UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

STUDY RESULTS OF 9 SITES USED BY OFF-ROAD VEHILCES THAT ILLUSTRATE LAND MODIFICATIONS

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GENERAL REMARKS ON THE PHYSICAL EFFECTS OF OFF-ROAD VEHICLES

This report was prepared at the request of the Council on Environmental Quality to illustrate the types of land modifications brought about by recreational use of dry-land off-road vehicles (ORVs) in arid and semiarid areas. The following general comments are drawn from studies conducted on about 500 sites in seven western states. The sites selected for description were chosen to illustrate problems of resource degradation from direct vehicle impacts, erosional losses resulting indirectly from vehicle impacts, the similarity of problems despite widely different direct management policies, and future problems of rehabilitation.

VEHICLE CAPABILITY:

Hundreds of measurements have shown that typical motorcycles driven in a straight line on a dry surface will impact one acre of land in about 20 miles, and a typical 4-wheel vehicle does the same in about 6 miles. The minimum surface disturbance caused by the vehicles occurs when the forward motion for each revolution of the wheel is equal to the circumference of the wheel; that is, when the tire simply rolls across the ground. Under this circumstance, the main stress transmitted to the soil is compression. When the distance travelled for each revolution of the wheel is less than the circumference of the wheel, a shear stress as well as a compressive stress is transmitted to the ground. The latter mode of travel applies to all hillclimbing, and to substantial parts of flat-land traverses.

The capability of the machines to traverse difficult terrain is enhanced by special tire design as well as use of ancillary equipment;

the special tire design generally acts to increase the soil disruption caused by vehicle passage. For example, the protrusions from "knobby" motorcycle tires may penetrate the soil so that shear failure takes place on soil-soil interfaces instead of between the tire and the ground surface as occurs with tires designed for street use. The "paddle" motorcycle tire, consisting of 12 or 18 hard rubber cups protruding from the tire, is designed to aid traversing steep slopes mantled by soft soils; such tires displace enormous amounts of soil with each traverse. Where the surface is hard and steep, chains are used to aid hillclimbing.

SOIL VULNERABILITY:

The type of terrain that is available for ORV use, as well as that which challenges vehicle capability, is varied and includes country with steep slopes. Such terrain normally has shallow soils that are sensitive to erosion. The stability that they have is afforded by plants, rock crusts, and chemical crusts. While these protective covers on the soil mantle vary in vulnerability to vehicle impact, none appears able to withstand repeated vehicle penetration. In arid and semiarid areas, a single vehicle pass is commonly sufficient to destroy the natural barriers to erosion. In thick chaparral with shrubs to 4 m high, several passes by 4-wheel vehicles are sufficient to destroy the plant cover.

VEHICLE MODIFICATION OF SOIL:

In addition to destroying the natural surface stabilizers, the vehicles themselves erode the upper, most fertile portions of the soil mantle. Soil displacement (excluding displacement caused by compaction) produced by single motorcycle passes across natural desert surfaces is commonly ½ ton per kilometer of travel, and ranges up to 2 tons/km in soft soils on flat surfaces. Displacements caused by a single passage of 4-wheel vehicles ranges from about 2 tons/km to more than 30 tons/km in soft soils on steep slopes. Stripping of vegetation, mechanical erosion of the upper, porous soil layer, and compaction result in greatly reduced soil moisture, greatly increased temperature extremes in the soil, and increased runoff of rain water. These effects combine to increase the erosion potential and decrease the land's ability to restore its barriers to erosion.

EROSION:

Direct mechanical erosion of the soil by the vehicles is a very important cause of soil loss in arid areas. In addition, however, the surface modifications caused by vehicle use also act to accelerate natural erosion processes. Increased runoff from compacted surfaces stripped of vegetation gives volume and velocity to the erosive power of water. In combination with direct erosion by the vehicles, this has commonly resulted in complete loss of the soil mantle from the zones of use. Where the damage to the soil is less severe, the scars heal in time. However, the processes of erasure of vehicle scars involve erosion and deposition, and soil losses involved in the "healing" process may be five times or more the displacement caused by the initial vehicle passage. The burial of more fertile soils by the eroded debris also results in loss of productivity where deposition takes place. These soil losses are setbacks that must be measured in millennia and are thus irretrievable in human terms.

In areas subject to wind erosion, vehicle disruption of the soil stabilizers leads directly to increased air pollution and may contribute to the spread of dust-carried disease. The vehicles themselves cause large increases in airborne dust; for example, the 1974 Barstow to Las

Vegas motorcycle race yielded more than 610,000 kg of airborne particulates.

REHABILITATION:

Efforts to rehabilitiate arid federal lands damaged by off-road vehicle use are extremely rare. While the Interim Critical Management Plan of the Bureau of Land Management calls for eventual "hillside rehabilitation and maintenance for recreation vehicle use" in Dove Spring Canyon, nothing has been accomplished to this end.

The difficulties and potential cost of rehabilitating disturbed arid lands, however,are well known from studies of mine reclamation (National Academy of Sciences, 1974; Wali, 1975). In addition, the example exists in the immediate area of Dove Spring Canyon of the new California Aqueduct, installed in 1965. Despite efforts to restore native vegetation in the construction corridor, the corridor remains a bare zone of accelerated erosion. In Panoche Hills, a semiarid area south of San Francisco, efforts were made by the Bureau of Land Management to rehabilitate an area used for two years by motorcycles. Restabilization of the surface was successful, at a cost of $80/acre, in terrain with low relief but failed on steep slopes where erosion rates are still, 8 years after closure, nearly 50 times the natural erosion rates.

Without the requisite pre-use planning for rehabilitation and careful monitoring of resource degradation, ultimate rehabilitation of vehicle-disturbed areas is likely to prove difficult and costly.

PLANNING FOR ORV USE:

The engineering requirements necessary to minimize erosion from land used by ORVs are generally known and are readily available from the Soil Conservation Service. They are costly and very restrictive in terms of vehicle capability. The planning required to construct properly drained trails on slopes appropriate to the soil capability, design and maintenance of erosion mitigation devices, and construction of facilities to contain runoff and sediment yield have not been carried out at any of the sites on Federal lands that we have examined.

Site 1. Ballinger Canyon

Los Padres National Forest

SITE DESCRIPTION:

Ballinger Canyon is located at the eastern end of Cuyama Valley in steep, dry country. Land less than 10 km downstream from the vehicle use area is farmed. Sensitivity of the soils and bedrock to erosion is illustrated by local development of badlands topography. The soils are shallow and highly susceptible to erosion. The plant community ranges from grass and small shrubs to juniper.

VEHICLE USE HISTORY:

Vehicle use, mainly by motorcycles, over a period of 7 to 8 years has impacted an area of more than 400 hectares, and an area of more than 3,000 hectares was designated open to ORV use in 1976 (U.S. Forest Service, 1976). The open designation did not apparently utilize any of the recommendations of a Los Padres National Forest (U.S. Forest Service, 1972) soils report which specified the types of soil and hill configurations most suitable for vehicle use, and recommended strict engineering standards and paving of trails above 4,000 foot elevations. In August, 1978 the area was closed to hillclimbing because of excessive damage. However, actual closure has not, as of November, 1978, been effected. Moreover, Los Padres National Forest has released a Draft Environmental Assessment Report recommending that a 500 motorcycle enduro be permitted in Ballinger Canyon and adjacent areas (U.S. Forest Service, 1978).

VEHICLE IMPACTS ON PLANTS AND ANIMALS:

Grass cover is destroyed by a single traverse by a motorcycle, and large areas have been stripped (Fig. 1). Junipers growing on steep slopes are vulnerable to direct vehicle impact and to secondary effects of erosion brought about by vehicle use (Fig. 2). Smaller shrubs are destroyed by multiple vehicle impacts. Impacts on wildlife have not been examined, but this canyon is habitat for an endangered species of lizard and a hybrid form of that species (U.S. Forest Service, 1976).

VEHICLE IMPACTS ON SOILS, AND EROSION:

Extensive erosion is evident in areas stripped of their protective plant cover. The combined effects of direct mechanical erosion by the vehicles and water erosion has produced deep scars that penetrate well below the soil horizon into underlying rock units (Figs. 3-5). Cobbles and boulders displaced from the crest of the hill shown in Figure 5 form a thick, infertile cover that buries the original soils and plants lower on the hill. Water erosion built the fan of sand identified in Figure 5, which also buries formerly productive soils. Stull and others (1979), in a study of vehicle-induced erosion in the campground area of Ballinger Canyon, determined an erosion rate of 19,000 tons/km^2/yr, a rate that exceeds Soil Conservation Service standards by a factor of 86. Sediment produced by this erosion has caused extensive burial of floodplain habitat, and the increased runoff has contributed to gullying of the floodplain and loss of habitat.

