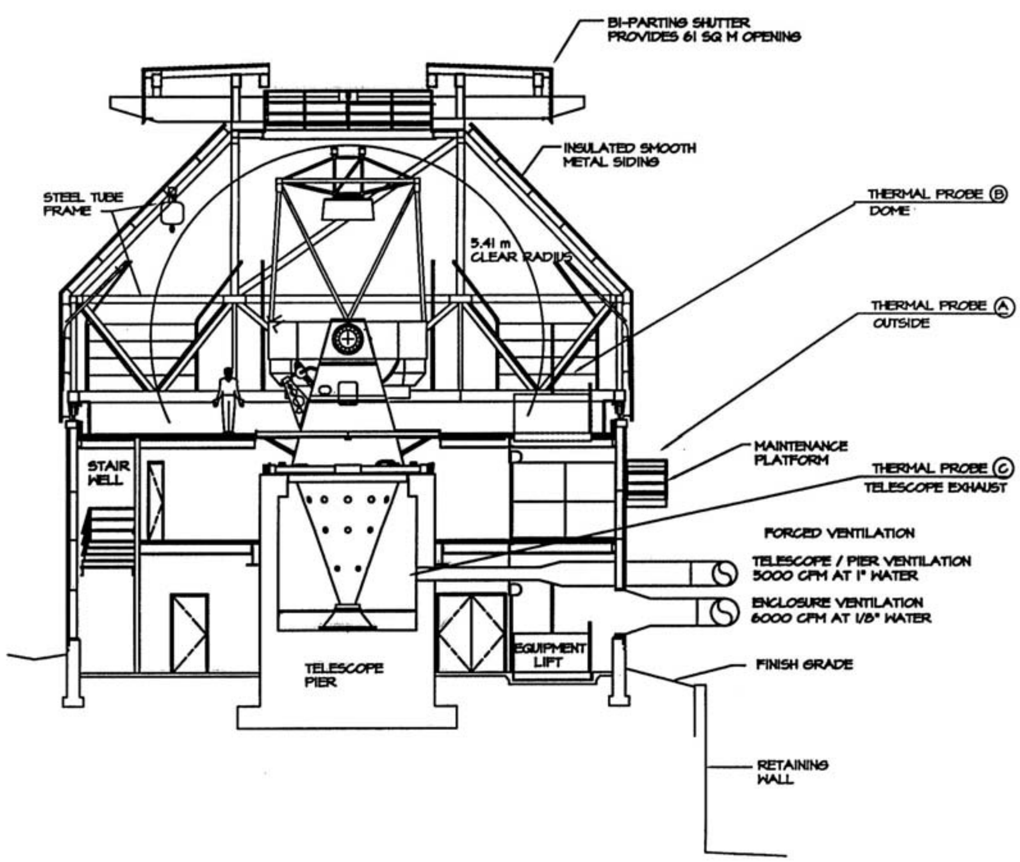
MIRROR: **PRIMARY**
Diameter - 3.5 meters - (138")
Weight 2 tons - (4320 lbs.) (Note: 4 Meter 15 Tons)
Material - Borosilicate
Edge Thickness-18"
Center Hole Diameter- 38"
Primary mirror was fabricated at the UA Steward Observatory Mirror Lab

SECONDARY
Diameter- 1.2 Meters - (47.25")
Weight - 263 lbs.
Material - ZERODUR
Secondary mirror was fabricated at Schott Glass and Contraves

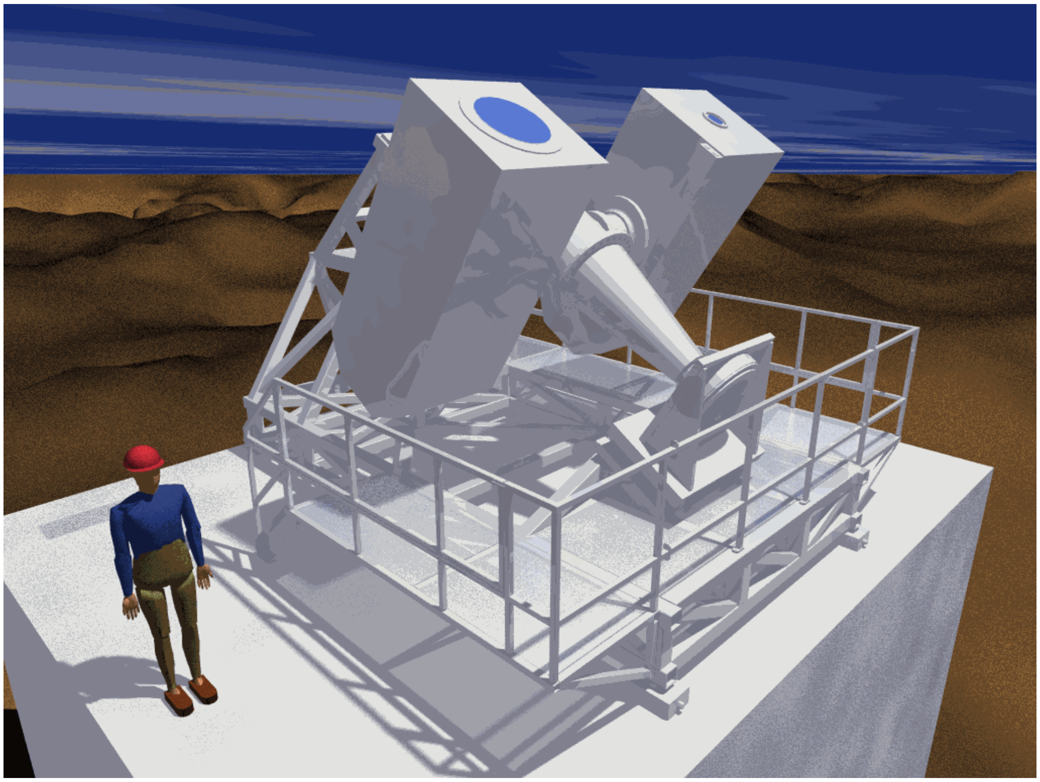
TERTIARY
Size - 1.2 Meters X 0.8 Meter Flat mirror
Weight -132 lbs.
Material - ZERODUR
Tertiary mirror was fabricated at Schott and Kodak

ACTIVE OPTICS 66 axial actuators to actively correct for aberrations caused by gravity vectors and thermal effects. 24 lateral supports to maintain lateral position of the primary mirror. Advances in technology developed for supporting new large lightweight mirrors of the 8-meter class.




BI-PARTING SHUTTER
PROVIDES 61 SQ M OPENING
INSULATED SMOOTH
METAL SIDING
STEEL TUBE
FRAME
5.41 m
CLEAR RADIUS
THERMAL PROBE (B)
DOME
THERMAL PROBE (A)
OUTSIDE
STAIR
WELL
MAINTENANCE
PLATFORM
THERMAL PROBE (C)
TELESCOPE EXHAUST
FORCED VENTILATION
TELESCOPE / PIER VENTILATION
3000 CFM AT 1" WATER
ENCLOSURE VENTILATION
6000 CFM AT 1/8" WATER
EQUIPMENT
LIFT
TELESCOPE
PIER
FINISH GRADE
RETAINING
WALL

SOLIS
Synoptic Optical Long-term Investigations of the Sun



SOLIS Science Impact

The long-term studies of the most important astronomical object to humanity will provide the fundamental data to help answer the following questions:

What causes the solar cycle? SOLIS will complement helioseismology and help to understand stellar and galactic dynamos, turbulent magnetic fields, cycle-related irradiance changes, and stellar differential rotation.

How is energy stored and released in the solar atmosphere? SOLIS will provide crucial data for space-weather forecasting and help to understand stellar flares, coronal mass ejections, and the heating of stellar chromospheres and coronae.

How does the solar radiative and non-radiative output vary? SOLIS will complement space-based X-ray and EUV measurements and help to understand solar input to global change, irradiance variations of solar-like stars, and convection in late-type stars.

SOLIS Instruments

Vector Spectromagnetograph (VSM)

- helium-filled 50-cm f/6.6 Ritchey-Chretien
- 256 by 1024 pixel 300 frame/s CCD cameras
- ferroelectric polarization modulators
- full-disk vector magnetic field in 15 minutes with 1" pixel size in photosphere
- full-disk chromospheric longitudinal field
- full-disk chromosphere-corona intensity (HeI 1083.0 nm)

Full Disk Patrol (FDP)

- 14-cm f/21 achromatic refractor
- two 2048 by 2048 pixel 4 frame/s CCD cameras
- liquid-crystal tunable filters from 390 to 1083 nm
- full-disk images and Doppler velocity maps in photospheric and chromospheric spectral lines

Integrated Sunlight Spectrometer (ISS)

- 8-mm light feed with fiber optic scrambling
- commercial double-pass grating spectrograph with movable CCD sensor
- highly accurate profiles of many spectral lines over the solar cycle with spectral resolution 300,000 continuing record of terrestrial atmosphere
- 8-mm light feed with fiber optic scrambling
- commercial double-pass grating spectrograph with movable CCD sensor
- highly accurate profiles of many spectral lines over the solar cycle with spectral resolution 300,000
- continuing record of terrestrial atmosphere

SOLIS Operations

- located on Kitt Peak Vacuum Telescope building
- remote-controlled, autonomous instruments
- synoptic and user-driven observations
- proposal and data access over the Internet
- completely open data policy

VERITAS
Very Energetic Radiation Imaging Telescope
Array System

VERITAS is a new major ground-based gamma-ray observatory with an array of four 12m optical reflectors for gamma-ray astronomy in the GeV - TeV energy range . The new telescope design will be based on the design of the existing 10-m gamma ray telescope of the Whipple Observatory. It will consist of an array of imaging telescopes which will be deployed such that they will permit the maximum versatility and will give the highest sensitivity in the 50 GeV - 50 TeV band (with maximum sensitivity from 100 GeV to 10 TeV). In this band critical measurements of SNRs and AGNs will be made. This VHE observatory will effectively complement GLAST well into the next millennium.

Because it is very difficult to produce gamma-rays, the objects that emit them are very interesting to astrophysicists. High-energy gamma rays are associated with exploding stars (supernovae), pulsars , quasars , and black holes rather than with ordinary stars or galaxies.

The emission of high-energy gamma-rays from cosmic objects always implies the presence of exotic and extreme physical conditions - high magnetic and electric fields, shock waves, cataclysmic explosions, etc. In fact, this emission offers the only direct probe of the extreme conditions in these exciting phenomena.

Electromagnetic radiation that does not penetrate the Earth's atmosphere, like gamma-rays and X rays, is usually studied by telescopes carried above the atmosphere in satellites. As a result, these detectors are limited in size and very costly. The Compton Gamma-Ray Observatory (CGRO), launched by NASA in 1991, was one of the largest scientific satellites ever launched and cost a half-billion dollars. Moreover, the flux of very high energy gamma-rays is so small that even the largest space-based gamma-ray telescopes cannot see enough photons to detect the actual sources of this radiation.

Kitt Peak Telescopes and Tenants

Kitt Peak National Observatory
1. 4-meter Mayall
2. 2.1-meter
3. 0.9-meter Coude feed
4. 0.5-meter Visitor Center Telescope
5. 0.4-meter Visitor Center Telescope
6. 0.4-meter Visitor Center Telescope
7. Visitor Center solar array

Planetary Sciences Inst., Western Kentucky U., S. Carolina St., Villanova U., Fayetteville St.
8. 1.3-meter

National Solar Observatory
9. 2-meter McMath-Pierce (main)
10. 0.9-meter McMath-Pierce (E. Auxiliary)
11. 0.9-meter McMath-Pierce (W. Auxiliary)
12. SOLIS (Synoptic Optical Long-term Investigations of the Sun)

WIYN Observatory (Wisconsin, Indiana, Yale, NOAO)
13. 0.9-meter
14. 3.5-meter

National Radio Astronomy Observatory
15. 25-meter VLBA (Very Long Baseline Array)

Case Western Reserve University Observatory
16. 0.6-meter Burrell Schmidt

Edgar O. Smith Observatory
17. 1.2-meter Calypso

MDM Observatory (Michigan, Dartmouth, Ohio St., Columbia)
18. 1.3-meter McGraw Hill
19. 2.4-meter Hiltner

SARA Observatory (Southeastern Association for Research in Astronomy)
20. 0.9-meter

Steward Observatory (University of Arizona)
21. 2.3-meter Bok Reflector

University of Arizona Lunar and Planetary Laboratory
22. 0.9-meter Spacewatch
23. 1.8-meter Spacewatch

Arizona Radio Observatory
24. 12-meter radio telescope

LOTIS (Livermore Optical Transient Imaging System)
25. 0.6-meter

WHAM (Wisconsin Hydrogen-Alpha Mapping)
26. 0.6-meter

General Information

National Optical Astronomy Observatory (NOAO) has three divisions: Kitt Peak National Observatory, Cerro Tololo Inter-American Observatory, and NOAO Gemini Science Center.

NOAO is operated by the Association of Universities for Research in Astronomy (AURA) Inc. under cooperative agreement with the National Science Foundation (NSF).

1 meter = 39.37 inches.

CHAPTER 4
KITT PEAK DISCOVERIES

2.1-m: The history of the 2.1-m Telescope includes many important discoveries in astrophysics such as the Lyman-alpha forest (a characteristic absorption pattern arising from the elemental hydrogen that provides important clues to conditions in the early universe), the first gravitational lens, the first pulsating white dwarf, and the first comprehensive study of the binary frequency of solar type stars.

3.5-m WIYN: The WIYN Telescope is already credited with important work in the area of supernovae in distant galaxies, in understanding the origin of gamma ray bursts, the evolution of stars in clusters, and the discovery of a new galaxy in The Local Group, the group of galaxies within 4 million light-years of our own Milky Way

4-m: The 4-m Mayall Telescope has played an important role in establishing the role of dark matter in the universe through observations of the rotation curves of galaxies, in determinations of stellar radii from occultations, in understanding the dynamical structure of elliptical galaxies, and in determinations of the distance scale and large scale structure of the universe.

McMath-Pierce: Important discoveries include: detection of water and isotopic helium on the Sun; solar emission lines at 12 microns; first measurement of Kilogauss magnetic fields outside sunspots and the very weak intra-network fields; first high resolution images at 1.6 and 10 microns; detection of a natural maser in the Martian atmosphere. See appendices for more information.

Smaller Scopes

- Extensive network of photometric standard stars as well as extensive contributions in stellar photometry of variable stars and of stars in clusters. (0.4m, 0.9m and 1.3m)
- Systematic studies of star formation, including the interactions of young stellar objects and the surrounding medium, and the initial mass functions in obscured star forming regions. (1.3-m)
- Spectroscopy of stars including spectral classification, stellar abundances, radial velocity curves of binary and variable stars, spectrophotometric studies of variable stars. (Coudé, 0.9-m)
- Studies of the morphology of a wide variety of extended sources including planetary nebulae, H II regions, and galaxies. (0.9-m, Burrell Schmidt)
- Imaging surveys including clusters of galaxies, HR diagrams of stellar clusters, samples of rare objects such as emission-line galaxies or dwarf C stars, large-scale structure, the Galactic halo. (0.9-m, Burrell Schmidt)

Current Research

Project Deeprange: Uses large-area CCDs to survey the I-band at the prime focus of the 4m. First of a new generation of deep, wide-area imaging surveys to study structure at high redshift. Its purpose is to understand the evolution of large-scale structure.

NOAO Deep Wide-Field Survey: The NOAO Deep Wide-Field Survey (NDWFS) is a deep optical and near-infrared wide-field imaging survey that sampled the sky in two 9 square degree fields. NDWFS investigates the existence and evolution of large scale structures at redshifts z>1 as sampled by a diverse set of objects; provides the astronomical community a sensitive multicolor-database of objects from which samples may be selected for the study of other interesting problems; and furnishes a set of interesting objects that can be investigated spectroscopically with the Gemini telescopes.

GONG: The Global Oscillation Network Group (*GONG*) is a community-based project to conduct a detailed study of solar internal structure and dynamics using ***helioseismology***. In order to exploit this new technique, *GONG* has developed a six-station network of extremely sensitive, and stable solar velocity imagers located around the Earth to obtain nearly continuous observations of the Sun's ``five-minute'' oscillations, or pulsations. *GONG* has also established a major, distributed data reduction and analysis system to facilitate the coordinated scientific investigation of these measurements. Helioseismology utilizes waves that propagate throughout the Sun to measure, for the first time, the invisible internal structure and dynamics of a star. There are millions of distinct, resonating, sound waves, seen by the doppler shifting of light emitted at the Sun's surface. The periods of these waves depend on their propagation speeds and the depths of their resonant cavities, and the large number of resonant modes, with different cavities, allows us to construct extremely narrow probes of the temperature, chemical composition, and motions from just below the surface down to the very core of the Sun.

SONG: Asteroseismology allows us to obtain quantitative information on the internal structure of stars, to compare stellar models to real stars in substantially more detail than now possible, to explore the behavior of matter under conditions which cannot be achieved on Earth, and to confront the discrepancy between stellar ages and the cosmological age from a new perspective. We propose to develop a ground-based network of (existing) telescopes and appropriate instrumentation and methodology to detect and study acoustic oscillations in solar type stars. NOAO could participate in this venture through the contribution of significant amounts of telescope time on the Mayall 4-m telescope (and also on the 2.1-m, WIYN, SOAR, Blanco 4-m, and Gemini telescopes) and through our own expertise in the development of instrumentation and support of scientific programs. Coordination with existing observing networks and potential space missions will also be important.

Other Telescopes

SOAR: The Southern Astrophysical Research Telescope is a 4.2-meter aperture telescope funded by a partnership between the US National Optical Astronomy Observatories (NOAO), the Country of Brazil, Michigan State University, and the University of North Carolina at Chapel Hill. The telescope sits atop Cerro Pachón at the Cerro Tololo Interamerican Observatory (CTIO) in the Chilean Andes. The telescope is designed to support science in both high quality imaging and spectroscopy in the optical and near infrared wavelengths. The f/16 Ritchey-Chrétien optical design delivers a 12-arcmin diameter field of view with a tip/tilt stabilized image through a telescope with 0.18 arcsec image quality. The SOAR Project Team is located at the NOAO offices. For more information please contact the SOAR Project Office.

CITO: Cerro Tololo Inter-American Observatory presently operates the Blanco 4-m, 1.5-m, 0.9-m and has shares in the YALO 1.0-m and the Michigan 0.6/0.9-m Schmidt. The SOAR telescope (30% share for NOAO) should begin science operations early in 2003, preceded by Gemini S in 2001B. Other southern-hemisphere facilities available to US-investigators are Magellan I (2001), and later, Magellan II (2003) and SALT (2005?).

NOAO Gemini Science Center: The Gemini Science Center is an international partnership operating 8.1-meter telescopes, one located on Hawaii's Mauna Kea, and the other on Chile's Cerro Pachón. The name Gemini comes from the mythological twins Castor and Pollux, whose stars will be visible to both telescopes. By building the telescopes on Mauna Kea (elevation 13,824 ft/4214 m) in Hawaii and Cerro Pachón (elevation 8895 ft/2737 m) in central Chile, both the northern and southern skies will be fully accessible to these scopes. Both sites also offer high percentages of clear weather and excellent atmospheric conditions for all types of astronomical studies. In addition to Gemini's strategic positioning on our globe, each of the Gemini telescopes is designed to provide some of the sharpest images of any telescope on (or even above) our planet. Engineers and scientists have gone to great lengths to optimize Gemini for infrared studies and most researchers agree that Gemini provides some of the best infrared views of our universe - ever!

What are the most important science discoveries from Kitt Peak?

Galaxy Rotation Curves: Study of spiral galaxy rotation curves provided the first indication of dark matter in the universe. Dark matter may dominate over ordinary matter in regulating the dynamics of galaxies and the entire universe.

High Redshift Galaxies: By using radio emission as a selection criterion, the highest redshift galaxies have been discovered. The systematic study of these galaxies, with redshifts greater than 5 and dating back to very early epochs, has resulted in a new understanding of the rate of galaxy formation.

Galaxy Evolution and Environment: Observations of galaxy clusters indicate that the environment of a galaxy plays a strong role in its evolution. For example, the local density of galaxies can have an impact upon star formation and stellar populations in those galaxies.

Large-scale Structure: The discovery of a void in the constellation Boötes lead to an early indication of the large scale structure of the universe. Later research programs established that very large scale structures in the universe are probably not in equilibrium, causing major revisions in cosmological models.

The Distance Scale: Supernovae have produced significant results as distance indicators. Planetary nebulae have also proven to be an effective tools for measuring distances in the universe. These differing techniques are helping to determine the Hubble constant, a measure of the rate at which the universe is expanding.

Star Formation: Research has provided a more detailed understanding of the evolution of protostars and protoplanetary disks, an early step in star formation. Accompanying the formation of young stars are complex and frequently very large bipolar outflows.

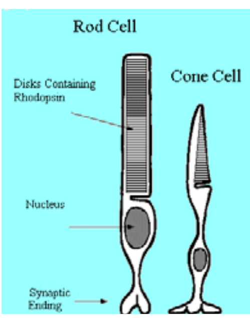
Continued Role: With improvement of delivered image quality and the application of state-of-the-art instrumentation such as the CCD Mosaic Imager and the WIYN Telescope, Kitt Peak National Observatory continues to play a central role in astronomical research in the United States.

Chapter 5
SEEING SCIENCE

In the course of the nightly public presentation, guests are given the opportunity to observe and see many wonderful objects in the night sky. These things can be seen by using one's unaided eyes, binoculars and, of course, the telescope. One of the important ideas presented is that professional astronomers do not look through telescopes with their eyes to make scientific measurements; instead they use sensitive instruments that are much more appropriate for doing the job. In fact, I generally do not have to work very hard to show people why that is. Human eyes are not designed for observing very dim objects in the night sky or a telescope. Ironically, unless you can get your hands on a larger telescope and plop it down at a darker site, the views given at the Visitor Center Observatory are as good as it gets! This program upholds the romanticism of astronomy: you get to see things like planets and galaxies with your own eyes through the telescope.

So, although our eyes are not suited for observing very faint sources, they are still remarkable light detectors. In order to use them to their best capabilities a little optical biology is necessary. When we enter low-light situations, our eyes begin to adjust and become more sensitive to light. Please refer to the diagram for an illustration of structures of the eye. After light enters through the cornea and passes through the pupil, it is focused by the lens behind the pupil on to the cells of the back of the eye (retina). The brain senses the intensity of the light and increases or decreases the size of the pupil accordingly. In bright sun light the pupil may open as little as 2 mm to restrict the amount of the light that enters the eye. In the dark the pupil may open to as much as 8 mm!

