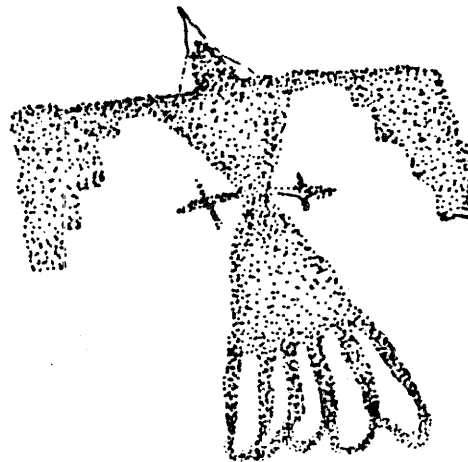
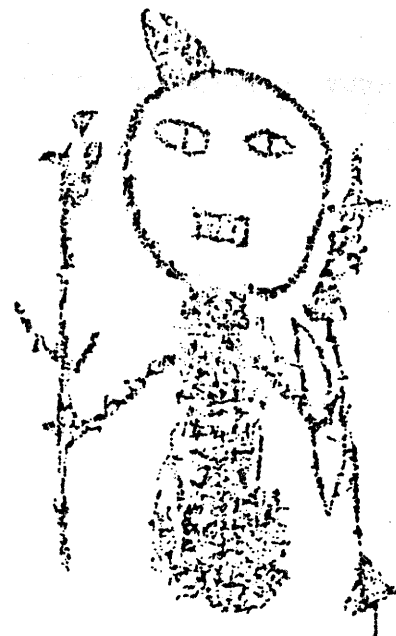
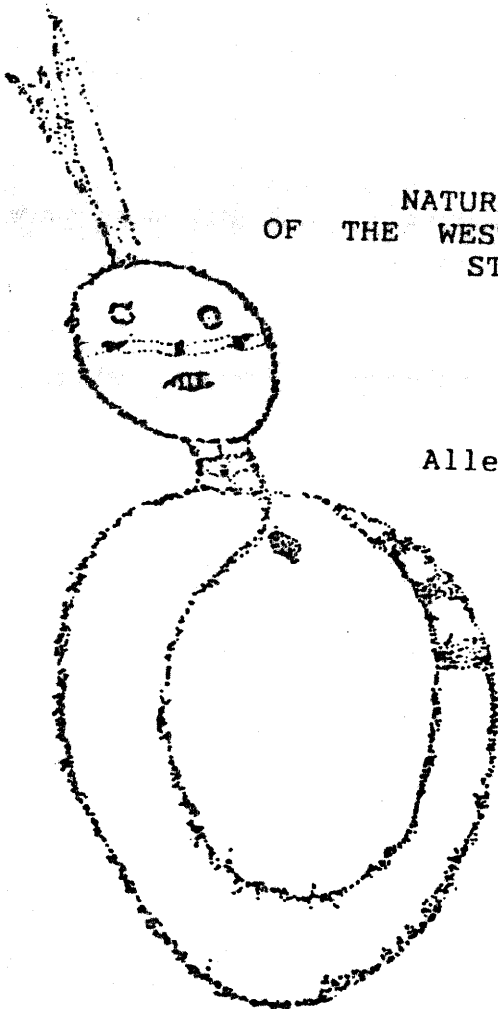




NATURAL RESOURCES
OF THE WEST MESA PETROGLYPHS
STUDY AREA

by

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STUDY AREA CHARACTERISTICS

(NATURAL RESOURCES)

Geographic Setting. West Mesa is immediately west of Albuquerque and the Rio Grande River in central New Mexico. It is part of the basin-and-range province, an immense region of alternating valleys and mountains extending from west Texas to southern California. West Mesa, at 5,000 to 6,000 feet elevation, provides habitat for several species of plants and animals at the upper limit of the Rio Grande valley section of the Chihuahuan Desert. The climate is semi-arid, with two thirds of the sparse 8 to 9 inches of annual precipitation falling as rain in late spring and summer.