MITIGATIONS:

No devices such as catchment dams or diversions are used at this site to prevent damage to land not allocated to this use, including downstream farmland. No devices such as water bars or diversions to retard erosion on-site are in evidence. The trails do not appear to have been planned and violate commonly understood principles of soil conservation such as slope length and grade control. No systematic information on soil distribution and sensitivity to erosion that would allow planned use to prevent unnecessary resource loss was presented in the Environmental Analysis Report (U.S. Forest Service, 1976), although it was available in an earlier Forest report (U.S. Forest Service, 1972) that was not distributed to the public. No standards of acceptable vegetative and soil loss were set by the EAR (U.S. Forest Service, 1976).

Site 2. Blythe Intaglios

National Resource Land (BLM)

The intaglios near Blythe, California are a valuable archaeological resource that has suffered significant vehicle degradation (Figs. 6,7). The figures were constructed simply by scraping aside a layer of dark pebbles at the surface exposing lighter material beneath. Motorcycles have damaged at least one figure, either before protective fencing was erected, or by gaining access through a gate in the fence. Two efforts were made by 4-wheel vehicles to break down the fence around one of the figures. In the Yuha Desert, protective fencing around an intaglio was cut and the figure destroyed by motorcycles (Los Angeles Times, August 6, 1975).

A single pass of a vehicle across mature desert pavement of the type in which the intaglios were made is sufficient to destroy it. As the intaglios are probably at least several centuries old, the vehicle scars are likely to remain as long.

Site 3. Red Rock Canyon State Recreation Area

SITE DESCRIPTION:

Site 3 is an unnamed ridge, informally called Tuttle Ridge, located in the Red Rock Canyon State Recreation Area. Land less than 1 km downstream is farmed. The ridge is 1.2 km long by 0.2 km wide and is mantled by soils that are highly susceptible to erosion. Vegetative cover is a creosote scrub community (Table 1).

VEHICLE USE HISTORY:

Use by motorcycles, dune buggies, and 4-wheel vehicles took place over approximately 5 years while the land was under the jurisdiction of the Bureau of Land Management. Use of this particular ridge was intensive, especially following partial closure of adjacent parts of Red Rock Canyon Recreation Area to ORVs in the summer of 1975, but substantial use has occurred over a large surrounding area exclusive of farmland. The ridge was closed to vehicular use in April, 1977 after acquisition by the State.

VEHICLE IMPACTS ON PLANTS AND ANIMALS:

Intensive vehicle use has destroyed all but the larger shrubs on most of the hill (Fig. 8; Table 1). Small plants were extensively destroyed, and the larger creosote shrubs underwent progressive degradation by direct vehicle impact, by erosional exposure of root systems of plants on the steeper slopes, and by burial by eroded debris on lower slopes.

VEHICLE IMPACTS ON SOILS, AND EROSION:

Vehicle use of the coarse sandy soils has churned the soil into an unstructured loose aggregate. Wind erosion has stripped some of the loose soil, and a portion of that has been deposited on the lee side of the hill. Severe water erosion of the destabilized soils is evident by comparison of figures 9 and 10. Erosion transects measured on this hill indicate loss of 11 million kg of material from the vehicle-disturbed parts of the hill (Wilshire and Nakata, 1977). Much of this material has been deposited on adjacent lower slopes where plant burial is evident. The remainder was carried southward into the agricultural lands. Although now closed to vehicle use, erosion remains active, and there are vehicle-created notches as large as 4 m wide and 1 m deep. Denuded slopes farther north in the Recreation Area that were closed to vehicle use more than 3 years ago are also undergoing active gully erosion.

MITIGATIONS:

No erosion control devices are used to mitigate off-site effects of accelerated erosion, and none are used to retard erosion on-site. The trails apparently were established by the vehicles according to vehicle capability without regard to sound soil conservation practice. No efforts have been made to rehabilitate the closed areas which are now, and will remain for the foreseeable future, sites of accelerated erosion. The unmitigated erosion of this area contrasts with the California State Public Resources Code policy (Section 5001.5, d, 3) which states that "State vehicular recreation areas....shall be chosen to insure that....no adjoining properties incur adverse effects from the operation and maintenance of vehicular recreation areas...." and under "....all circumstances, conditions of accelerated and unnatural erosion shall be anticipated and prevented to the extent possible. Where the occurrence of such erosion is unanticipated, every measure shall be taken to restore the area."

Site 4. Jawbone Canyon

National Resource Land (BLM)

SITE DESCRIPTION:

Jawbone Canyon is a desert-facing canyon in the southern Sierra

Nevada. The terrain is steep, and soils are shallow and extremely sensitive to erosion. Vegetation is a creosote scrub and joshua tree community.

VEHICLE USE HISTORY:

Use by motorcycles, dune buggies, and 4-wheel drive vehicles over a period of perhaps less than 10 years has impacted extensive areas of the valley floor and 20 km of canyon walls. About 2,000 hectares of the canyon have recently been designated open to vehicle use (Bureau of Land Management, 1976a).

VEHICLE IMPACTS ON PLANTS AND ANIMALS:

Intensive vehicle use has stripped all but the larger shrubs and joshua trees from large areas; some hillsides have been completely denuded, and floodplain habitat has been extensively degraded (Fig. 11). Surviving plants near intensive use zones are undergoing progressive degradation by wind and water erosion which expose the root systems (Fig. 12). Only modest root exposure of the shallow-rooted joshua trees makes them vulnerable to toppling by wind. Small plants undergo sand blasting by sand blown from the vehicle-disturbed areas. No studies have been published of the effects of habitat loss or direct vehicle impact on animal populations at the site.

VEHICLE IMPACTS ON SOILS, AND EROSION:

Destabilization of the very sandy soils of Jawbone Canyon has produced an erosional response like that at the Red Rock Canyon site, but erosion is exacerbated by steeper and longer slopes. The canyon walls are extensively denuded, and bedrock has been exposed by erosion. As the bedrock exposures enlarge, vehicles can no longer negotiate the trails and new ones are established (Figs. 13,14). Figure 15 is a view down a trail used by both 2- and 4-wheel vehicles. Rain produced a thick slurry of the churned soil that flowed out over the valley floor much like a lava flow burying valley bottom soils and plants, and doubtless trapping many burrowing animals. In this manner, fine-grained soils that had been locked in a vertical section anchored by plants are now spread in a thin sheet with a large surface area exposed to wind erosion. Moreover, the deep leveed channel through which the slurry flowed now forces traffic to the sides and causes expansion of the damage. Some slopes with very shallow and sensitive soils have been stripped entirely of their soil mantle (Fig. 16). Such hills, underlain by hard bedrock, are no longer negotiable by most vehicles, and new sites are sought where the inevitable sequence is repeated.

Denudation of the floodplain (Fig. 11) as well as the hillsides acts to increase the frequency and magnitude of flooding, both in the canyon and downstream where highway hazards and threats of flood damage to crops have been exacerbated. This is a growing problem in other desert-facing canyons in the southern Sierra Nevada such as Dove Spring Canyon, Bird Spring Canyon, Horse Canyon, and Sage Canyon which are being progressively denuded by vehicle use.

The Jawbone Canyon lands are among nearly 45 percent of lands in the El Paso and Red Mountain Planning Units (Bureau of Land Management, 1976 a,b) that were mapped by the Bureau of Land Management as severely susceptible to erosion, but which were opened to ORV use. The Yuha Desert Management Framework Plan (Bureau of Land Management, 1975a) permits ORV use of at least 50 percent of the lands that the plan designates as severely susceptible to erosion. All three plans declare that such lands will be protected by limiting uses that disrupt the soil.

MITIGATIONS:

No erosion control devices are employed to limit off-site effects of accelerated erosion in Jawbone Canyon, which is catchment for the Fremont Valley agricultural area. Flood stage drainage carries the finer grained sediments into the agricultural area where they add to a chronic dust problem. No on-site measures have been taken to curb erosion. ORV trails are suitable to vehicle capability but directly violate soil conservation practices such as avoiding disturbances on long or steep slopes. No systematic information on soil distribution or capability to sustain vehicle use was presented in the Management Plan that authorizes this use (Bureau of Land Management, 1976a). No standards of acceptable vegetative or soil loss were set by the Management Plan (Bureau of Land Management, 1976a), and no systematic monitoring has been undertaken to record the level of resource damage. Although the Interim Critical Management Plan (Bureau of Land Management, 1973) states that ORV areas in this region will be rehabilitated, this may not be possible in view of the severe damage already sustained.

Site 5. Hungry Valley

Combination of National Forest, National Resource

and Private Lands

SITE DESCRIPTION:

The Hungry Valley site is located in the San Emigdio Mountains near Gorman, California. The terrain is steep to moderately steep, and soils are deep to shallow and sensitive to erosion. Valley floors are farmed, and the grasslands are grazed. The area is in the catchment of Pyramid Lake Reservoir (Knott, 1978).