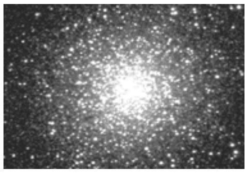
There are two kinds of light-detecting cells on the retina: cones and rods. (See zebra rod cells as viewed through a microscope to the right). The cones are responsible for high light-level observing (photopic vision), while the rods are for low light vision (scotopic). In the human eye there are approximately 5 million cones and a hundred million rods! The cones occupy a small spot centrally located on the retina (fovea) whereas the rods surround the cones and cover a much greater area (macula). Cones specialize in color perception, while rods are the cells used to detect things that you see in your peripheral vision, especially under low light levels.



So, when the public begins observing the dark night sky, everyone's pupils dilate and let in as much light as possible. In addition (and more importantly) the eye begins to produce a chemical called rhodopsin (visual purple) and increases the sensitivity of the rod cells in the eye. This process may take from 10-20 minutes to reach a good level of dark adaptation. This extra sensitivity is very necessary in order to observe the dim and diffuse objects in the night sky (and through the telescope). Looking at bright sources of light will cause the eye to re-adjust and lose its night vision. You can feel this adjustment when bright lights are suddenly turned on! You may notice that most of the lights used at observatories or by amateur astronomers are colored red. This is because at low light levels the eye is not very sensitive to this wavelength (or color) of light and one's dark adaptation can be maintained while still being able to see what one is doing.

Having said all of this, the main challenge with observing dim objects is knowing how to see them. When I point something out in the sky, it is very natural for the guests to begin by looking directly at it (especially in the telescope, when the object is put in the center of the field of view). However, under low light levels the most sensitive cells (the rods), which are not concentrated in the "center" of vision (fovea), do not come into play when looking directly at something.

Furthermore, this is why you do not see color well (if at all) in dim conditions. Those cones need a lot of light to get them to go!



For example, when looking in the telescope at an object like M13 (see picture), if you look directly at the cluster, it, will appear dim and possibly disappear! Instead, if you look off to the side (up, down, left, or right just a little) suddenly the cluster will appear to brighten and look like the picture shown! This is an effect that most people are unfamiliar with. The method is called using "averted vision". Amateur astronomers use this to their advantage whenever they look through telescopes. It will help you out tremendously!

There are a few other unfamiliar effects that can be noticed when observing in the dark. Although the above may seem to highlight inadequacies of the eye, the eye has many remarkable strengths. For example, when observing objects that have both very bright and very dim aspects, the eye, unlike most linear detectors, can "see" both portions at the same time. This is due to the logarithmic response to brightness levels. The Great Orion Nebula is one of the few objects that I believe is better seen in an eyepiece than photographed. This is because the eye can clearly see both the bright Trapezium stars without saturation and, at the same time, the eye can detect the faint wisps of gas that enshroud those stars.

The other effect is even more subtle. Guests will often describe how the "blackness" of space in the telescope field of view seems to somehow shimmer or look spotted. This is actually noise in the signal from our eyes to our brain! Under very low light levels it can look as if the background (not just in the telescope) is a dim version of static on television, rather than appearing completely black. The neurons that are connected to the cells on the retina can "fire," indicating a detection of light without any light actually entering the eye. This level of noise is very low, but easily seen, and perhaps startlingly so, when you are in the dark.

Infinite Points of Light

When The Stars Grow Dim

Consider this. It is never truly dark in this city. On an overcast night, the clouds become a rosy-orange canopy, illuminated by the millions of city lights below. On a clear night, there is no spangling array of stars hanging in the sky; instead, there's an orange haze, through which only a few stars can be seen.
This is not some strange vision of another world or of a time when the stars grow dim. It's a reality in the present day. According to the Royal Astronomical Society (RAS), "about 99% of people in the USA and western Europe never see a truly dark starry sky from where they live." The cause is a relatively recent phenomenon known as "light pollution."

At first, it's difficult to see how light, a form of energy that we depend on, can act as a pollutant. But there is an excess of artificial light in the atmosphere around urban areas — so much that it's blocking our view of the stars. According to the RAS, "humans are enveloping the world in a luminous fog."

The Challenge for Astronomers

It's easy to understand how this is of concern to astronomers, both amateur and professional. Trying to see a fainter star from an urban area is like trying to spot a candle's light amidst a blaze of fireworks.
"Skyglow" is the term astronomers use to describe a night sky illuminated by light pollution. It is obviously very pronounced around urban areas; in huge cities like New York, the sky is super-saturated with light. Interestingly though, skyglow is not always associated with cities. Sometimes it can be found in rural areas where local sources, such as gaudily lit shopping malls, cast light skyward.

Astronomers use terms such as "pristine" and "dark-sky" to describe sites where the view of the heavens is crystal clear. As urban areas develop, such views are becoming a rarity on Earth, a source of great frustration for stargazers. One astronomer, John E. Bortle, has developed a scale for evaluating levels of skyglow. He explains his scale in this *Sky & Telescope* magazine article. Some astronomers see light pollution as tantamount to an assault on the sky. Astronomer Fred Schaaf writes in *Sky & Telescope* magazine, "Would we allow billboards on all the walls of the Grand Canyon? The sky is a thing even more awesome, diverse, mysterious, promising of knowledge, and beautiful than a geologic wonder." The sentiments Schaaf expresses point to the wider issue of how light pollution will affect human culture as a whole. Will losing sight of the universe affect us in deeper ways than we realize?

Light Pollution and Human Culture

Dr. Malcolm Smith, former director of the Cerro Tololo Inter-American Observatory in Chile, believes that human culture will be affected: "Bit by bit, without realizing, we are all losing a direct connection with the universe. Not only that, light pollution is one of the most rapidly increasing alterations to the natural environment created by humans. Human culture, from philosophy to religion, from art to literature and science, has always developed in relationship with the night sky and the universe beyond. Are we going to deprive future generations of that unnecessarily?"

It may sound dramatic, but it's difficult to argue with the figures — or the images of Earth's illuminated surface. An RAS study found that night never really comes to areas where half the world's population lives. The International Dark-Sky Association reported in a small study it conducted that the majority of respondents — all 16- and 17-year-olds — had never looked up at the stars before.

The situation is forecasted to deteriorate rather than improve. The Light Pollution Science and Technology Institute in Italy calculates that light pollution is increasing at a rate of 5-10% per year in the US and Europe.
Is there a solution, or is light pollution inevitable in our increasingly urbanized — and electrified — world?

Turning Out the Lights

Urbanization is a trend that will continue to grow, but even so, light pollution can be reduced. The greatest problem is that so much light is directed at the sky when there's actually no need for it. It's the ground, not the sky, that we need to illuminate. As light pollution activists see it, this is an easy problem to correct; all that's needed is better lighting design.
For light pollution activists, the biggest offenders are often commercial outlets such as car dealership lots, gas stations, and shopping malls. Activists also refer to the decorative exterior lights used on buildings (such as hotels) as "vanity lights" — an excessive and wasteful kind of lighting that should be outlawed.

The International Dark Sky Association campaigns for darker skies. They point out the importance of using properly designed light fixtures that focus light where it's needed, don't consume excessive amounts of energy, and minimize glare. The benefits, they say, will not only include a better view of the sky, but also a more comfortable nighttime environment and increased safety for drivers and pedestrians.

Another benefit would be vast energy savings. In casting so much light to the sky, where it effectively goes unused, there is considerable waste of electrical energy. The International Dark Sky Association puts the cost to the United States at $1 billion per year. As valuable energy is drained from power plants, this gives rise to further pollution: burning fossil fuels releases polluting gases into the atmosphere.

According to the Royal Astronomical Society, thousands of millions of dollars of energy "are tossed uselessly upwards into the sky each year — instead of down onto the ground which we want to illuminate." The authors of the *First World Atlas of Artificial Night Sky Brightness* found that Venice, Italy, produced a modest amount of skyglow relative to its population. This was attributed to the "romantic" kind of lighting prevalent in the city.

So, perhaps restoring our view of the night sky is simply a matter of turning down the lights, much as they do in Venice. And wouldn't that be ironic — turning down the lights in order to see things more clearly?

CHAPTER 6
NATURAL HISTORY: GEOLOGY OF KITT PEAK

A number of geological processes over a period of millions of years shaped Kitt Peak as we see it today.

Some of those are..

Volcanism

Plate Tectonics

Uplift

Faulting

Erosion

Volcanism-The process by which magma and its associated gasses rise into the crust and are extruded onto the earth's surface and into the atmosphere. **Volcano–** A vent in the surface of the earth through which magma and associated gasses and ash erupt.

Plate Tectonics– a theory of global tectonics in which the lithosphere is divided into a number of plates whose pattern of movement interacts with one another at their boundaries, causing seismic and tectonic activity along these boundaries.

Uplift– Mountain forming

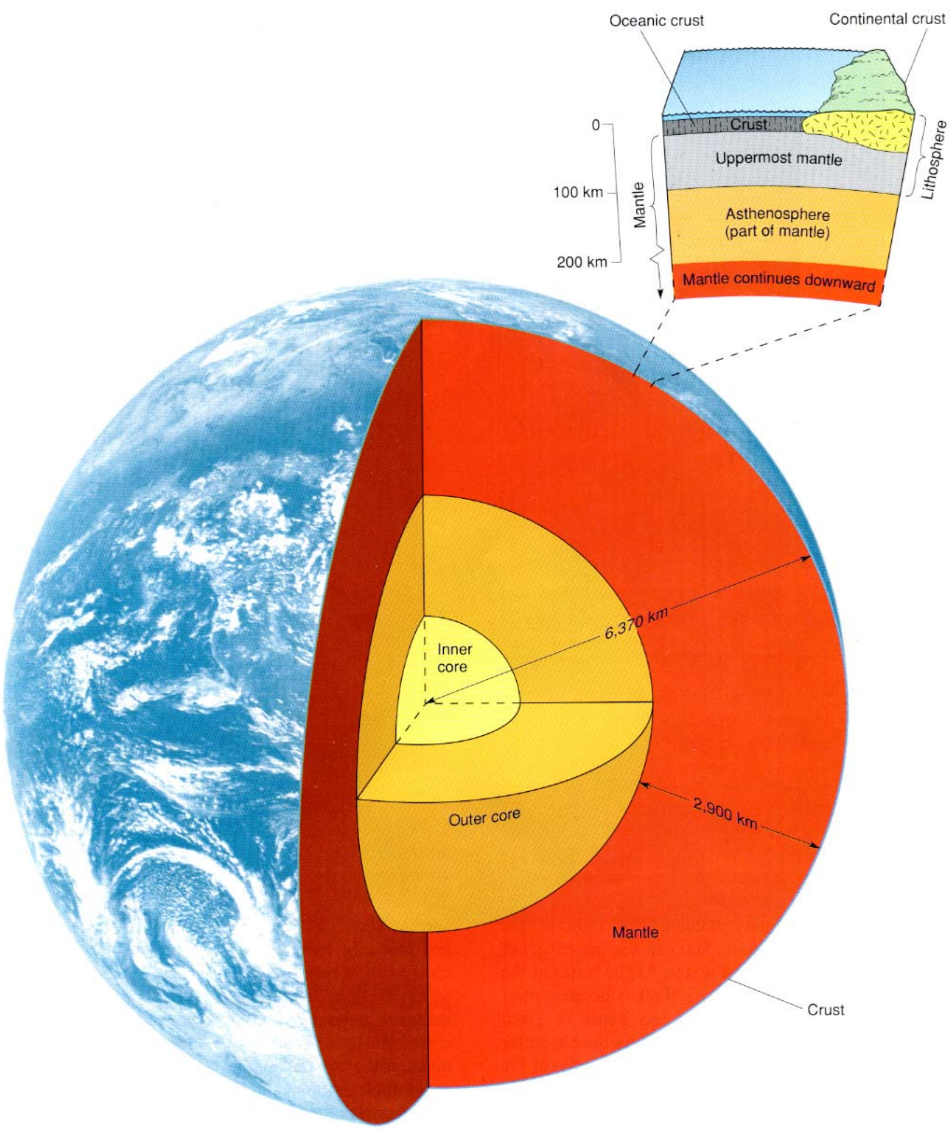
Faulting– The process of fracturing and displacement that produces a fault.

Erosion– The wearing away of soil and rock by weathering, mass wasting (gravity), and the action of streams, glaciers, waves, wind, and underground water.

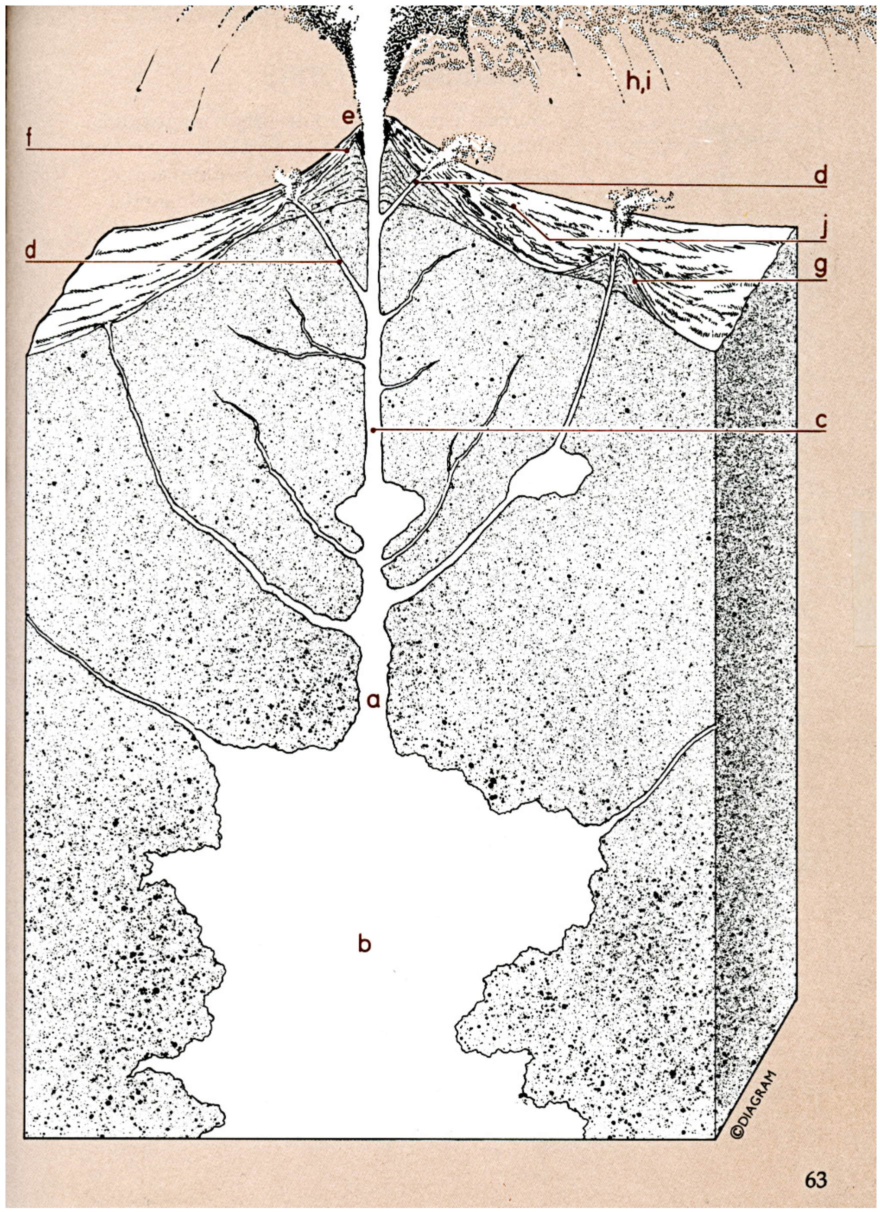
Earth's Cross section—see diagram

Volcano Cross Section—see diagram

Cross Section of the Earth

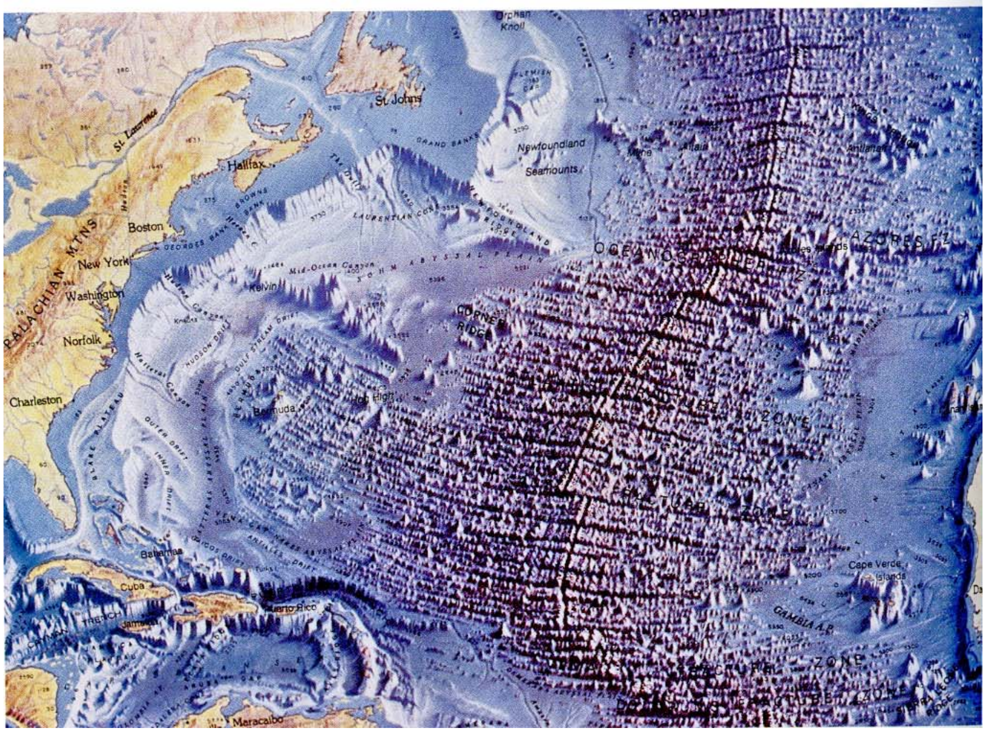


Cross Section of a Volcano

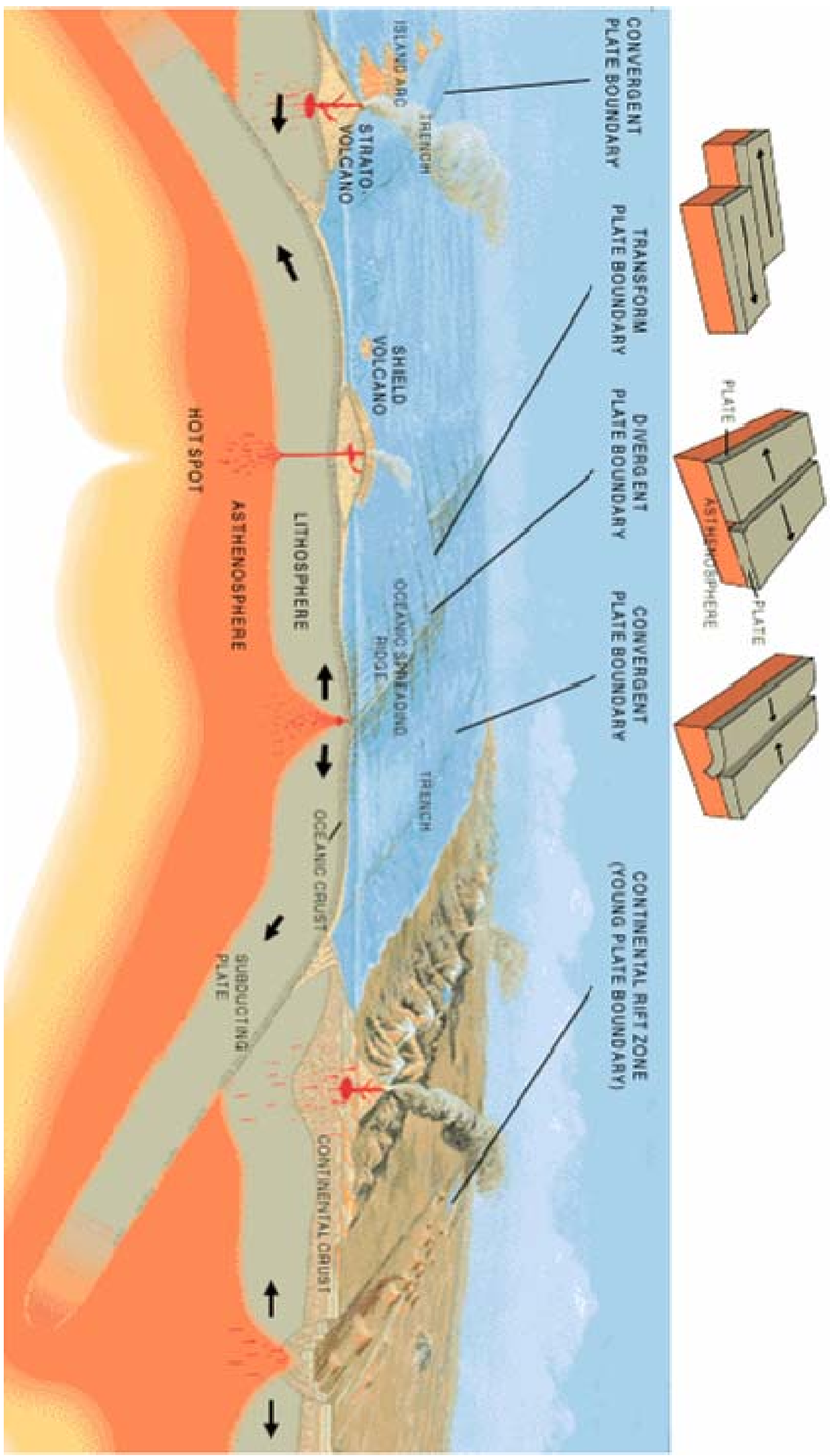


Ocean Topographical Map
Plate Boundaries

B



Typical Example of a Plate Boundary



Geologic Time Scale

EON	ERA	PERIOD		EPOCH	TIME SPAN
Phanerozoic	Cenozoic	Quaternary		Holocene	11,000yrs - today
				Pleistocene	1.8mya* - 11,000
		Tertiary	Neogene	Pliocene	5.3 - 1.8mya
				Miocene	23.7 - 5.3mya
			Paleogene	Oligocene	36.6 - 23.7mya
				Eocene	57.8 - 36.6mya
				Paleocene	66.4 - 57.8mya
	Mesozoic	Cretaceous			144 - 66.4 mya
		Jurassic			208 - 144 mya
		Triassic			245 - 208 mya
	Paleozoic	Permian			286 - 245 mya
		Carbon-iferous	Pennsylvanian		320 - 286mya
			Mississippian		360 - 320mya
		Devonian			408 - 360mya
		Silurian			438 - 408mya
		Ordovician			505 - 438mya
		Cambrian			570 - 505 mya
Proterozoic	**Grouped as Precambrian**				2500 - 570 mya
Archean					3800 - 2500 mya
Hadean					4500 - 3800 mya

(mya = million years ago)

* The age of the beginning of the Pleistocene is in dispute

Geology of Kitt Peak (Quinlan Mountains)

Kitt Peak gets it name from a relative of a surveyor. The Mountain range Kitt Peak is on is called the Quinlan Mountains, named after James Quinlan who use to run a stage stop at the base of the mountain.