Geology. West Mesa lies within Albuquerque Basin, one of several linked basins forming the Rio Grande depression. Albuquerque Basin has been subsiding the past ten million years and filling with sediment eroded from surrounding regions. During relatively recent geologic time, perhaps no more than the past one or two million years, the Rio Grande River became a through-flowing stream and contributed its sediment as well. One of the world's great troughs, Albuquerque Basin is underlain by sedimentary rock layers with a total thickness of four miles. The upper half is alluvial silt, sand and gravel deposited during the Tertiary and Quaternary periods, including the Sante Fe "formation" which is exposed widely through the Albuquerque area. The basin is still sinking, and the geologic processes of faulting, erosion, and deposition that formed Albuquerque's mountains, mesas, and river valley are still active.

The most obvious evidence of faulting is the rugged Sandia range east of Albuquerque which is bounded along its west base by the great Sandia

(Tijeras) fault. Faulting of far less magnitude is related to the lower landforms along the west side of the Rio Grande valley, including West Mesa and the Albuquerque Volcanoes.

The east rim of West Mesa is a sixteen-mile-long escarpment of dark lava rock extending northeast-southwest along the west side of Albuquerque. Set back from the escarpment about three miles to the west and rising above the relatively flat surface of West Mesa is the line of five volcanoes that forms Albuquerque's west skyline.

The volcanoes erupted 190,000 years ago along fissures that tapped magma (molten rock) at great depth below the valley floor. Six separate flows erupted in rapid succession, the entire sequence probably beginning and ending in a matter of months. The earlier flows were the hottest and most fluid and poured onto the surface along the entire five-mile-long fissure. They flowed eastward in broad, relatively thin sheets that may have reached the river (but since have been eroded back to the west to form the escarpment face). Later flows were cooler and more viscous, each one covering less area. The last eruptions were small and partly explosive eruptions from central vents that built up the five steep cones in a line along the original fissure.

Lava flows and a variety of volcanic cones occur elsewhere in Albuquerque Basin at Cat Hills, San Felipe and other locations. Most were formed by the same processes of fissuring and extrusion of lava. The Albuquerque Volcanoes, neither the youngest or oldest of the flows in the basin, are extinct. It is quite possible in the next hundred thousand years or so lava will again erupt somewhere within 50 miles of Albuquerque.

The Albuquerque flows are ordinary basalt and contain many features common to volcanic rocks of this composition. This includes reddish "baked zones" where the hot lava oxidized iron in the underlying sediments; sharp contacts between upper and lower surfaces of successive flows; cooling fractures (contraction joints) that form the vertical columns seen along eroded edges of the flows; and evidence of horizontal tubes, or lava caves, in the flows. In addition, scientists have collected rock samples and determined the orientation of the earth's magnetic field at the time the flows cooled.

In three places narrow promontories of lava rock jut out from the general cliffline of the escarpment. These reveal where arroyos existed at the time of the flows. The lava followed the ancient streambeds and is locally thicker and more resistant to erosion in these locations. Thus the lava-capped ridges at Mesa Prieta, Rinconada, and Marsh Peninsula all mark the position of former stream channels, now elevated rather than depressed.

During the past 190,000 years, erosion by modern West Mesa streams has gradually removed the western portion of the earliest flows and formed the escarpment. The escarpment is retreating slowly to the west as soft underlying sediments erode and blocks of basalt at the rim break along joints and tumble down the steep slope.

The basalt rimrock and the scattered angular blocks below are coated with black "desert varnish." This thin layer of iron and manganese oxide, formed by weathering processes common in the arid Southwest, was the type of surface most frequently used by prehistoric artists to carve their petroglyphs.

The basalt boulders on the escarpment slope sometimes slip and turn over naturally or, more frequently today, are displaced by humans. The bottoms of

the overturned boulders formerly rested on mineral-rich sediment and are encrusted with white "caliche." The white surfaces of overturned boulders stand out in stark contrast to their dark surroundings.

In the middle of West Mesa, the three main branches of Boca Negra Arroyo have eroded through the lava flows and formed the geologic "windows." Apparently these three gaps were once hills of soft sedimentary rock that were surrounded by the lava flows. Subsequently the streams eroded the hills to their roots, leaving "holes" and revealing along their sides the flows that once surrounded the hills. The windows are important in mapping the geology of West Mesa and understanding the sequence of lava flows that would otherwise be concealed in the subsurface.