VEHICLE USE HISTORY:

Use by motorcycles, dune buggies, and 4-wheel vehicles has been intensive since 1971. In this time more than 800 hectares have been severely impacted by vehicle use; 130 hectares of National Forest land were designated open to vehicle use by the Los Padres National Forest (U.S. Forest Service, 1976). Plans are presently underway by the State Parks and Recreation Department to purchase 19,000 acres of land here for a State Vehicular Recreation Area.

VEHICLE IMPACTS ON PLANTS AND ANIMALS:

Vehicle use has quickly stripped grass cover, and direct vehicle impacts on the chaparral community are expanding in marginal areas and along cross-country trail systems that branch from the main use area. A small hill near the entrance was closed after substantial use to avoid a traffic hazard. Parts of the trails have revegetated, partly with Russian thistle, but others in which erosion had reached bedrock have not recovered (in approximately 2 years) and are actively eroding. In addition to direct vehicle stripping of vegetation, substantial loss of grazing capability has been sustained by burial of productive soils by debris washed from the ORV hillclimbs (Fig. 17). No study has been published of vehicle impacts on wildlife or wildlife habitat.

VEHICLE IMPACTS ON SOIL, AND EROSION:

Two contrasting types of soil-response problems are well-illustrated at Hungry Valley: (1) certain steep slopes and hills capped by terrace gravels (Fig. 18; Figs. 20-23) are vulnerable to direct mechanical erosion by vehicles and to gully erosion; (2) more commonly, the soils are of a nature that resists direct displacement by vehicles and instead respond by compaction and formation of hard surface seals (Fig. 19). In this case, runoff is greatly accelerated and the erosional response is felt lower in the drainage system (Knott, 1978); this is visible in figure 19 where incision of the drainages by excessive runoff has migrated headward into the denuded zone.

Erosion and deposition monitoring results for these contrasting problem areas are shown in Table 2. Column 1 (Table 2a) shows incremental average losses recorded by exposure of three benchmarks that had been emplaced in 1969 at the crest of a hill (Fig. 17) capped by terrace gravels. By April, 1977 all three benchmarks had been entirely eroded out. Other columns in Table 2 record gully development in drainages receiving high runoff from off-road vehicle use areas. The first two columns in Table 2b record gully development in the cluster of oak trees at the top of figures 19-20. Headward erosion in the main gully below the trees, greatly accelerated by runoff from vehicle-denuded slopes, ultimately resulted in fusion of gully segments across a small depression that served as a temporary sediment storage area. Once this fusion occurred, the upper gully system began more rapid headward erosion resulting in fusion of higher gully segments.

The effects of denudation of steep slopes underlain by the more erodible soils is shown in figures 21-22, photographed in May, 1976 and March, 1978.

MITIGATIONS:

No erosion control devices are employed to limit off-site effects, and accelerated runoff and increased sediment production may be adversely affecting downstream property as well as contributing sediment to Pyramid Lake Reservoir. No on-site techniques of erosion mitigation are used with the consequence that both the valley bottom farmland and grazing land are being degraded by increased runoff and deposition. Trail breaking violates commonly understood soil conservation practices. No systematic information on soil distribution or capability was provided by the Los Padres National Forest EAR (U.S. Forest Service, 1976) on the forest portion of the land.

Site 6. Barstow to Las Vegas Course

National Resource Land (BLM)

SITE DESCRIPTION:

This 250 km-long motorcycle race course traverses a wide variety of Mojave Desert terrain (Bureau of Land Management, 1975b; Wilshire and Nakata, 1976). All soil types traversed, except perhaps certain dry lake deposits, are shallow and sensitive to erosion. Vegetative cover ranges from nil on dry lake surfaces to grass, creosote communities, joshua tree communities, and cactus-juniper communities.

VEHICLE USE HISTORY:

Similar, but not identical, courses were used for this 1-day motorcycle race in each of 8 years. As many as 3,000 vehicles participated in the races, which were run partly on existing roads and partly cross-country. Efforts to restrict use to a pre-planned course failed, and permit applications have been denied after 1974. However, each year following 1974 unauthorized races have been run on this course, starting with only a few participants in 1975 and reaching an estimated 500 to 600 participants in 1978.

VEHICLE IMPACTS ON PLANTS AND ANIMALS:

Extensive loss of small plant cover, both annual and perennial, was documented by the Bureau of Land Management (1975b) and Wilshire and Nakata (1976). Annual plants were reestablished in many of the tracked areas after 1974, but recovery of perennials is likely to be a much slower process. The effects of accelerated erosion on plants has not been examined. Trapping studies before and after the 1974 running of the race indicated 90 percent loss of small mammals (Bureau of Land Management, 1975b). A study made a year later (D. Hicks, A. Sanders, and A. Cooperrider, 1976) revealed population densities of certain mammals to be 80 percent lower in the race course area compared to unused similar habitat. This is the first study indicating severity of the effects of habitat modification by ORVs.

VEHICLE IMPACTS ON SOILS, AND EROSION:

The only quantitative measurements made on soil modification on this course are surface strength measurements (Bureau of Land Management, 1975b; Wilshire and Nakata, 1976), which indicate substantial modification of soil structure. Direct mechanical erosion of soil during the 1974 race produced more than 610,000 kg of airborne particulates (Bureau of Land Management, 1975b). Predicted erosional consequences of surface disruption (Wilshire and Nakata, 1976) have been subsequently confirmed by Wilshire and Nakata (1977). Figure 23 is an aerial view of trails left by the 1974 race. The dark stripes crossed by the trails are very ancient surfaces capped by mature varnished desert pavements. With vehicular stripping of this cover, erosion has begun (Fig. 24).

MITIGATIONS:

Efforts to mitigate damage during the 1974 running of the race by channeling the course failed (Bureau of Land Management, 1975b). Damaged surfaces have not been restored, nor has any attempt been made to mitigate erosion, which will continue at an accelerated rate for the foreseeable future. The large areas of disrupted desert pavement surfaces will continue to yield wind-erodible fines that are winnowed out and carried to main drainages by water erosion for an indefinite time, thus contributing to long-term air pollution problems.

Sites 7-9. Lancaster, Stoddard Valley, Shadow Mts.
Natioanl Resource Land (BLM) and Private
Land

No systematic studies have been made of these sites although they represent intensive use of public lands. Figure 25 illustrates extensive denudation of flat terrain near Lancaster, mainly by motorcycles, Figure 26 illustrates severe impacts in Stoddard Valley mainly from 4-wheel vehicle competitive events, and Figure 27 shows denuded pit and trail areas in the Shadow Mts. used for random vehicle recreation and competititve events by both motorcycles and 4-wheel vehicles. Soil disturbances of the types illustrated create fetch areas for wind erosion; wind erosion of the denuded soils in turn contributes to air pollution and may cause dissemination of disease forms endemic in the soils.

The lack of systematic data on the quantitative effects of this land damage contrasts with presidential instructions (E.O. 11644) to monitor the effects of vehicle impacts on public lands, and the apparent magnitude of the impacts on vegetation and soils contrasts with presidential instructions (E.O. 11989) to immediately close areas that have suffered such damages to the types of vehicles that have caused the damage. Many other sites in the California desert are in like condition, such as Johnson Valley, the Rand pit area, Wagon Wheel, Bean Canyon, Koehn Dry Lake, El Mirage Dry Lake, Rasor Road, Rabbit Dry Lake, Piute Butte, Dove Spring Canyon, Horse Canyon, Bird Spring Canyon, and Afton Canyon, to name some of them.

Table 1. Plant Species on Tuttle Ridge (July 21, 1978).

On slope (less disturbed)

Cassia armata (desert senna)

Oryzopsis hymenoides (rice grass)

Acamptopappus sphaerocephalus (goldenhead)

Lycium cooperi (peach thorn)

Eriastrum densifolium--a phlox (Mojave gilia)

Ambrosia dumosa--burrobush

Larrea tridentata--creosote

Opuntia basilaris and *enchinocarpa*--(beavertail and silver cholla)

Ephedra nevadensis--Morman tea

Eriogonum plumatella--flat-top buckwheat

Stipa speciosa--Needlegrass (?)

Eriogonum fasiculatum--California buckwheat

Heavily disturbed slope:

Larrea tridentata

Cassia armata

Acamptopappus sphaerocephalus

Oryzopsis hymenoides

Ambrosia dumosa

Hymenoclea salsola

Eriastrum densifolium mohavense

Salsola iberica (Russian thistle)

Ephedra nevadensis

Opuntia basilaris and *enchinocarpa*--these are small and protected near bushes

Table 2a. Erosion, Deposition Data, Hungry Valley.

Date	Average Cumulative Denudation at 3 Benchmarks, Crest of Benchmark Hill
1969	Emplaced
1/8/76	20.9 cm
9/23/76	38.1 cm
4/24/77	54.3 cm

Table 2b. Gully dimensions, landslide north side Long Ridge Tributary from landslide to gully along base of slide.