Historical Perspective:

In order to understand Kitt Peak Geology, a brief chronology of the formation of the Sonoran Desert must first be given.

HEADLINES: Earth & Life Originate!
Precambrian Era.

About 1,700 million years ago, a great mountain range formed in this region, and then eroded completely away, back down to sea level. Eroded rocks of those mountains' roots (mainly schist and granite) form the "basement" for much of the Sonoran Desert.

HEADLINES: Sea life conquers converging continents
Paleozoic Era.

From about 550 to 250 million years ago, inland seas came and went many times, leaving behind thick layers of sediments. These hardened into limestone, sandstone, and shale, covering the Precambrian basement and resembling the layers of the Grand Canyon.

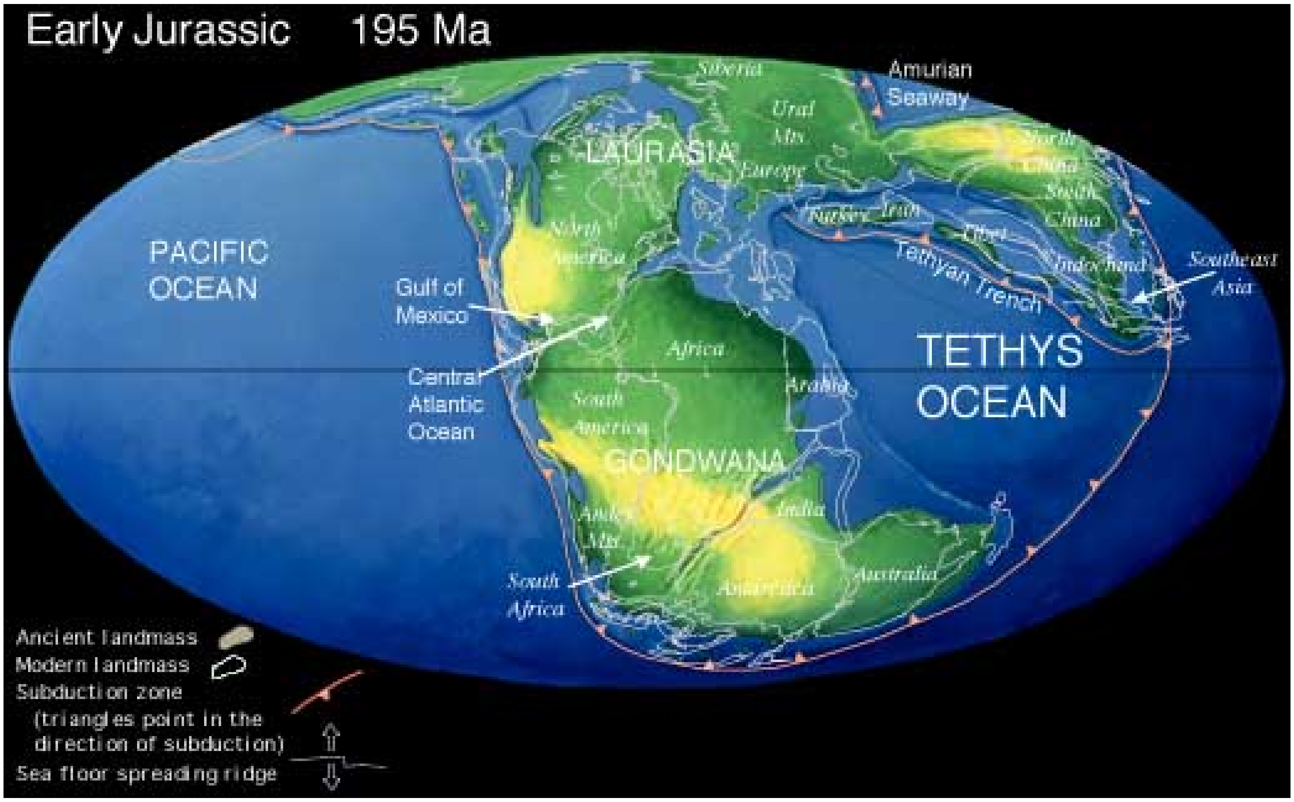
HEADLINES: Dinosaurs come Go: Pangaea Breaks Apart
Mesozoic Era.

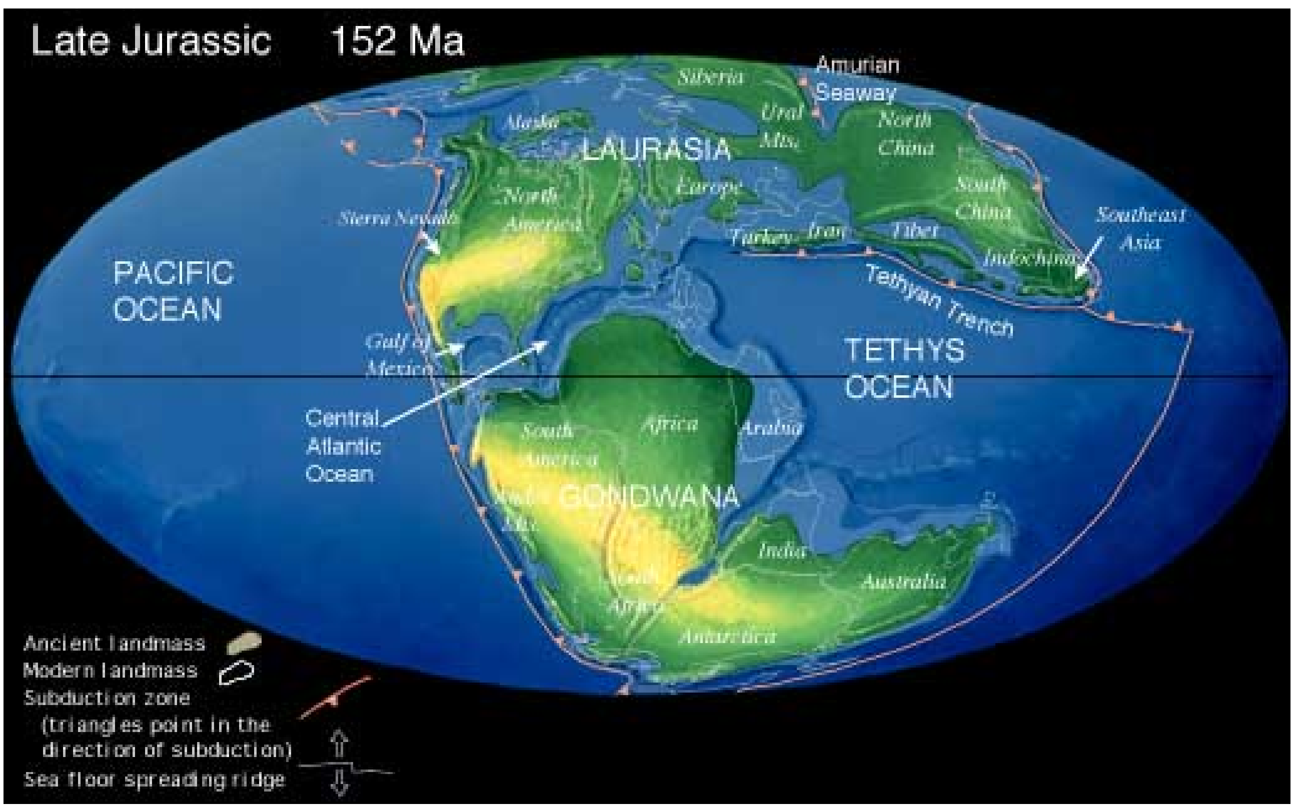
From 250 to 65 million years ago, the flat-lying layers of Paleozoic rocks were disrupted by increasing intense igneous (molten rocks) activity. Volcanoes erupted at the surface while large bodies of granite formed deep beneath the surface.

HEADLINES: Rockies peak out: Humans manage despite chill
Cenozoic Era.

This era dates from 65 million years ago to present time. A renewal of igneous activity occurred in the middle of this era. Afterward, the Basin and Range disturbance gave our landscape its distinctive character during the period from about eight to 15 million years ago.

Kitt Peak Formed 165 Million Years ago





Formation of the Quinlan Mountains

Basin and Range

Basin and Range mountain structure are characterized as long, thin, rugged ranges isolated between broad , wide valleys. The blocks of rock that form the mountain ranges and the valley floors are bounded by faults, cracks in the earth along which some rock movement has taken place. In the Basin and Range province, the rock movement on either side of the faults has lifted the mountains up and dropped the valleys down. The lower valley floor has filled in with debris from the eroding mountains approx. 5,000 feet thick of gravel, sand and clay which make up our current desert aquifers. Basin and Range Faulting occurred 12 to 6 million years ago. See diagram. Basin and Range disturbance was the culmination of several events that have taken place over the last 40 million years. (See diagram)

Kitt Peak Rock

The rock making up Kitt Peak was formed some 165 million years ago during the Jurassic Period. *Kitt Peak Granodiorite* is an excellent example of an *igneous* rock that crystallized from a melt. The course grain size of the granodiorite indicates slow cooling, deep within the Earth. Subsequent uplift and erosion have exposed this deep-seated material at the surface.

The most conspicuous feature of the Kitt Peak Granodiorite is its large, tabular crystals of an aluminum-rich mineral called *potassium feldspar*; these are typically lavender-or pinkish gray in color. Three additional minerals can be readily identified: small, blocky, black crystals of *hornblende*; shiny black flakes of *biotite* (a mica); and tiny, wedge-shaped, honey-colored crystals of *sphene*. Hornblende and biotite are common magnesium-iron silicate minerals: sphene is the most common mineral of the element titanium.

- Kitt Peak is part of a three mountain range system. Coyote Mts., to the east and the Baboquivari's to the south.

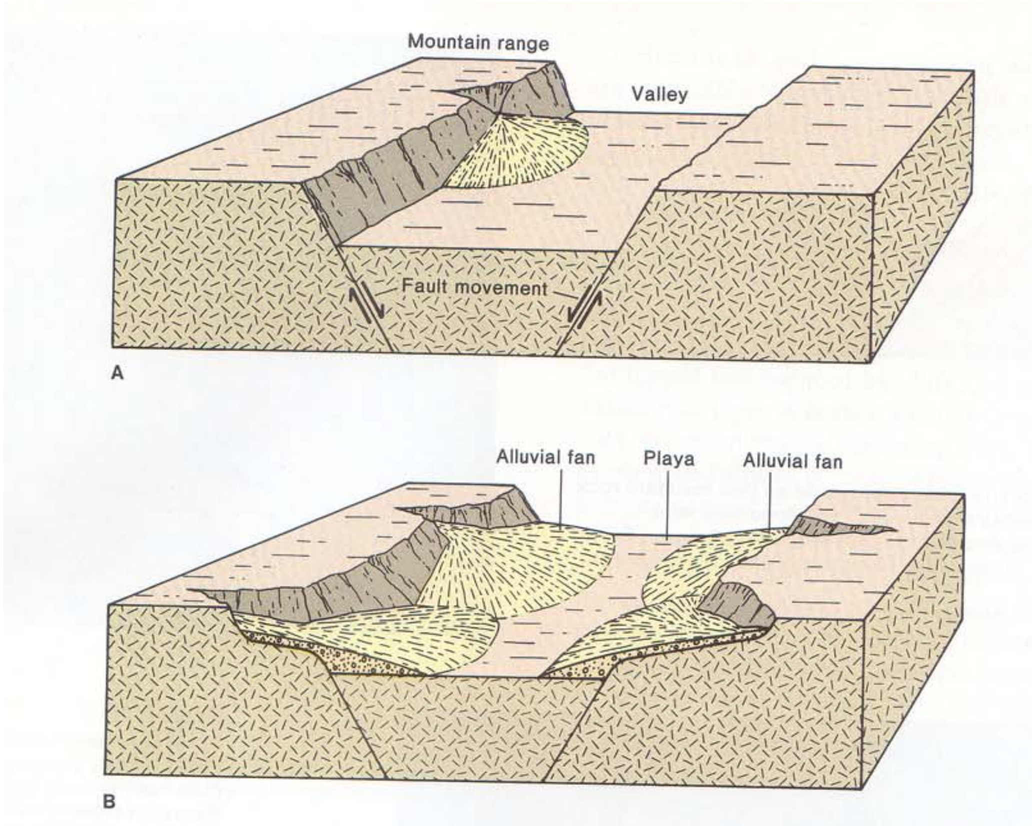
- Baboquivari extends 40 miles south to Pozo Verde mountain in Mexico

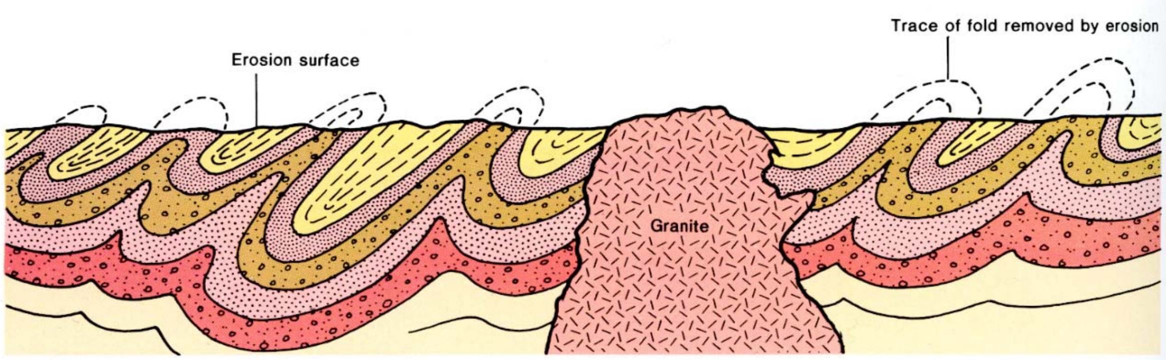
- Most of the Baboquivari/Qunin chain is made up of Grantic, volcanic and sedimentary rocks ranging in age from 190 to 145 million years.

- Coyote Mountains is a small rugged range to the east of Kitt Peak. Composed mostly of a light colored tertiary granite 58 million years old.

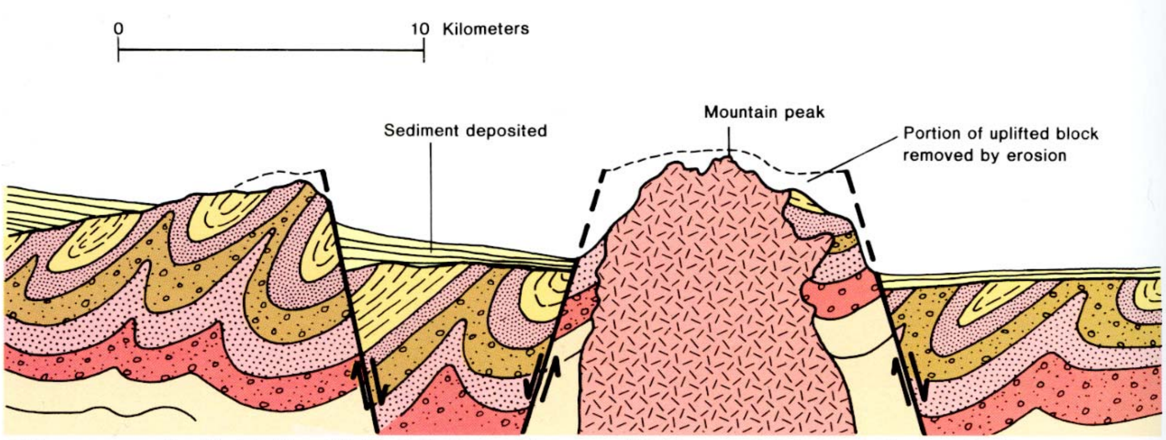
- Baboquivari Peak is 7,734 feet above sea level and is made of red alkali rich granite approx 145 million years old.

- Granite is in a constant state of mechanical and chemical disintegration. At the base of the 4 M the granite there contains iron– and copper sulfide minerals which react to produce sulfuric acid which speeds up the decomposition of the other mineral in the rock.

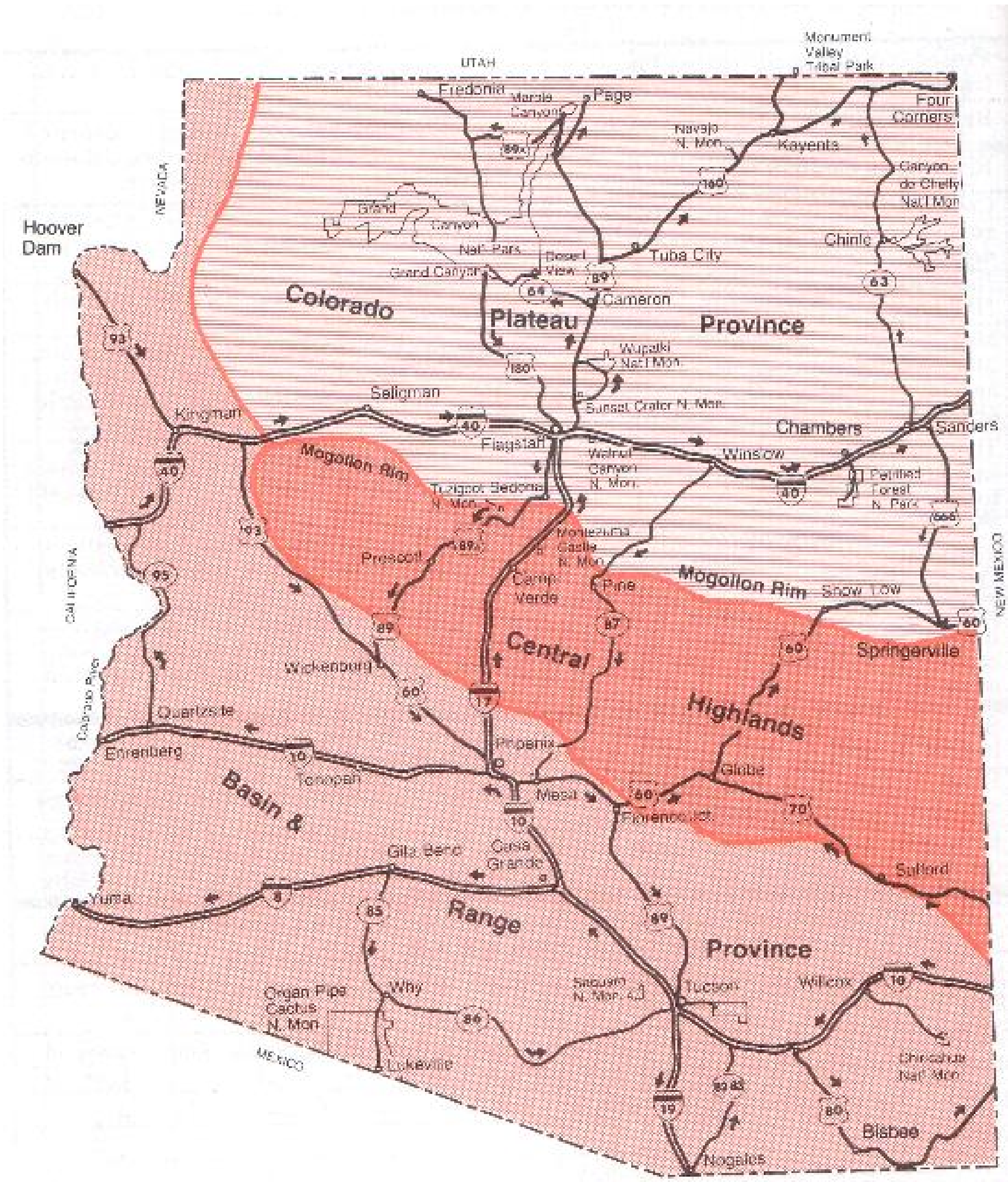




A Before block faulting. Folding and intrusion of a pluton during an orogeny has been followed by a period of erosion.

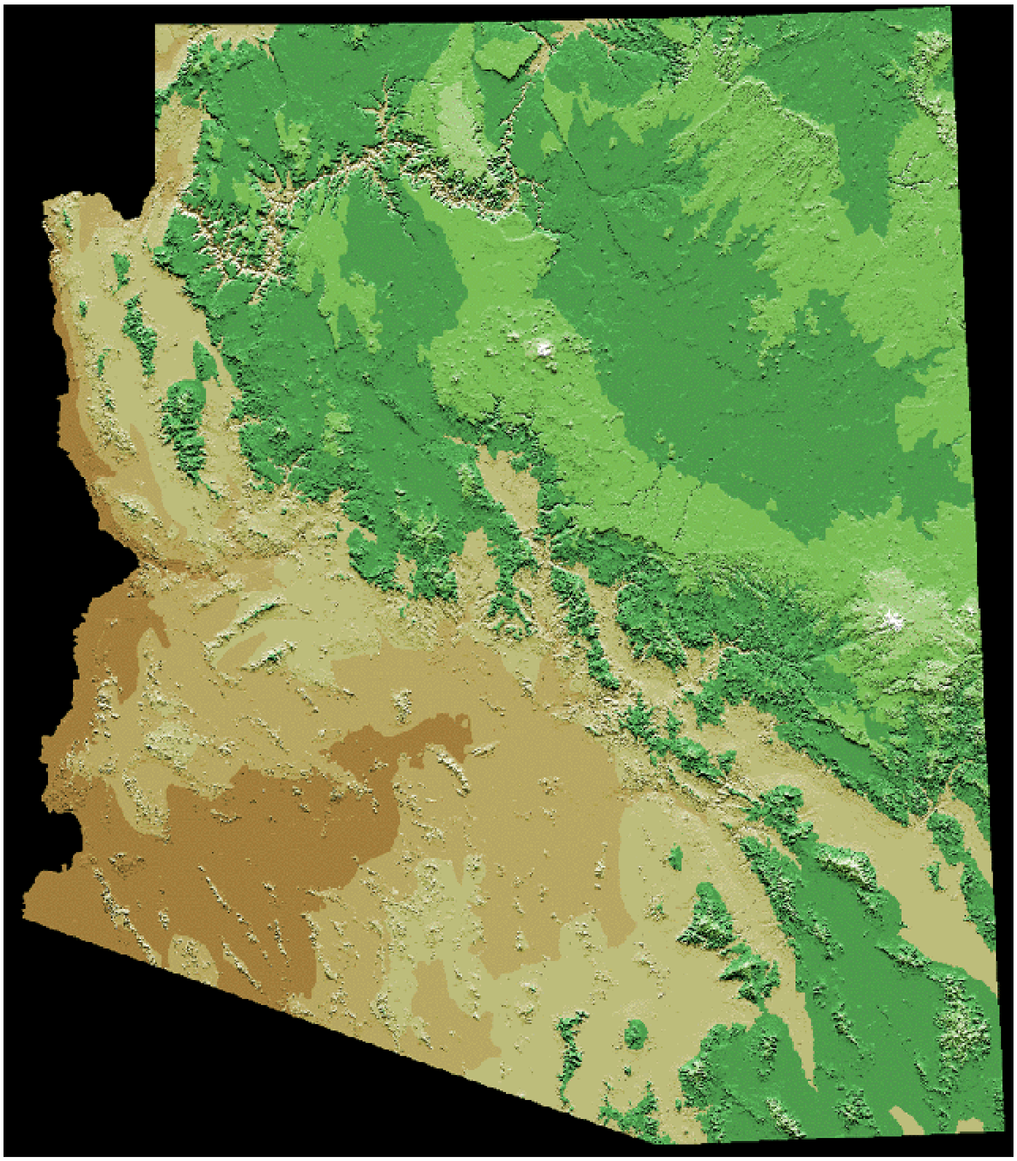


B The same area after block-faulting. Tilted fault-block mountain range on left. Range to right is bounded by normal faults.

