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MAPPING MONTANE VEGETATION IN SOUTHERN CALIFORNIA
FROM COLOR INFRARED IMAGERY

by

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FOREWORD

A significant contribution to the techniques of resource analysis through the use of remote sensor data has been made by Mr. Richard Minnich.. The 1,500 sq. mi. vegetation mosaic of the San Bernardino Mountains was mapped to expedite comparison with maps previously made of parts of the area, thus revealing landscape modifications by nature and man. Mr. Robert Hicks, who assisted Minnich in many of the arduous tasks and performed a substantial amount of the field work and imagery interpretation, also deserves considerable credit and is given a vote of thanks for a job well done.

The research, however, was more than a dual effort by Minnich and Hicks in that the expertise and knowledge of both plant geography and Aero Ektachrome Infrared (type 8443) film characteristics by Dr. Pease made the project possible. Approximately eight to ten months were spent by the three mentioned above and the principal investigator in discussion and analysis of the classification, imagery interpretation, field observation and report preparation. It is the belief of the principal investigator that without the aid of remotely sensed imagery, the project would have required many years of tedious field mapping with less satisfactory results than presented here.

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Site 130

ABSTRACT

Geographers and other earth scientists need large area maps of contemporary vegetation in order to understand the landscape better. The requirement is difficult to fulfill because of general disagreement among scientists as to whether floristic, physiognomic or similar classifications are best suited to the widest range of application. Identification through the media of remotely sensed imagery partially solves the problem because classes have to be designed that are compatible to data extracted. Mapping a large area in California, such as the San Bernardino Mountains, also demonstrates that color infrared is a suitable sensor package for detailed mapping and offers potential for quantitative mapping in future systems. The level of information presented is comparable or superior to the most tedious mapping by ground survey and was accomplished in a fraction of the time.

MAPPING MONTANE VEGETATION IN SOUTHERN CALIFORNIA FROM COLOR INFRARED IMAGERY

Introduction

Color Infrared film (CIR) is evaluated, using Kodak Ektachrome Infrared Aero, Type 8443, over Southern California mountain areas. The effectiveness of color infrared film as a means to investigate plant life often depends on point of view. For example, the evaluation of a forester, interested in vegetation cover, lumber indexes, blight and watershed characteristics may differ from a meteorologist concerned about the distribution of highly flammable vegetation, biomass, grass cover, and other biotic variables related to rate of spread and intensity of wild fires. In this report, written by geographers, a more general approach is taken, that of mapping the vegetation of a large area. Although the report avoids delving into highly specialized or micro studies, attempts are made throughout to indicate potential uses beyond mapping.

CIR film has been credited with many advantages over other film types for the study of plant life. Besides providing greater contrast through the use of "false" colors and superior atmospheric penetration, an often claimed advantage of CIR is tone signature, i.e. plants can be identified on the basis of color tone and hue in addition to the patterns produced by physiognomic characteristics. The advantage claimed is that growing plant life reflects in the invisible near-infrared red (a reflection which CIR is capable of recording) and the vegetative landscape appears in variations of red on CIR imagery (Pease, 1969). However, interpretation is not simple.¹

¹Pease reports that "plant tissue appears red on CIR film, not because of high reflectance per se, but because of the difference between the infrared reflectance and that in the visual wavelength.... The visual reflectance will rise to reduce the spectral contrast that is necessary to yield the red color...."

Identification of plant types on the basis of color signatures can also be complicated when infrared reflectance varies seasonally. Fortunately, the seasonal variance can be of advantage to the researcher if photographic parameters are known and kept constant. Color contrasts are related to such vegetation differences as leaf structure, crown density, flowering, formation of fruits, and other phenotypic properties of the plant. Color balance will also be affected by air luminance from light upscatter between the target and airborne camera (Pease, 1969). Added caution is necessary because an image taken near the ground and one taken from an aircraft or spacecraft may differ due to resolution and angle of sensing. From an aerial view the sensor does not resolve individual components such as a leaf, but the total plant, combination of plants, and other observable elements above and including ground surface. The differences, however, can be turned to the interpreter's benefit in mapping vegetation with CIR, as is demonstrated by using the San Bernardino mountains, an area of extreme topographic and elevational differences. Within short distances the biotic landscape is highly diversified, including such elements as islands of Lodgepole pine (Pinus murrayana) on highest mountain summits, a well developed Chaparral zone along the lower slopes in the San Bernardino Mountains, and Desert Woodland vegetation on the east and north flanks.

The Area of Study: The San Bernardino Mountains are the easternmost extension of the transverse mountain ranges of Southern California, located approximately 75 miles N. 70° E of Los Angeles and immediately north and east of the cities of San Bernardino and Riverside. An east-west trending range, it is made up of three crystalline blocks all of which are bounded by faults. The main block which extends eastward from Cajon Pass is (except for its margins) essentially

undissected and has a rolling "upland" surface. In Cajon Pass the northern edge of the main block grades into Baldy mesa of the Mojave desert, a truncated alluvial fan that forms the summit of the Pass. Eastward from the Ord Range, located on the northern apex, the crystalline block is bounded by a thrust fault resulting in a steep eroded north facing scarp overlooking the Lucerne Valley and running eastward to the Big Horn Mountains. The faulted south front is extremely steep and rugged with numerous small canyons. West of the Santa Ana River, the continuity of the scarp is broken by a partially separated secondary line of frontal peaks (e.g. Harrison Mountain) that increases the amount of north facing slopes within the southern escarpment.

The southeastern corner of the range, south of the main mountain "plateau" is comprised of two prominent blocks between the Santa Ana, Mill Creek, and San Andreas faults. The ridge that includes San Gorgonio Mountain and San Bernardino Peak is highest in the area of study (San Gorgonio Peak is 11,502 feet) with elevations consistently greater than 10,000 feet. At the extreme eastern end of the mountain complex all blocks merge and slope precipitously as an eastern face into the Salton Sea trough.

The result is an impressive variation in environments, maximized by slope and elevation. The climate, while montane, has a mediterranean regime with the bulk of the annual precipitation falling between November and April. Summers are usually dry except for thundershower activity over the higher eastern parts of the range. Climatic types, according to the Köppen scheme as modified by Russell (1926), range from Csa in lower elevations to Dsb on highest mountain summits, to BWh on desert slopes. Temperature and precipitation data for key stations in the study area are listed in Appendix C. A location map showing the relative position of the San Bernardino Mountains is in Appendix A.

The Plant Classification

Before mapping the vegetation from CIR imagery, it was necessary to devise a plant classification suitable for the purpose. Because the "natural" environment is classified in terms of arbitrary categories, certain inherent prejudices have been included. One classifies an environment according to his study needs and since this study is an evaluation of a new technique as well as a consideration of mapping problems in a Southern California montane area, the floristic approach was deemed appropriate. Identification of individual or groups of species provides for a rigorous test of the imagery. That species identification is more difficult than classification by physiognomy is a consensus shared by many; but the authors were able to use their floristic knowledge of the area to make this possible. Species identification requires utilization both of color signatures, and physiognomic analysis and the study is therefore a good test of both the sensor and the method of mapping vegetation.

Throughout the study it is assumed that plant groupings are not organisms or discreet units, but are a result of complex interaction between individual species with overlapping ranges of tolerance. Occasionally there are species that exist well together to the competitive exclusion of others, even though the area may not be outside the environmental limits of the excluded species. In the vegetation continuum, therefore, are fairly homogeneous plant groupings, whose borders are determined by various unstudied environmental factors. In the plant classification used for this study there are approximately 25 minor plant groupings. To some degree the classification follows Horton, (1960) although his classes are physiognomically based, according to dominance. The term "plant units" and "plant groupings" in this report are used in order to

avoid such words as "communities," biome, etc. which have physiological, ecological, and general biological connotations and assume foreknowledge about them. The present classification is believed to be a result of empirical evidence observed from the imagery and field observation. The symbol abbreviations used on the vegetation map refer to this classification and therefore are included with the descriptions of the categories.²

I. CS COASTAL SAGE SCRUB (Artemisia californica, Salvia spp., Eriogonum fasciculatum, Encelia farinosa, herbaceous undergrowth)

II. C CHAPARRAL

A. C True Chaparral (Brush)

1. C_S "Soft" Chaparral Chamise dominant with some Ceanothus crassifolius, scattered individuals in Arctostaphylos spp. Rhus spp. and Cercocarpus betuloides.
 - a. C_{af} Pure Chamise Chaparral (Adenostema fasciculatum). Possibility for widely scattered bushes of Eriogonum fasciculatum or Rhus ovata.
2. C_H Hard Chaparral Ceanothus leucodermis dominant with C. crassifolius, Arctostaphylos glauca, A. glandulosa, Cercocarpus spp. and scattered chamise.
3. C_{SO} Scrub Oak Chaparral Quercus dumosa likely dominant with Q. chrysolepus increasingly evident above approximately 3500 feet.
4. C_{WD} Emergent Oak Woodland in Hard Chaparral scattered or clustered individuals of Quercus wislizenii and/or Q. chrysolepus in C_H.
5. C_{WD}' Interior Oak Woodland Quercus wislizenii with no C_H, but with possible mixing of PJ, PF, species.
6. C_D Desert Chaparral Non-contiguous cover, Ceanothus greggii, C. crassifolius, Arctostaphylos spp., Cercocarpus spp., Fremontia californicus some Quercus wislizenii. Many small scrubs and herbaceous plants between the principle shrubs.

²In symbolization presented here, the initial capital letters usually identify the name of the group. In subheadings, if capital letters are used, it is a descriptive name (C_{SO}-Scrub Oak Chaparral). In reference to names of individual species (Knobcone Pine-CE_{kb}), small lettering is shown.

B. CF Forest Enclaves in Chaparral

1. CF_{bs} Big Cone Douglas Fir dominant (Pseudotsuga macrocarpa)
2. CF_{co} Canyon Oaks dominant (Quercus chrysolepus)

In both cases, chaparral undergrowth absent.

CE Conifer Emergents in Chaparral

1. CE_{cp} Coulter Pine dominant (Pinus coulteri)
2. CE_{kb} Knobcone Pine dominant (Pinus attenuata)

In both cases, scattered individuals with Chaparral undergrowth.

- III. DF DRY FOREST Coulter Pine and Black Oak (Quercus kelloggii) of about equal incidence; occasionally there are nearly pure strands of Black Oak.

IV PF MONTANE CONIFEROUS FOREST

- A. TF Marginal Conifer Forest Basically an ecotone. A mixture between PF species with CF, and occasionally CE tree species.

B. PF Yellow Pine-White Fir Forest

1. PF "Pure" Yellow Pine-White Fir Forest Pinus ponderosa, P. jeffreyi, P. lambertiana, Lebocedrus decurrens, Abies concolor, - Juniperus occidentalis in drier margins.
2. PF_M Mixed Yellow Pine - White Fir Forest with Black Oak
All the species in PF and Quercus kelloggii.
3. CT Timberland Chaparral Arctostaphylos patula, Ceanothus integerrimus, Castanopsis sempervirens with scattered trees of the PF and occasionally LP groups.

V. LP Subalpine Forest Pinus murrayana, P. flexilis

VI DW DESERT WOODLAND

A. PJ Pinyon-Juniper Woodland (Pinus monophylla dominant)

1. PJ_D "Dense" Western Juniper and Mountain Mohogany prominent
Juniperus occidentalis, Cercocarpus ledifolius and scattered Great Basin sage species (Artemisia tridentata, Chrysothamnus nauseosus).

2. PJ "Pure" Mostly Pinyon Pine with scattered Juniperus californica or J. occidentalis.
3. PJ₀ "Open" with desert undergrowth, a few chaparral species in Arctostaphylos, Quercus; Pinions and Junipers widely scattered.

- B. GB Great Basin Sage Artemesia tridentata, A. spp. Chrysothamnus nauseosus. Sediment flats.

VII. D_H HIGH DESERT VEGETATION

- A. JS Joshua Tree Woodland Yucca brevifolia with GB or D undergrowth
 1. JJ Juniper-Joshua Woodland Yucca brevifolia and Juniperus californica with GB or D undergrowth.
- B. D Open desert vegetation

MISCELLANEOUS

- S SUBCLIMAX VEGETATION
- G GRASSLANDS OR MEADOWS
- B BARREN
- R RIVERINE VEGETATION - in the absence of trees species of the prevailing plant grouping, i.e., this vegetation type includes tree or bush species ecologically adapted to stream environments only.
 - A. Below 4000 feet, either Sycamore (Plantanus racemosa) or Cottonwood (Populus trichocarpa).
 - B. 4000 feet to 7000 feet, White Alder (Alnus rhombifolia)
 - C. above 7000 feet, Willow (Salix)
 - D. Fish Creek, Quaking Aspen (Populus tremuloides).