Date	Depth at entry to main gully	Depth Knick Point	Length	Maximum Depth
2/22/78	2.0 m	1.85	26	
3/10/78	2.35 m	1.65	33	33

Main gully along base of landslide:

Date	Depth at lowest oak	Depth at top oak	Depth upper Knick Point	Upstream Migration of Upper Knick Pt.	Width at Straddling oaks	Depth at Straddling oaks
4/24/77	2.13 m					
1/7/78	3.00+ m					
2/22/78	3.4 m	0.66			0.80	2.58
3/10/78	4.4 m	0.76	1.12	21.0	2.12	3.00
4/6/78		0.74	1.30		2.30	3.25

Gas pipeline gully, parallel to main access road:

Date	Maximum Depth	Migration of Knick Point	Gully Width at Straddling Posts	Maximum Width
1/7/78	1.7 m			
2/22/78		5.8 m	1.67 m	
3/10/78	3.0 m	5.7 m	3.5+ m	6.0 m+

Cultivated field adjacent access road:

Date	Debris Fan	Gully Depth at road	Gully Length from road
3/10/78	30 × 125 m	2.2 m	100 m
	13 × 58 m	1.25 m	195 m

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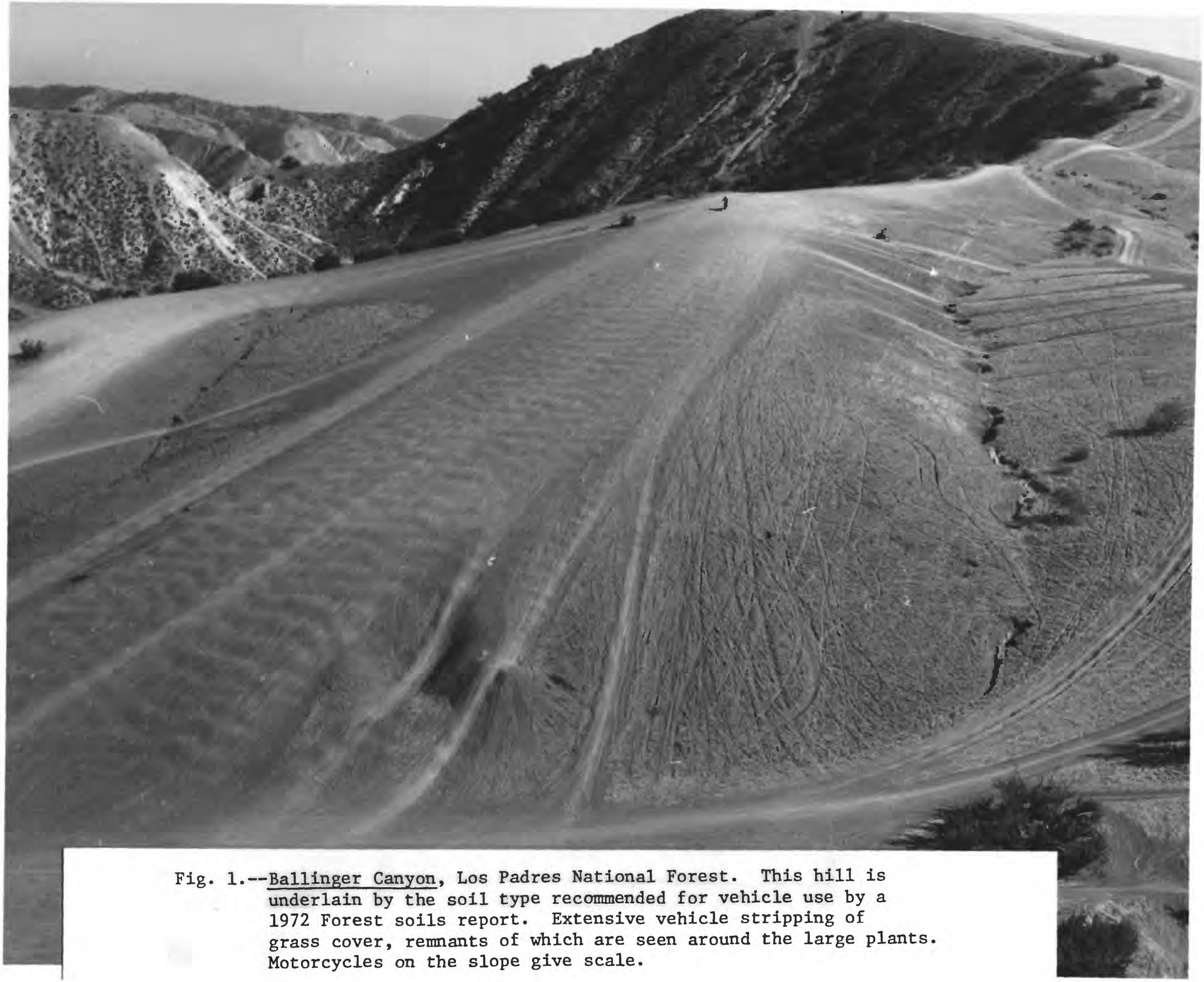

Fig. 1.--Ballinger Canyon, Los Padres National Forest. This hill is underlain by the soil type recommended for vehicle use by a 1972 Forest soils report. Extensive vehicle stripping of grass cover, remnants of which are seen around the large plants. Motorcycles on the slope give scale.

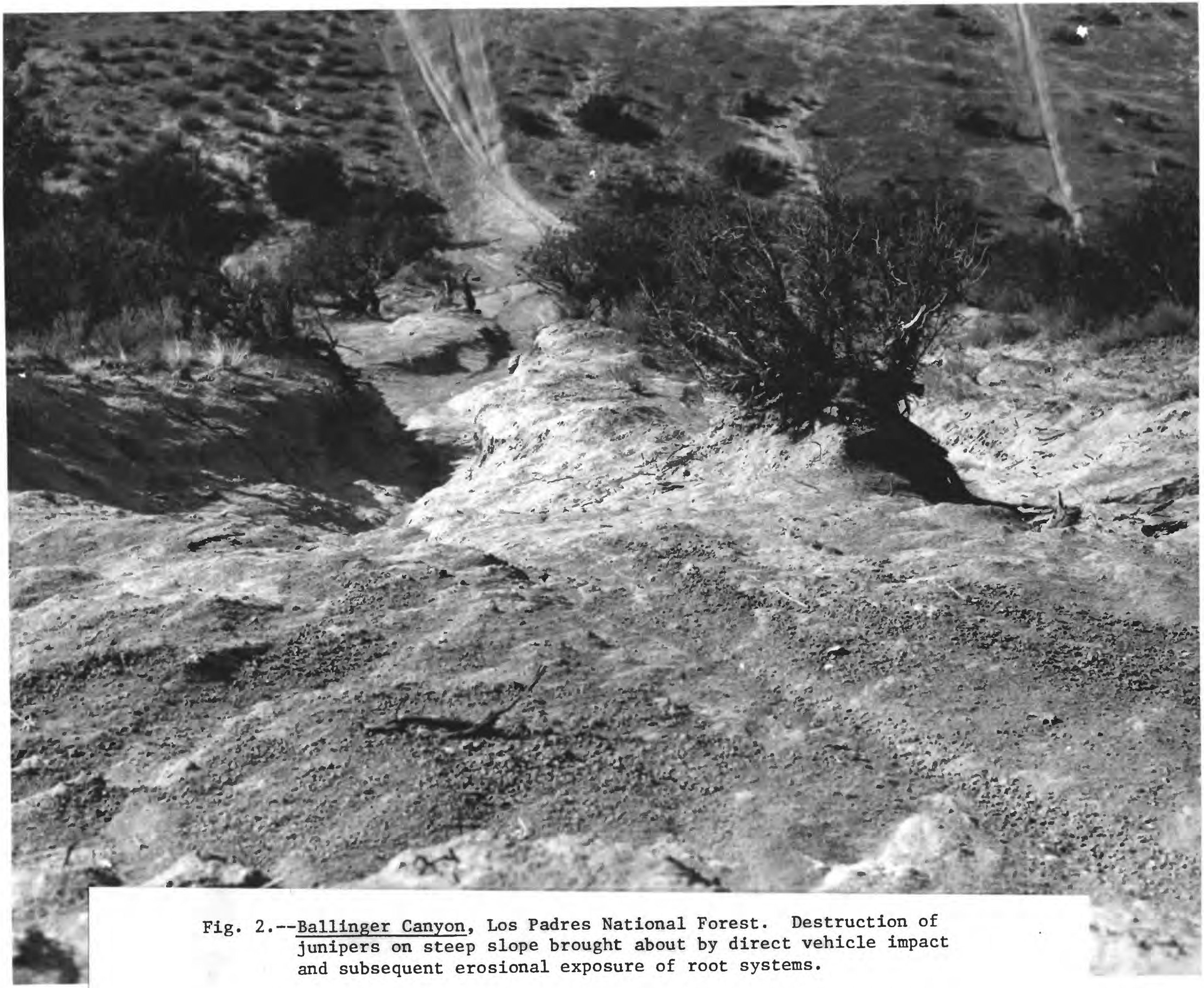

Fig. 2.--Ballinger Canyon, Los Padres National Forest. Destruction of junipers on steep slope brought about by direct vehicle impact and subsequent erosional exposure of root systems.