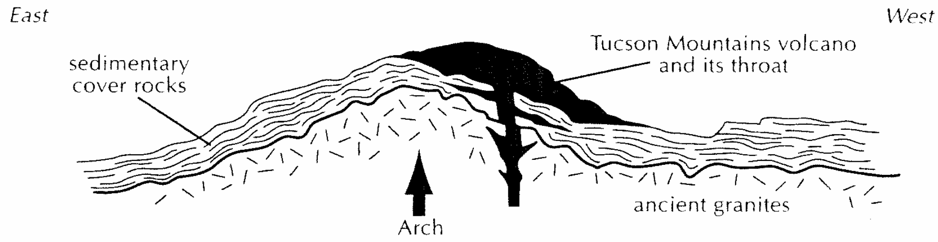


UTAH
NEVADA
CALIFORNIA
NEW MEXICO
MEXICO
Hoover Dam
Monument Valley Tribal Park
Fredonia
Page
Navajo N. Mon.
Kayenta
Four Corners
Canyon de Chelly Nat'l Mon
Chinle
Grand Canyon Nat'l Park
Grand Canyon
Desert View
Tuba City
Cameron
Colorado
Plateau
Province
Wupatki Nat'l Mon.
Sunset Crater N. Mon.
Seligman
Kingman
Flagstaff
Chambers
Sanders
Winslow
Walnut Canyon N. Mon.
Petrified Forest N. Park
Mogollon Rim
Sedona
Prescott
Montezuma Castle N. Mon.
Camp Verde
Pine
Mogollon Rim
Springerville
Central
Highlands
Wickenburg
Quartzsite
Ehrenberg
Tonopah
Phoenix
Mesa
Globe
Florence Jct.
Basin &
Range
Province
Casa Grande
Gila Bend
Yuma
Safford
Why
Organ Pipe Cactus N. Mon
Lukeville
Tucson
Willcox
Chiricahua Nat'l Mon.
Bisbee
Nogales

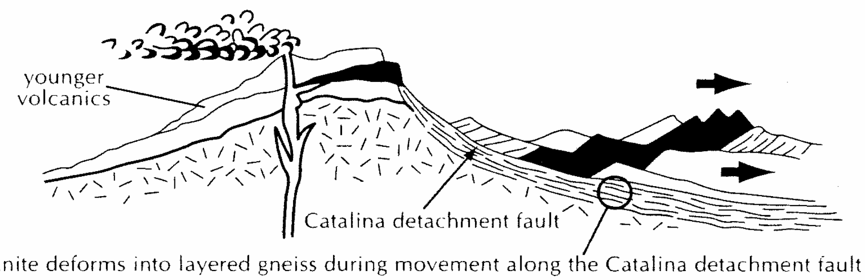
Kitt Peak Basin & Range Mountain Formation



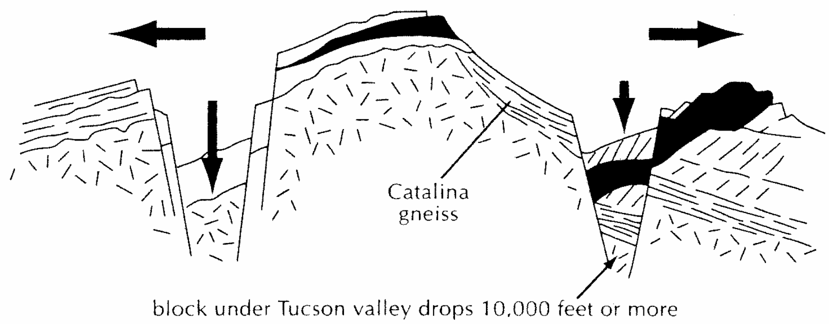
A. Heating from Beneath, Arching (30 million years ago)



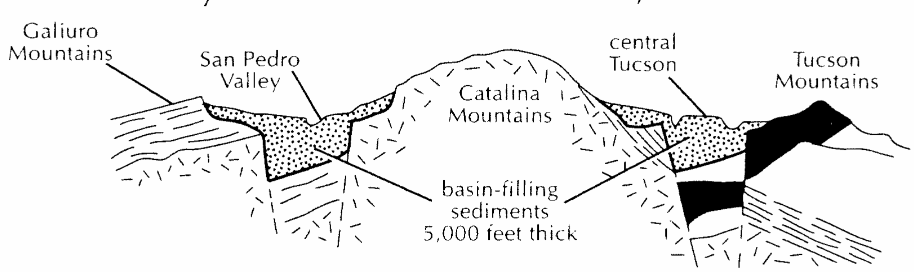
B. Volcanism and Detachment Fault (25 million years ago)



C. Basin and Range Faulting (12 to 6 million years ago)

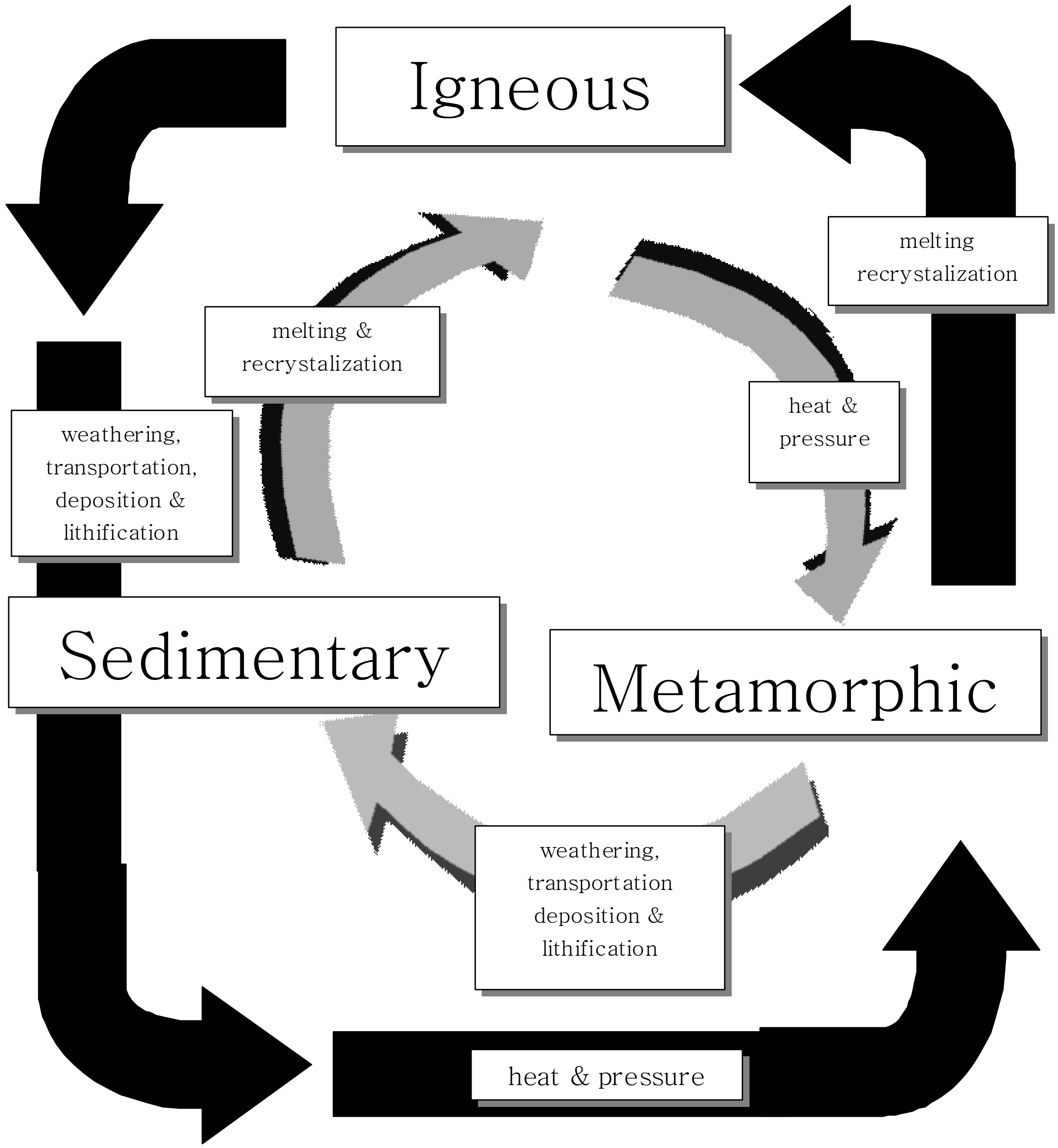


D. Today–Basins Filled with Sand, Gravel and Clay



Geologic cross-sections through the Tucson area illustrating
the recent geologic history of the Sonoran Desert

the rock cycle



WEATHERING/EROSION

Breakdown of rock by chemical and physical processed:

Some examples include:

Water-freezing & Thawing
Plant roots and lichens
Wind
Rain
Glaciers

Misc Kitt Peak Facts

State route 386 was opened in 1963 it is maintained by the State of Arizona. It has a constant grade of 6%.

The Donut found in from of the visitor center is the concrete double of the 4 Meter mirror. The blank mimics the dimensions and weight of the 4 –M mirror.

The mosaic in front of the Visitor center was created by Juan Baz of Mexico City– it represents 2 distinct Mayan aspects of Ancient Astronomy.

The catchments basins on the mountain holds 10 million gallons of water.

The Scientific Process Simplified

- Develop a Hypothesis
- Conduct the Experiment
- Analyze the Data
- Compare the results
- Modify your Hypothesis or Determine a Conclusion

CHAPTER 7
NATURAL HISTORY: MOUNTAIN/DESERT ECOLOGY

The Sonoran Desert

Kitt Peak lies in the Sonoran Desert. A concise non-technical definition of a desert is "a place where water is severely limiting to life most of the time." The Sonoran Desert covers over 100,000 square miles in two countries. It is home to approximately 130 species of mammals, 500 kinds of birds, 20 amphibians, 100 or so reptiles, 30 native fish and around 3,500 native species of plants. The Sonoran Desert is one of the four desert types found in North America.

- The Sonoran Desert is around 10,000 year old. Fairy young desert.
- It receives approx. 10" of rain annually in the lower elevations
- It has a biseasonal pattern of rainfall with gentle winter rains and more active summer rains.
- There are actually five seasons in the Sonoran desert.

  SPRING- February to April

  FORESUMMER or DRY SUMMER– May and June

  SUMMER MONSOON– July to Mid-September

  FALL– Mid-September to November

  WINTER– December and January

The Sonoran Desert region has a great variety of both habitats and species, ranging from extremely hot, arid desert to semiarid tropical forest to frigid subalpine meadows.

The Kitt Peak environment can be classified as warm-temperate forest and woodlands zone. This region is classified by the type of vegetation found.

Biomes

Biomes are a entire community of living organisms in a single major ecological region.

All of the world's biomes occur in the Sonoran Desert region.

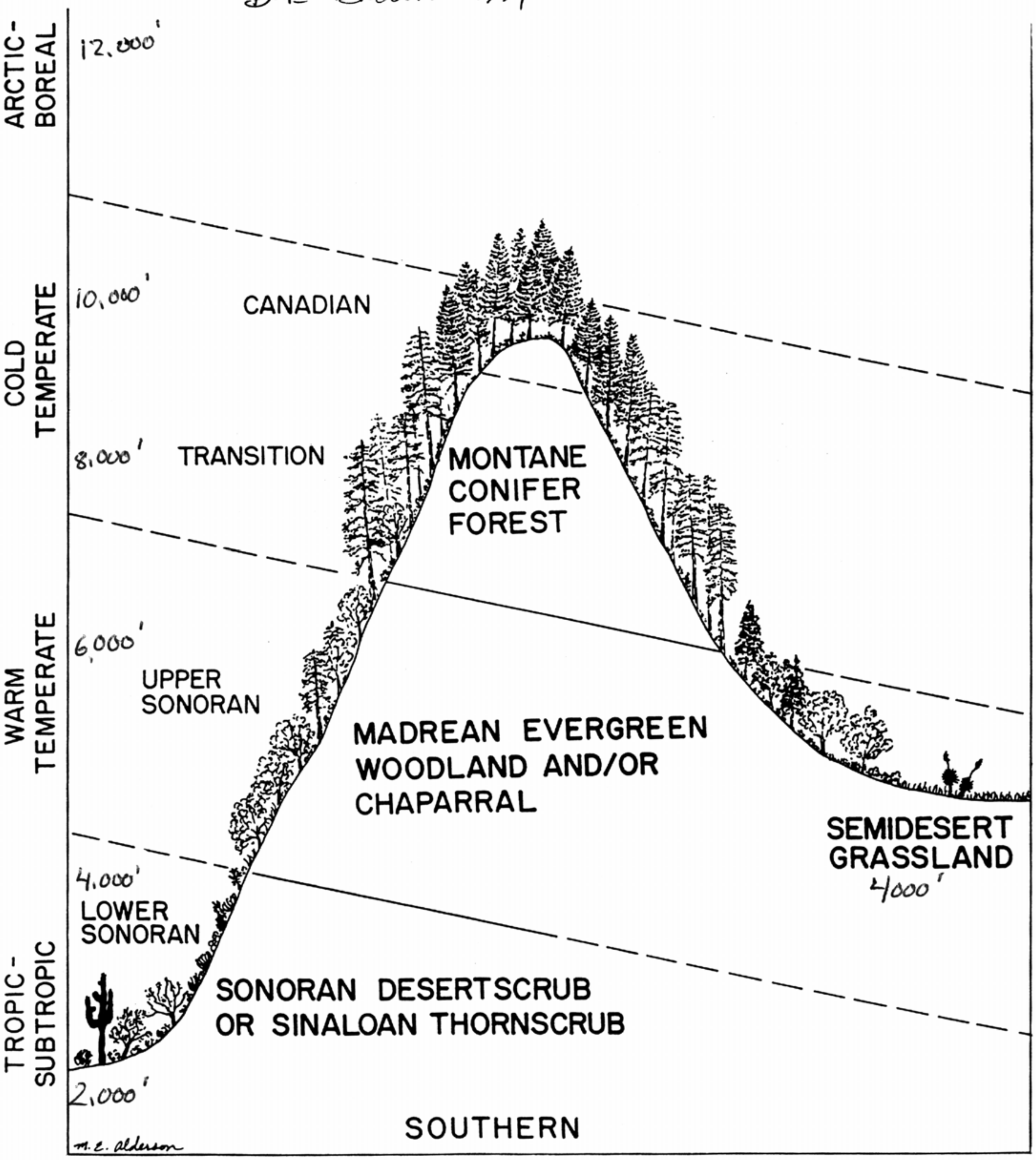
Biotic Communities

Plants and animals living and interacting with each other and with their physical environment in a given locality.

Kitt Peak Mountain Top is classified as the biotic community called warm-temperate forest and woodland zone.

This biotic community is classified by the type of vegetation found.

Biotic Communities
S.W. U.S. & NW. Mex.
D.E. Brown 1994



"Sky Islands"

The Sonoran Desert lies within the Basin and Range physiographic province. This province is characterized by parallel mountain ranges and basins, all tending approximately north to south. The basins are filled up to several miles deep with debris eroded from the surrounding mountain ranges.

Isolated mountain ranges "popping up" from the "oceans" of the hot lower deserts are sometimes called "Sky Islands" due to the analogy of islands in the desert. Kitt Peak is one of these "Sky Islands" rising some 6,875 feet from the desert floor.

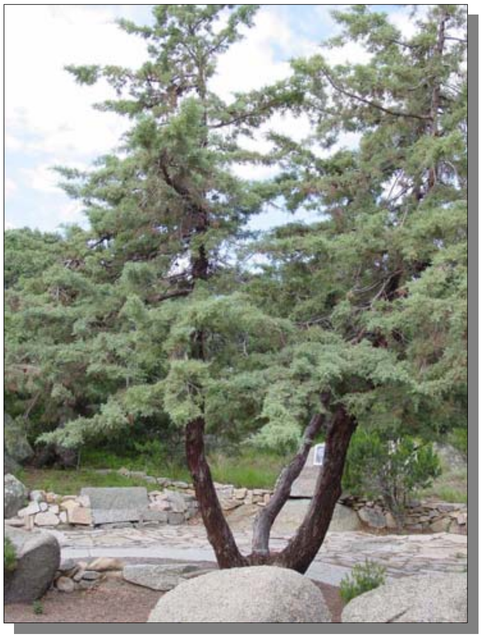
Sky Islands are unique for a number of reasons. The first being greater habitat diversity for living organisms thus a greater diversity of plant and animal life. These mountains are also biologically isolated because they are separated by a barriers (hot deserts), thus one can find a variety of unique plants and animals that evolve there.

Limiting Factors for "Sky Island" Life

- Elevation specific (air temp drops by 3.5 degrees for every 1,000 feet)
- Availability of water- the higher you go in elevation the damper the climate. As moist, ascending air cools and forms clouds that produce rain. This is the reasons for changes in plant life.
- Microclimates
- Competition between other species
- Basic necessities for life, food, shelter, water, etc

Kitt Peak receives on average around 18" of precipitation (rain & snow) per year

COMMON TREES & SHRUBS ON KITT PEAK



Smooth-Bark Arizona Cypress *(Cupressus glabra)*

Location:

On right side of the road, on the way to the cafeteria and admin office.

Arizona White Oak *(Quercus arizonica)*

Location:

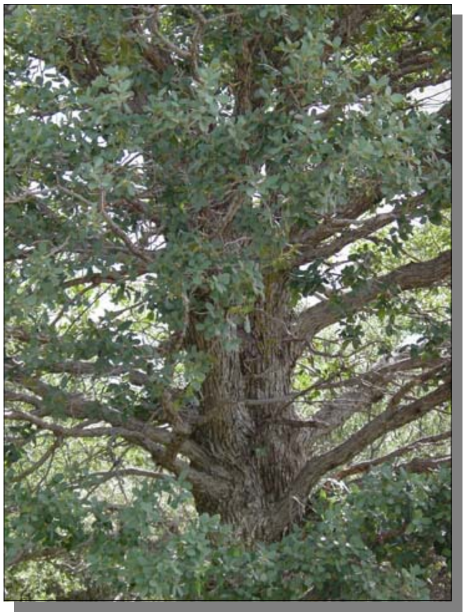
Throughout the mountain, in front of the Visitor Center and road in median.

Bear Grass *(Nolina microcarpa)*

Not a true grass. Native Americans use the plant for basket making. Actually in the Agave Family. The bud stalks are sometimes used for food.

Location:
Next to the refreshment stand at the Visitor Center and on the way to the admin offices.

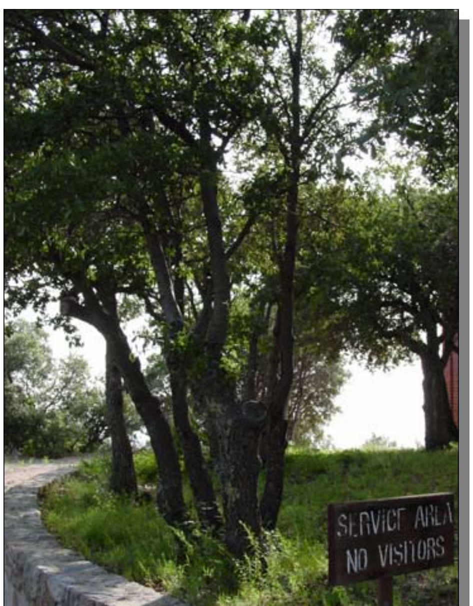
Mexican Blue Oak (*Quercus oblongifolia*)



Location:

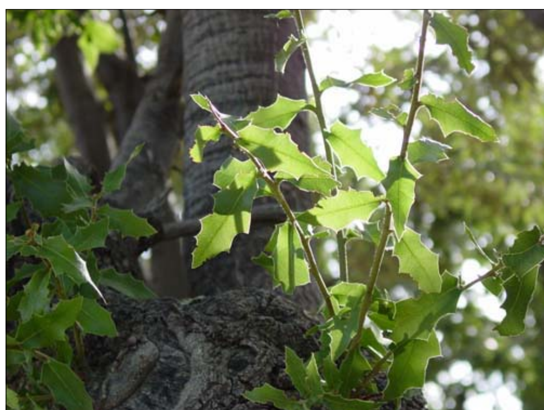
Left side of the road on the way to the solar telescope.

Emmory Oak (Quercus emoryi)



Location:

In front of the Visitor Center.



Common names, Black Oak, blackjack oak. The Emmory Oak acorns are an important food source for both wildlife and people.

Pointleaf Manzanita *(Arctostaphylos pungens)*

Location:

On the way to the solar, on the right side of the road.

Common names, bearberry, manzanilla, Mexican manzanita. Native Americans use the berries on this plant for food and making a beverage. Jelly is made from unripened fruits. Manzanita is Spanish for "little apple". Local Native Americans call Kitt Peak "Ioligam", which meant mountain of the manzanita wood.