Major Vegetation Groups - A Rationale for the Plant Classification

The classification has six major units which may be termed "associations" because their distribution is related more to climate than to local edaphic factors. Three of the major units are characterized by clear-cut spatial distribution: Chaparral, Montane Coniferous Forest, and Desert Woodland. Personal observation indicates that these major units have sharp floristic boundaries, i.e., there may be considerable mixing among the minor units internally, but little mixing occurs between associations. Descriptive names may cause

confusion unless it is kept in mind they apply strictly to floristic units. For example, Chaparral is a term applied to plants with a certain physiognomy, growing in concert. Much of the dominant flora in Chaparral are brush types, but three coniferous tree species, Big Cone Douglas Fir (Pseudotsuga macrocarpa), Coulter Pine (Pinus coulteri), and Knobcone Pine (P. attenuata) also occur in this association in certain locations. All three coniferous species, while common in Chaparral association, rarely mix in Montane Coniferous Forest. In fact, physiological ecological studies on the latter two offer evidence that their basic association is with Chaparral, rather than moister coniferous forest. Knobcone Pine has a most intriguing relationship with Chaparral because of its dependence on fire for reproduction. While the factors controlling the distribution of Coulter Pine are more complex, it appears that the combination of early germination (which is unlikely in the heavily shaded Montane Conifer Forest) and a deep rooting habitat before summer drought, makes Coulter Pine (and Knobcone Pine) more highly adapted to the desiccating Chaparral environment (Wright, 1966).

While autecologies have been conducted for selected plant species, few synecologies have been carried out concerning the limiting ecological factors yielding the sharp floristic boundaries of the major plant units. In the case of Chaparral, the plant grouping covers a wide latitude of annual precipitation ranging from about 18 to 36 inches. Precipitation therefore seems to be a minor factor except perhaps for seasonal distribution, i.e., its existence is based on a consistent summer drought.

Other patterns are evident in the field. One is the pyrophytic dependence of Chaparral for self reproduction, a property not inherent to the other associations. In fact, fire has been a detriment to the other groups where regeneration is exceedingly slow. Horton and Kraebel (1955), and others have

pointed out that repeated fires may deter tree development in preference to the highly adapted brush types. In the case of Pinyon-Juniper Woodland, fire has caused it to be replaced by Desert Chaparral (Horton, 1960). A second pattern is the differential reaction of Montane Coniferous Forest (PF) and Chaparral to snow. In Chaparral snow accumulates mostly on the vegetative canopy and is subject to rapid melting due to air circulation underneath. In forest areas, the snow accumulates on the ground surface and remains a significantly greater length of time. Often the winter snow line is almost parallel to the Conifer Forest - Chaparral border. This one contrast has important implications on the nature of ground moisture storage, particularly with respect to Chaparral which exists without soil moisture during the dry summer (Kramer, 1952). The relationship between Montane Coniferous Forest and Pinyon-Juniper woodland seems to be related to simple annual precipitation. The boundary between Montane Coniferous Forest and Pinyon-Juniper woodland meanders through the mountain range often not correlating to slope orientation. The importance of moisture as a boundary control is evidenced by stands of Conifer Forest species along water courses and suggests that edaphic considerations are less important with the boundary in question.

There is an absence of physiological studies on Montane Coniferous Forests in Southern California. Wright (1966,67) in his study of one Montane Coniferous Forest species, Sugar Pine (Pinus lambertiana), observed many opposite properties to Chaparral conifers. Sugar Pine was characterized by broad rooting systems (typical of other montane tree dominants) and late germination but with resistance to drought in the seedling state. Found only as low as the upper boundaries of areas subject to repeated fire, all these qualities of Sugar Pine seem to point out the importance of greater available surface moisture during the summer drought season. While there is at present little research for the physiological ecological bases for the distribution of the major and minor units, there are

nevertheless empirically identifiable plant groupings as seen in the field and on the CIR images.

There are certain other practical aspects inherent in a plant classification. As it evolved during the interpretation of imagery, the classification became structured by nonacademic needs. The interpreter maps what is easily observed or what is observable. The result is a classification of dominant species, and occasionally of particular kinds of dominants. Consistency between the practical and theoretical aspects was provided by the structuring around the floristic basis. As an example, all species in the genus Quercus appeared a distinctly bright red on CIR images which resulted in several categories in the classification being identified by the existence of certain oak species.

As stated earlier the classification is based on empirical evidence observed from CIR transparencies and in the field. Ecologic studies are cited not to justify, but to give correlating evidence for the structuring of the major and minor categories used. The purposes of the final vegetation map (see Appendix A) are to provide a general survey of the vegetative landscape of the San Bernardino Mountains and to show extent of detail observed on CIR imagery. The map showing the vegetational boundaries is reproduced on eight USGS topographic sheets covering the entire study area. The quadrangles are delimited and titled in an accompanying Index sheet. As previously noted, symbolization is defined in the plant classification.

The Interpretation Process

An evaluation of CIR requires that actual method of interpretation of the various plant units be explained and described. In the following, therefore, methods of analysis of each of the plant groupings in the classification are examined. Included in Appendix D are 13 plates, each containing a photograph

from the field and a photograph of the imagery at the same location. Details relating to interpretation are to be found in the captions. The photographs of imagery have been magnified about three times to simulate appearance through a hand lens.³ Most of the interpretation was based on the imagery taken during the summer of 1968, when the study was covered in its entirety. Comparison was made, however, with imagery flown in March and September, 1967 of the Mill Creek and Santa Ana Canyon areas. The 1968 images were made with an 80B filter, auxiliary to the minus-blue filter of the CIR System (Pease and Bowden, 1968). The earlier NASA flown images were made with a 15 only (March 1967) and with a 12 only (Sept 1967). (See Appendix B). In this study, CIR probably displayed its greatest potential when differentiating internal structure within Chaparral (C) and when separating Chaparral from adjacent plant types because of the presence of a continuous leaf canopy. It was separated from an adjacent brush type, Coastal Sage (CS) by the absence of such a continuous leaf canopy in the latter.

Chaparral: Phenotypic variation of leaf types among the chief species in Chaparral is exceptionally broad, taking two general forms, the fasciculate or needlelike leaves of Chamise or "soft" Chaparral and the broadleaf characteristic of Hard Chaparral. There is also a broad range in size and density of the plants. In Chaparral are areas of definite color contrast. While north facing slopes are distinctly red, south facing slopes range from purple along lower slopes to red again above 5000 feet.⁴ While the color continuum along the

³The Kodacolor X prints used in the plates to portray the Aero Ektachrome Infrared transparency should not be construed to reproduce the quality or resolution of the transparencies. Quality of both color and definition are lost in reproduction.

⁴An illustrative example of the above is seen in Appendix D, Plate 1-A.

south facing slopes is gradual, detectable breaks in this continuum were present. A comparison of the map submitted in this report with previous U.S. Forest Service vegetation surveys and personal field notes revealed such discontinuities to represent actual boundaries among Chaparral units. Color tone and hue therefore were valuable tools for plant identification in both Chaparral and Coastal Sage, particularly when the average bush in some units was too small to be identified by physiognomic characteristics. General colors associated with each plant groupings when the 80B auxiliary filter was used are listed below.

Coastal Sage	CS	Purple-grey
Soft Chaparral	C _S	brown
Hard Chaparral	C _H	pale red, invariably a blackish background
Scrub Oak Chaparral	C _{SO}	red
Oak Emergent Woodland in Hard Chaparral	C _{WD}	red oak crowns in pale red background
Interior Oak Woodland	C _{WD} ¹	oak trees (red) among other trees from other associations
Desert Chaparral	C _D	pale red with white background of the ground surface

The steady increase in a red infrared record with altitude is to date inadequately explained and unquantified. Chaparral plants in lower elevations undergo extended desiccation during the dry season to such a state that foliage is brittle or even falls off the bushes. Some major dominants such as Chamise, Buckwheat (Eriogonum fasciculatum) and Bush Penstemon (Penstemon antirrhoides) are characterized by fasciculate leaves. In the case of Chamise, leaf surface is reduced by shedding of individual leaves (Hanes, 1965).⁵ Such phenotypic tendencies reduce the ratio of leaf surface to intervening stems and ground as vertically sensed by CIR film. Leaves of Coastal Sage (Artemesia californica)

⁵All botanical nomenclature in this report is after Munz, P. A. and D. Keck, A California Flora, U. Calif. Press, Berkeley, 1958.

are narrow, numerous and clothed with stiff hairs again with total leaf surface proportionately reduced.

With increased elevation along the south facing slopes, leaves of the major dominants, mostly Manzanita (Arctostaphylos spp.) and Ceanothus (Ceanothus spp.) are broader and more ovate, but leaf size is generally small (2-8 cm.). While leaf size is small (2-6 cm.) in Ceanothus it is characterized by a dense network of well foliated rigid divaricate branches (especially Ceanothus leucodermis). Relative leaf surface therefore is greater. On Manzanita (A. glauca), a somewhat more erect shrub than Ceanothus, leaf coverage is often still more complete due to larger average leaf size, but since leaves are generally glaucous or whitish, it records as only a reddish-gray. A comparison of Arctostaphylos glauca to Oak (Quercus) both of which have relatively complete leaf surfaces exposed to a vertical optical path, indicates some contrasting influences on color signatures, at least during the summer season. The bright reds common to Quercus, found on north facing slopes and south facing slopes above 5000 feet, seems to be a property related distinctly to the genus. Pease Broadband Spectroradiometer readings in December 1967 confirm this trend with consistently high IR/VIS ratios for several species in this group (unpublished data). That seasonal change of infrared tone on CIR was not evident for Evergreen Oaks is added supporting evidence for Pease's observation (see discussion on seasonal change below). Desert Chaparral, composed of related species in the same genera found in Coastal Chaparral, also retained some red infrared record despite rather sparse covering of the landscape. Further field work was required to identify internal floristic composition.

A complication in vegetation mapping of Chaparral is due to the nature of

the entire plant. The combination of spindly foliage (a low leaf/stem ratio), small leaves sometimes vertically oriented, and a branch structure that allows penetration to internal plant shadows and plant litter all darken the image. Specific examples are the Chaparral on well drained terrace surfaces on the south facing slope where favorable edaphic conditions produce plants twice normal size. Such slopes are composed of both hard and soft Chaparral and plants appear dark-gray, barely tinged with red, on most CIR images. Physiognomic differences within species sometimes confuse floristic character for plant unit identification.

It was necessary to identify some brush forms in the Chaparral zone by form rather than color. Manzanitas could be distinguished from Ceanothus, for example, by its more erect appearance, although there was no need to segregate these two Hard Chaparral dominants. Quercus dumosa could be distinguished from the larger North slope Oak (Quercus chrysolepus) by the presence or absence of distinct crowns.

While identification of brush types by color is feasible in summer, it may not be so during the wet season (Dec-May). Growth of new leaf surface along with sprouting of annual grasses and other herbaceous material among coastal sage elements give lower slopes in winter color signatures as red as higher slopes in July.⁶ Herbaceous undergrowth in Chaparral less affected color than a more continuous shrub canopy. At this season, because colors are similar, the mapper is forced to make boundaries on the basis of physiognomic patterns which is close to impossible at a scale of approximately 1:62,500. A comparison of the present map with an earlier attempt to map Chaparral from imagery flown in March, 1967, showed the wet season attempt to be less accurate. In the

⁶ Refer to Appendix D, Plate 2.

earlier mapping, adjoining zones with similar color signatures had to be separated solely on a physiognomic basis.

Factors which influence seasonal color variation in Chamise Chaparral and Coastal Sage Scrub are still poorly understood. In a preliminary study, Pease and Bailey (1968) suggest new growth and its consequential phenotypic influences to be important. The period of higher tonal reflection (December-May) in Chamise areas did correlate with the findings regarding peak growth and photosynthetic rates determined by Hanes (1965). More intensive study of this visible parameter is needed.

As mentioned previously, the Chaparral association frequently contains three major conifers which fail to mix readily in true conifer forest. Each could be easily identified on the CIR images with limited knowledge of their typical ecological habitats, physical appearance and spatial location. The most widespread forest enclave in the Chaparral association is Big Cone Douglas Fir (Pseudotsuga macrocarpa) which is easily identified in the field and on CIR imagery by its conspicuous extended branch structure. The Big Cone Douglas Fir occasionally possesses a brighter pink tone signature than other conifers although this property is not as reliable as physiognomy. Found on moist north facing slopes below 6000 feet and in riverine sites of any exposure in Chaparral, it is considered "enclave" because it tends to dominate an entire slope at the expense of surrounding Chaparral brush types which may have previously occupied the area during inferior stages of the plant succession. A trained observer with foreknowledge can immediately suspect this species under such ecological circumstances.

The Chaparral association also contains two conifers which appear as scattered emergents out of the brush, Coulter Pine (Pinus coulteri) and Knobcone

Pine (Pinus attenuata). They are considered "emergents" which coexist with but do not eliminate the brush. Because both trees are pines, their needle foliage is similar enough to eliminate color signature as a means of identification and both appeared brownish-red. They can be differentiated, however, by their contrasting height and spatial distribution. Coulter Pine is larger, approximately 15-25 m., and appears in the landscape as widely scattered individuals. Knobcone Pine, although an emergent, predominates and even masks the Chaparral brush when it occurs in dense groves as a result of its dependence on fire for reproductive spread. It is a smaller tree than Coulter Pine, often only 5-10 m. tall. Floristic identification of the latter two species can be narrowed down in that (1) they are the only two pines to exist in Chaparral and (2) unlike the Big Cone Douglas Fir, both are typically found on south facing slopes.