The most interesting volcanic features are not the early expansive lava flows but rather the five steep volcanic cones on the mesa top. The three southern cones -- JA, Black and Vulcan -- are the highest and illustrate clearly the characteristics of the final eruptions. Rather than spreading out widely like the early flows, these late viscous lavas and lava fragments piled up in steep mounds around central vents. By this stage the lava had decreased in temperature; some of it retained gas that was released explosively, forming showers of spatter and cinder which heaped up in place. Although one cone of nearly pure cinder was formed near Black Cone, in most cases the cinder eruptions alternated with viscous lava flows. Thus the sides of JA and Vulcan are composed in some places of crumbly cinder and in others of dense lava.

The most interesting volcano is JA which contains not only the most diverse and colorful mixtures of lava, spatter, and cinder, but also shows how these

materials interacted to build up the cone. In one place the crust of a steep lava flow cooled and hardened and the fluid interior drained and formed a small lava cave. After most of JA's steep cone had formed, lava filled the crater on top, poured over the rim, and cascaded down the flanks in narrow contorted "dribblet flows" that resemble candle wax in form and behavior. Finally the lava pond broke through the rim, collapsed the crater wall, and emptied down the east flank of the cone as a tongue-shaped lava flow. This phenomenon -- pools of lava that overflowed or broke through the crater rim -- occurred to varying extent on Black, Vulcan, Bond and Butte cones to the north of JA and is generally characteristic of the Albuquerque Volcanoes.

Soil. Soil has formed on West Mesa as the rocks slowly weather. The common parent materials are basalt and fine alluvial silt and sand of the Santa Fe "formation". Sand is common in this environment and if not part of the parent rock is soon added by the wind. All these sandy soils have moderate to highly permeability, and absorption is rapid.

On the mesa top soil varies in depth from zero on the escarpment rim and volcanic cones to more than five feet in broad areas of little slope. Weathered fragments of the basalt bedrock are part of the lower soil profiles, but windblown sediment is the most common material.

Mesa top soils impose certain constraints on development related either to the fineness of soil particles and low density, or to shallowness or absence of soil in some places. Vertical joints along the rim of the escarpment are planes of weakness, and as the soft sediments below the basalt are weakened by erosion, blocks of rock detach and roll down the slope. Locating development on the rim may lead to problems. Trenches cut into the bedrock

for utility lines could collect surface water, channel some of it into the joints, and weaken the soft sediment that supports the cliff edge. Indiscriminate use of explosives to construct the trenches also could increase instability at the base of the cliff and cause blocks to collapse.

Back from the rim where the soil is deep enough to bury utility lines without disturbing bedrock, development would be less costly but still would have some limitations. The principal engineering constraint is low soil density and therefore low bearing strength. To correct this problem, the soil should be precompacted before constructing streets and building foundations. Another constraint is susceptibility to wind erosion. Blowouts can occur in exposed areas, and during windy periods dust would be an aggravation to residents. Frost heaving is probably not a large issue, but piping (formation of horizontal conduits below the surface) could be a problem if soils are locally saturated for extended periods.

Below and east of the mesa, especially along the northern and central parts of the escarpment, the soil is fine silt and sand developed in the Santa Fe "formation." The low density and erodability of these soils by wind require construction techniques such as precompaction and as little cut-and-fill as possible. Beyond the south end of the escarpment the soil is also deep and has similar constraints on development, but because it is coarser sediment -- sand and gravel in addition to silt -- it has greater bearing strength. The potential for constructing buildings, roads, and sewage treatment facilities in these soils is better than in other places in the West Mesa area. Trails on sandy flats and on the steep sand-and-boulder slopes below the rim should be aligned and constructed with special care. To control erosion, it is necessary that trails be hard surfaced and that the

public be kept on these surfaces.

Hydrology. Several arroyos and their branches drain West Mesa. Surface water in most places is almost immediately absorbed by the porous soil and is either gradually dissipated to the atmosphere by evaporation or transmitted directly to the regional water table 400-500 feet below the mesa top. Evidence for an unusually low volume of surface runoff is seen in the lack of clearly defined streambeds along the arroyos, both on the mesa top and in the sandy flats below.