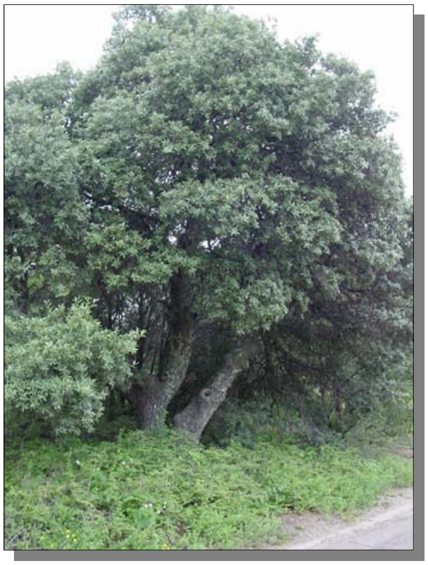
Mexican Pinon Pine *(Pinus cembroides)*

Slow grower can reach an age of over 350 years.Pinyon nuts are used for food for both people and wildlife. Pinyon pitch is used as a jewelry cement and for waterproofing baskets.

Location:

Throughout the mountain, by the bench and drinking fountain at the Visitor Center

Silver Leaf Oak *(Quercus hypoleucoides)*



Location:

In front of the Visitor Center. Large tree on the way to the Solar, on the left side of the road.

True Mountain Mahogany *(Cercocarpus montanus)*

Hardwood shrub browsed by livestock, bighorn sheep and deer. In the rose family. Navajo Indians use shrub to make red dye for wool.

Lichens

Found worldwide, lichens are characterized by three major types: flattened, crust-like types that grow tightly pressed against rock or bark: those that adhere less closely to the surface; and those that are branched and bush-like or hang from trees.

Colors vary greatly, depending on the acids produced by the fungus. They are an important factor in the breakdown of rock. The plant excretes organic acids which disintegrate rock, thus forming soil.

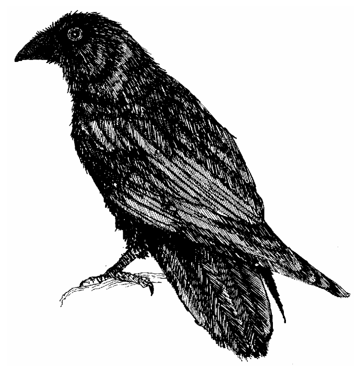
Lichens grow very slowly and a colony may live thousands of years. A small patch may be several hundred years old.

Lichens are actually two plants in one, and is an excellent example of *Mutualism* , where both organisms benefit. Lichens consist of both algae and fungi growing together in a close relationship. The algae makes its own food which it shares with the fungus. The fungus in turn provides the algae with water, minerals and support.

SOME COMMON BIRDS OF KITT PEAK

Common Raven

Found in a variety of different habitats from Mexico to Alaska. A very "intelligent" bird, it seems to apply reasoning in situations entirely new to it. Its "insight" behavior at least matches that of a dog. It is a general predator and opportunistic feeder. Related to the crow family.



Turkey Vulture

One of North America's largest birds of prey, the Turkey Vulture can be found in every state and into Canada and Mexico. It forages for carrion and or road kill. You can find Turkey Vultures in all the different elevations of Kitt Peak. They spend a lot of time riding the thermals looking for food.

Red-Tailed Hawk

Are the most common and widespread raptors in North America. They eat mainly rodents. Red-tailed Hawks in the Southwest usually have light under parts and lack a belly band. Look for the reddish colored tail while the bird is in flight.

Road Runner

Member of the cuckoo family the roadrunner is a very effective predator. They eat any animal small enough for it to kill and swallow. Hunts by walking briskly and running toward prey. The bird is able to jump straight up in the air when small birds or flying insects are overhead.

Photo by Marcus Martin

Photo by A. Wilson

Acorn Woodpecker

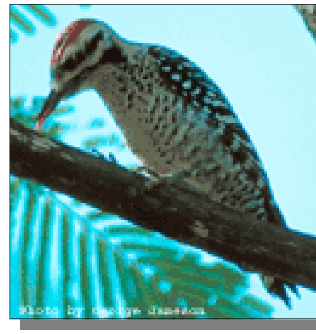
Found in oak-pine forests. The Acorn woodpecker harvests acorns and stores them tightly in individual holes so that squirrels cannot pry them out. Acorns seem to be emergency food; on mild winter days these birds have been observed eating flying insects.

Golden Eagles

A very large brown raptor with a golden neck and head. Golden Eagles soar with their wings slightly raised. The young show white patches in the wings and a white base to the black tail. They prey upon rabbits, small mammals, and carrion.

Ladder-Backed Woodpecker

Black and white barred backs with a face that has black and white stripes. The eat insects living under the bark of trees. They have strong heads and neck muscles which enable them to absorb the shock of looking for food.



Mexican Jay

Similar to the Scrub Jay. Nesting territories of Mexican Jays are small and adjacent; when a predator approaches, an entire colony moves to the defense, scolding loudly from a safe distance. Acorns are their staple diet but they also eat insects, and rob eggs and young from nests.

COMMON MAMMALS of KITT PEAK

Coatimundi

Related to the raccoon, Coatis are curious-looking animals with a long nose, facial mask and a long tail.

Their ideal habitat is mountain canyons with oaks and sycamores.

Coatis have a varied diet. They are omnivores and eat a lot of grubs, beetles and other invertebrates along with fruits, and nuts, rodents, eggs, snakes, lizards, and carrion (dead animals). They dig in the soil, turning over large rocks in search of food.

They are very social animals living in bands of up to 20 or even 30 or more. The band consist of females and their young. Adult males are not welcome except during mating season. Females usually have 4 to 6 babies.

Coatis are diurnal, mostly active in the morning or later afternoon. At night they spend time in trees or caves.

When foraging they travel with their 2 foot tail standing straight up.

Mountain Lions

Shy and elusive, mountain lions are masters of camouflage.

They live in rugged, heavily vegetated areas and areas which support a good prey population.

Mountain Lions are carnivores and feed on deer, javelina, bighorn sheep, jack rabbits, porcupines, squirrels and many other small mammals.

Mountain Lions are stalkers, they use the element of surprise to catch their prey. They are powerful predators.

Mountain lions breed at about 2 or 3 years of age. Females give birth to 3 or 4 spotted kittens and remain with the mother for up to a year and a half.

Mountain lions are solitary animals except when a breeding pair stays together for a few days

Bob Cats

They live in rugged, heavily vegetated areas and areas which support a good prey populations.

Bobcats are carnivores and eat mainly jack rabbits, cottontails, birds, snakes, and rodents.

Bobcat’s have to hunt everyday for their food. Bobcats are stalkers, they use the element of surprise to catch their prey.

Bobcats are solitary animals only coming together to mate.

Females give birth to 2 or 3 kittens.

The bobcat’s home range is a few square miles, however if prey is scarce the cat may wander extensively in search of food.

Coues Deer

Arizona's other deer, the Coues, is a subspecies of the white-tailed deer. Coues deer are most common in Arizona's southeastern mountains. They are most abundant in areas of predictable summer precipitation. They prefer woodlands of chaparral, oak, and pine, with interspersed clearings.

In contrast to a mule deer's equally branching antlers, those of the whitetail consist of a number of tines arising from a main beam which curves forward. Mature bucks generally have three to four tines per side.

Coat color is grayish-brown salt-and-pepper with white underparts; the face is marked with white 'halos' around the eyes and a white band across the muzzle. The most distinguishing characteristic of the whitetail is its long, broad tail. The tail is all white on the underside, gray to reddish-black on top, and is often carried high as an alarm signal.

The Coues deer is much smaller than most of its eastern cousins. Bucks stand just over 30 inches at the shoulder and rarely weigh over 100 pounds. Does average 65 pounds.

A doe's first pregnancy usually results in a single fawn; thereafter she may bear twins. Fawn drop coincides with the new growth following the summer rains.

The Coues has a flagging white tail and a more natural run. In Arizona's southern mountain ranges whitetails are generally found at higher elevations than are mule deer.

Skunks

Spotted Skunk, Striped skunk, Hooded skunk, Hog-nosed Skunk are all found on or around Kitt Peak.

Skunks live in a variety of habitats from riparian canyons and wooded areas to Arizona uplands and suburbs. They prefer thick, brushy areas. The spotted skunk is common in rocky, riparian canyons, while the hog-nose is found the middle to higher elevations.

Skunks are nocturnal animals and are related to the weasel.

Their form of defense is an odoriferous spray which stops most predators in their tracks. With the exception of the Great Horned Owl which has almost no sense of smell.

Skunks can spray up to 12' and 5 or 6 times.

Skunks sometimes build their own dens, but also share the dens of other animals such as pack rats, or live in brush piles, hollow logs, underneath buildings or in rock piles.

Skunks eat insects, lizards, bird eggs, mice and fruit.

Black Bear

Rarely seen on Kitt Peak

Range, Black Bears are found from above the Artic Circle southward to central Mexico. Found in the mountains of Southern AZ.

Lack bears are true omnivores, feeding on a variety of fruits, vegetable matter, carrion, small rodents, insects, and other animal material.

An average of two young are born in winter during hibernation. The weight at birth is less than 1 pound. Females usually have litters every other year.

The black bear hibernates, but its method of hibernation differs in that it does not urinate or defecate, its body temperature remains relatively high, and females give birth during hibernation.

A very large mammal between 100 to 300 pounds or more. The fur varies in color from blonde to black.

Ring-tailed Cat

Raccoon Family

Omnivores will feed on animal matter like spiders, scorpions, grasshoppers, crickets, mice, squirrels, rabbits lizards, juniper, hackberries and mistletoe.

Lives in arid rocky regions and woodland areas.

Mostly nocturnal and will sleep during the day in a den. When it wakes in the dusk it will groom itself before it goes off to forage for food.

Predators include the great horned owl and bobcat.

Ring-tailed cats are generally a greyish brown color, with between 14-16 alternating bands of black and fawn on their tail. They have white markings above and below each eye and on their muzzle, with black markings coming from the inside corner of each eye leading down the side of the muzzle.

COMMOM REPTILES and AMPHIBIANS/Insects OF KITT PEAK

Black-tailed Rattlesnake

This snake is an ecological generalist and can be found in a wide variety of habitats. It can occur in mountainous terrain with rocky outcrops or wooded canyons. It is most frequently found near rocky habitats. It is also found within arroyos in the desert. It is found from sea level to around 9600 feet (3150 m). It appears to avoids grasslands and barren desert.

This species is known to be a mild-mannered snake which will quickly retreat if encountered in the field. Through radiotelemetry studies, it has been found that females will protect their new born babies until their first shed. Maternal care is thought to be rare in snakes, although this may simply represent our lack of understanding of these animal's secretive behavior.

The Black-tailed Rattlesnake will eat a wide variety of vertebrate animals including pocket mice, woodrats, squirrels, rabbits, chipmunks, and birds. Juveniles are also known to eat lizards.

Mountain Spiny Lizard

Size is 2 1/4 to 3 7/8 inches in length. Males have a black collar lined with white and are further distinguished from females by the rich blue patched on the throat and belly. The scales on the back are reflective bronze with black edges, presenting a lace-like appearance. Females are more drably colored.

Feeds on insects and spiders. The mountain spiny lizard is a dietary staple of the mountain rattlesnake. Predatory birds also eat them.

Sonoran Desert Toad

The largest native toad in the United States. Adults can reach over 8 in. in length, and weigh as much as 900 grams. The Sonoran Desert Toad is olive brown to dark green, and is covered with a soft, leathery skin. Usually has one large, white, or light colored wart behind each jaw hinge, directly below the large parotoid gland. Hind legs are covered with numerous large warts.

Found in a variety of arid communities primarily in the Sonoran Desert, often near permanent water sources.

A voracious predator that may be able to consume anything it can overcome, including other amphibians. Strongly nocturnal, this species will breed independently of rainfall, however the largest breeding aggregations usually take place after strong downpours in July and August. The advertisement call of this toad is a short, low volume honk, and is not indicative of its size. Although large, this species is hardly clumsy. If disturbed, it can flee using a fast unamphibian-like gallop, that surprises most observers.

The most infamous toad of the Southwest. Gained notoriety with the discovery of the hallucinogenic properties of its parotoid glands. Reports of humans dying from these properties are erroneous, however pets have become ill.

Red-Spotted Toad

This is a small squat, rusty-colored toad with reddish spots all over its body. They have round glands instead of the elliptical of most toads.

Mainly prefers rocky canyons and foothills. Found in wet areas.

They eat mostly insects and is eaten by snakes and other small predators.

Canyon Tree Frog

A small, well camouflaged frog, and colored from grey to dusky brown to olive.

Exclusively riparian, usually found in rocky streams. The canyon tree frog is found at all elevations where habitat exists.

Canyon Tree Frogs eat insects, and is eaten by snakes, predatory mammals and birds.

This frog is capable of changing its skin tone to more closely blend into the rocks upon which it lives.

Gopher Snake

A large, heavy-bodied snake, it can reach lengths over 8 feet. Colors vary on different snakes of the same species.

When disturbed, the gopher snake hisses, flattens its head and shakes it tail.

This behavior, along with the markings, causes many people to mistake it for a rattlesnake

Gopher snakes live in a variety of habitats and elevations.

It feeds on rodents, rabbits, birds, eggs, and occasionally lizards. It kills prey by constriction.

Sonoran Lyre Snake

This snake reaches 18 to 48 inches in length. It has a narrow neck, and a large head with a lyre-shaped marking. It is light brown with darker brown markings. The eyes have vertical pupils.

It may be found in rocky areas in all elevations.

Lyre snakes are known to prey on lizards, mice, birds, other snakes and bats which they catch in roosts. Prey is caught by venom and constriction.

Mildly venomous, this rear-fanged species is not dangerous to humans.

Western Coral Snake

Often confused with the Kingsnake, the coral snake is smaller in size and has a different banding pattern. Coral snakes are venomous which is similar to the Cobra.

Arizona Mountain Kingsnake

This snake has smooth scales and is marked from head to tail with alternating bands of red, black, and white.

Arizona Mountain Kingsnakes live in mountain environments.

They feed upon lizards, snakes, and rodents which it kills by constriction. It is fed upon by a variety of predators including birds of prey.

Kingsnakes are non venomous. They are often confused with the coral snake which usually lives in lower elevations. One way to distinguish the difference between the two species in the motto “red touch yellow, harmful fellow”, referring to its stripe pattern.

Night Snake

This is a small tan snake 12 to 16 inches in length with darker spots and elliptical pupils. The eyes are located near the top of the head; the pupils can be seen from above. It usually has two large dark blotches just behind the head.

They occur in a variety of habitats.

The night snake becomes active at twilight and nighttime. It feeds on lizards, small amphibians and small snakes.

The night snake is venomous but not dangerous to humans.

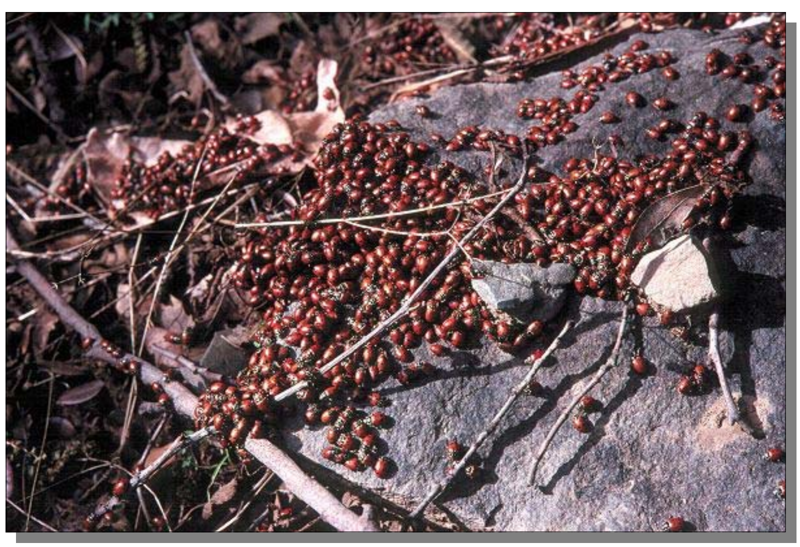
Lady Bugs

Found throughout the world the convergent ladybird beetle, occurs in the western US.

In summer, large numbers of adults can be found collected on the trunks of trees in the higher elevations.

Different species of ladybugs feed upon different species of insects.

The ladybug gives off a foul smelling liquid which seems to discourage predators.



CHAPTER 8
THE TOHONO O'ODHAM INDIANS

by Linda Mueller

The Tohono O'odham, formally know as the Papago, have lived in the Sonoran Desert for thousands of years. The desert, although thought by many to be unrelenting in its severe weather conditions, supplied the Papago with their sustenance for many years. In the 1980's the Papago officially changed their name from Papago, which means "Bean Eaters," to Tohono O'odham, which means "desert people" in their language (Tohono O'odham). The name change reflects the tribe's desire to retain its identity and traditions.

The Tohono O'odham belong to the Piman branch of the Uto-Aztecan Linguistic family and are closely related to the Pima tribe. The tribe's territory extended west and southwest across the desert Papagueria and on into Sonora, Mexico. Piman peoples are probably descendents of the prehistoric Hohokam Culture (Tohono O'odham Literature).

In 1694, Father Kino became the first white man to visit the Tohono O'odham. He found a very large population numbering in the thousands. Census figures in 1937 listed 6,305 members of the Papago nation (Tohono O'odham Literature).

The Tohono O'odham live on the second largest reservation in the United States. It stretches for over a hundred miles along the Mexico/Arizona border and extends far into Southern Arizona (Tohono O'odham). The Tohono O'odham reservation lies in the arid Sonoran Desert, characterized by wide valleys, plains and jutting mountain ranges which rise to nearly 8,000 feet. One of the peaks, Baboquivari, 7,730 feet high, home of the ancient god I'itoi, is considered sacred by the O'odham (Lifelines). The reservation consists of four separate reservation lands, Tohono O'odham, Gila Bend, San Xavier, and Florence Village. The combined reservation covers 2,854,881 acres, which is about the size of the state of Connecticut. The largest section is the Tohono O'odham Reservation, which stretches 90 miles across Pima County, contains 2,773,357 acres and also extends across the Mexican border.

The O'odham language is still very much alive. There are seven different dialects spoken among them, which are centuries old. One individual who has been instrumental in the rebirth of the Tohono O'odham language is Ofelia Zepeda. She is a member of the Tohono O'odham tribe and holds a doctorate in linguistics from the University of Arizona. Dr. Zepeda authored the first grammar of the Tohono O'odham language, *A Papago Grammar* (University of Arizona Press, 1983). She has also been a contributor to the development of Native American literature, a poet in her own right, and is an associate professor in the Department of Linguistics at the University of Arizona in Tucson.

Most of the O'odham who had lived in what is now Mexico have moved north across the U.S./Mexican border into the United States, but a small remnant population still lives in Sonora, Mexico. Although most of the O'odham are Catholics, since many of their ancestors were converted during the missionary activities in the late 17th century, they have also maintained their traditional beliefs.

Historically, The Tohono O'odham farmed non-irrigation crops and relied extensively on wild crops such as saguaro fruit, mesquite bean pods and cholla cactus flower buds. They also hunted America's only native swine, the peccary or javelina (Desert Peoples). To farm, they took advantage of heavy flooding that followed the summer thunderstorms in the desert. They erected brush weirs (embankments) to redirect the flood waters to channels designed to irrigate their crops. They set up temporary encampments and villages around the wash channels and the petroglyphs and pictographs etched into rock are still visible today. They also learned to hunt the dry washes for beans from the mesquite and ironwood bushes, paloverde and acacia. They harvested the fruit of the saguaro and organ-pipe cactus, stems of the agaves, and sand food.

At the beginning of the 20th century there were still meandering streams that were fed by the washes which descended down the mountains in a system of interconnecting channels. These channels flowed year-round in some parts of southern Arizona. There were dense areas of cottonwood and sycamores along the banks and forests of mesquite covered the flood plain. Now only a few of the streams remain active.

The Tohono O'odham continued to rely on the infrequent summer rains and their unique irrigation systems to water their crops until the coming of groundwater pumps in the 1930's. The coming of cities and urban expanse interrupted the Papago's way of life. The wash channels were interrupted, altered, or lined with concrete, which changed forever the Papago's irrigation system and their way of life. The surface runoff was forced into fewer channels, which overloaded their capacity and created severe flooding and erosion. Continued urban expansion has forced deeper and deeper wells using water stored in the underground aquifers for millions of years. Use of the aquifer resources lowered the water table, adversely impacting the available surface water and ultimately changing the Tohono O'Odham's existence in the desert. Few contemporary O'odham grow traditional crops and most live in either permanent villages watered by deep wells or in cities surrounding their reservation.

The loss of the traditional way of life was not only the loss of water to grow crops but also the loss the plants that for centuries had provided the Papago health. When the O'odham gave up their agrarian heritage they replaced wild foods with processed. Soon they developed the health problems that occur in our modern culture, obesity, high blood pressure and one of the highest rates of Type II diabetes in the world.

In the 1980's the nutrition program Meals for Millions cam to help supplement their diets with homegrown vegetables like broccoli and tomatoes. The O'odham accepted their help but began asking for the foods they remembered from childhood: yellow-fleshed watermelon, striped sunflowers, fast-ripening corn, the fiery chilies, called chiltepines, all varieties that had all but died out when commercially processed foods became available. The hunt for the past lifestyle began. Surrounding reservations were contacted and small pockets of cultivable wild plants were rediscovered in forgotten canyons and valleys. Native Seeds/SEARCH (Southwest Endangered Arid Lands Resources Clearinghouse) was born.

Baboquivari – To the Tohono O'odham people, baqoquivari Peak (Waw Kiwulik, which means "narrow about the middle" in O'odham language) is a sacred mountain, a home to I'itoi, (pronounced EE-E-TOY), who brought the People into this world. According to the legend (there are many different versions) after creating fire, deer, humans, vultures and a lot of mischeif, I'itoi retired to the center of the earth in a cave complex whose entrance is below the sacred peak. O'odham basket weavers depict this maze as a spiral with a man inside it; the picture is an allegory of man searching for the deeper meaning of life.

The baboquivari is sometimes referred as "the navel of the world" or "center of the Universe".

Baboquivari is 7,830 feet high and is made of solid granite thrust up through the Earth's crust more than 100 million years ago.

Facts about the Tohono O'odham Nation

The Tohono O'odham (T.O.) Nation is comparable in size to the state of Connecticut. Its four non-contiguous segments total more than 2.8 million acres at an elevation of 2,674 feet.