Conifer forest: CIR was less successful in identification of the major conifer forest types, Dry Forest (DF), Montane Coniferous Forest (PF), and Subalpine Forest (LP) than with Scrubs and Chaparral. The problem was most extreme with the middle category. In Montane Coniferous Forest the major tree dominants, Ponderosa Pine (Pinus ponderosa), Jeffrey Pine (P. jeffreyi), Sugar Pine (P. lambertiana), Incense Cedar (Lebocedrus decurrens) and White Fir (Abies concolor) all displayed the same color hue. As phenotypes each was approximately the same height (30-50 m.) and at an imagery scale of 1:50,000, displayed the same full crown structure. Even Sugar Pine, which like the Big Cone Douglas Fir is characterized by extended branch structure, was too subtle for the interpreter. The fault appears to lie with the character of the forest type rather than sensor deficiency. Montane Coniferous Forest possess a highly integrated and exceptionally rich co-dominant flora. In an examination of CIR imagery intended for a "smog

"kill" study along a transect running from Crestline to Big Bear Lake, only Sugar Pine and Incense Cedar could be identified with certainty at a scale as large as 1:1,000. Montane Coniferous Forest was therefore segregated by the incidence of "alien" species, notably Black Oak (Quercus kelloggii), Big Cone Douglas Fir (Pseudotsuga macrocarpa) and Coulter Pine (Pinus coulteri), which migrate into this seemingly well organized floristic community under particular edaphic circumstances. Dry Forest (DF) was separated from Montane Coniferous Forest by a still higher incidence of Black Oak, and the more diminutive average size of the pines. The two plant groupings would be difficult to separate in winter because Black Oak is winter deciduous. Timberland Chaparral has a rather distinguishable color signature that is difficult to confuse with low land Chaparral types. A strong red is evident in both summer and winter images. Excellent boundaries could be placed around Subalpine Forest (LP) in which the dominants are Lodgepole Pine (Pinus murrayana) and Limber Pine (P. flexilis), due to remarkable homogeneity as a forest with stout trunks and spindly crowns. A subtle color signature was observed and needles diseased either by "smog kill" or by insects did not confuse interpretation when the 80B auxiliary filter was used.

Desert Woodland: CIR demarcation was less successful with Desert Woodland (DW) than with Chaparral because of the small size of most plants as compared to image resolution. Furthermore, a red infrared record was not detected on the film for most plants.⁷ The outstanding dominant is Pinyon Pine (Pinus monophylla),

⁷ Later examination hints that the reason may be due to improper back lighting of the light tables. ISCO Spectroradiometer readings indicate many of the well known, commercially available tables are deficient in the red spectrum and may hinder interpretation. An investigation on the problems due to back lighting is being undertaken by Pease and Bowden.

and internal boundaries within this major unit are based on the incidence and size of this species (Pinyon Pine expresses remarkable phenotypic flexibility along a continuum from its wettest to driest margins). The boundaries therefore are physiognomically determined because it was impractical to map boundaries according to the falling out of old and encroachment of new sub-dominant species into the Pinyon landscape. The boundary between Pinyon-Juniper Woodland and Montane Coniferous Forest was easily defined due to the obvious discrepancy of average tree size between the two groups. Pinyon Pine also appeared much browner in tone than Montane Coniferous Forest species, and has a more rounded crown. Only in "dense" Pinyon-Juniper (PJ_D) were some of the subdominants invariably identified. Western Juniper (Juniperous occidentalis), a small area of which occurs in the mountains, could be discerned from Pinyon by larger size and pointed crown. Mountain Mahogany (Cercocarpus ledifolius) could be identified because it was the only important understory species and did not possess the bright color signature or the rounded and flattened crown structure of Timberland Chaparral. In fact the boundary between "pure" Pinyon-Juniper and Pinyon-Juniper "dense" is determined by the absence of these two species, as well as degree of cover of the landscape. Two items were used for separating Pinyon-Juniper from Pinyon-Juniper "open": (1) the occurrence of scattered plants with bright tone signatures, usually Quercus wizlizenii, and (2) wide spacing between Pinyon Pines. Pinyon Pines are usually spaced more than 100 feet apart so the boundary was interpreted in a subjective manner related to the pattern of distribution. As in previous vegetation surveys, the boundary between Desert Woodland and true Desert vegetation was placed where Pinyon Pine dropped out as a vegetation element. While these mapping parameters for Desert Woodland are crude, they represent the most detailed mapping of this plant unit to date.

Riverine vegetation: All riverine vegetation types, whether in coastal or arid environments, exhibited a high strong red infrared record on CIR. Color is comparable to that of Black Oak. Most riverine species are characterized by broad leaves with little glaucous covering on upper sides of leaves and relatively continuous leaf surface in the crown. While little effort was made to carry out complete mapping of riverine areas, the four tree and bush types, Sycamore (Platanus racemosa), Cottonwood (Populus trichocarpa), White Alder (Alnus rhombifolia), and Willow (Salix spp.) could be discerned by physiognomy. Bright color signatures of Riverine plants (including live grasses and herbaceous material) made identification of springs and other surface water features easy. In fact, Mr. Minnich has identified and verified three unmapped springs in the San Geronio Wilderness Area. If a strong red record is a universal characteristic of riverine vegetation in a non-deciduous condition, CIR could be valuable in locating potential water sources, particularly in arid lands.

Evaluation

The inherent problem of mapping "regions"⁸ as determined by a plant classification is that as the regions are not yet studied the basis for the classification was of necessity preconceived. In this report, an attempt was made to present the closest possible representation of empirical data, i.e., the distribution of various combinations of plant species recorded on CIR transparencies. While some limited ecological evidence for secondary hierarchies in each unit of the plant classification is cited, the distribution was based on the sharpness of floristic boundaries and dominance of observable plant life at a scale of approximately 1:50,000.

⁸ and plant communities, since both are theoretically homogeneous units occupying space.

In perspective, a pure floristic approach is not completely practical. In some situations the individual species are too small to be observed. Single or groups of species at times must be identified by a combination of color, physiognomy and common distribution. Nevertheless most of the well known plant units common to Southern California mountain areas were mapped and described. CIR is considered superior to other film types examined, covering portions of the study area.

Color signature, while not fully understood, aided immensely in the interpretation. The red record seemed to be related to three morphological properties of the plant:

- (1) The nature of leaf surface exposed to the camera: A glabrous or smooth leaf surface seems to give the highest infrared record. Glaucous leaves which have a white covering, as in some Manzanitas, tend to diminish IR reflectance rate. Leaf hairs, if vertically oriented and not too numerous, may not affect the red record.
- (2) Leaf density and orientation of the plant: The ratio of leaf surface to leaf stems and visible ground will affect color signature. The color record of conifers, for example, seems to be dampened by a complex internal network of shadows among the needles.
- (3) Morphological structure of the plant: Plants with a rounded complete leaf canopy will record better than more fragmented structures with more interior shadows.

The importance of morphology is seen in two contrasting species, Black Oak (Quercus kelloggii) and Chamise (Adenostema fasciculatum). Black Oak is characterized by a non-fragmented leaf canopy where leaves are normally exposed to the optical path and are large and glabrous. These qualities seem to combine to produce a pronounced red color signature. Chamise possesses many opposite qualities which seem to work against detection of plant reflectance. It is characterized by fasciculate leaves randomly arranged in various angles. Because leaf size is small, leaf cover is sparse. Fragmental morphology results in a marked spindly crown. In summer, Chamise tends to yield a still poorer

red record because multi colored fruits persist at the ends of the stem during this season.

Color signature was a more valuable tool when 80B filters were used with the camera. The 80B filter as a supplement makes plant life appear more red than when the minus-blue filter of the CIR system is used alone, which permits better discrimination of red tones and hues. In the study, the red enhancement eliminated confusion of diseased trees in the process of interpretation. Color signature, while an excellent aid for Chaparral was not beneficial in Montane Forest and Desert Woodland environments. The failure may be due to similar reaction of plant morphology to infrared and visible radiation, but further experimentation with different filter combinations is needed. In Montane Forest, testing of filters with less red enhancement may produce more information.⁹

With normal color (Aero Ektachrome) imagery of Mission 42, identification by tone and hue was nearly impossible. All categories, even *Quercus* species, were hard to delineate. Only the obvious morphologic discontinuities, such as between Montane Coniferous Forest and Chaparral or perhaps the more subtle Montane Coniferous Forest to Subalpine Forest, were recognized with any certainty. USGS panchromatic black and white imagery at a larger scale revealed even less information.

The red infrared record of CIR, while superior to other film types for vegetation mapping, is not consistent. Considerable success was achieved with Chaparral vegetation and other areas dominated by broadleaf plants, but a drop off of information to be extracted was noted in areas dominated by Conifers. CIR adds few advantages for desert vegetation over normal color film due to diminutive size of the plants. The significance of infrared reflection as detected by CIR film and infrared reflectance as a property of the plant must be

⁹Later experiments, conducted in cooperation with Eastman Kodak Research Labs, substantiate that red enhancement is a variable of both film quality and age as well as care. Several other additive filters such as the 82B or 80C often give more effective results if quality control is maintained.

investigated further.

To insure species color as a reliable mapping criteria, relative infrared reflectance from plant species must be quantified. The record on a CIR transparency represents only one point in time for a vegetation landscape in which there was a given sun angle, growth state, leaf surface densities, etc. The patterns pointed out in this report could well be modified at another point in time. A case for seasonal tonal contrast for Chaparral has already been made. If the IR/visual reflectance ratio (Pease, 1968) correlates to the degree of redness on CIR film, then the following quantitative parameters of a reflectance ratio should be determined for desired species involving (1) the annual cycle; and (2) changes due to elevations at any given time, i.e. Chamise concurrently imaged from 2,000 feet may possess a different reflectance compared to Chamise imaged from 5,000 feet. Knowledge of reflectance trends for each species allows for greater certainty of identification and a more intelligent decision as to what season greatest tonal contrasts take place. Tentatively it appears that greatest tonal contrast for Chaparral, for example, occurs in summer.

The study established, however, that an inexperienced person can be trained as an interpreter for this system of analysis with little difficulty. Part of the interpretation was carried out by an undergraduate student (Robert Hicks) who at the onset of the study had little experience with the San Bernardino Mountains. In a matter of two months, he was able to conduct a vegetation analysis comparable to that presented in this paper. His training took the following progression: First, there was an initial adjustment to the imagery--orientation to gross patterns and their relation to terrain. Several roadside field trips were taken in the study area, correlating CIR patterns to specific areas. Finally, there was a field trip in which the general ecological notions were pointed out in

accordance to plant distribution. The recognition of species and their general distribution was more heavily emphasized. This proved to be the key required to analyze the imagery to best advantage.

The following were the chief interpretive problems experienced by Mr. Hicks:

1. Variation of tone, if pertinent, within one classification.
2. Subtle differences between plant units not related to tone or morphology--such as several coexisting species which are identified by recognition of an "indicator" species.
3. Subtle differences related to a combination of plant size and density (and also phenotypic variation within one species), particularly in Desert Woodland areas.
4. The variation in tonal quality with different flights due to inconsistent filter combinations and exposure. Related to this is darkening of the edges of each frame due to the camera lens characteristics.

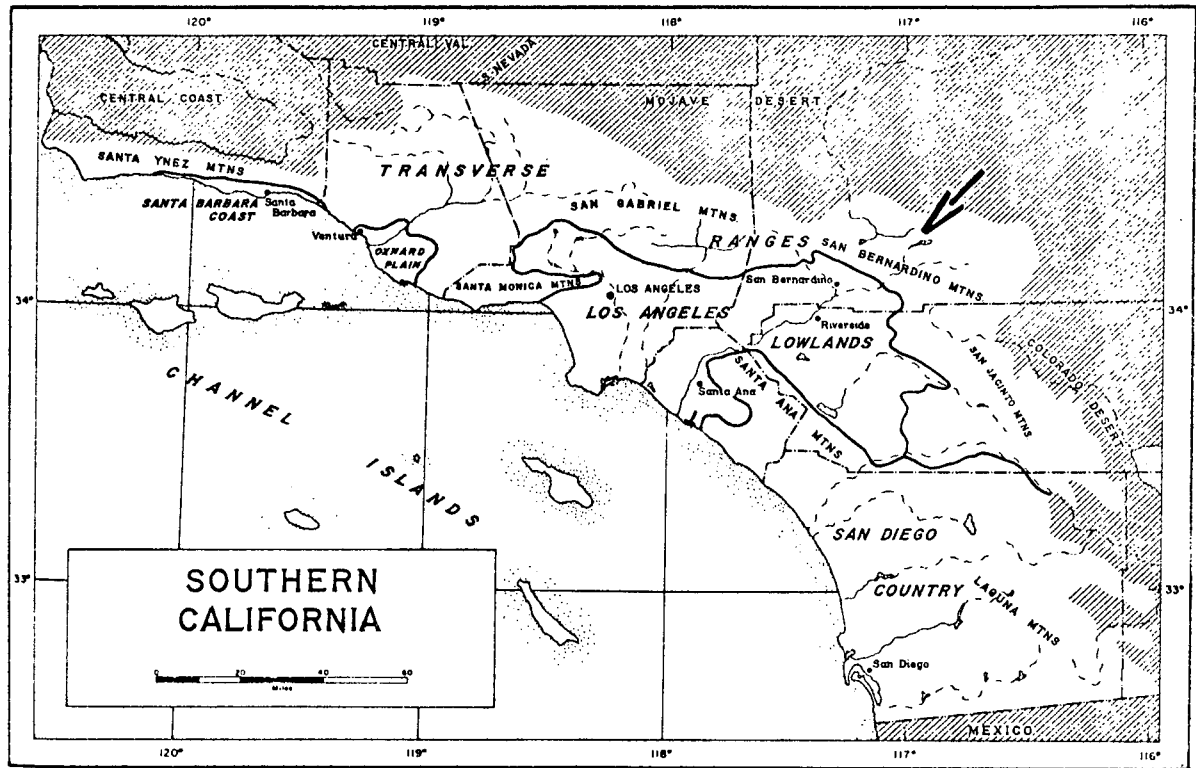
These difficulties are common to all aerial imagery interpretation or are related to photographic parameters of CIR already discussed. Of greater importance is that limited ecological knowledge and access to the field ^{are} ~~is~~ required before CIR can become an effective tool. While CIR may not be the ultimate answer, the evidence from the vegetation mapping, and the illustrative example indicates CIR is a superior alternative. In Mr. Hicks' opinion, which is shared by the authors, CIR coverage of any mountain area in Southern California would enable vegetation mapping in a relatively brief period of time with only the knowledge of materials and illustrations included in this report.