Fig. 3.--Ballinger Canyon, Los Padres National Forest. Rill erosion characteristic of the soil type recommended for vehicle use by a 1972 Forest soils report. Note depositional fans at base of slope. Vehicle use quickly obliterates this direct evidence of accelerated erosion. Hammer is 32 cm long.

Fig. 5.--Ballinger Canyon, Los Padres National Forest. Deep slots (to 2 m) cut in hillside by motorcycles. Rock and soil eroded from the slots forms a thick apron (A) burying plants and soils lower on slope. Water erosion of the trails formed the large sand fan at B.

Fig. 4.--Ballinger Canyon, Los Padres National Forest. Steep slope underlain by the soil type recommended for vehicle use by a 1972 Forest soils report. The deep notches, which extend into bedrock, were cut dominantly by direct vehicular erosion.

Fig. 6.--Blythe, California. 1932 photograph of unspoiled intaglios. The largest figure is about 50 m long. Courtesy National Geographic Society.

Fig. 7.--<u>Blythe, California</u>. 1975 photograph of intaglios showing extensive vehicle damage (there are three sets of intaglios in the immediate area; this is not the same set as shown in Fig. 4, but all three sets have suffered similar degradation).

Fig. 8.--<u>Red Rock Canyon State Recreation Area</u>. Aerial view of small ridge showing that areas between larger shrubs have been saturated with vehicle tracks.

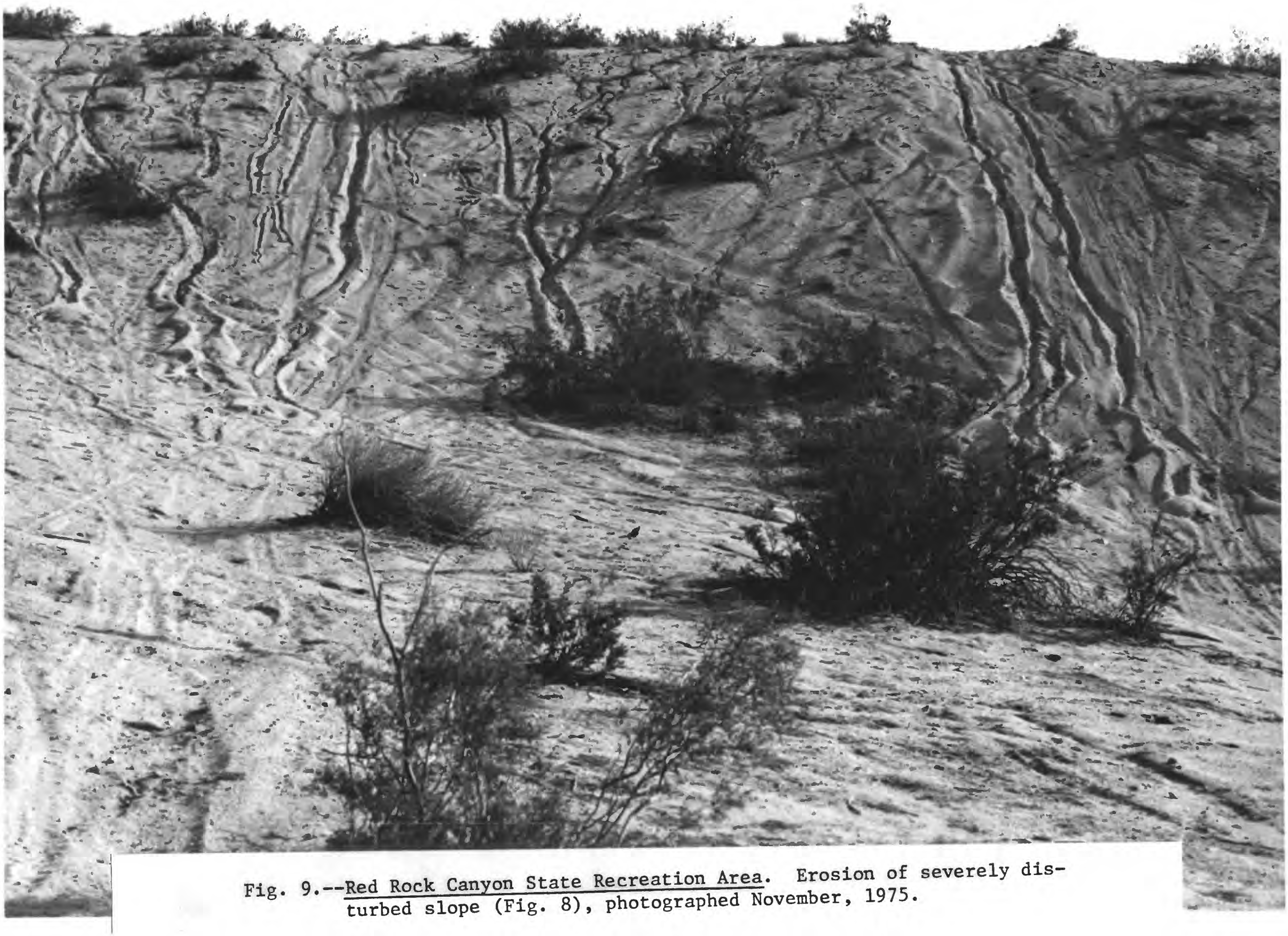

Fig. 9.--Red Rock Canyon State Recreation Area. Erosion of severely disturbed slope (Fig. 8), photographed November, 1975.

Fig. 10.--Red Rock Canyon State Recreation Area. Same scene as in figure 9, photographed September, 1976.

Fig. 11.--Jawbone Canyon. Aerial View of Blue Point in Jawbone Canyon showing extensive denudation of the floodplain.

Fig. 12.--Jawbone Canyon. Severe root exposure of creosote shrubs caused by excessive runoff from ORV trail and headward erosion of gullies in the trail.