The lands of the Nation are located within the Sonoran Desert in south central Arizona. The largest community, Sells functions as the Nation's capitol.

Of the four land bases, the largest contains more than 2.7 million acres. Boundaries begin south of Casa Grande and encompass parts of Pinal and Pima Counties before continuing south into Mexico.

San Xavier is the second largest land base, and contains 71, 095 acres just south of the City of Tucson. The smaller parcels include the 10,409-acre San Lucy District, located near the city of Gila Bend, ad the 20-acre Florence Village , which is located near the city of Florence.

As of December, 2000, the population was reported at nearly 24,000 people.

Kitt Peak National Observatory

Tohono O'odham

Kitt Peak is located on the Tohono O'odham Reservation, stretching 90 miles across the Sonoran Desert southwest of Tucson. This has been the ancestral homeland of the Tohono O'odham Nation for over 2,000 years.

Tohono O'odham means "Desert People" in the O'odham language, and many Native Americans refer to themselves as "the People" in their own language.
To the O'odham Nation, Kitt Peak is a sacred mountain although not as sacred as Baboquivari Peak, the large granite dome found to the south. The O'odham regard Baboquivari to be the navel of the world, the opening in the Earth from which they emerged after the world flood.

When the tribal council of the Tohono O'odham Nation was first approached with the plan to build an observatory on their sacred mountain, they refused. However, a solution was achieved. Like many Native Americans, the Tohono O'odham have a significant relationship with the stars because they figure prominently in their religions and ancient stories. The astronomers invited the tribal council to visit Steward Observatory at the University of Arizona and observe the stars through the 36-inch telescope. The impressed tribal council granted permission for the observatory to be built on the mountain and remain "as long as only astronomy research was conducted."

Hand Woven Tohono O'odham Baskets

The meeting of the Schuk Toak district council with AURA representatives on March 5th, 1958, authorizing the lease of Kitt Peak to the National Science Foundation.

In a signed agreement, the O'odham Nation received a variety of concessions. Kitt Peak National Observatory continues to benefit the Tohono O'odham nation today. The top 200 acres of the mountain are leased by the National Science Foundation and all electricity is purchased from the tribal utility authority. The observatory provides many jobs, and sales of arts and crafts in the Kitt Peak National Observatory Visitor Center, such as the baskets shown here, support O'odham traditional culture.

The flag of the Tohono O'odham reflects their reservation's topography and flora in a simple but effective way. The main element of the flag is the bicolor of yellow over purple (sample flag provided by "The Turquoise Turtle", Sells, AZ). In these colors one can see the sun breaking over the mountains (a distant purple). Crossing this field on the obverse only is a red staff of leadership from which hang eleven feathers. These feathers stand for the eleven districts into which the huge reservation is divided.

With this new order a change has occurred in the flag. The tribal name has been added to the canton emphasizing the identity of the flag. In Sells, as one drives through the heart of the town, the popularity of the flag is quite evident. It can be seen at the tribal schoolhouse, the Tribal HQ, the tribal courthouse and several other buildings. This new design appeared only in the year 2000. Prior to that time, a streamer bearing the tribe's name flew above the flag keeping one of the simplest and most dramatic native flags in the United States uncluttered with writing.

CHAPTER 9
INTERPRETATION 101

What is Science Interpretation?

As a Kitt Peak Visitor Center (KPVC) staff member or a volunteer you will have many opportunities to interpret throughout your day. Interpretation takes on many different forms. For example, you will have the opportunity to interpret the 4-meter or the Solar Telescope. You may also find moments to interpret when you are showing someone how an exhibit works or simply giving directions. But what does it really mean to interpret?

in·ter·pret (in tûr` prit), *v.t.* **1.** to give or provide the meaning of; explain; explicate; elucidate. **2.** to translate. **3.** to bring out the meaning of by performance or execution. –*v.i.* **4.** To explain something; give an explanation.

Scientific interpretation involves translating technical language into terms and ideas that people who aren't scientists can readily understand (Ham 1992).

Interpretation is an educational activity, which aims to reveal meanings and relationships through the use of original objects, by firsthand experience, and by illustrative media, rather than simply to communicate factual information. Interpretation is the revelation of a larger truth that lies behind any statement of fact (Tilden 1967).

[Interpretation is] a kind of educational enterprise where the concern is that which is interesting to the visitor, or that which can be made interesting to the visitor, not that which someone else thinks the visitor ought to know, regardless of how interesting it is (Makruski 1978).

Interpretation conveys the meaning of something through exposition or explanation. Information is the knowledge derived from study, experience or instruction (Knudson 1999).

Interpretation uses information as raw material, then works it and presents it in ways that entice, interest, and make clear what the information means to people (Tilden 1967).

Be sure to keep KPVC overall mission in mind: ***To inspire a sense of wonder and awe of the Universe through interactive exhibits and programs. To inform and educate public visitors about basic and current themes in astronomy, the scientific process, and how KPNO/NOAO plays a major role in US astronomical research.***

Take a minute to think about how effective interpretation of the telescopes fits into KPVC mission. Remember that our number one priority is to inspire a sense of wonder and awe of the Universe —not to overload them with facts. Have fun with science!

GOAL of INTERPRETATION: To communicate a message

Serve Organizational Objectives by educating the public

Interpretation serves the visitor!

Interpret the site and involve the visitor

Serve as a link between the visitor and the site. Must have knowledge of their area.

Visitors are on their time and are seeking inspiration and recreation. Interpretative programs should involve the senses, challenge the intellect, and touch the emotions. They should entertain as well as inform

Foundations:

Enos Mills (1870-1922) - Father of interpretation. Started out as a nature guide, naturalist, interpreter, and author of 15 books about nature. Father of the Rocky Mt. National Park, founder of the trail school, and trainer of interpreters. He laid the foundation for modern interpretation.

Freeman Tilden (1883-1980) - newspaper reporter, playwright, non-fiction author, and keen observer/commentator. He traveled for years observing ranger walks, talks and other ways park professionals communicate with visitors. He wrote a book in 1957 called *Interpreting Our Heritage*. Tilden captured the essence of a profession. He spent the next 20 years teaching the art and science of interpretation. He developed the six principals of interpretation.

Among Tilden's Principles of Interpretation:

- Any interpretation that does not somehow relate what is being displayed or described to something within the personality or experience of the visitor will be sterile.

- Information, as such, is not interpretation. Interpretation is revelation based upon information. But they are entirely different things. However, all interpretation includes information.

- Interpretation is an art, which combines many arts, whether the materials presented are scientific, historical, or architectural.

- The chief aim of interpretation is not instruction, but provocation.

- Interpretation addressed to children (say, up to the age of twelve) should not be a dilution of the presentation to adults, but should follow a fundamentally different approach. To be at its best, it will require a separate program.

How does Interpretation Differ from Formal Instruction?

KPVC is not your ordinary classroom. Visitors can walk through our "classroom," stop where they want, play games, and really use their senses to experience the exhibits. As interpreters/teachers we are not required to quiz our visitors to test comprehension and we can *always* center our "lessons" around what the visitors are most interested in. Alternately, in a traditional classroom teachers can:

Assign background reading

Expect students to take notes

Follow through with additional material at a later date

Expect undivided attention

Teach in a setting without any distractions

Obviously, we cannot hold the same expectations for visitors at KPVC that a teacher can hold of his/her class. The major difference between these scenarios is that students in a classroom are a *captive audience* and at KPNO we are often dealing with *noncaptive audiences*.

Is there one way to interpret?

Absolutely not! Your interpreting style is a personal thing, which is molded by your personality and what feels comfortable to you, not by any list of communication "rules" or standard techniques. As you are developing your interpretive style remember:

- No style is inherently more effective or better than any other style.

- Pay attention to what others are doing and learn from their example, both good and bad. But keep in mind that their successes may not fit your style, and that what failed for them may work well for you. Likewise, don't be discouraged if a borrowed technique doesn't work well for you.

The best style is the one you feel most comfortable with. It's your unique approach to communication, one that fits your personality, skill base and attitude. Your style is an approach that will develop and change over time—as you do.

Differences Between Captive and Noncaptive Audiences

Captive Audiences

Involuntary audience
Time commitment is fixed
External rewards important
Must pay attention
Will accept a formal, academic approach
Will make an effort to pay attention, even if bored
Examples of motivations:
- Grades
- Diplomas
- Certificates
- Licenses
- Jobs/employment
- Money
- Advancement
- Success

Typical Settings
- Classrooms
- Job training courses
- Professional seminars
- Courses required for a license (e.g. driving)

Noncaptive Audiences

Voluntary audience
Have no time commitment
External rewards not important
Do not have to pay attention
Expect an informal atmosphere and a nonacademic approach
Will switch attention if bored
Examples of motivations
- Interest
- Fun
- Entertainment
- Self-enrichment
- A better life
- Passing time

Typical Settings
- Parks, museums, reserves, etc.
- Extension programs
- At home watching television
- Listening to radio, reading a magazine

Where at Kitt Peak can we interpret?

There are ample opportunities to interpret on Kitt Peak. It is important to get familiar with the physical spaces of the Visitor Center and telescope on the mountain. This means that you should know what kinds of props, visuals, and signage you will have available to you in each position. Here is a list of places to interpret, keep in mind, however, that this list is not complete—opportunities to interpret may arise when you are least expecting it!

All three telescopes
2.1 over look
4 meter deck
4 meter overlook
Petroglyph
In special exhibits
Solar View
4 Meter walk
Baboquivari Peak

When can we interpret?

There are scheduled times to interpret. Examples of these are the 10am to the solar telescope, 11:30 to the 2.1 and 1:30 to the 4 meter. You can also find time to interpret on the way to each of the telescopes.

Taking a bit of time to think about what and how you want to interpret will greatly improve your experience on the mountain. It is a good idea to get to know your audience, the Visitor Center, your information and your props *before* you present. This section will help guide you through the preparation process.

In between tour times when you are in the Visitor Center is another opportunity. Don't be afraid to walk up to people exploring the exhibits and initiate an interpretive conversation!

You can also interpret when you have been assigned cart time. The cart program is set up so that you can study a subject and then take a cart of props out on the floor to present to visitors. Taking a cart out is like giving an informal presentation and involves a great deal of interpretive skill.

Who are our visitors and what are they like?

A wide variety of visitors come to Kitt Peak. We attract school groups of all ages, tourists (foreign and not), families, babysitters with kids, members, adults, etc. A good interpreter will adjust his or her talk or demonstration to fit the crowd in front of them. It is important to keep in mind the differences between various age groups. See the appendix in this manual to understand general differences among age groups and how to appropriately interpret to each group.

What information is relevant to interpret?

Plan to talk about information that is relevant. Here, we will define information as relevant when it is both meaningful and personal. Meaningful information is said to have "context" since we often only understand information in the context of something else that we already know. You can do this using examples, analogies, and comparisons:

> **Examples:** Quickly refer to something that is like or in some way represents that kind of thing you are talking about. "Refer to the mirror display when explaining about aperture or the dimension cited in reference to a particular telescope such as the 4-meter.."

Analogies: Show many similarities to the thing you are talking about to some other thing that is highly familiar to the audience. "The light gathering ability of a telescope is analogous to the aperture of a bucket: the greater the diameter of the bucket, the more material that can be poured into it. Similarly, the greater the aperture of a telescope, the more light it gathers. Think of the telescope as a light bucket."

Comparisons: Show a few of the major similarities and/or differences between the thing you are talking about and something else which can be related to it. The result is that one or both of the objects become clearer in relation to the other. " In the Sun/Earth model above, the image and the model earth are proportionate in size. If the model of the earth was at a proportional distance for that scale, it would be 155 yards away. If the sun was a mere eight inches in diameter, Pluto would be a thousand yards away. And if we reduced the entire solar system to fit on a penny, the next nearest star would be across the parking lot, near the restrooms."

You can make the information you interpret personal to KPNO visitors by using self-referencing techniques, i.e. getting them to think about themselves and their own experiences as they are interacting with the exhibit. Use phrases like:

"Think of the last time you…"
"Have you ever…"
"How many of you have ever…"
"At one time or another most of us have…"

How should I structure my talk?

Try structuring your talk around several major objectives. Your objectives, clearly stated, should be exactly what you want your audience to gain from your interaction. For example, if you were interpreting the Solar Telescope, one objective might be to instill an understanding of why the telescope is shaped and positioned the way it is.

The ideas you present should follow a logical train of thought. Organizing information is like putting a piece of tape or velcro on every idea and fact that you're presenting, and then sticking each one to some larger idea. When we connect a piece of information to an idea (like a plot or major point) that we already have in our memory, the new information is easier to remember. Keep the number of main ideas you present manageable. Try presenting only 5 ideas or less. Research has shown that the sheer amount of information presented to an individual, as well as how it's organized, make a difference in how well one is able to sort it out and use it.

Limiting Your Ideas

If you limit yourself to no more than one second, which group is easier to count, A or B?

A	B
****	*********

How about this one, A or B?

A	B
********	++++****

Now try this one.

A	B
TWAFBIPHDIBMCIA	TWA FBI PHD IBM CIA

Obviously, if your ideas are kept to a reasonable number, are organized into categories, and relate to things your audience already knows your presentation will be easier to follow.

With this information about structure in mind, know that the structure of interpretation is highly variable. It can be long, short, thoroughly planned out, completely spontaneous, involve many people, or involve only one individual. It is a good idea to have an idea of how you want to structure your talk, but never be bound to it.

THEMATIC INTERPRETATION:

When Interpretation has a theme it has a message. Topic does not equal theme.

Topic of a presentation is simply its subject matter. The theme of the presentation is the specific message about the subject we want to communicate to the audience. In other words:

Topic = Subject Matter

Theme = Message

People remember themes not facts

Do I need a theme?

Keeping your ideas centered around one major theme helps people retain your "take home message." Your theme is different than the topic in that it is specific and conveys your central idea. When a good presentation (or informal talk) has been completed, the audience should be able to summarize it in one sentence. Development of a theme provides organizational structure and clarity of understanding. You should repeat your theme several times during your presentation, usually at the beginning, middle, and end. Once a theme has been decided, everything else usually falls into place. Themes should:

Be stated as short, simple, complete sentences.
Contain only one idea.
Reveal the overall purpose of the presentation.
Be interestingly worded (if possible using active verbs).

Examples of themes:

Topic: Electromagnetic Spectrum; **Theme:** Visible Light is just a small portion of the electromagnetic spectrum

Topic: Telescopes; **Theme:** There are different kinds of Telescopes

Topic: Sky Islands; **Theme:** Kitt Peak is know as a Sky Island

Topic: The Sun; **Theme:** The sun is our closest star

Feel free to develop multiple themes around one topic that you are familiar with.

How can I hook people?

A hook is something that initially grabs a visitor's attention and convinces them to stick around and hear what else you have to say. Your hook can be startling or humorous, a rhetorical question, or an apt quotation. Your goal is provocation, you need to grab the audience with your first words. Here are a few examples of hooks:

A costume

A prop (a piece of equipment, an artifact, etc.) that is either within the exhibit or separate

A provocative question or statement such as: "In about 4 billion years the sun is going to explode in a gigantic explosion taking most of the solar system with it"

"Hey! I've got a little quiz for you…"

"Did you know… The universe is made up of 90 % of dark matter a substance we know very little about?"

"What do you and the milky way have in common?"

Hooks are a great way to engage visitors who might otherwise be too shy to approach you with questions. A good hook will set the tone for a quality interaction.

Should I practice?

It always helps to practice your interpretation routine before you head out on the mountain. Find a method of practicing that makes you comfortable whether it's talking things through to yourself in a closed room, in front of a mirror, friend, or coworker. Don't be afraid to ask for feedback either, an objective friend can give you constructive criticism and explain to you what they did or did not understand—this can be very helpful! What ever you do, don't memorize your talk word for word!

How should I present myself?

An interpreter is more effective, communicates better, and appears more confident when he or she uses appropriate body language. Here are a few tips about how to present yourself:

Communicate through facial expressions.

Some experts claim that fifty-five percent of understanding from messages is from facial expressions, not words. Eyes are especially important. Look at your audience all the time and make friendly eye contact with everyone.

Communicate through posture.

Alert posture conveys confidence.

Avoid distracting mannerisms.

Convert nervousness to energy, but don't let nervousness spill out into distracting mannerisms. Guard against:

- weight shifting
- body rocking
- table leaning
- arm swinging
- hand hiding
- clothes fidgeting
- foott scuffling

Communicate through gestures.

Punctuate and describe points with your hands. Use natural, unexaggerated gestures. Good gestures do not call attention to themselves. They fit the content of the message and reinforce ideas.

Walk with purpose.

The way you walk conveys your image. Every movement should have a purpose; it should either draw the audience's attention or punctuate an important point.

How do I keep things lively and entertaining?

There are many ways to keep visitors engaged in what you are interpreting. Remember, one of our main goals is to make science fun. Here are a few simple ways to keep things entertaining:

Smile.

Remember: "When you are smiling, the whole world smiles with you." The energy of your audience will reflect your energy. If you present yourself as relaxed and having fun because you are smiling, you will start to see smiles amongst the visitors. Being too serious can create a formal atmosphere.

Use Active Verbs.

Verbs are power in any language. Don't take away their power by making them passive (e.g., "The bat pollinated the tree," not "The tree was pollinated by the bat.") Academic writing stresses passive verbs too much. Use powerful, active verb forms.

Show Cause-and-Effect.

People like to know what things cause other things to happen. Try to show direct relationships between causes and their effects. (e.g., "Watch what happens when you put a piece of ice on your forehead in front of the infrared camera—it turns black. Why do you think it does that?")

Link Science to Human History.
Research shows that nonscientists are more interested in science if it can be related to people from a different time. Telling about any aspect of a natural or physical science through the eyes of those who explored it, discovered it, overcame it, succumbed to it, worried about it, were empowered by it, or who otherwise affected or were affected by the thing in question, will generally make it more interesting to nonscientists.

Use a "Vehicle" to Make Your Topic More Interesting.

A vehicle is part of a communicator's strategy to make a topic more entertaining by telling about it in the context of some overriding scene, setting or situation. Examples:

Exaggerate Size: "If we were to shrink down the solar system to the size of a penny the closest star would be would be.."

Exaggerate Time Scale: "If time were sped up so that a thousand years went by every second, you'd be able to stand right here and watch the constellations change position in the sky."

Use an Overriding Analogy

That is, an analogy that your entire presentation revolves around (e.g. likening the earth to an onion's layered skin in order to tell about certain geological processes).

Use a Contrived Situation

Make up a story going forward or backward in time; pose a hypothetical problem or set up an illustrative situation "What would life on earth be like if the sun were to expand to the orbit of Mercury?"

Use Personification

Give selected human qualities to non-human things "What might the planet mars say if it could talk?" or "How will the Milky Way Galaxy react when it collides with the Andromeda Galaxy?" "What do you and the stars have in common?"

Focus on an Individual

Make up a fictitious but scientifically accurate story about one particular person or object. Give an account of what this person or thing experiences in terms of the technical information you are trying to get across to your audience. (Examples: follow a single star as it goes through birth to death).

Can I use props?

Props are objects, either the real thing or a representation (like a model or drawing), that an interpreter can use to enhance a presentation. Generally, props can be divided into these categories:

Real things: This includes objects that are shown to an audience (e.g. an old glass plate, a CCD chip etc.).

Models: 3D representations of real things that would be difficult to see when life size (e.g. a globe, a telescope model, etc.).

Graphics: Two dimensional representations of real objects that would be impractical or impossible to transport (e.g. a globe of the constellations, a photograph of a galaxy, a demonstration of two galaxies colliding, etc).
Graphs, Charts, and Diagrams: These can be used to simplify the information you present into a visible format.

Guidelines to remember when using props:

Make sure the prop is visible to everyone in the audience to see. If it is small, pass your prop through your audience while you give your talk.

If you are holding a prop, hold it steady and at an appropriate height. Turn to your sides to make sure everyone can see it.

Try not to talk to the prop. Maintain eye contact with the audience except when you must look at the prop to point out something specific.

Make slow exaggerated gestures to point out certain features of your props. Not every person in your audience will be looking at you every second, so make sure you are able to catch everyone's attention when you need to.

Props can be used as analogies. Analogies help bridge the familiar and unfamiliar. For example, you could assemble a common flashlight and batteries to show how different parts of an ecosystem are interdependent.

Whenever it's possible, make active use of props. Even a two dimensional graphic can be active. For example, can you write on it? Can you stick something else to it? Can you pick it up? Can you invite an audience member to come forward to hold it for you? When possible, encourage your audience to use additional senses.

Rehearse how you will use each prop in your presentation. Try to plan the exact moment when each prop comes into play.

How should I question visitors?

Questioning is a useful skill to add to your interpreting repertoire. Questions serve many purposes, they:

- Stimulate interest
- Help organize a program
- Encourage creative thinking

Emphasize important points.

Offer visitors a chance to share thoughts and feelings.

There are many different types of questions and asking questions with a preconceived purpose is key to a good presentation:

Focus questions ask for specific information, they often begin with "who, what, when or where." Focus questions can help assess the knowledge base of your audience. For example:

"What are Tohono O'Odham baskets made out of?"
"Who made the first telescope?"

Process questions have a wider scope of possible answers than focus questions. Process questions ask people to integrate information rather than just remembering or describing. Process questions often begin with "What does this mean? What would happen if..? Why did…?" For example:

"Why are most observatories located on mountain tops?"

"How do astronomers control temperature in a telescope?"

Evaluative questions usually deal with matters of value, choice or judgment of the participants. They offer visitors a chance to express their feelings and/or propose hypotheses concerning various scenarios. Evaluative questions often begin with “What do you think? What about…?” For example:

“Why is astronomical research important?”

“What do you think should be done to cut down on light pollution?”

Questioning Tips

Direct most questions to the entire audience rather than a single individual. This indicates to the group that everyone is expected to think. After the question has been asked, ask for volunteers to answer if need be.

Ask only one question at a time.

Allow time for an answer. This is called “wait-time.” Research has shown that the longer the questioner allows for an answer, the better the answer will be. Never answer your own question. If no one offers a response, leave it open to be answered later or rephrase the question.

Do not start a question with “Does anyone know…” or “Can anyone tell me…” Such phrases express doubt that the question can be answered.

Pace questions to the ability of the group.

Develop ideas and concepts through a series of questions. Build from focus questions to process questions to evaluative questions. This challenges your group to higher levels of thinking.

Accept answers to questions gracefully, even if the answers are wrong. You can say things like, “That relates to part of the answer,” or “That is an excellent hypothesis.” Never make someone feel foolish for participating in the program.

Finally, try to avoid questions that require a simple yes or no.

How should I answer questions asked of me?