BIBLIOGRAPHY

- Hanes, T.L., 1965, Ecological Studies on Two Closely Related Chaparral Shrubs in Southern California, U.C. Press, Ecological Monographs, 35: 213-235.
- Horton, J.S., 1960, Vegetation Types of the San Bernardino Mountains, U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, U.S. Department of Agriculture Technical Paper No. 44.
- Horton, J.S. and C.J. Kraebel, 1955, "Development of Vegetation After Fire in the Chamise Chaparral of Southern California," Ecology, Vol. 36, pp. 244-262.
- Kramer, P.J., 1952, Plant and Soil Water Relations on the Water Shed, Bulletin, California Academy of Sciences, Vol. 2, pp. 515-520.
- Pease, R.W., 1969, Predicting the Relative Dye Layer Densities of Color Infrared Transparencies, Technical Report I of Status Report III, USDI Contract No. 14-08-0001-10674.
- Pease, R.W., 1969, Plant Tissue and the Color Infrared Record, Technical Report II of Status Report III, USDI Contract No. 14-08-0001-10674.
- Pease, R.W. and H.P. Bailey, 1968, Drought and Plant Leaf Reflectance of Southern California Vegetation Types, U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, U.S. Department of Agriculture.
- Pease, R.W. and L.W. Bowden, 1968, "Making Color Infrared Film a More Effective High Altitude Remote Sensor," Remote Sensing of the Environment: An Interdisciplinary Journal, Vol. 1 (in press).
- Russell, R.J., 1926, Climates of California, University of California Publications in Geography, Vol. 2, No. 4, pp. 73-84.
- U.S. Weather Bureau, 1958, Climatic Summary of the United States - California, Supplement for 1931 through 1952, Washington, D. C.
- U.S. Weather Bureau, 1964, Climatic Summary of the United States - California, Supplement for 1951 through 1960, Washington, D. C.
- Wright, R.D., 1966, "Lower Elevational Limits of Montane Trees, I," Vegetational and Environmental Survey in the San Bernardino Mountains of California, Botanical Gazette, 127: 184-193.
- Wright, R.D., 1967, "Lower Elevational Limits of Montane Trees, II," Environmental--Keyed Responses of Three Conifer Species, Botanical Gazette, 129: 219-226.

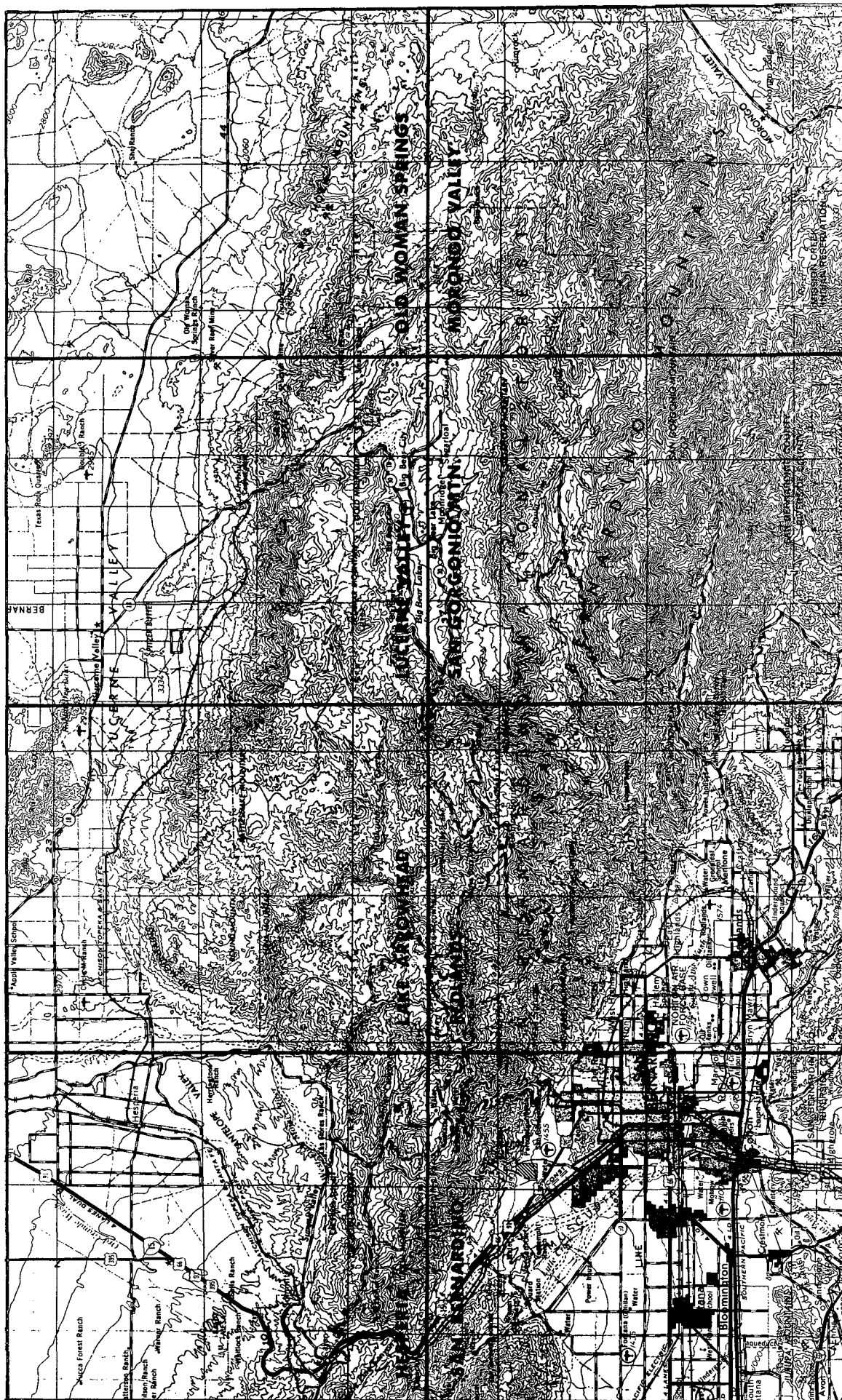
Appendix A

Vegetation Maps of the San Bernardino Mountains with Accompanying Location and Index Maps



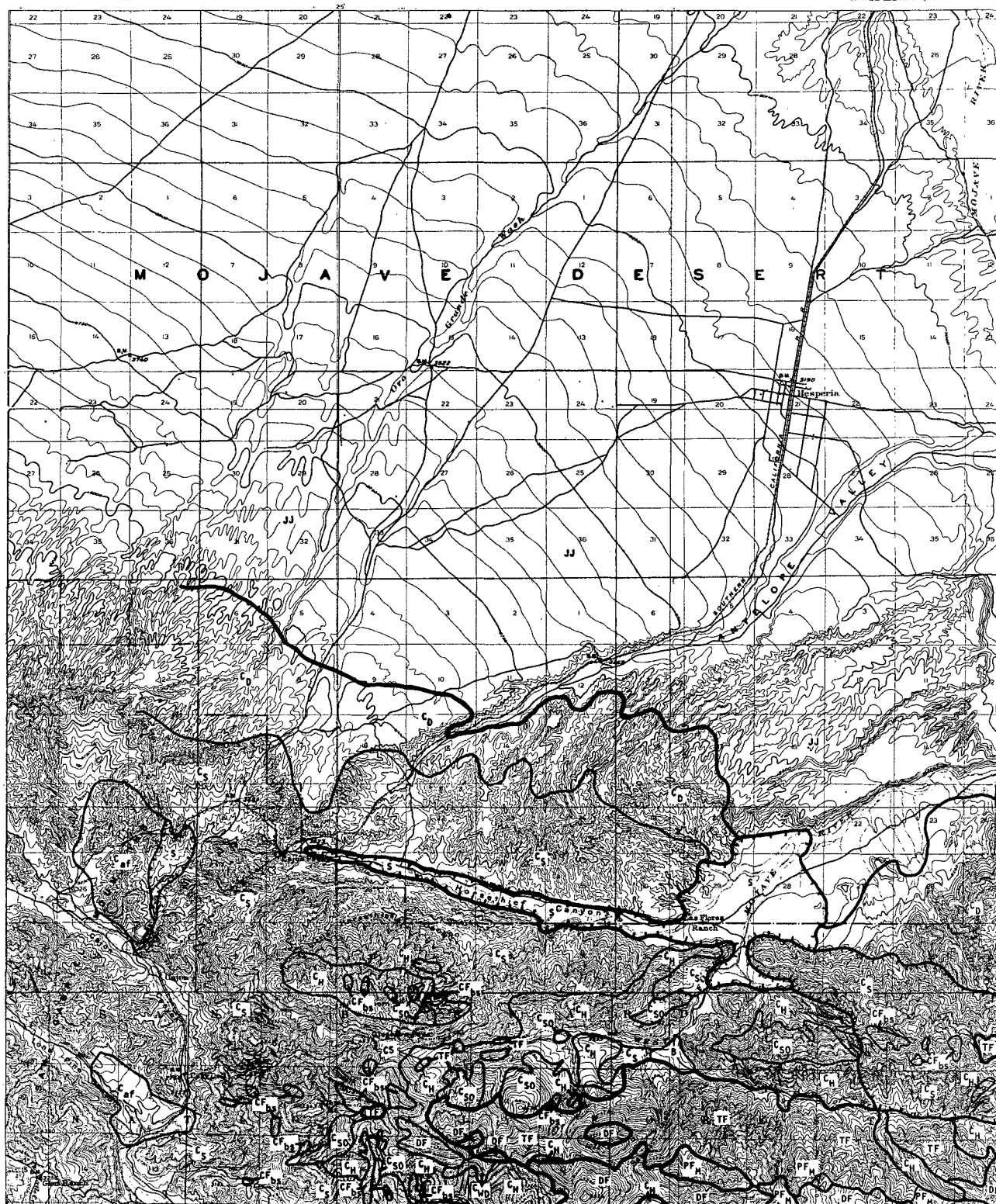
LOCATION MAP OF SAN BERNARDINO MOUNTAINS (ARROW) IN SOUTHERN CALIFORNIA

(Source: Lantis, et al)