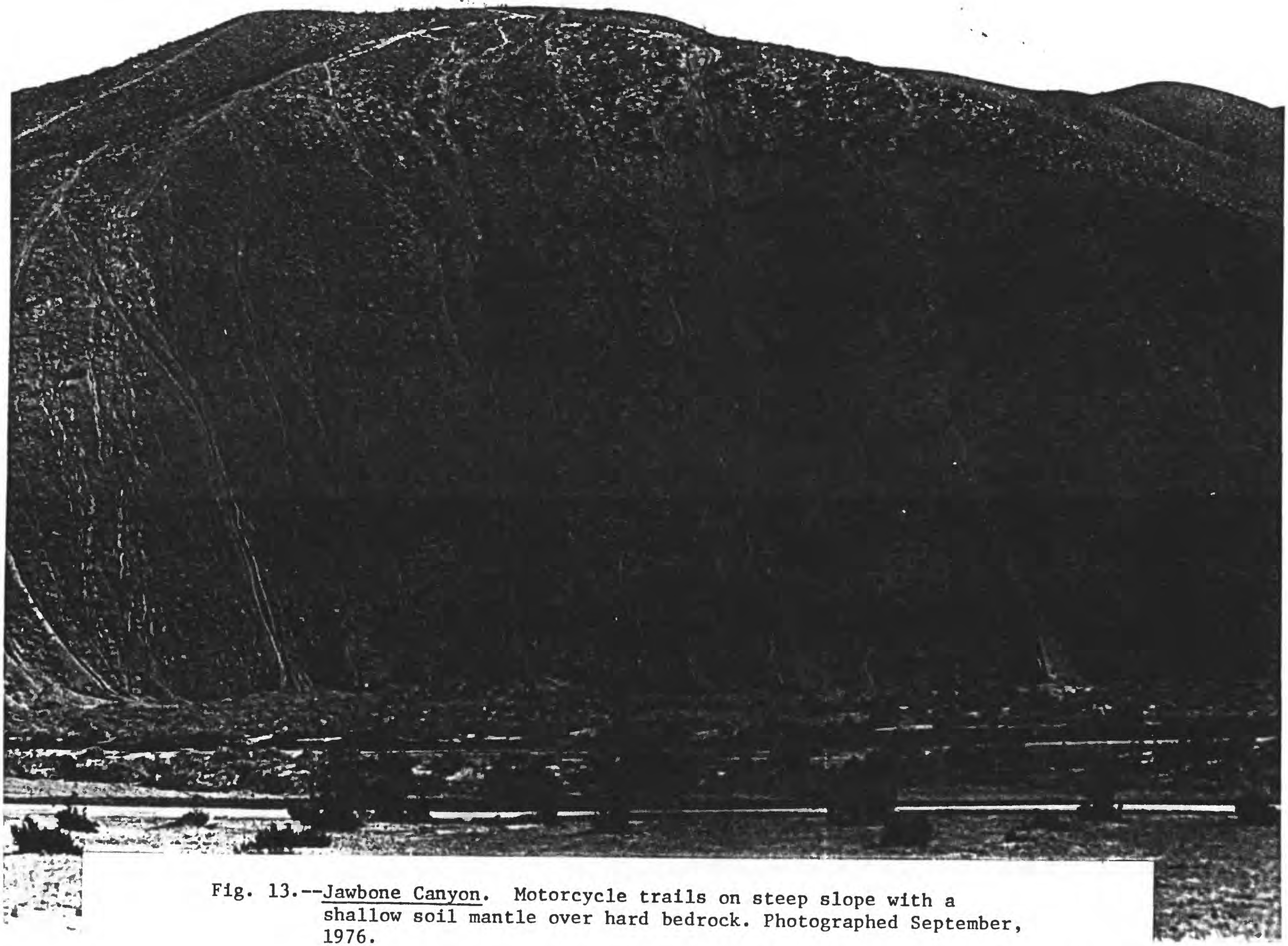

Fig. 13.--Jawbone Canyon. Motorcycle trails on steep slope with a shallow soil mantle over hard bedrock. Photographed September, 1976.

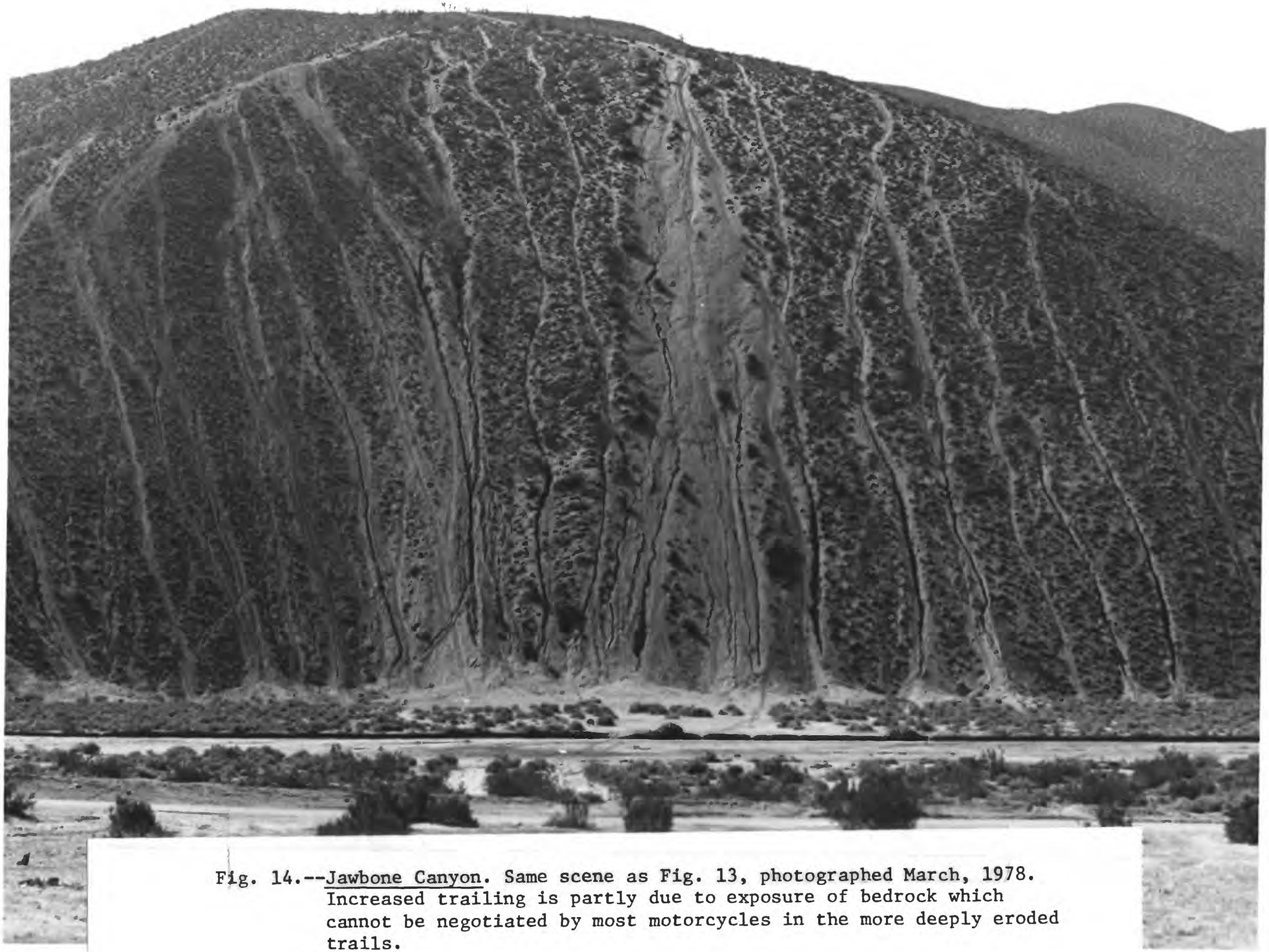

Fig. 14.--Jawbone Canyon. Same scene as Fig. 13, photographed March, 1978. Increased trailing is partly due to exposure of bedrock which cannot be negotiated by most motorcycles in the more deeply eroded trails.

Fig. 15.--Jawbone Canyon. View down an ORV trail on steep canyon wall. Rain formed a thick slurry that flowed through the deep channel in the foreground and out over the valley floor like a lava flow (edges marked by arrows).

Fig. 16.--Jawbone Canyon. Central part of this hill has been completely stripped of soil exposing hard bedrock. Remnants of deeply gullied soil at right and center-crest reveal the cause: vehicle destruction of plant cover.

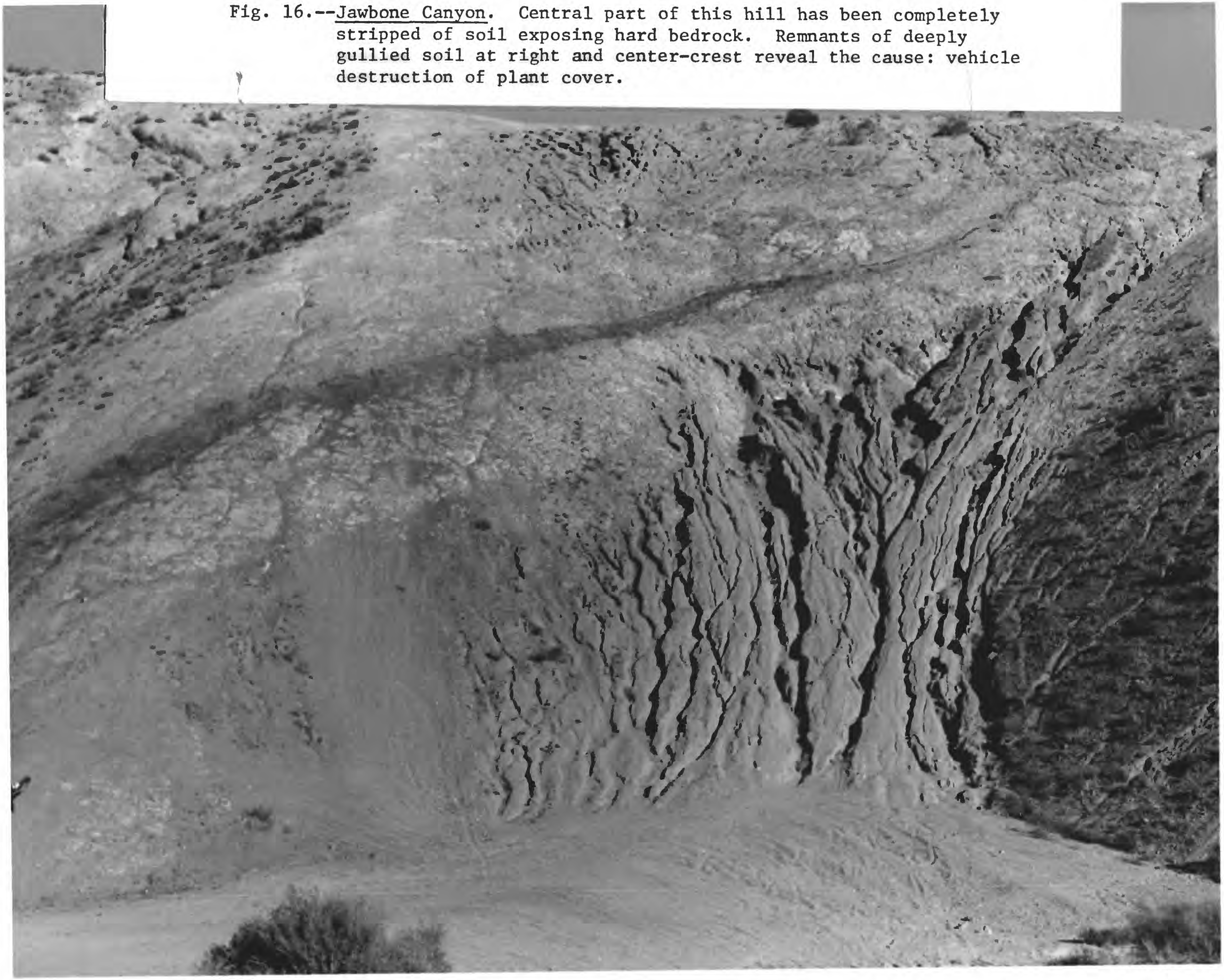

Fig. 17.--Hungry Valley. Burial of floodplain vegetation by debris eroded from areas denuded by off-road vehicles.