The number one thing to remember when you are responding to questions is to act confident! This will encourage your audience to ask you more questions and listen carefully to your responses. You don’t have to be an expert in the topic you are discussing to give a good answer. Questions are a good time to inspire curiosity in your audience. Try re-phrasing the question and throwing it back at your audience so that through a series of questions they are able to answer the original question. Here is an example on the next page.

Questioning Dialog

Visitor: “Why are all the observatories painted white or silver?”
Interpreter: “Well, its sort of like your roof if you live in town —why do you paint that all white?”

Visitor: “ So it stays cooler.”

Interpreter: “You are right, but why not another color?”

Visitor: “Because, the white and silver reflect the suns rays and make it cooler.”

Interpreter: "Yes, you are right, Why is temperature important to astronomers looking through a telescope?"

Visitor: "It has to do with distortion."

Interpreter: "That is exactly right. Ever drive down the road on a hot summer day and notice the distortion on the horizon due to the heat being reflected back up creating that mirage effect."

Visitor: "Yes, its all distorted."

Interpreter: "Exactly, that same distortion caused by heat effects the quality of the image being produced. That's why all the observatories are painted white or silver. They also have vents and fans to help stabilize (cool) the air. It's important to keep the temp inside the dome closet to the same temp as the previous night.

This type of interaction promotes inquiry-based learning and gives visitors a sense of accomplishment because they answered their own question. It is also more interactive and makes your answers feel less like a lecture.
If you don't know the answer to a question, remain confident! It is understood that you will not know the answer to every question that you are asked. If this happens there are several ways you can handle the situation:

> **Comment that it is an interesting question.** Explain why you think it is interesting.
>
> **Explain that you don't know the answer, but offer a hypothesis as a possible explanation.**
>
> **Throw the question back at the visitor.** "I don't know the answer, what do you think it might be?"
>
> **Offer to look up the information you don't know, or suggest a place the visitor themselves could find the answer.** Find a book, look it up on the computer at "computer works," or ask another staff or volunteer for help.

Remember, no question is a bad question. Never make the visitors feel stupid and treat every question equally.

Can I ever abandon my plan?

Visitors may take your presentation in unintended directions. If these directions are interesting to the group, or it is a one-on-one interaction, feel no obligation to strictly stick to your plan. Any interaction that is interesting and relevant to the visitor is going to be more meaningful. Don't, however, let one odd visitor detract from the rest of the group's experience.

How do I know if it worked?
It is often hard to tell if your audience has retained any of the information you have presented. You can check for comprehension by asking follow up questions that integrate the information you presented together or hold an informal "quiz" section at the end possibly handing out prizes like stickers. With children you can also pretend to forget the information—"Which one was that again?"—and they will remind you. With time you will learn to assess your audience to check for comprehension as you go.

How can I evaluate my performance?

It is helpful to gain written and/or verbal feedback from your visitors and supervisors about your performance. There are many methods of doing this—here are some ideas:

Fill out a self-evaluation checklist.

Invite a co-worker or supervisor to observe your presentation and offer suggestions.

Have an "expert" observe and analyze your presentation.

Ask your audience. Use a written form (short) or simply ask selected visitors if objectives were clear. Ask if they understood a particular point, or what they liked most, etc.

Can I share ideas with my co-workers?

Of course! If you have some material or a technique that works really well, write it down and bring it to the next docent meeting—we can share it with others or include it in future trainings. We can also write it up in the docent newsletter.

How can I get more help?

There are many resources available to you to help you hone your interpretive skills and increase your base of science knowledge. Never feel afraid to ask a staff person or another supervisor for advice or help finding the appropriate resources. There are several books on interpretation in the volunteer office for you to look through and also many science resource books and articles. If you want time to look through these materials ask the docent coordinator.

What if it just doesn't work?

Don't be discouraged! All audiences are different and some are just unresponsive no matter how hard you try. Don't assume that it is your fault if people don't seem interested—you never know if their cat just died, if they stood in line for over an hour, or if they happen to just hate astronomy. Don't force people to listen to what you have to say and be gracious and let them move on if and when they want. In this situation, above all, keep your confidence high and get ready for the next group.

What are these skills good for?

Knowing how to effectively interpret information and exhibits will improve your ability to communicate and speak in public and provide quality customer service. These life skills will add to your qualifications for a variety of jobs in the future. Employers may look for good interpreters when hiring teachers, informal educators, tour guides, sales people, media personnel, or for any position that deals regularly with the public. There are obvious differences in the range of topics a professional "interpreter" might deal with. However, good communication (by that I mean communication that captures attention and makes a point) always seems to have the same qualities regardless of who's doing it or the subject matter being addressed. Beyond acquiring advanced knowledge in some subject area, being an interpreter first means knowing about *communication*, and being able to recognize the qualities that make it work best.

Procedure for large tour groups

The ideal tour group size is 20 people and the maximum is 30. When the group exceeds 30, safety concerns become an issue, and the quality of tour tends to decrease. For these reasons, we request that tour guides follow the guidelines below for larger groups.

Groups greater than 30

- Begin the tour in the Visitor Center.

- Give the introductory lecture about Kitt Peak and the history of NOAO.

- Explain to the group that it is difficult to see the telescope from the visitor gallery in large groups.

- After the initial lecture, proceed to the telescopes together, and rotate people through the visitor gallery in groups of 10 - 15, so that everyone can see the area and have major features pointed out.

- When everyone has seen inside the area, gather the group together for additional information and questions

MORE PRACTICAL ADVICE FOR KITT PEAK DOCENTS:

A. Punctuality and appearance determine the first impression a docent makes. If you end up driving your own vehicle up to the mountain always arrive for your tours at least 5 minutes early and take the time to get to know the group as they begin to assemble for the tour. In addition, always look your best, arriving in uniform with name badge clearly visible. Shirts should be well-fitting, clean and pressed. Remember you represent the institution, and the impression created by you contributes to the overall image of Kitt Peak which visitors take with them.

B. Introductions begin a good tour. Take the time to ask some questions and establish rapport with the visitors. Tell them why Kitt Peak is here, who are the docents and what they do. Then ask the visitors where they are from, and any other questions that might help "break the ice". Encourage the visitors to ask questions as the tour moves along. Give them an idea of where the tour will go, how long it will take, and what things they will see and do etc.

C. Your pace and position will help keep the group together and interested. Don't walk too fast or too slowly. Vary the pace from group to group, depending on the age and physical ability of your audience. Don't forget that you are at a higher elevation which can have a profound effect on visitors.

   - Take rest breaks and point out other interesting Mountain sites and/or natural history topics such as plants or rocks. Remember to spend only a few minutes standing in one place. Fatigue and disinterest set in much more quickly when people stand still than when they walk. Be sure to be aware of safety issues walking along the roadside and be aware of the direction your group is facing. Are they looking into the sun? Can they see what your trying to point out?
   - Be aware of your position in relation to the group. Don't hide or block telescope view or signs. Do not stand at one end of the group, as people at the opposite end will not be able to hear you. Try to encourage half the group to collect on one side of you and the other half to remain on the other side. Face your group. Never turn your back while speaking, as this prevents the group from hearing you. Avoid walking and talking at the same time: this invariably means your back would be turned to the visitors and only those right next to you would receive the benefit of your interpretation.

D. Continue to let your group know what to expect throughout the tour and let the visitors know that this is **their** tour.

E. “Problem” visitors can be hard to handle. Develop tactful, effective ways to deal with these problems. A problem visitor might be anyone from the slowpoke photographer who joins a tour and then slows it down, to the aggressive opinion-pusher who takes issue with something. Suggestions to handle these problem visitors are as follows:

- For the slowpoke photographer or other staying behind, try saying “I need to move the tour along now, folks. We will be heading down to the ____________. Why don’t you get the pictures you want and join us there?” Even if they don’t catch up, it could mean they realized their “photographic pace” was holding up the tour. This is probably better for all concerned.

- For the monopolizing visitor who wants all your attention, try saying, “I would like to spend more time talking with you about this after my tour. I hope you can stay a few minutes.” This is a subtle, polite approach if the right tone is used.

- With the opinion-pusher who is spoiling for a fight, it is extremely important not to allow yourself to be baited into a confrontation. This visitor is best handled by a tactful explanation such as: “This tour is really not the proper forum for discussion of personal opinions or beliefs concerning________________ . If you take exception to the Visitors Center interpretation of this, I invite you to stop by the Visitor Center on your way out and fill out an evaluation form. For now, however, we have a lot of ground to cover, so why don’t we move on?”

F. Use language correctly and audibly. Watch your vocabulary and pronunciation. People dislike jargon. Technical definitions and terms, or scientific names, should always be explained simply and thoroughly. This can be an excellent learning device but it should be done sparingly and without showing off.

- All names and terms should be correctly pronounced. Many of our visitors are from areas where these terms are never used and they look to us for the correct pronunciation; therefore, always be certain you are using the accepted pronunciation of the words you use, especially when it come to Tohono Oodham names. If you know you have trouble pronouncing a particular word, tell your audience that it is a difficult word for your to pronounce.

- Remember to repeat all visitor questions for the benefit of the group before answering them. This makes each group member a participant.

G. Sum up the tour. This is very important, in order to answer all the questions and tie up the loose ends. Rather than abruptly announcing that the time is up, try inviting the group to help you recap what they’ve seen and learned

- Also remember that docents NEVER accept tips, but they happily accept donations on behalf of the Visitor Center.

HINTS ON INTERPRETATION:

Be the host/hostess with the "mostest."

- Think of yourself showing off your house and its beautiful things.
- Dress nice.
- Be friendly and confident.
- Make sure everything is set up and working properly.

Fear of public speaking

- Talk to people as if they were all friends, not a crowd of strangers.
- Even though you're nervous, take your hands out of your pockets and look at the group.
- Smile.
- Tell them your name, "Hi, my name is _______. Welcome to Kitt Peak National Observatory. I'll be taking you on your tour today."

Storytelling

- Share tidbits, factoids, stories and concepts rather than facts.
- Don't try to tell your audience everything you know. Store that information for later because someday, someone will ask you.

Props

- People are drawn to props. Props are fun and help you become more confident. They involve the visitor and allow for interaction with the group.

Humor

- Humor relieves tension
- Humor aids with rapport
- Humor helps illustrate a point.
- Your audience will pay attention to you. It requires timing and delivery to be effective.

Delivery

- Memorization of a speech sets you up for failure.
- Use action words, concrete nouns, familiar objects and ideas.
- Use some inflection and a strong voice so you don't lose your audience.
- Conversely, speak softly at times to draw the group's attention.

Empower the Visitor

- Think of ways you can make them feel confident and smarter.

The local expert

- If you don't know the answer, say, "I don't know. I'll see if I can find out for you."
- Use index cards or signs to jog your memory.
- Suggest that they look it up at school or write to you.

VISITORS LIKE:

Sensory involvement
Humor
New information made understandable
An enthusiastic interpreter

VISITORS DO NOT LIKE:

Dry Lectures
An interpreter that talks too much
A program that is too technical
Long and unenthusiastic presentations

Interpreting to All Ages

Age group	What are they like?	How to interpret with them
Under 6 years	• lots of energy • self-centered view of the world • imitate others • learn through senses and body movements • learn through repetitive actions • learn through immediate cause and effect • notice similarities and differences • short attention span • ask lots of questions	• use their energy; (e.g. role-playing games) • have them hold objects • let them describe things in their own words • ask simple questions • keep interactions short • keep vocabulary simple • I do one/you do one
6 to 9 years (gr. 1 to 4)	• enjoy new experiences • imitate others • naturally curious • read a bit • desire adult approval • lots of energy, short attention span • don't accept failure well	• I do it/ you do it • show something "cool" • have them help you with the exhibit • ask questions like "What would happen if…" • positive, empowering experiences • keep interaction short
10 to 12 years (gr. 5 to 7)	• experiment on their own • imitate others (especially older kids) • eager to learn new things • read pretty well • can take new information and relate it to what they know • can hypothesize • may challenge authority • like to be in charge	• show them how to use the exhibit • show something "cool" • relate exhibit to everyday life • have them show you or others what they can do • jokes • ask questions like "what would happen if…" and "why do you think…"
Teenagers (High school)	• read well • experiment on their own • imitate others • can take new information and relate it to what they know • can hypothesize • interested in social issues • challenge authority • want to be independent • fear embarrassment • easily bored	• allow them to explore the exhibit • show them how to use it • show something "cool" • tell them interesting facts or stories • relate exhibit to their lives • direct them to other sources of information • entertain • provide positive experiences • ask questions like "what would happen if…" and "why do you think…" • never embarrass or single out
Adults	• read well • experiment on their own • watch and/or copy what others are doing • ask questions • can take new information and relate it to what they know • can hypothesize • interested in social issues • may be shy, especially if English is not their first language • may have weird misconceptions	• let them explore the exhibit • show them how to use it • show something "cool" • tell them interesting facts or stories • relate exhibit to everyday life • direct them to related exhibits and other sources of information • let them tell you what they know • show them something they can show others (especially their kids)

EVERY TOUR **MUST** INCLUDE

Welcome
An introduction to what they will be doing today.

Who we are?
AURA
NOAO
NSF

STRESS
NOAO
SAFETY ISSUES

Rules to Follow:
No running
Keep voices down day sleepers
Walking on the correct side of the road
Stay with the tour leader

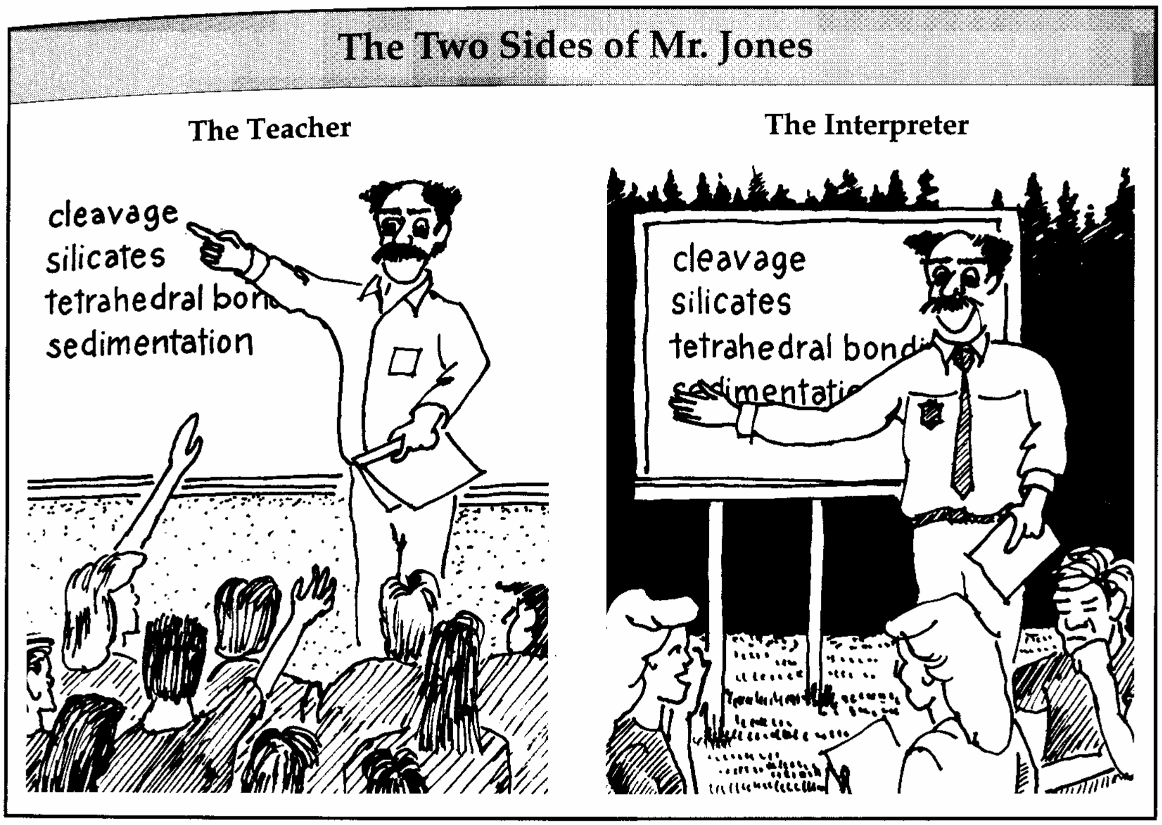


Figure 1-1. Contrasting formal education and interpretation. (Drawings by Jeff Egan)

**A GOOD TALK HAS A GOOD INTRODUCTION,
A GOOD BODY, AND A GOOD CONCLUSION**

In every good talk, there is an introduction, body, and conclusion—each of which accomplishes a different set of purposes. Preparing an effective talk is simple if you think of it as developing these three different parts, and if you concentrate on designing each part to accomplish its specific purpose. *Taken from Sam Ham's book "Environmental Interpretation"*

Part of the Talk	Purpose(s)
1. The Introduction	To create interest in the theme, and to make your audience want to hear more about it. (Remember, they're a noncaptive audience) To orient the audience to the theme, and tell them how your talk is going to be organized. (Remember the "Magical Number 7 plus or Minus 2.") To establish the conceptual framework that you rely on in the body, and to introduce the vehicle (if your using one). To set the stage for the conclusion.
2. The Body	To develop the theme, organized just as you said it would be organized, and using whatever facts, concepts, analogies, examples, comparisons, etc. that are needed to make the information entertaining, meaningful, and relevant to your audience.
3. The Conclusion	To reinforce the theme-to show one last time the relationship between the theme that you revealed in the introduction and all the information you presented in the body. Many conclusions summarize the key points that were made earlier, and some offer ideas about the larger meaning of the theme (e.g., what the "bigger picture is" or "where we go from here").

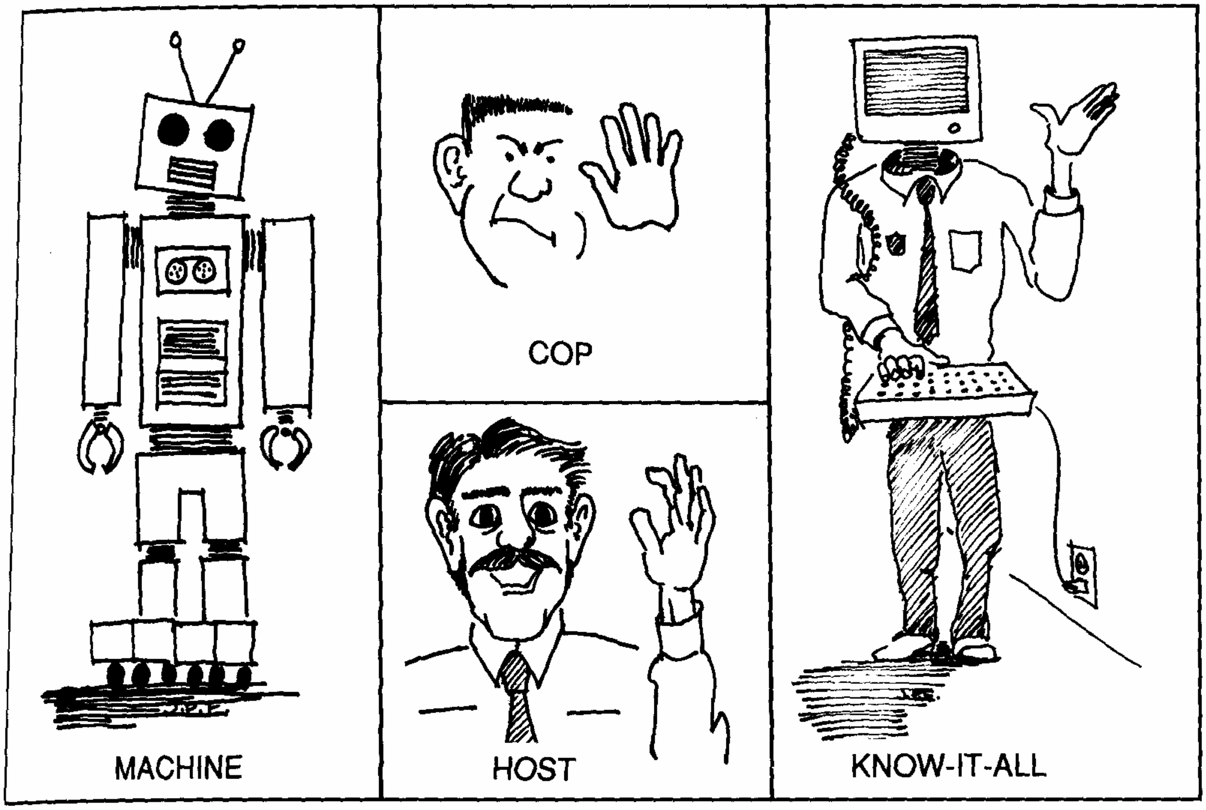


Figure 5-2. The four personalities of a tour guide. (Drawings by Jeff Egan)

ASKING GOOD QUESTIONS CAN IMPROVE A GUIDED TOUR

Type of Question	Typical Purposes	Examples
Focusing	To focus attention on something of interest	"Can you all see this yellow line in the soil?' "What do you suppose this is?" "How many of you have seen a plow like this one before?"
Comparison	To bring out similarities and differences between things	"How would you compare these two rock?" "In what ways are people and social insects alike?" "What does this smell like? Does it remind you of anything?"
Inference	To get the group to generalize or reason beyond the information you have given: to explore possible conclusions and implications	"If that's true, then how might we explain such and such?" "What do you think could be concluded from this?" "So how do you think this field will look in another twenty years?"
Application	To get the group to see how certain information applies in different situations	"Could you apply this knowledge at home?" "Why might it be important to know such and such?" "What do you think a tool like this could have been used for?"
Problem-solving	To get the group to think of solutions to real-world problems and issues	"What do you think is needed to stop this erosion?" "How would you make a shelter if all you had were grass and mud?" "What needs to be done to protect this species from extinction?"
Cause-and-effect	To get the group to think about relationships that explain the occurrence of different events and objects	"Why are there so many more frogs on this side of the river?" "Look around-what do you think causes this water to be so contaminated?" "Why you suppose these beans are growing faster than those over there?"
Evaluation	To get people to express their opinions and to hear those of others; to illustrate possible choices and judgments	"What do you think would be the fairest solution?" "Who do you think was right?" "Do you believe this is good or bad?"

References

Note: This handbook has been complied from a variety of sources, each of which has been modified. The author does not claim *all* of the words and/or ideas presented in this handbook to be original. The following texts and people should be credited with many of the ideas in this handbook and can be used as follow up resources. Parts of this handbook were compiled by Lauren Russell of the Pacific Science Center.