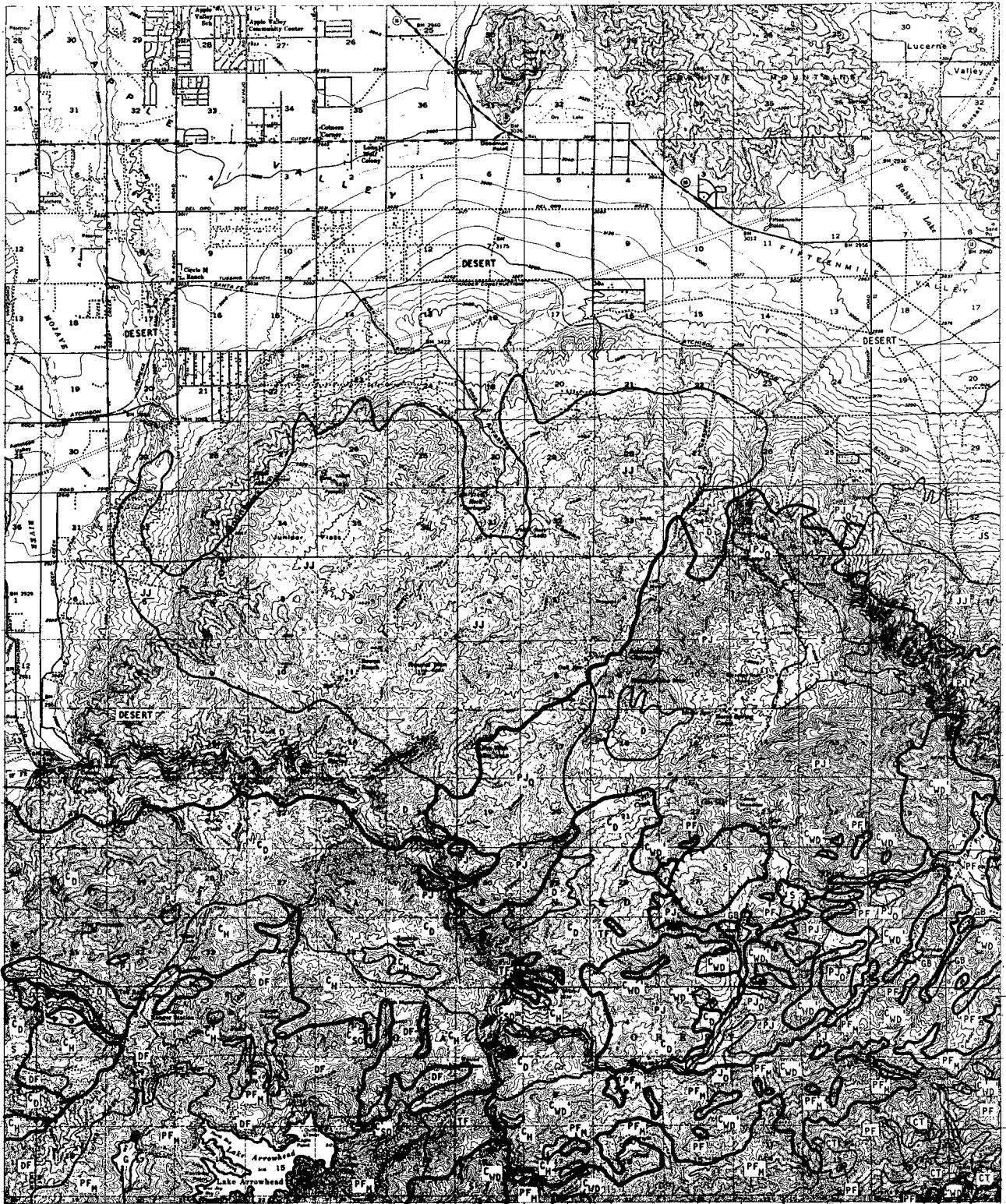
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CALIFORNIA
(SAN BERNARDINO COUNTY)
HESPERIA QUADRANGLE



UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

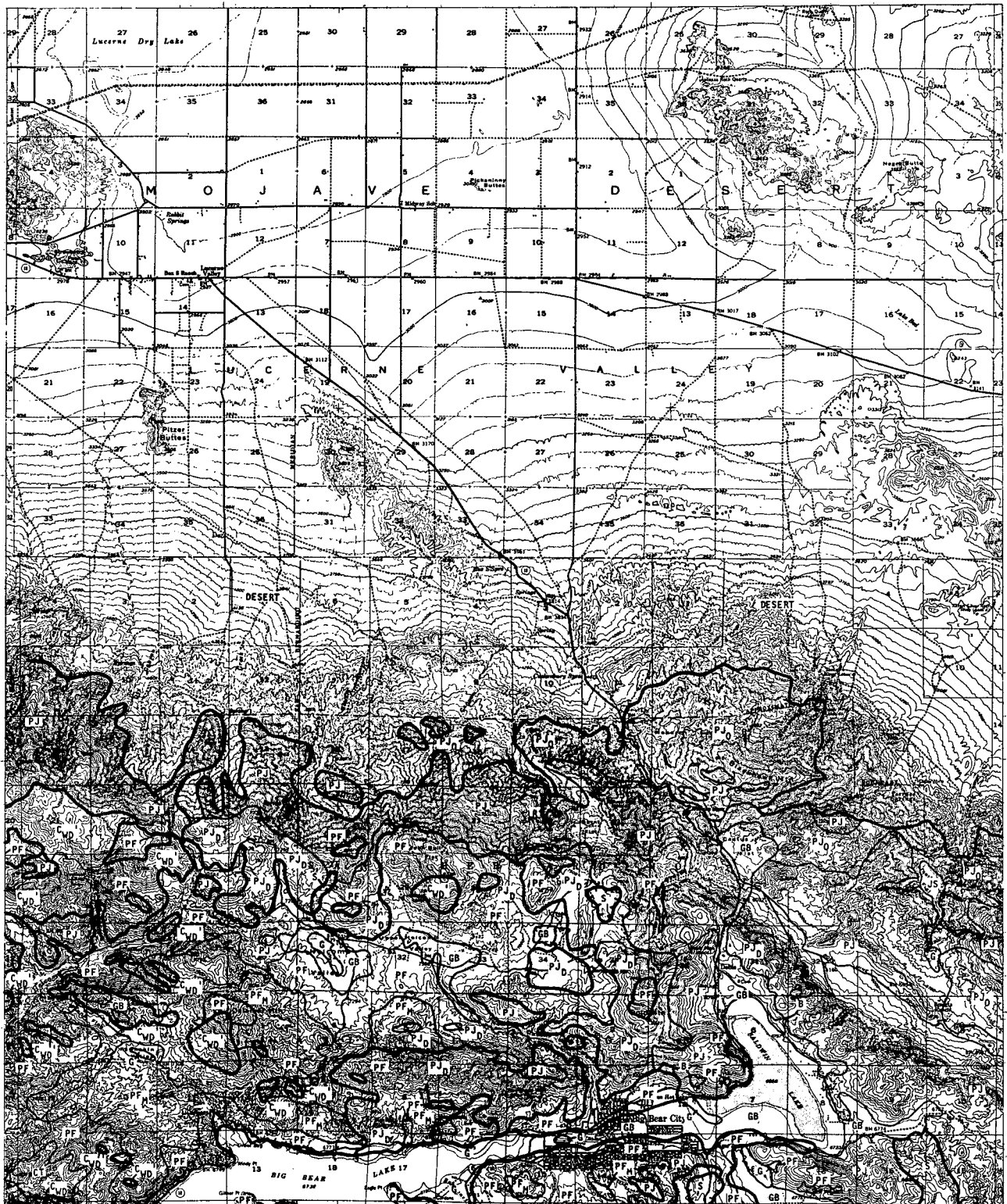
LAKE ARROWHEAD QUADRANGLE
CALIFORNIA—SAN BERNARDINO CO.
15 MINUTE SERIES (TOPOGRAPHIC)



0 1 2 MILES
0 500 1000 1500 2000 FEET
0 1 2 KILOMETERS
CONTOUR INTERVAL 40 FEET
DASHED LINES REPRESENT 25 FOOT CONTOURS
DUTUP IS MEAN SEA LEVEL

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

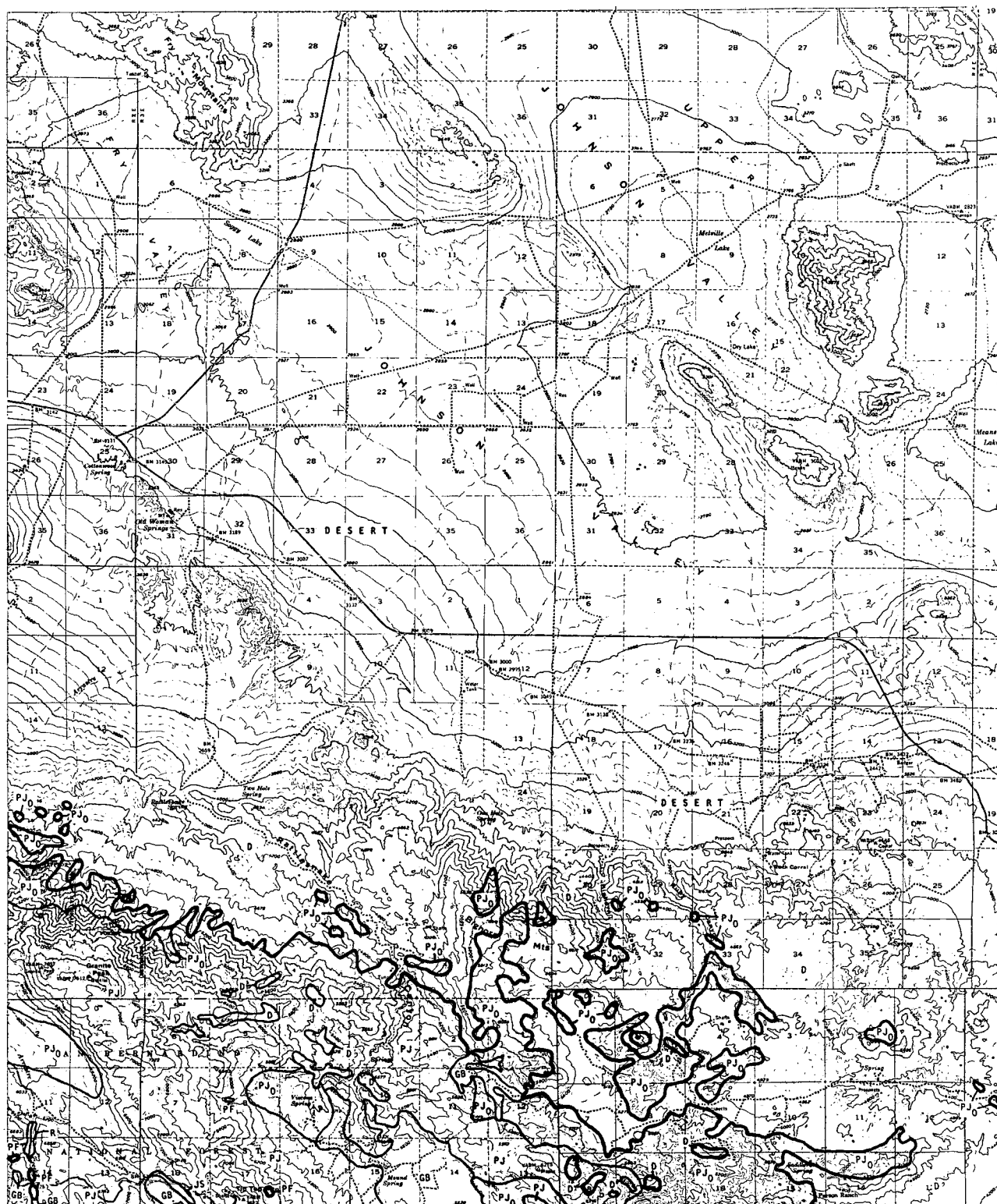
LUCERNE VALLEY QUADRANGLE
CALIFORNIA-SAN BERNARDINO CO.
15 MINUTE SERIES (TOPOGRAPHIC)



0 1 2 3 4 5 6 7 8 9 10 MILES
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 FEET
0 1 2 3 4 5 6 7 8 9 10 KILOMETERS
CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

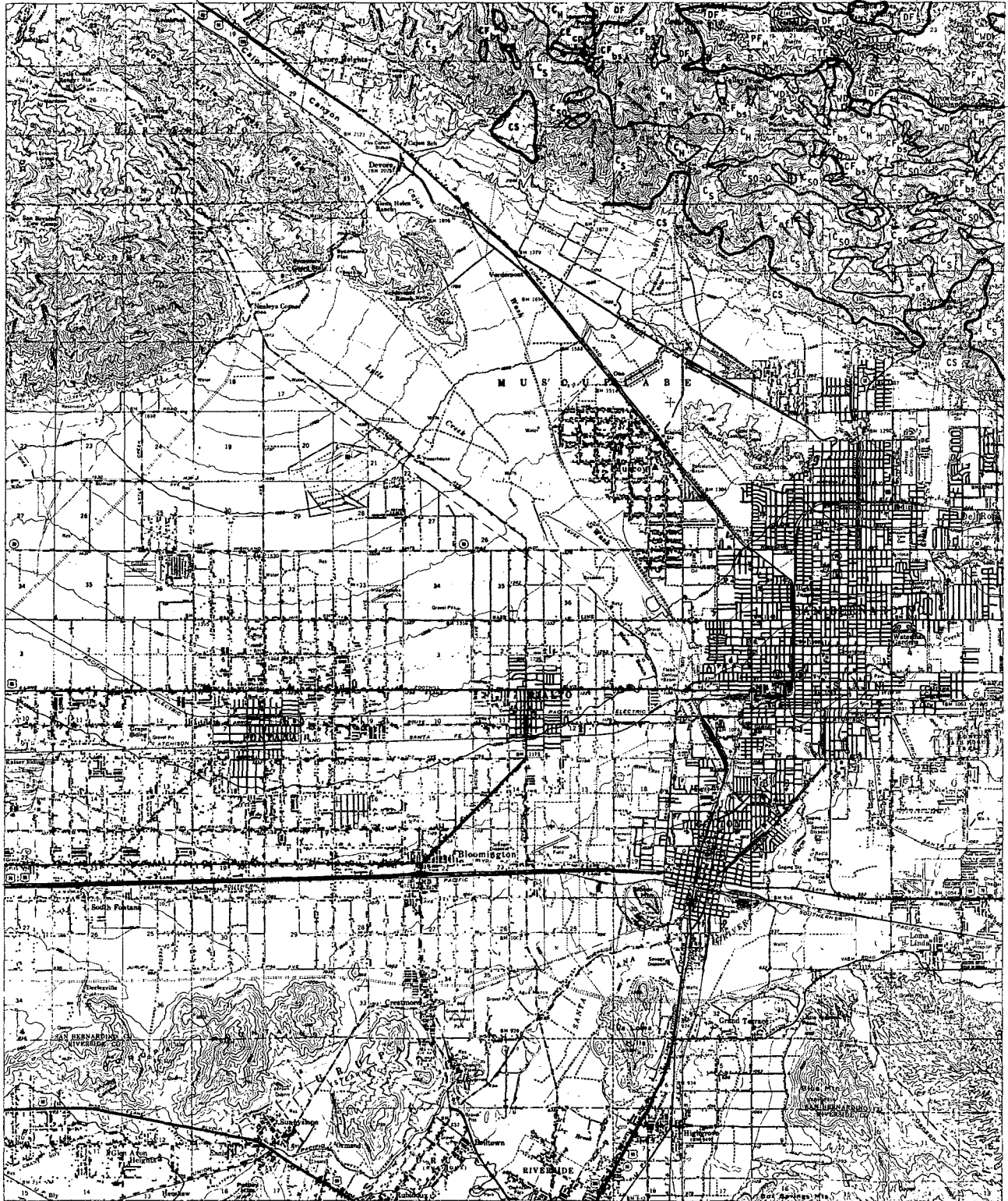
OLD WOMAN SPRINGS QUADRANGLE
CALIFORNIA—SAN BERNARDINO CO.
15 MINUTE SERIES (TOPOGRAPHIC)