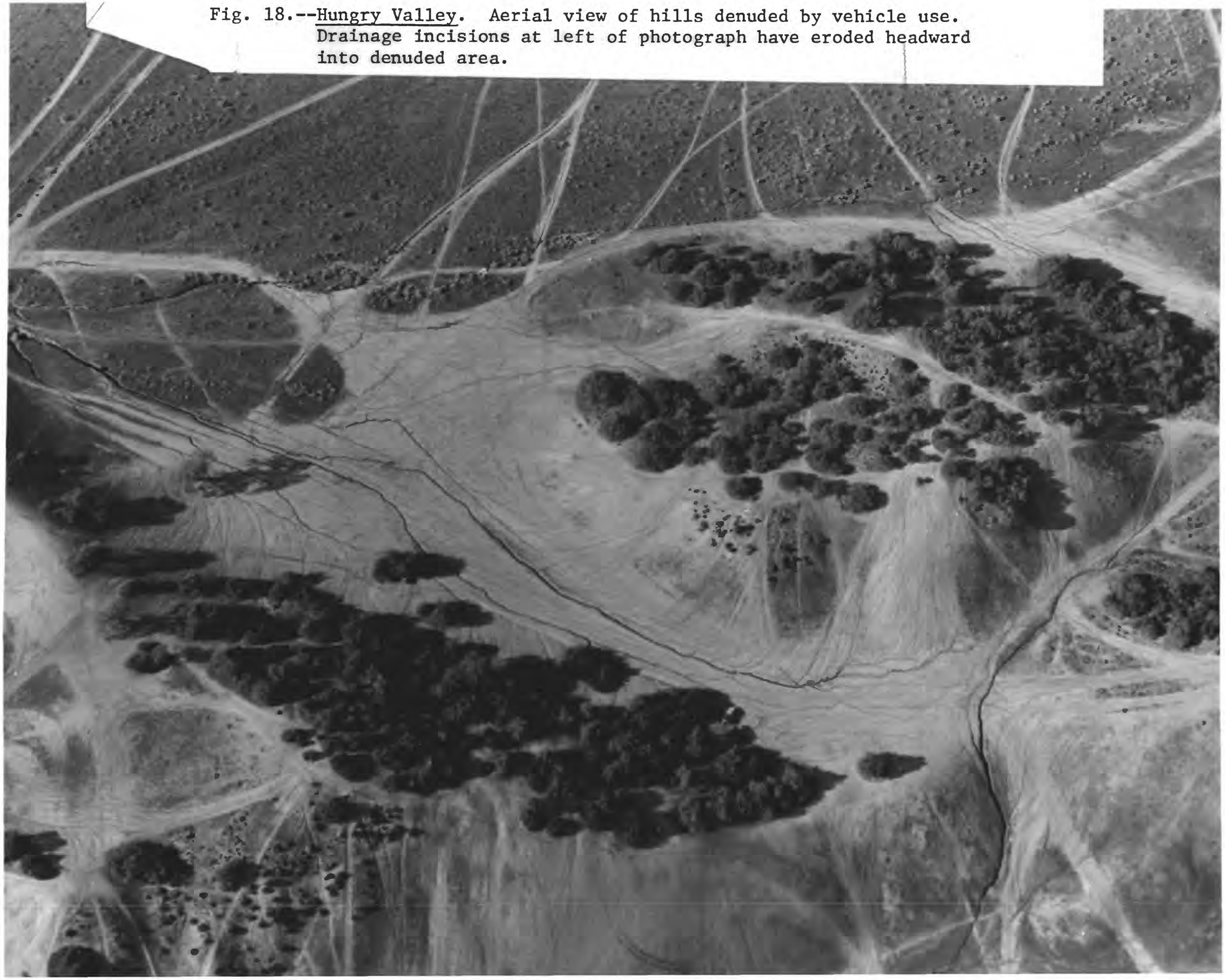

Fig. 18.--Hungry Valley. Aerial view of hills denuded by vehicle use. Drainage incisions at left of photograph have eroded headward into denuded area.

Fig. 19.--Hungry Valley. Debris washed from gullies in ORV trails has accumulated in a local depression 17 X 50 meters across at base of slope. Very much more debris was carried beyond this local depression downstream. Photographed September, 1976.

Fig. 20.--Hungry Valley. Same scene as Fig. 19, photographed March, 1978. Note enlarged gullies in foreground and new gullying of flat area above trees.

Fig. 21.--Hungry Valley. Erosion of steep slope denuded by ORV traffic.
Photographed May, 1976.

Fig. 22.--Hungry Valley. Same scene as Fig. 21, photographed March, 1978.

Fig. 23.--Barstow to Las Vegas Motorcycle Race Course. Aerial view of trails left by races.

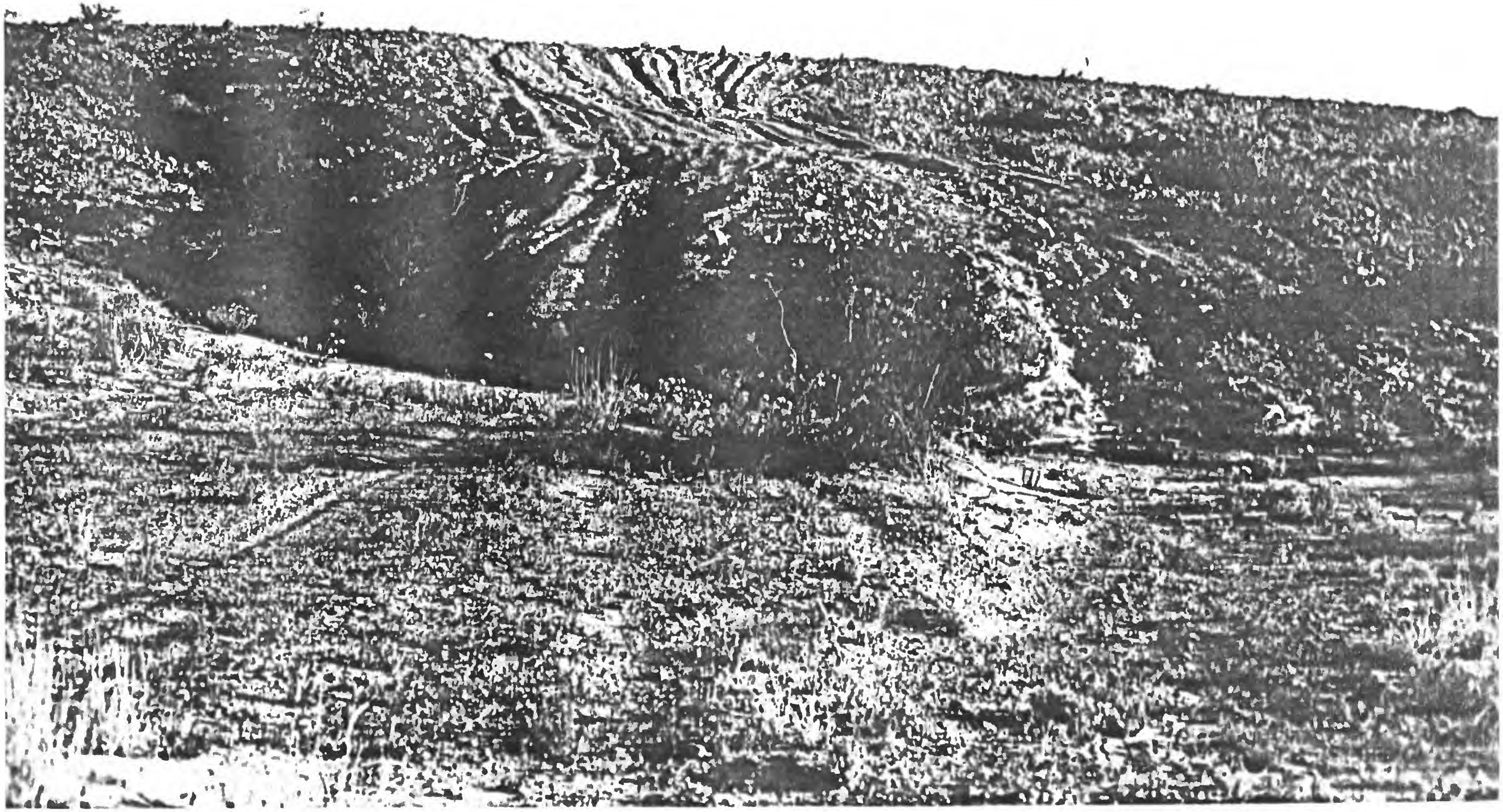

Fig. 24.--Barstow to Las Vegas Motorcycle Race Course. Ground view of erosion of trails shown in Figure 18. Photographed March, 1977.