Despite the high permeability of soil and the arid climate, major rainfall in a short period is possible. Such rain, although infrequent, could flood the arroyos and damage development if adequate drainage structures are not built into the community utility network.

The Rio Grande trough is a natural underground reservoir for an immense volume of water. The high porosity and great thickness of the Santa Fe "formation" and other alluvium which fill the trough comprise a huge conduit through which water moves southward with relative ease (Titus, 1961). Mapping of the regional water table in 1961 showed that the most rapid southward movement of ground water past Albuquerque occurs beneath West Mesa about 400 feet beneath the surface. The city well immediately west of Petroglyph State Park taps this aquifer and pumps chemically potable water.

Vegetation. West Mesa with its low and relatively sparse plant cover is located near the northern limit of the upper Chihuahuan Desert. The Soil Survey of Bernalillo County (Hacker, 1977) describes the individual natural plant communities. Because of human-related disturbance such as grazing (and mining and offroad use to lesser extent) the plant species in these

communities are seldom present in ideal natural proportion. For example, broom snakeweed would never be the dominant shrub on undisturbed sites, but because of overgrazing it is probably the most common shrub in the flat areas of West Mesa.

The natural plant community that would be expected on top of West Mesa is generally a galleta-black grama grassland, with saltbush, winterfat and apache plume the dominant shrubs. Because of overgrazing, sand dropseed and broom snakeweed are more common.

The sandy flats extending out from the escarpment are, ideally, a mixed shrub grassland with Indian ricegrass and sand sagebrush the dominant species. Grazing and other human activities have reduced the grass and increased certain shrubs such as sand sagebrush, rabbitbrush, broom snakeweed, Russian thistle, and others. The only area beyond the base of the escarpment with similarity to an undisturbed vegetative condition is at Piedras Marcadas.

The escarpment with its steep, bouldery slopes is also a mixed shrub grassland. Because some of the extremely rocky areas have been little disturbed by recent grazing, they are close to an ideal natural condition where black grama and bush muhly are the dominant grasses and four-wing saltbush is the dominant shrub. Along the south end of the escarpment where the rim reaches maximum elevation above the flats, the basalt cliffs and talus contain protected ledges and pockets dense with four-wing saltbush and non-disturbance grasses such as grama.

Although some plants are abnormally common, these "disturbance" species contribute in their own way, season by season, to visitor enjoyment of West

Mesa. In summer, mustards and composites add spots of white and yellow to the landscape and silverleaf nightshade contributes purple to the floral display. In early autumn the land is yellow with blossoms of rabbitbrush and snakeweed, with purple accents from asters.

Wildlife. West Mesa animals are typical of the upper Chihuahuan Desert, and most are ordinary species. Some animals are year around residents; others, especially birds, may be present only during the migration or breeding season.

Similar to the plants at West Mesa, different animal species take advantage of the specific habitats that meet their environmental needs. Thus the fauna associated with each of the broad geographic areas -- mesatop, escarpment, and sandy flats below the escarpment -- has a predictable composition. Many animals are mobile, however, so depending on the species, their ranges may occupy more than one habitat. The populations of some are in decline due to the nearness of human activity.

The escarpment has special ecologic significance. This long narrow zone consisting of the cliff, slope, and sandy flats below is an "ecotone" with varied plant life where many animals find shelter for concealment and nesting and/or have the best opportunity for preying on or in other ways interacting with other species. Yet this is also a zone increasingly disturbed by humans. Impacts mount as residential areas expand into the corridor.

Twenty or thirty years ago, mammals such as ringtail and deer passed unhampered between the Rio Grande woodland and the escarpment, but with development rapidly filling the lands between, these species are on the

decline at West Mesa. Birds, on the other hand, range widely, and many species are far less affected. The escarpment is still an "island in the desert" for hawks and other raptors that nest or use the rock outcrops for perching while foraging in adjacent areas.