CONTOUR INTERVAL 40 FEET
DASHED LINES REPRESENT 20 FOOT CONTOURS
DATA IS MEAN SEA LEVEL

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GEOLOGICAL SURVEY

SAN BERNARDINO QUADRANGLE
CALIFORNIA
15 MINUTE SERIES (TOPOGRAPHIC)



0 1 2 3 4 5 6 7 8 9 10
MILES
0 1 2 3 4 5 6 7 8 9 10
KILOMETERS
CONTOUR INTERVAL 80 FEET
DOTTED LINES REPRESENT HYPOSYNTHESES
DATUM IS MEAN SEA LEVEL

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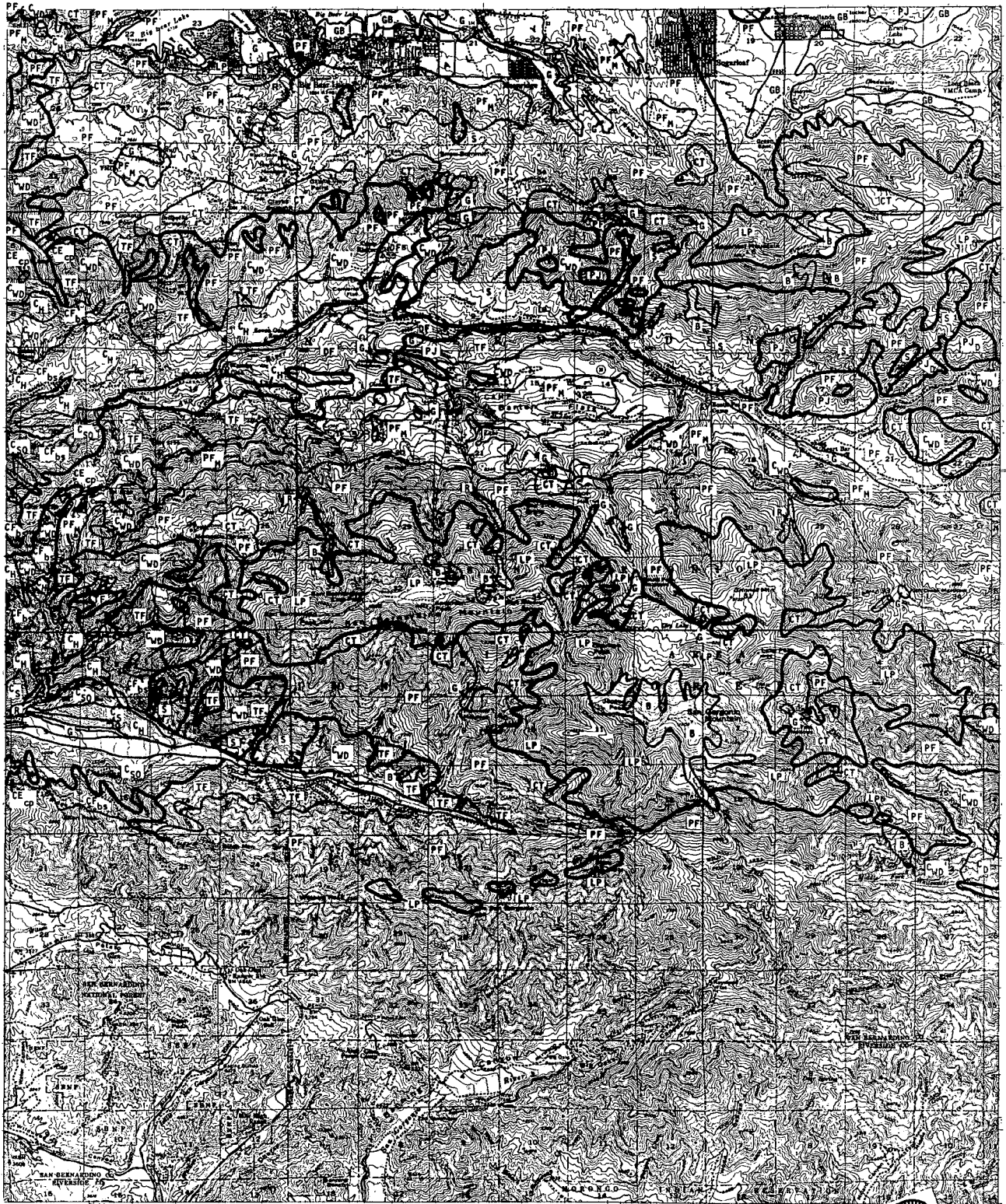
REDLANDS QUADRANGLE
CALIFORNIA
15 MINUTE SERIES (TOPOGRAPHIC)



Figure 1 is a diagram illustrating the relationship between contour interval, elevation, and distance. It consists of two main parts: a profile view at the top and a plan view below it. The profile view shows a series of contour lines with elevations of 3000, 4000, 5000, 6000, 7000, 8000, 9000, 10000, 11000, 12000, 13000, 14000, 15000, 16000, 17000, 18000, 19000, and 20000 feet. The plan view shows a series of horizontal lines representing contour lines, with distance markers in feet (0, 5000, 10000, 15000, 20000, 25000, 30000, 35000, 40000, 45000, 50000, 55000, 60000, 65000, 70000, 75000, 80000, 85000, 90000, 95000, 100000) and kilometers (0, 1, 2, 3, 4, 5). The contour interval is 80 feet. The diagram is labeled "CONTOUR INTERVAL 80 FEET" at the bottom.

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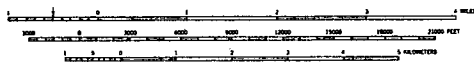
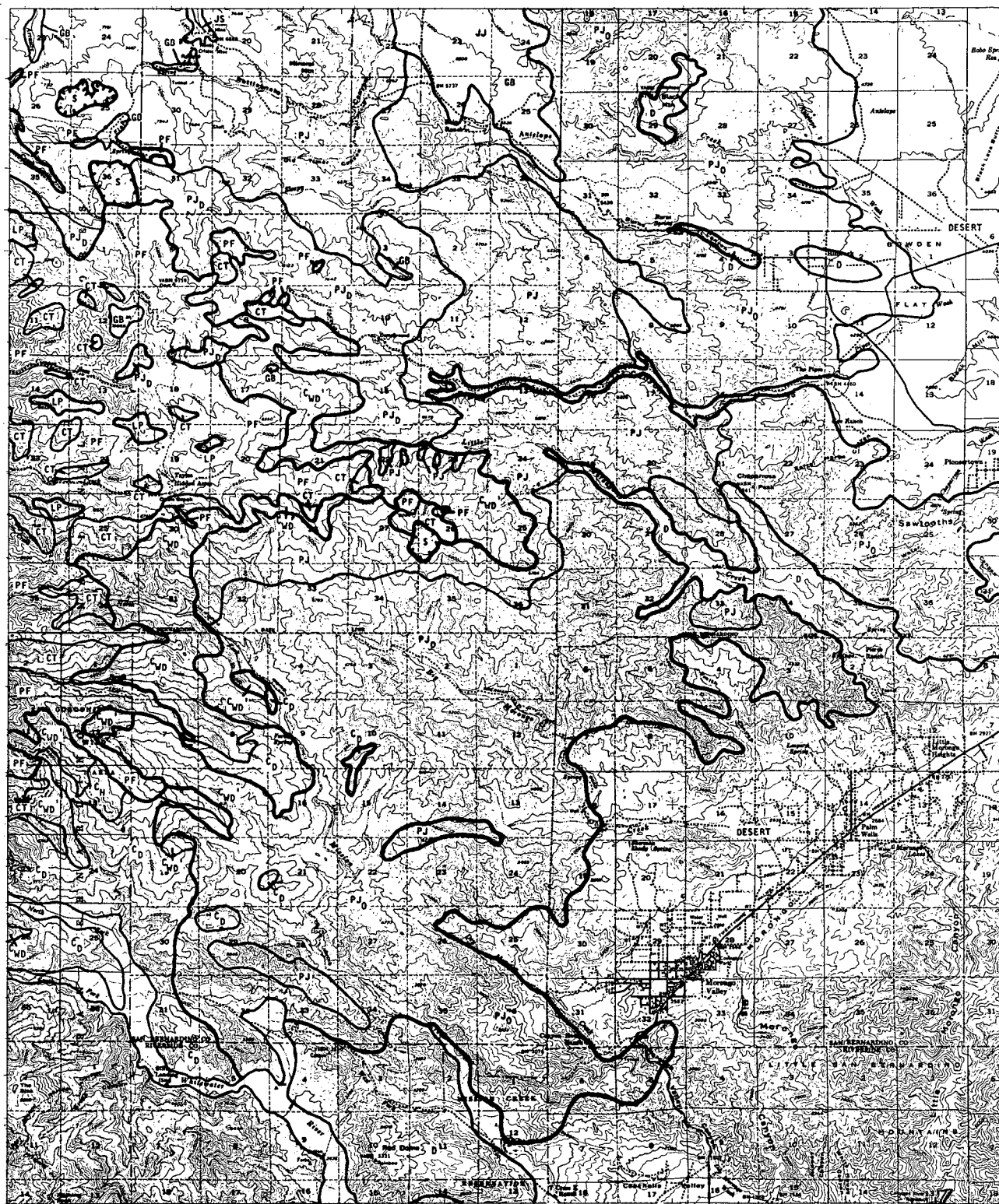
SAN GORGONIO MOUNTAIN QUADRANGLE
CALIFORNIA
15 MINUTE SERIES (TOPOGRAPHIC)



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MORONGO VALLEY QUADRANGLE
CALIFORNIA
15 MINUTE SERIES (TOPOGRAPHIC)



Appendix B

Data Sources and Flight Conditions

Four flights utilizing color infrared film (8443) were made over the study area. In 1967 two flights were made on a preliminary basis following limited flight lines along the Santa Ana River or Mill Creek, and the White-water River. During the summer of 1968 approximately 90% of the San Bernardino Mountains was covered. Stereo was available for only minor portions of most flights. With at least 10% overlap on all imagery, however, it was still possible to consider the vertical dimension. Weather was excellent except for afternoon "smog and haze" which tended to reduce detected infrared reflection in Chaparral along the foothills. "Smog" was especially pronounced during the flight along Mill Creek July 15, 1968 with resultant "bluing" of the imagery. Resolution for all the imagery was judged "good" or "excellent." In Chaparral landscape, for example, each bush was visible and in forest landscape, general branch structure could be ascertained. Black and white and Kodak Aerial Ektachrome (8442) coverage of portions of the study area were also observed as a contrast. (Very small scale coverage of a transect running from Big Bear to Crestline intended for smog kill studies was also examined.) Data for the flights are shown on TABLE 1.

TABLE 1.

Date	Source	Approx. Time Coverage	Film	Filter	Camera Type	Scale	Resolution	Weather
*1. 3/8/67	NASA 927 Mis. 42	1200	8443	15	RC-8	1:32,000-1:56,000	excel.	haze
2. 9/7/67	NASA 927 Mis. 56	1200	8443	15	RC-8	1:32,000-1:56,000	excel.	
3. 5/15/68	Western Aerial Survey, Inc.	1400	8443	15+80B	A-19	1:2,000	good**	
4. 7/14/68	" "	1100-1300	8443	15+80B	A-19	1:6,000-1:24,000	good	haze
5. 7/15/68	" "	1400	8443	15+80B	A-19	1:6,000-1:24,000	good	smog

* Ektachrome used simultaneously with CIR.