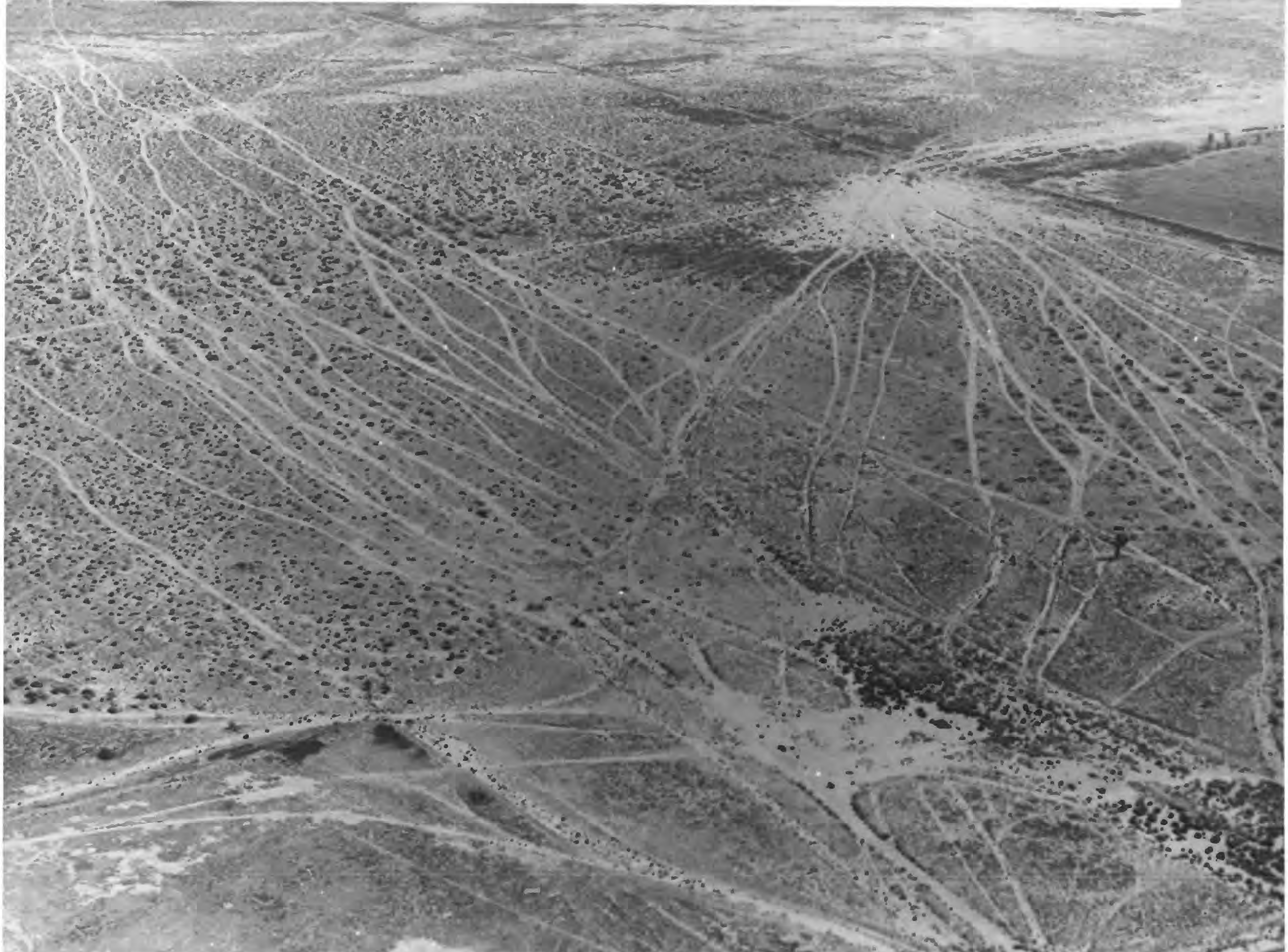

Fig. 25.--Lancaster. Aerial view of denuded pit areas and trails northeast of Lancaster. Dark vegetation in and adjacent to trails and pit areas is Russian thistle.

Fig. 26.--Stoddard Valley. Aerial view of trails left by 4-wheel vehicle competitive events.

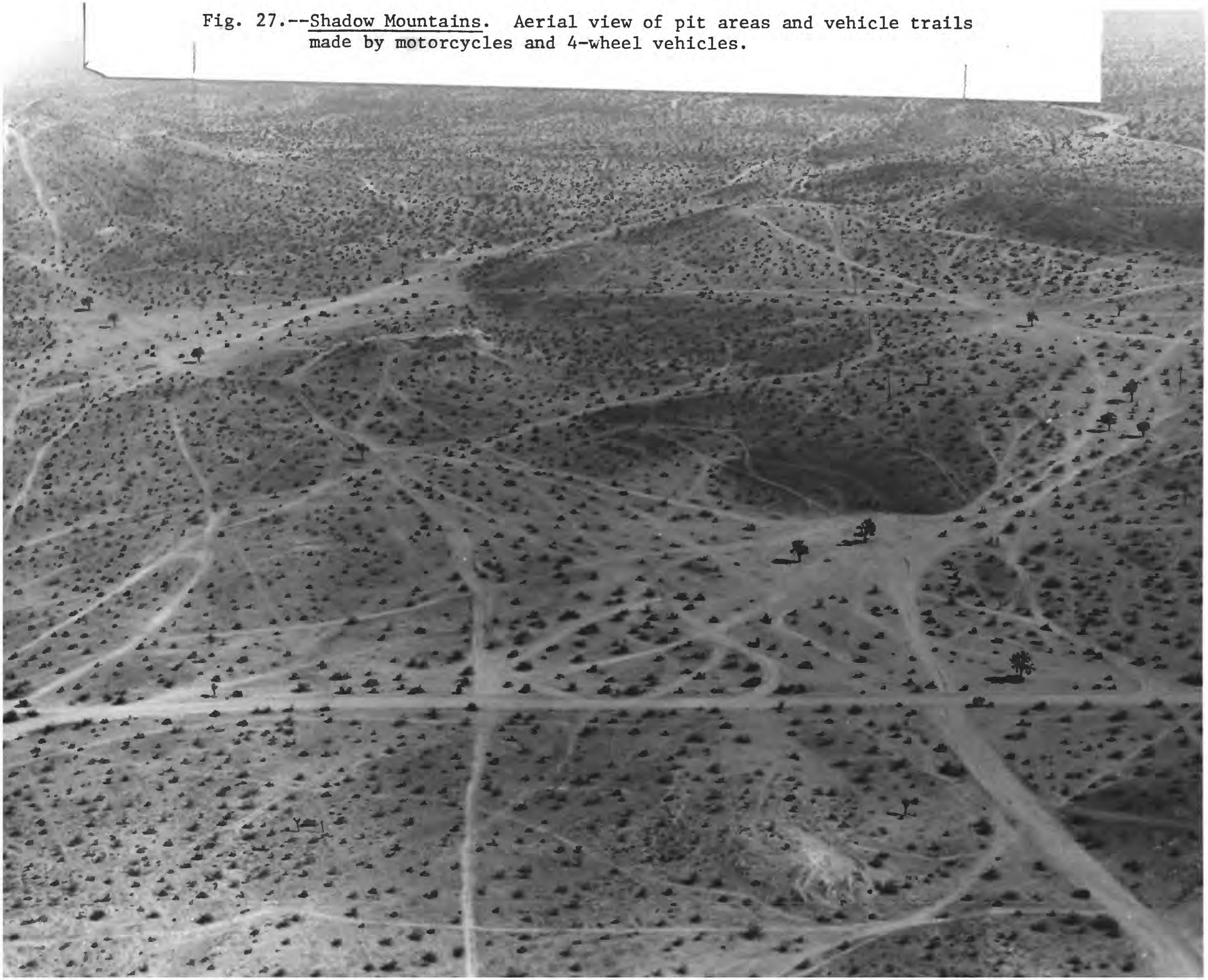

Fig. 27.--<u>Shadow Mountains</u>. Aerial view of pit areas and vehicle trails made by motorcycles and 4-wheel vehicles.