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Contact List

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In Case of Emergency, from Kitt Peak .... x 8444

Only if above number is not successful .... x 9911

Visitor Center Hours and Programs

The Visitor Center is open daily to the public from 9:00 AM to 3:45 PM. It is closed January 1, Thanksgiving Day, and December 24 and 25.

Guided tours are available at 10:00 AM, 11:30 AM, and 1:30 PM. Visitors may choose to take a self-guided tour.

The Visitor Center has a Nightly Observing Program (NOP) and an Advanced Observing Program (AOP) for the public. Both require advanced reservation by calling 318-8726. The NOP begins approximately thirty minutes before sunset. The program is conducted on the 16-inch Visitor Center telescope.

Giving Tours

A. Sample Docent Tour - (Revised February 2001)

Note: The following is provided more as a guideline than as a strict script for tours. All docents are encouraged to add their own personal anecdotes and personalities to the information listed below.

Greetings and Welcome to Kitt Peak National Observatory (KPNO). Have any of you previously visited the observatory? That's great, thanks for coming back! First of all let me state that Kitt Peak is a National Observatory - this means that those of you who are taxpaying U.S. citizens are actually part owners. Some small part of the taxes that you folks pay to the federal government eventually finds its way to the top of this mountain and supports the astronomy research that we conduct.

KPNO was founded in l958, and was the first National Observatory. Prior to that time, if you were interested in conducting high-level astronomy research, you would be limited to what facilities might be available through the particular institution with which you were affiliated. For instance, if you were a faculty member of the California Institute of Technology, you were in good shape because they own and operate the Mt. Palomar Telescope, which until recently was the largest in the world. However, if you were connected to a smaller school, you would be confined to whatever facilities may or may not be available to you. Telescopes are expensive items and even major universities often cannot afford to fund and operate one.

The historical context of the late fifties is also an important factor. You may remember that our government was involved in the cold war with the Soviet Union. In 1957, the Soviets launched the first satellite, Sputnik, which came as a great shock to our scientific community. We were feeling technologically superior after the end of WWII, and were unprepared for the Soviets one-upping us in such a manner. This event became a major catalyst for the formation of our space program, and its obvious partner, astronomy research.

In 1953, a number of US astronomers petitioned the federal government for the funding to build a National Observatory, to serve as a research center for our astronomy community. The government granted the funds, and a search began to find the best site for a National Observatory within the continental US. They originally surveyed over 150 different mountains in the western US including CA, AZ, and NM. The sites were narrowed down to 11 finalists. Kitt Peak was the final choice because it had the greatest percentage of positive attributes or factors.

There were four primary categories that led to the final decision:

1. Light Pollution - which is the greatest negative factor for astronomical observing. In 1958, Tucson was a much smaller city with a minimum amount of extraneous light. (a brief description of the effects and costs of light pollution should follow.)

2. Humidity - As you all know, we are in the middle of the Sonora Desert and the entire area is extremely arid. However, many of the mountains in this region are called "sky islands" which refers to the fact that they receive more rainfall and have less desert-oriented ecosystems. The altitude on Kitt Peak is 7000 ft. At the same altitude on Mt. Lemmon for example, you will find a very different type of environment. You will find large pine trees. Mt. Lemmon receives greater rainfall, and has much more ground water than Kitt Peak. These contribute to a higher level of relative humidity. As anyone who wears glasses knows, lenses fog up when humidity is high. Essentially, the same thing happens to the mirrors in our telescopes, and it is an expensive and time-consuming operation to dry them. Incidentally, all the water we use here on Kitt Peak comes from rain and snow. There are no perennial springs to provide a reliable water supply.

3. The next factor in the site selection of KPNO was the proximity of the University of Arizona. In the late fifties, the U of A had a small but excellent astronomy program, and if you are searching for persons to staff an observatory, a university is a great place to look. At Kitt Peak we not only need astronomers, but

opticians, mechanical and electrical engineers, electronics experts and a host of other highly educated people, and a wide range of skilled crafts and facilities persons. On any given day as many as 75 staff members are engaged in the operation of this observatory.

4. The last but certainly not the least factor that contributes to the site selection was “seeing”. When astronomers use this term they are describing the effect of turbulent atmospheric motion on the quality of the image of an astronomical object. Kitt Peak has a remarkably steady atmosphere overhead, which truly makes this a great site for viewing the heavens.

Well, it seemed that Kitt Peak was a nearly perfect site for a national observatory except for one significant fact: Kitt Peak is located on an Indian reservation. We are in the ancestral homeland of the Tohono O’odham Nation, who have lived in this part of the Sonoran Desert for at least 2,000 years or longer. These Native Americans who are descendants of the Hohokam culture, were formerly called “Papagos”, a word of Spanish derivation that means “bean eaters.” Now the O’odham never referred to themselves as Papagos, which was a term that the Spanish applied to them when they first entered the southwest. Tohono O’odham means “Desert People” in the O’odham language, and many Native Americans refer to themselves as “the People” in their own language. Kitt Peak is a sacred mountain to the O’odham, although not as sacred as Baboquivari Peak, the large granite dome to our south you may have noticed on the drive up. To the O’odham, Baboquivari Peak is the navel of the world, the opening in the Earth from which they emerged after the world flood. They were then led down into the desert by their “Elder Brother,” I’itoi, who created many of the desert animals, taught the people to grow plants in a very arid environment, and also gave them many of their sacred ceremonies. He still lives in a cave on Baboquivari and apparently spends a great deal of time on Kitt Peak. Incidentally, the name for Kitt Peak in the O’odham language is “Ioligam,” which means manzanita.

When the tribal council was first approached with the plan to build an observatory on their sacred mountain, they refused. What followed was an elegant solution to a potentially difficult problem. Like many Native Americans, the Tohono O’odham have a significant relationship with the stars because they figure prominently in their religions and ancient stories. The astronomers invited the tribal council to visit the University of Arizona Steward Observatory and observe the stars through their 36-inch telescope. The result was that the tribal council granted permission for the observatory to be built on the mountain and remain “as long as only astronomy research was conducted.” In exchange for permission to use the mountain, the O’odham Nation received a variety of concessions. First, we lease the top 200 acres of the mountain from the tribe; we also give Tohono O’odham people hiring preference; we purchase power from the tribal utility authority, and we support O’odham traditional culture through our store that carries an excellent selection of arts and crafts sold at our cost. By the way, it is mandatory for all visitors to purchase a basket before leaving the mountain so please do not forget!!! Seriously, our store is the primary means we have of supporting our programs and your donations are greatly appreciated.

Building telescopes on Kitt Peak began in 1960 and we haven’t stopped yet - there are currently 24 telescopes on the mountain, making Kitt Peak the largest collection of research telescopes in the world. We don’t have the single largest telescope, just the most!! We receive our funding from the National Science Foundation (NSF) who entered into a contract with the Association of Universities for Research in Astronomy (AURA). They act as our Board of Directors and grant funding to the people who administer Kitt Peak, the National Optical Astronomy Observatory (NOAO). We currently maintain two observatory sites: KPNO, and Cerro Tololo Interamerican Observatory (CTIO) which is located in Chile at the southern end of the Atacama Desert. The National Solar Observatory (NSO) is also partly situated on Kitt Peak and partly on Sacramento Peak in southern New Mexico.

If you would like to follow me, we will be taking a little walk to the 4-meter telescope. Please be warned, the walk is uphill both ways - if you have any respiratory or cardiac problems please let me know immediately. I promise that I will take my time. So if you are ready - let’s go. Incidentally, if you have any questions don’t hesitate to ask - we are very informal here at Kitt Peak.

As we walk up to the 4-meter, please try to keep to designated walkways and be aware of mountain vehicles. I will stay on the left side of the roadway so just stick with me.

(After the group is assembled on the observation deck please point out the major telescopes.)

Example: If you look to my left, the large triangular-shaped object is the McMath-Pierce Solar Telescope, the largest solar instrument in the world. It was completed in 1962 at the insistence of a man named Robert McMath who was the president of the AURA board. Even though it was constructed several decades ago, a solar telescope larger than the McMath-Pierce has not been built to date. In the foreground, between the solar telescope and us is a large concrete area that is our water catchment basin. All of the water we use on Kitt Peak comes from rain and snow, so please be conservative in water usage during your visit. The large telescope on the hill directly across from us is the 2.1-meter Telescope, the second large telescope built on Kitt Peak. The unusually shaped telescope to the right is the WIYN Telescope, completed in 1994. WIYN is an acronym for Wisconsin, Indiana, Yale and NOAO - those three universities put up the construction funds for this instrument and NOAO donated the site. It is currently the second largest telescope on the mountain, and if you compare its size with the 4-meter building we are standing in, you can see that there has been a lot of intervening technology between 1973 when this one was constructed and today. (Any additional facts about the WIYN could now be presented.) If you will look to the right, the large dish on the southwest ridge is the 25-meter radio telescope of the National Radio Astronomy Observatory (NRAO). This telescope is part of the Very Long Baseline Array (VLBA), which is a linkup of radio telescopes that stretches from Mauna Kea on Hawaii to St. Croix in the Virgin Islands. I'm sure that you folks frequently hear that Radio Astronomers listen to the Universe. Well, that's not really true. Radio waves are light waves that are beyond the visual capabilities of our senses. Radio waves have a longer wavelength than visible light and are therefore invisible to our eyes. So radio astronomers are really looking at light that we cannot see with the naked eye. The human eye responds to very short wavelengths, which are called visible light. Each wavelength of visible light is associated with a different color and the arrangement of colors according to wavelength is called the visible spectrum: the rainbow effect that results when light is broken into wavelengths.

Now its time to go upstairs and actually look at the 4-meter telescope, the largest one we have here at Kitt Peak.

I'm sure that this telescope looks very different than you had imagined, unless you have seen a large research instrument like this one before. There are really two basic types of telescopes; reflectors and refractors. Refractors are probably the most familiar; they are shaped like a long tube and have a series of lenses that refract and magnify the image of the object. Reflectors on the other hand, don't have lenses but mirrors, and all of the telescopes on Kitt Peak are reflectors, and yes it is true that most Astronomy these days is done with mirrors. The types of optics that this instrument has are called Cassegrain optics. They are named after a French optician of the 18th century, Guillame Cassegrain, who invented the mirror configuration. We've been describing telescopes by various numbers: 4-meter, 2.1-meter, 0.9-meter etc. and this refers to the size of the diameter of the primary mirror inside the telescope. This 4-meter mirror is a solid piece of quartz glass, weighs approx. 15 tons, and is ground into a parabolic shape: it is concave-shaped like a bowl. If we point the telescope at an object, let's say a distant galaxy, light from that galaxy will fall upon the reflective surface of the mirror and bounce off of it in a conical pattern. The point of this cone will then strike the secondary mirror, located in the large black tube you see up there. The secondary mirror is convex or hyperbolic. It is the opposite of the primary mirror. The light path will then bounce off the secondary and back to the primary mirror. There is a large hole in the middle of the primary mirror, and the light path will pass through the primary and come to focus at the detector, an electronic camera, or a spectrograph that is attached to the bottom of the telescope.

One fact that is surprising to many of our visitors is that astronomers no longer look through telescopes! Many people have a very unrealistic notion of the way astronomy works. They often picture a person, usually a male, in a white lab coat with a pocket protector and many pens, peering into the universe through the night. All of these stereotypes are wrong! First, not all astronomers are men.

Second, the telescopes on Kitt Peak don't even have eyepieces to look through. If you can imagine these instruments as large light buckets with cameras attached to record the images, you will have a pretty clear concept of how they actually work, until a few years ago, most of the imaging of objects was done with photo-sensitive glass plates. These plates were 14" X 14", and gave a very wide surface on which to capture a lot of light. The problem with glass plates was the fact that they could only capture about 15% of the light that would strike them. This would mean that long time exposures, where the telescope would track the object across the sky and gradually expose the plate were necessary. The other problem is that, once computers became the primary tool of astronomers, it is difficult for a computer to read a photograph. Computers think only in terms of numerical sequences, digitally, and photographs are not digital.

All of these problems became irrelevant with the invention of a silicon chip called a CCD, or Charge Coupled Device. This chip was initially designed for memory storage like other computer chips. However, this particular type is extremely light sensitive. The first industry to realize their potential was the entertainment industry, and if you have a video or programmable 35mm camera, you have a CCD. It is the little chip inside your camera that tells it how much light to admit for the correct exposure. The CCDs that we use in our detectors are much larger than the ones in cameras, and also much more expensive, some cost as much as $130,000. After the light path passes through the hole in the primary mirror, it is directed onto the surface of the CCD. This surface looks like a microscopic series of tiny buckets, and if you can imagine a field lined with buckets collecting rain from a thunderstorm, you can imagine how CCDs gather the light from the telescope. The ones we are currently using have approximately 4.2 million buckets or 'pixels' on a surface that is 4" x 4" square, so you can see that they are very small. If you compare the pixel count with that of the average number of pixels in a video image, which is about 400,000, you will have an idea of the resolution quality of a CCD image. Light has qualities that are described in terms of waves and particles. The particle nature of light is related to the emission of electromagnetic energy in discrete packets, called photons. Photons fall into the pixels, and for each one, a charge is given off and a digital message is sent to a computer in the observing room. The computer then reconstructs the image of the object that the telescope is observing and the astronomer sees that image on her computer screen. The advantage here is that the image is immediately digitally encoded so the computer can read it, store it, and reduce it. The other great advantage is that CCDs can acquire nearly 95% of the light that they receive, making them very efficient indeed. The bad news is that they are small. They are not nearly so large as the glass plates that were formerly used. Now, scientists are never satisfied with things as they are. They are always trying to make technology fit their needs, and so we are currently building mosaics or arrays of CCDs to try to equal that large format. Perhaps now you folks can understand why astronomers really don't look through telescopes.

I'm sure that you are wondering who these mysterious guys are - who actually gets to play with these really big and expensive toys? The truth is, all of you could get to use one of our telescopes if you could write a proposal that would be acceptable to our jurying committee. You would need to submit a one-page detailed proposal outlining your project and what you would hope to accomplish. Naturally, there is very stiff competition for the use of our facilities and for every 10 proposals submitted for time on the 4-meter, only 4 are accepted.

So, lets say that you people are all astronomers and submit proposals for use of the 4-meter telescope and amazingly you are all accepted. Proposals for observing time at KPNO and CTIO are submitted twice a year to NOAO-Tucson. Proposal deadlines for electronic submissions are the end of September (for the following February - July observing period) and the end of March (for the following August - January observing period). A Telescope Allocation Committee made up of one NOAO and five outside scientists reviews the proposals. From the time your proposal is submitted until your observing run, the wait could be as long as 9 months.

After the 5 - 9 month wait, you would fly out to Tucson and take a shuttle up the mountain. Dormitory facilities are available to scientists, and there is a cafeteria for meals. After dinner you come up to the 4-meter, ready to begin your run. What happens if it rains? Or it is cloudy? ---Well, you are just out of luck, because the person that is going to use the telescope after you are done has waited just as long! You would have to go back, resubmit your proposal, and begin all over again! Astronomers are accustomed to living with uncertainty, because very mundane factors can limit the possibility of their collecting data. Not only is our astronomy laboratory, the universe, incredibly large and humbling, but clouds, rain, humidity over 80%, and wind velocity over 45 mph can all prevent them from completing their work.

Many people want to know how astronomy affects them - what bearing does it have on my life here on Earth. This is a difficult question because astronomy is a form of pure research - it has few practical applications outside of the quest for information about the way the universe works and where we are in it. But, if you remember the first law of relativity - matter can neither be created nor destroyed - you may see some interesting implications. The molecules that comprise our planet and everything in it have always existed in the universe. The very stuff we are made of was once part of a star, and we are descendants of stars. Also, in recent years, astronomy has been able to identify many of the chemical components necessary for the composition of life. This means that the possibility of life on other planets is entirely real and, if you take into account the size of the universe, it becomes probable. For example, our galaxy, the Milky Way, is thought to be 250,000 light years across. So, if you could travel at the speed of light, which is 186,000 miles per second, it would still take you 250,000 years to cross it!! Our galaxy has about 200,000,000,000 (200 billion) stars-quite a few, but consider the fact that astronomers believe that the universe has more galaxies than the Milky Way has stars, and that the bowl of the Big Dipper contains at least a million galaxies. Well, I think that I have probably overloaded your circuits enough for one day, but I will be glad to answer any questions you may have! Thanks for visiting Kitt Peak National Observatory and please do come again!!

RESEARCH IMPACT
OF THE
NSO/KITT PEAK MCMATH-PIERCE TELESCOPES

The McMath-Pierce Telescope is the largest unobstructed-aperture optical telescope in the world with a diameter of 1.5m. The two auxiliary telescopes are the second and third largest solar telescopes in operation.

The large light-gathering power, the extended wavelength range from the UV to the far IR, and the well-behaved polarization characteristics of the telescope make them unique instruments and have simulated a variety of solar and night-time research. Some of the post-focus instruments are state-of-the-art. The Fourier Transform Spectrometer is a unique national resource in wide demand by atmospheric physicists and chemists as well as astronomers.

The capabilities of the McMath-Pierce Telescope have enabled a number of important discoveries and 'firsts'. To mention just a few:

discovery of 3He, B, Ho, F, Cl, H20 on the sun
discovery of emission lines around 12 μm
best published atlases of spatially resolved and unresolved solar spectrun from 0.3-22 μm
best determination of solar limb darkening
first measurements of magnetic fields at 1.6 and 12 μm
discovery of complex magnetic fine-structure in the quiet Sun
first direct measurement of kilogauss magnetic fields outside of sunspots
discovery of intra-network fields
best upper limit of the field strength of unresolved, turbulent magnetic field
discovery of 'canopy' magnetic fields
first magnetic vector field observations in the chromosphere
discovery of cold structures in the solar chromosphere
first observations showing that 5 min. oscillations must arise from waves trapped below the photoshphere
first measurements of internal sound speed and solar rotation throughout most of the Sun
first interferometric observations of solar granulation and sunspots
highest resolution images at 1.6 and 10 μm
detection of cycle-dependant variation of photosperic convection
discover that the atmosphere of Venus contains little or no water
highest resolution spectrum of a daytime comet
discovery of a natural maser in the atmosphere of Mars
detection of magnetic fields on late-type dwarf stars

To select one recent highlight, the measurements of weak magnetic fields in the quiet Sun in the visible and 1.6 um provide the basis to understand an important component of the solar magnetic field that has been neglected during the last two decades. The capability of the McMath-Pierce Telescope to observe the sun at wavelengths longer than 2.5 um great light-gathering power in the world.

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SkyChart III. Southern Stars Software.

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http://astronomylinks.com/

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http://www.as.utexas.edu/mcdonald/scope/scope.html

http://www.astro.uiuc.edu/~kaler/sow/const.html

http://www.astro.uiuc.edu/~kaler/sow/star_intro.html

http://www.astronomy.com/home.asp

http://www.nasa.gov/today/index.html

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A Visitor's Guide to the Kitt Peak Observatories. Sage, Leslie, Aschenbrenner, Gail, 2003, Cambridge Press.

KITT PEAK DOCENT PROGRAM

INTERPRETIVE EVALUATION OF ____

	Best				Worst	
Friendliness and courtesy	5	4	3	2	1	N/A
Eye contact and body language	5	4	3	2	1	N/A
Voice projection and enunciation	5	4	3	2	1	N/A
Enthusiasm during presentation	5	4	3	2	1	N/A
Encourages group participation	5	4	3	2	1	N/A
Focused on subject of tour	5	4	3	2	1	N/A
Effectively answers questions	5	4	3	2	1	N/A
Techniques for controlling group	5	4	3	2	1	N/A
Keeps VC portion of tour brief	5	4	3	2	1	N/A
Grooming and attire	5	4	3	2	1	N/A

Average rating ________________

COMMENTS

EVALUATOR'S SIGNATURE

DOCENT'S SIGNATURE DATE

Interpreter Self-Evaluation

Name ____ Date _____________

Interpretive Technique:
Please rate your response to something in the following statements.
4=Never 3=Sometimes 2=Most of the time 1=Always

Before the beginning of my program/shift:

4 3 2 1 I go over the program's theme and messages to focus my interactions.

4 3 2 1 I review universal concepts and potential misperceptions of content.

4 3 2 1 I adjust interpretation content and style for audience (children, adults, etc…)

During my program/shift:

4 3 2 1 I greet visitors and gather information about their previous knowledge.

4 3 2 1 I let visitors know what to expect and give permission to ask questions.

4 3 2 1 I encourage participation and tap visitor knowledge with questions.

4 3 2 1 I include information that reinforces the theme.

4 3 2 1 I listen to visitor questions/remarks and incorporate them into interactions.

4 3 2 1 I relate interpretation to the visitor's lives (making it real, meaningful, etc.)

4 3 2 1 I express my enthusiasm/passion for the subject and the mountain.

4 3 2 1 I provide information in a narrative style, rather that just a series of facts.

4 3 2 1 I help visitors to discover something new, rather that just point it out.

4 3 2 1 I encourage visitors to use two or more of their senses

4 3 2 1 I regularly use props and exhibit elements to engage visitors

4 3 2 1 I refer visitors to other programs or activities that might be of interest.

4 3 2 1 I thank visitors for coming and invite them to come again soon.

Additional training or research that would increase my effectiveness in this program:

My strengths as an interpreter are:

1.

2.

Two things I can improve by the next time I offer this program or work in this gallery:

1

2.

Kitt Peak Docent-Trainee Evaluation

To be completed by the mentor

Dear Mentor,
Write the trainee's name on the line below this paragraph and rate him/her in the areas below. 1 indicates poor performance and 5 indicates superior performance. Please discuss this form with your trainee prior to and following the actual evaluation to allow the trainee every possibility to refine his or her techniques and performance as a docent. Once completed the form should be forwarded to the program coordinator. A copy may be given to the trainee prior to submitting it for filing.

____

Appeared confident and friendly	1	2	3	4	5
Welcomed visitors and engaged them in conversation	1	2	3	4	5
Began tours on time	1	2	3	4	5
Limited the introduction to no more than 20 minutes	1	2	3	4	5
Addressed critical elements of intro (NSF, T.O., safety)	1	2	3	4	5
Brought intro to a focus on the subject of the tour	1	2	3	4	5
Maintained control of visitors during tour	1	2	3	4	5
Created dialog with guests to involve them in tour	1	2	3	4	5
Described accurately the telescope and its functions	1	2	3	4	5
Mentioned discoveries made with telescopes	1	2	3	4	5
Concluded tour with appropriate remarks	1	2	3	4	5
Displayed competence with the science demonstrations	1	2	3	4	5
Included KP natural history in tour material	1	2	3	4	5

Comments: ____

____________________________ ____________
Mentor's Signature Date

____________________________ ____________
Trainee's Signature Date