** Overexposed

Interpretation was made from color infrared transparencies on light tables.

Appendix C

NORMAL TEMPERATURE AND PRECIPITATION DATA FOR STATIONS IN THE SAN BERNARDINO
MOUNTAINS AREA*

STATION	ELE.	TEMPERATURE			ANNL PREC	ANNL SNOWFL	KÖPPEN CLASSIF
		JAN	JUL	ANNL			
San Bern. Co. Hosp. (90)**	1125	51.4	77.6	63.8	16.57	T	Csa
Mill Creek No. 2 (58)	2940	50.3	78.8	63.2	22.26	3.2	Csa
Santa Ana R. PHNo. 1 (57)	2765	48.0	76.3	60.5	25.86	3.4	Csa
Beaumont IE (21)	2605	47.1	75.8	60.1	16.29	1.9	Csa
Seven Oaks (25)	4900	38.0	63.3	49.2	26.26	51.7	Csb
Lake Arrowhead (24)	5205	37.3	69.1	51.9	39.90	78.5	Csb
Squirrel Inn No. 2 (30)	5680	38.8	69.1	52.7	40.98	95.2	Csb
Running Springs (8)	5965				36.66		
Big Bear Lake Dam (28)	6745	28.5	61.4	44.3	36.19	123.5	Dsb
Raywood Flats (28)	7070				34.24	134.1	
Kee Ranch (15)	4325				6.60		
Lucerne Valley ISSW (11)	2975				4.26		
Victorville PP (21)	2858	42.4	78.6	59.5	5.41		BWh

* From Climatological Data, Summaries 1931-1952 and 1951-1960. Precipitation decreases rapidly north and east of the highest summits. Snowfall becomes important above approximately 5000 feet.

** Length of record in years.

Appendix D

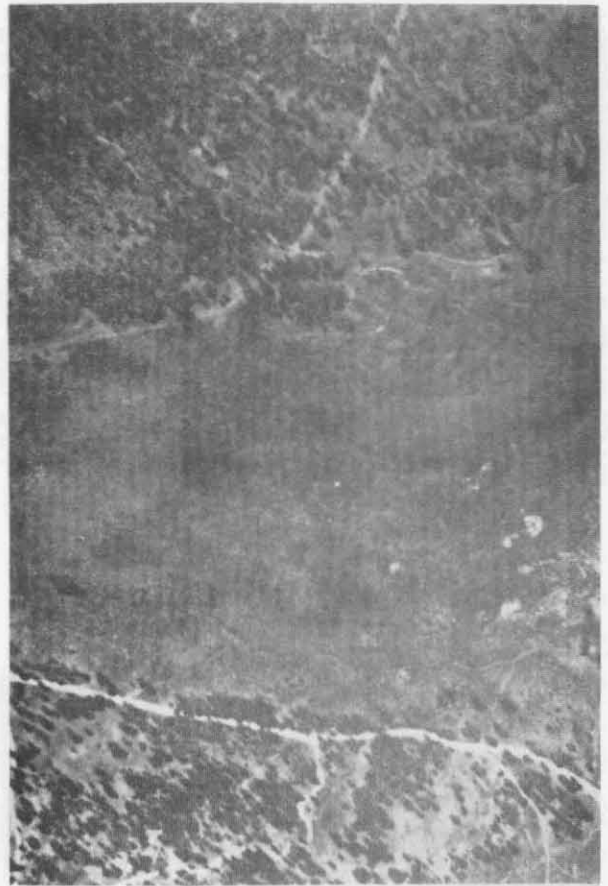
Plates

The following plates are illustrative examples of the vegetation units listed in the plant classification. Their order of presentation simulates a transect that would begin in the foothills near San Bernardino, rising across the crest of the range, and continuing north and east into the Mojave Desert. Most of the ground photos (Kodachrome II and High Speed Ektachrome) were taken by Richard Minnich or Robert Hicks in the fall of 1968. Because precipitation during that season was subnormal, moisture conditions and degree of desiccation of the vegetation was comparable to that in July 1968, when the study area was flown. Kodacolor photographs of the CIR transparencies were taken by Dr. Robert W. Pease. Their resolution is not comparable to the original transparencies because they are enlarged to simulate viewing through a 5-power hand lens. The plates usually contain four photographs and the order of reference in the captions is a) upper left; b) upper right; c) lower left; and d) lower right. Plates 3 through 15, which refer to specific plant units, contain two sets of two photographs, each set composed of a field shot and a Kodacolor reproduction of the CIR transparency of the same location. After discussion of each plant unit, the source, location and elevation, date, and filter combination used in the CIR imagery, is given. Arrows indicate direction of view of accompanying ground shots and circles at the end of the arrows show the location from which the photograph was taken. If no arrow appears then the ground shot is a similar vegetation type but its area is not that of the aerial photograph.

PLATE 1

Shown here are sample images of the three major plant units in the study area: Chaparral, Montane Coniferous Forest, and Desert Woodland. Also shown is the typical appearance of riverine vegetation, meadows, and grasses.

- a. Section of Chaparral in lower Waterman Canyon. CIR appears to be most suitable for Chaparral identification due to a continuous leaf surface canopy exposed to the camera. Chaparral is characterized by well defined tonal boundaries which are related to different plant units. (Lower Waterman Canyon, 3000 feet, Western Aerial Survey, Inc., July 1968, 15+80B)
- b. Typical appearance of Montane Coniferous Forest as viewed on CIR imagery. The trees casting the dark shadows are conifers. Montane Conifers are characterized by robust crowns and uniform height so that floristic differentiation was impossible. The broad bright red crowns on the right half of the illustration are Black Oak (Quercus kelloggii), the only broadleaf deciduous tree of importance in the forest. Little woody undergrowth is found under the forest canopy. (Big Bear Lake, near Fawnskin, 7300 feet, Western Aerial Survey, Inc., July 1968, 15+80B)
- c. General appearance of the third major association, Pinyon-Juniper Woodland. The chief dominant is Pinyon Pine (Pinus monophylla), a small tree with a rounded dark brown crown. Undergrowth is chiefly Great Basin Sage species which display a poor red record. The bright red riverine vegetation is mostly Willow (Salix). (Arrastre Creek, E. of Big Bear, 6200 feet, Western Aerial Survey, Inc., July 1968, 15+80B)
- d. Live herbaceous plants and riverine vegetation are easily identified by their strong red record and edaphically restricted distribution. Shown on this plate is the Holcomb Valley meadow. The blue-gray bushes surrounding the meadow and the Pine forest are Great Basin Sage species. (Holcomb Valley, 7400 feet, Western Aerial Survey, Inc., July 1968, 15+80B)



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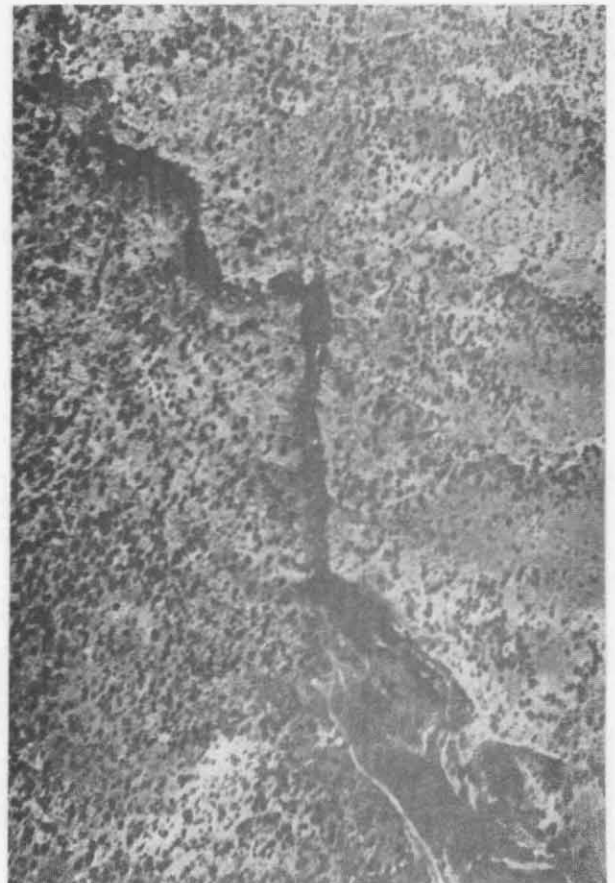


PLATE 2

Sequence of CIR images of Chaparral showing seasonal variation in the red record which is most pronounced on south facing slopes. While all subunits in Chaparral appeared in red tones in the winter (Plate 2a), a marked "bluing" of Coastal Sage and Chamise Chaparral occurred during the summer season (Plates 2b, 2c). Greatest seasonal color contrast for mapping takes place in summer. Listed below are locations, times, and filters used.

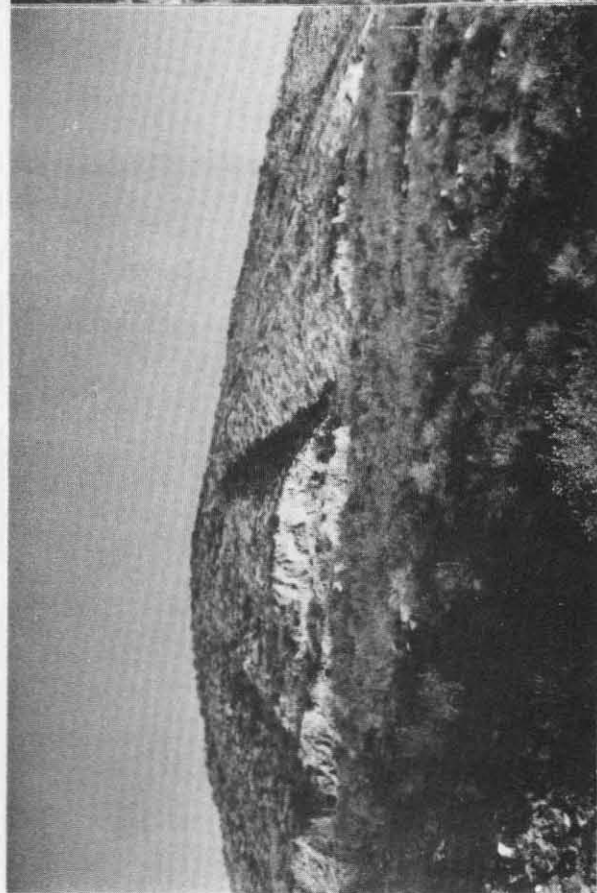
- a. Santa Ana River Canyon, NASA 927, Mission 42, RC-8 format, March 1967, 15 only.
- b. South facing front of the San Bernardino Mountains toward Cajon Pass, July 1968, 35 mm film, 15+80B.
- c. Lower Mill Creek Canyon, NASA 927, Mission 56, RC-8 format, September 1967, 15 only.



PLATE 3

- a. The scrubby vegetation just above the roadcut is Coastal Sage Scrub which is usually identified in the field from adjoining plant groupings by its discontinuous cover of the landscape. Coastal Sage is also distinct floristically in that the major dominants, California Sage (Artemisia californica), Brittle Bush (Encelia farinosa), and Salvia spp. fail to mix readily in the Chaparral upslope. Coastal Sage is also associated with a high incidence of grasses and herbaceous undergrowth.
- b. The same slope is seen immediately above the unpaved road just to the left of the riverine trees. On CIR transparencies the slope appeared purple-gray, taking on a grainy appearance due to the diminutive size of the plants as compared to resolution. Because the average plant is only .5 to 1.5 m in height and spread, little physiognomic detail can be observed on the imagery, in this case at an original scale of 1:20,000.
(Waterman Canyon Road, 1700 feet, Western Aerial Survey, Inc., July 1968, 15+80B)
- c. The darker green vegetation beyond the firebreak exhibits the typical appearance of "Soft" or Chamise Chaparral. The term "soft" is used because leaves of most important plants except for Hoary Leafed Ceanothus (Ceanothus crassifolius) and the Sumacs (Rhus spp.), both minor subdominants spatially, are fasciculate or needle like. "Soft" Chaparral is characterized by larger bushes compared to Coastal Sage, increasingly clustered spatially with their crowns often touching. Unfortunately, during the dry season it is difficult to distinguish Chamise Chaparral from Coastal Sage Scrub because both are in a withered state.
- d. The two plant units described in c are discernible on CIR transparencies by color contrast--Chamise Chaparral appearing brown instead of purple-gray. While it could be maintained that the "purpling" of the Coastal Sage is a consequence of afternoon haze and smoke, the imagery shown on this plate was photographed on a remarkably clear day for summer. Further, tonal boundaries here and elsewhere are too sharp to be confused as a haze boundary. The widely scattered non-riverine reddish bushes in the Coastal Sage and Chamise Chaparral are mostly Sugarbush (Rhus ovata).
(Waterman Canyon Road, 2000 feet, Western Aerial Survey, Inc., July 1968, 15+80B)