Mammalian carnivores include the wide-ranging coyote and bobcat. Gray fox, desert kit fox and long-tailed weasel are common along the rocky base of the escarpment slopes and in the sandy flats beyond.

Rodents are common in all the West Mesa habitats. Those found in rocky areas include whitethroat woodrat, rock squirrel, and rock pocket mouse, whereas in open sandy areas there are large populations of kangaroo rats. Other rodents such as antelope ground squirrel and white-footed mouse adapt to a variety of habitats and are found throughout the West Mesa area . The common lagomorphs, black-tailed jackrabbit and desert cottontail, live in open areas above and below the escarpment. Bats such as western pipistrell roost in rock cavities along the escarpment.

The bullsnake and western coachwhip are common in open areas, as is the prairie rattlesnake which sometimes winters in large numbers in rocky dens. Common lizards, the other main group of reptiles, include the whiptail, prairie, and lesser earless. Leopard (collared) lizards are distinctively marked carnivores of rocky areas, whereas round-tailed horned lizards are common in open sandy areas.

Common resident birds include scaled quail, horned lark, meadowlark, and road runner. Birds of the rocks and cliffs include rock wren and great horned owl. Burrowing owls frequently perch on boulders along the base of the escarpment and forage in adjacent open areas. Other raptors including red-

tailed hawk and marsh hawk are common hunters on the mesa top and in the open areas below.

Insects -- highly specialized and often wide ranging animals -- are very numerous. Other invertebrates including several species of spiders, sun spiders (solpugids), and scorpions occupy habitats both in rocks and in open areas. The escarpment supports a thriving population of the common desert millipede Orthoporus ornatis whose dried, segmented bodies are often seen among the boulders.

The seeming absence of wild animals at West Mesa, except for birds and insects, is misleading. In fact, most mammals and reptiles and some invertebrates are nocturnal and are not apt to be seen by daytime visitors. The actual faunal diversity is well known to the few local naturalists who make observations at dawn and dusk. As parkland and open space at the outskirts of a large city, certain parts of the West Mesa area have potential for long-term protection of many species which might otherwise be replaced by human environment.

ANALYSIS OF STUDY AREA SIGNIFICANCE

(NATURAL RESOURCES)

A. Local Significance

Geographic Setting. The volcanic escarpment forms a low, dark line beyond the river woodland the length of central Albuquerque. Above the escarpment in a line along the western horizon are the five volcanic cones. The escarpment and cones are one of three major elements that make Albuquerque landscapes distinctive. The other two -- the Rio Grande woodland and the Sandia Mountains -- can be seen from many places on West Mesa as well as Albuquerque, and remind visitors at the petroglyphs that these three elements were the larger scale day-to-day world of prehistoric people who lived here.

Geology/Prehistoric Inhabitants. Nearly all aspects of the observable natural environment were probably assigned significance in the livelihood and religion of the Native Americans living here for at least the past ten thousand years. For most^{of} that time, the inhabitants were hunters and gathers and moved with the game and harvest of wild plants.

There are several links between the geologic resources of West Mesa and prehistoric human lifeways. All the cultures found that certain types of stone such as chert and petrified wood, common in several places, could be used to make implements including projectile points. The technology of those tools was culturally transmitted and over time their shape and use evolved to meet the changing needs of their makers. Some influences for change were the innovations imported from distant cultures that resulted in entirely new ✓

types of implements such as pottery. Perhaps the most potent change was the "invention" of a new food plant in Mesoamerica -- corn -- which was eventually carried to the American Southwest. Primitive strains of corn (one discovered archeologists in a cave on West Mesa) were gradually improved by hybridization. Corn played an important part in evolution of Pueblo culture and, with its companion crops of beans and squash, enabled prehistoric people in many places to assume a more sedentary life and to increase their populations. No wonder that corn, so important in the diet and religion of Pueblo culture, appears in the rock art of West Mesa.

To Albuquerque's prehistoric farmers, the Rio Grande river bottoms were the most important cropland, but they took advantage of other environments too. On ledges along the southern part of the escarpment they discovered that patches of sandy soil were kept moist by runoff from the nearby cliffs and were ideal for small garden plots. Some of these plots were improved by building rock dams and ditches to intercept natural drainage on the mesa tops and by diverting the additional water to the gardens. Many of these agricultural pockets were protected from the prevailing wind and their dark rocks retained the sun's warmth, thereby extending the growing season. The Pueblo farmers were observant and resourceful users of favorable microclimates along the escarpment. They knew West Mesa intimately and not only used its resources ingeniously, but also found its black boulders a surface for artistic expression.

Inhabitants of earlier West Mesa cultures had discovered that the thin veneer of "desert varnish" on the escarpment's boulders could be incised, but ^{their} petroglyphs were relatively few. With the advent of Pueblo IV culture including religious symbolism borrowed from distant places, the art expanded

into thousands of petroglyphs the entire length of the escarpment. Many figures are repetitions and variances of religious themes, some showing humans, other animals, and natural forces combined in body and power. The inseparability of humanity from the rest of the biological and physical world is most impressive in this art.

Shrines on West Mesa are another connection between geologic phenomena and Pueblo religion. Several small natural caves in the basalt were formed when still-liquid lava flowed out from beneath hardened surface crusts and formed "drain out" cavities. Certain openings in the lava flows have long been regarded as passages between this earth and underworlds of former human existence, and some are still revered by Rio Grande Native Americans.

Open Space. Modern inhabitants of Albuquerque relate to the world differently than the prehistoric people. They do not rely so directly on the local natural environment for their daily livelihood, and they believe with their own logic that it is important to preserve nearby natural and cultural resources for enjoyment and education. West Mesa is an important study area for students of geology, biology and archeology from Albuquerque's schools, museums and organizations. In addition to nature study and research, local residents value the area for passive recreation. The city has dedicated large tracts on the mesa tops as parkland in anticipation of future demand for open space. The latest public concern is that sufficient land base on West Mesa, including the escarpment petroglyphs, be protected.

Ecology of the Escarpment. The escarpment and the flats below, formerly a continuous "natural gallery" of wildlife along Albuquerque's west side, is becoming fragmented as development continues. Sections of this ecologically

continue
with
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fragile zone that are still little disturbed such as the south end of the escarpment, the Rinconada, and Piedras Marcada, will be increasingly important remnants of natural environment as human-built environment expands.

B. Regional Significance.

Geology. Many relatively young volcanic rocks of New Mexico lie in a line extending northeast from Springerville, Arizona, to Clayton, New Mexico. Half a dozen sizable volcanic fields comprise this group, and in addition in Albuquerque Basin there are smaller eruptive centers, including the volcanoes at West Mesa (Albuquerque Volcanoes). Most volcanic rocks in this large region are basaltic in composition with the notable exception of those in the Jemez Mountains west of Santa Fe. The lava flows that form West Mesa and its escarpment do not differ significantly from other basalt flows in the region. However, the five steep volcanic cones composed of cinder, spatter and small lava flows, and further distinguished by lava ponds that overflowed or broke through their summit craters, are not so common. Other groups of volcanic cones in the region have their own distinct characteristics, some perhaps more unusual in the larger world of volcanic phenomena than Albuquerque Volcanoes. An example is the Ocate field northwest of Wagon Mound, New Mexico, where geologists are mapping cinder cones with lava ponds, domes, and radial dikes -- in complexity perhaps more interesting than the Albuquerque Volcanoes.

The flows at El Malpais near Grants, New Mexico, are very recent, their surfaces rougher and far less weathered than the basalts at Albuquerque. The steep Albuquerque cones, however, are at the fortuitious stage of erosion that some original flow structures are still present, yet some that

might otherwise be covered are exposed for improved interpretation of the volcanic story.

Vegetation and Wildlife. The vegetation of West Mesa, grazed intensively for more than two centuries, is potentially restorable to the Chihuahuan Desert plant communities typical of the upper Rio Grande Valley. A few sites have been less altered by grazing (at least in recent years) and therefore have partly recovered. One is the high ledgy area between the two lava flows at the south end of the escarpment where four-wing saltbush and native grasses are dense and provide a strong impression of the natural vegetative community. The flats in Piedras Marcadas are closer to an ideal vegetative condition than any other sandy areas observed; this mixed shrub grassland in a semi-protected cove is dominated by sand sagebush and Indian ricegrass and has other species such as indigo bush that are representative of the Chihuahuan Desert.

Two plant species classified as sensitive by the state of New Mexico are unlikely but potentially could be found at West Mesa; these are Astragalus feensis and Pediocactus papyracantha. Another state-sensitive species, Dalea scariosa, is very likely present in sandy areas such as Piedras Marcadas. There are no known animals at West Mesa listed on the state's classified list of sensitive species.

C. National Significance.

Geology. The standard of national significance used in this report is based on an informal but comprehensive survey of the units of the National Park System where volcanic rocks, particularly basalts, occur. In addition, a National Park Service report that inventories all the volcanic fields of the

United States was consulted for reference to areas outside the System (Rose, 1970). Three features of the Albuquerque Volcanoes are nationally significant.

The mixed variety of pyroclastics (spatter and cinder) and lava flows which compose the five Albuquerque cones is not clearly represented among other small basaltic cones in the National Park System. Lava ponds in cone craters that overflowed and broke through the crater rims to form small flows is documented in only one place in the System at Craters of the Moon National Monument, Idaho. Although the theme of flows dribbling over or breaking through crater walls is common in some volcanic districts of the world and therefore has no new or special scientific significance, the Albuquerque cones are an interesting variant somewhat uncommon in the United States and are not well represented in the National Park System.

The erosional "windows" on each of the three branches of Boca Negra Arroyo on West Mesa penetrate all the lava flows at each site and expose alluvium of the Santa Fe "formation" below. The windows have been described as "kipukas" or hills of alluvium that were surrounded by the flows and were later removed entirely by erosion to form basins. As "holes" in the lava which help geologists map the extent of each flow, the windows have local stratigraphic significance. But as "negative" landforms representing removal of former hills of sedimentary rock protruding up through lava rock, they have geomorphic significance and are probably unrepresented in the National Park System.

When the Albuquerque flows cooled 190,000 years ago, the orientation of the earth's magnetic field was recorded by crystals of iron-bearing minerals

in the basalt. Dr. John Geissman of the University of New Mexico recently discovered that the magnetic field at that time was radically different from its present orientation, and does not match any other departure or "excursion" of that age elsewhere in the world. It is not known if major excursions have been found in other rocks of the National Park System. However, this particular excursion "frozen" in the rocks of all six flows probably matches no other paleomagnetic records and has global significance.

Vegetation and Wildlife. In consultation with the U.S. Fish and Wildlife Service, it has been determined that no known plants or animals at West Mesa are on the federal list of threatened or endangered species. However, an unusual millipede has been found by Dr. Clifford ^aCrawford of the University of New Mexico in only one small area of Petroglyph State Park. Recent comparison of specimens indicates this millipede is Toltecolus chihuanus (Chamberlain), and its only other known occurrence in the world is at the city of Chihuahua, Mexico. Both the Fish and Wildlife Service and the state of New Mexico should be notified of this finding to determine the federal and state status of this disjunct population.

REFERENCES

Hacker, L.W., 1977, Soil survey of Bernalillo County and parts of Sandoval and Valencia counties, New Mexico: U.S. Dept. Agriculture, Soil Conservation Service, 101 p.

Kelley, V.C., and Kudo, A.M., 1978, Volcanoes and related basalts of Albuquerque Basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circular 156, 30 p.

Kelley, V.C., 1969, Albuquerque, its mountains, valley, water and volcanoes: New Mexico Bureau of Mines and Mineral Resources, Scenic Trips to the Geologic Past, No. 9, 3rd ed., 1982, 106 p.

Lambert, P.W., 1968, Quaternary stratigraphy of the Albuquerque area, New Mexico: PhD thesis, University of New Mexico, 329 p.

Titus, F.B., 1961, Groundwater geology of the Rio Grande trough in north-central New Mexico: New Mexico Geological Society, Twelfth Field Conference, p. 186-192.

Rose, R.H., 1970, The works of volcanism--sites recommended as potential natural landmarks: U.S. Dept. Interior, National Park Service, 203 p.