H1A



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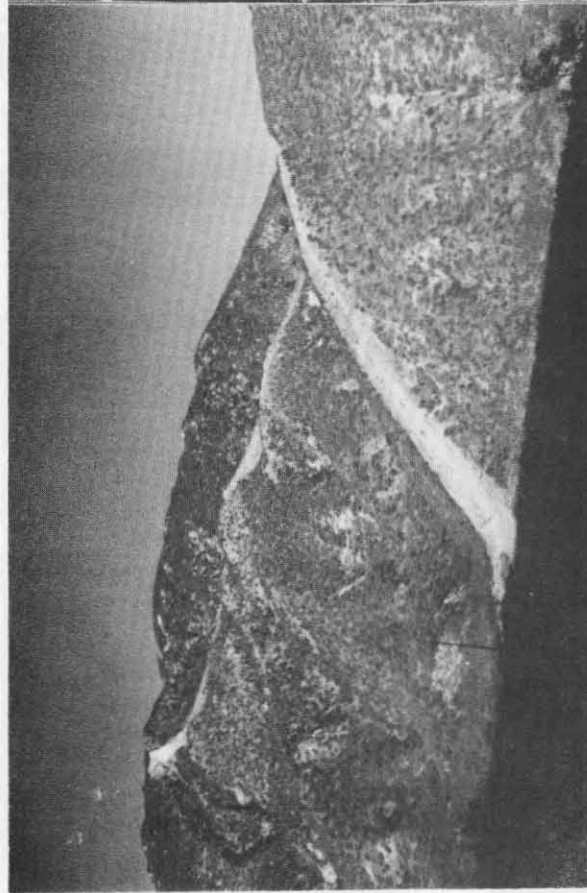
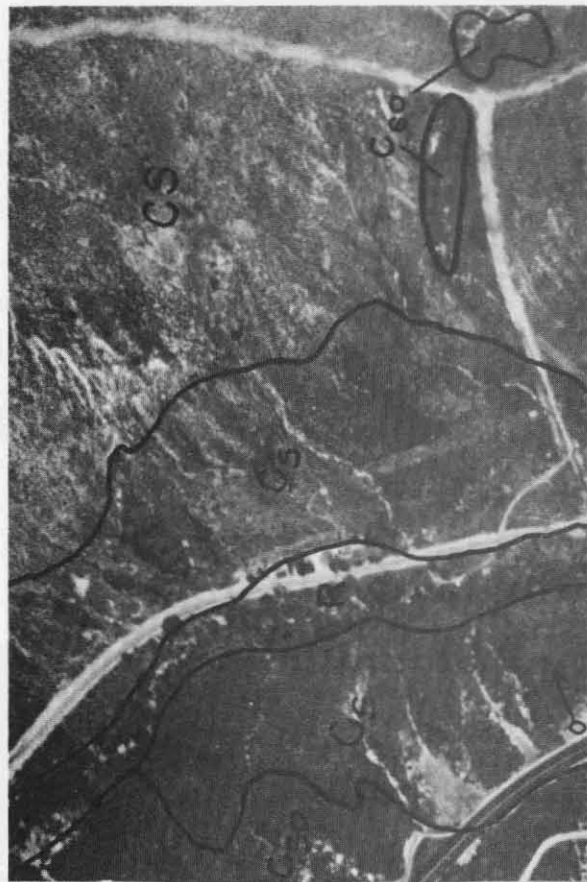
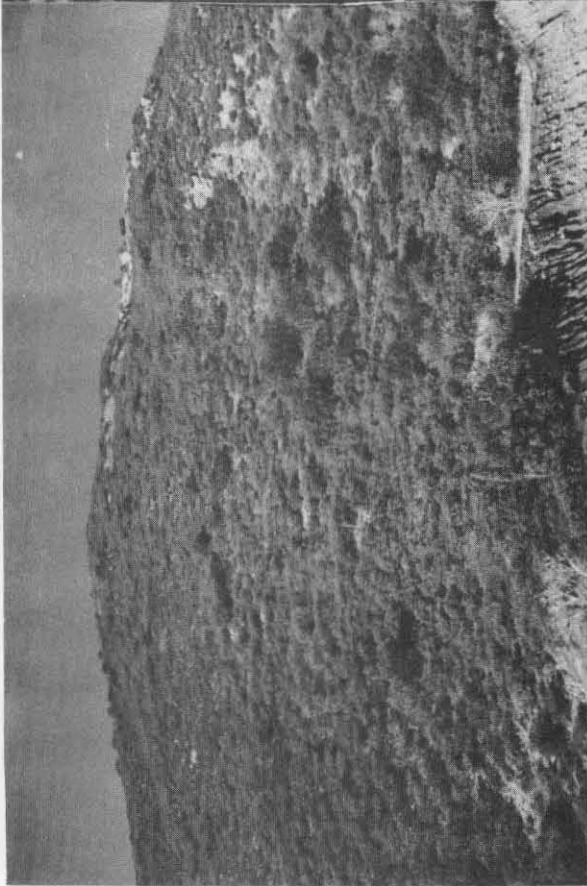


PLATE 4

- a. With increasing elevation, south facing slopes become dominated by plants of increasing size and sturdiness which in combination form a dense network of stiff rigid branches sometimes camouflaging an entire slope surface. Average height of a Hard Chaparral canopy is one to two meters. It is termed specifically "Hard" Chaparral because most plants possess broad leaves. The dominant species are generally Arctostaphylos (Manzanita) and Ceanothus. Shown here is chiefly Ceanothus leucodermis which has a very flattened appearance, typical of the genus.
- b. On CIR imagery this slope appears pale red. The larger bright red bushes are oaks (Quercus). The higher crown density of "Hard" Chaparral allows further contrast from the physiognomically similar Chamise Chaparral downslope and also decreases the amount of visible ground surface (white) which usually contrasts sharply to the vegetation.
(Waterman Canyon Road, 4400 feet, Western Aerial Survey, Inc., July 1968, 15+80B)
- c. The other dominant genera in "Hard" Chaparral is Manzanita (Arctostaphylos glauca or A. glandulosa). It can be separated from Ceanothus by its more erect nature, the blue-green color of the foliage, and its reddish bark.
- d. Manzanita can be identified on CIR imagery by its brownish-red color record. Like Ceanothus, it possesses an intermediate red record between the "Soft" Chaparral species and the oaks (i.e. the bright red bushes seen nearby). The purple bushes are mostly Chamise.
(Highway 38, Mill Creek, 4700 feet, Western Aerial Survey, Inc., July 1968, 15+80B)

42A



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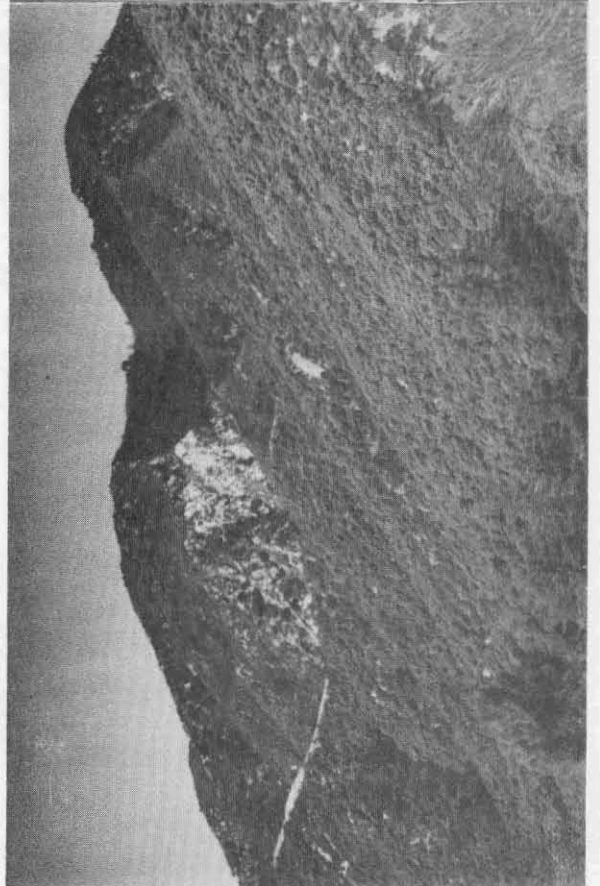
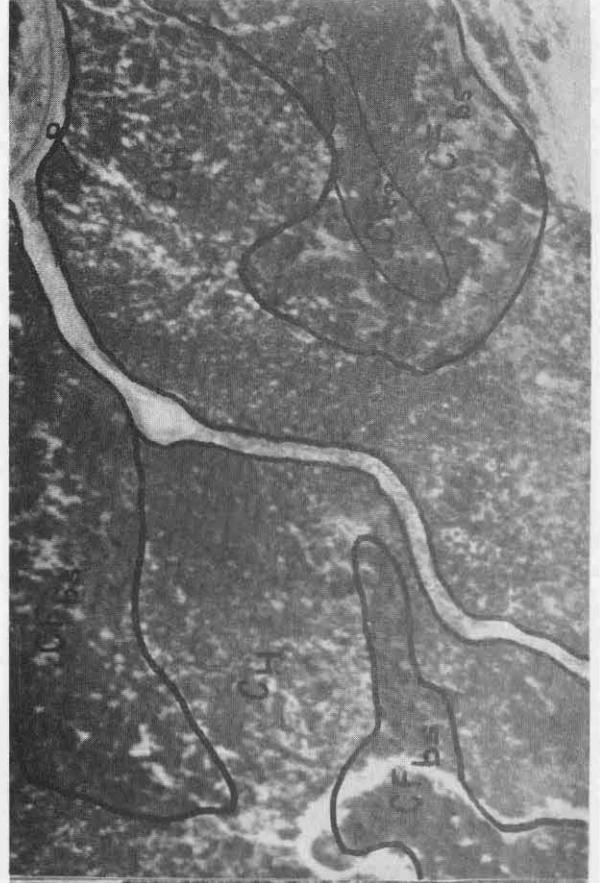


PLATE 5

- a. Along the Santa Ana River Fault are uplifted well drained terraces covered by luxuriant Chaparral. Favorable edaphic conditions allow coexistence of both "Hard" and "Soft" Chaparral types, but twice their normal size.
- b. Such terrace vegetation appears pale red but with a blackish cast on CIR transparencies and could create confusion for the interpreter. Consequently this pattern was set off as another category, "terrace" Chaparral. Further field checking is required to determine the dominant species composition of each terrace. The interpreter must be aware of physiognomy as it affects the color record.

(City Creek Road, 2800 feet, Western Aerial Survey, Inc., July 1968, 15+80B)

43a

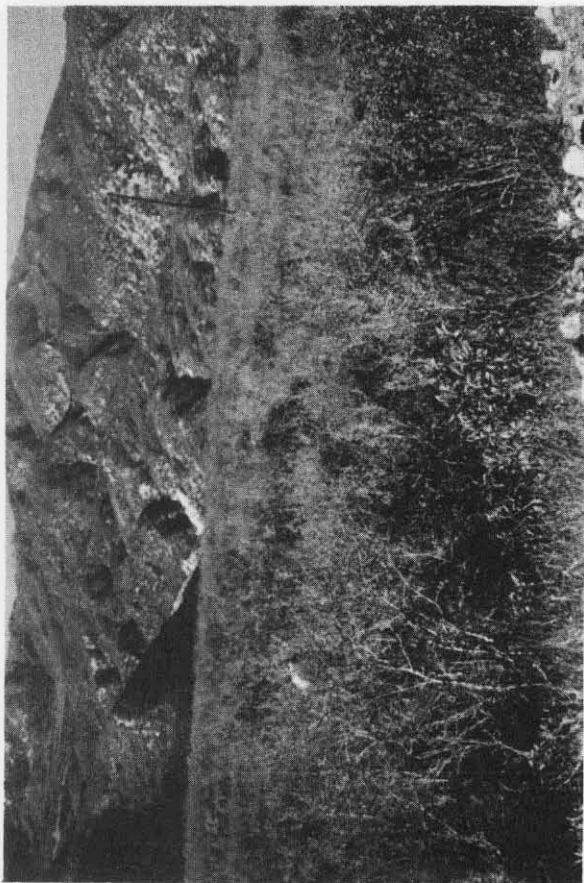


PLATE 6

- a. On north facing slopes between 3000 and 5000 feet are plants chiefly in the genus Quercus forming contiguous canopies of interlocking crowns, the classic image of Southern California Chaparral and has been termed Scrub Oak Chaparral. This particular slope is dominated by Quercus dumosa, a fairly small bush to tree, approximately 3-5 m in height.
- b. Characteristic of oaks, Quercus dumosa exhibits a high red record on CIR transparencies. Unlike the other oaks, Quercus dumosa can be identified by its continuous crown canopy with individual crowns not being evident.
(Waterman Canyon Road, 4200 feet, Western Aerial Survey, Inc., July 1968, 15+80B)
- c. Above 3500 feet, a larger oak (Quercus chrysolepus) becomes more important on north facing slopes. Quercus chrysolepus is contrasted to Q. dumosa because distinct crowns do appear on CIR imagery (refer to Plate 8d). Both north slope species were included in the same floristic category because considerable mixing occurs between them.
(Mill Creek Canyon, Highway 38, 4700 feet, Western Aerial Survey, Inc., July 1968, 15+80B)

44a

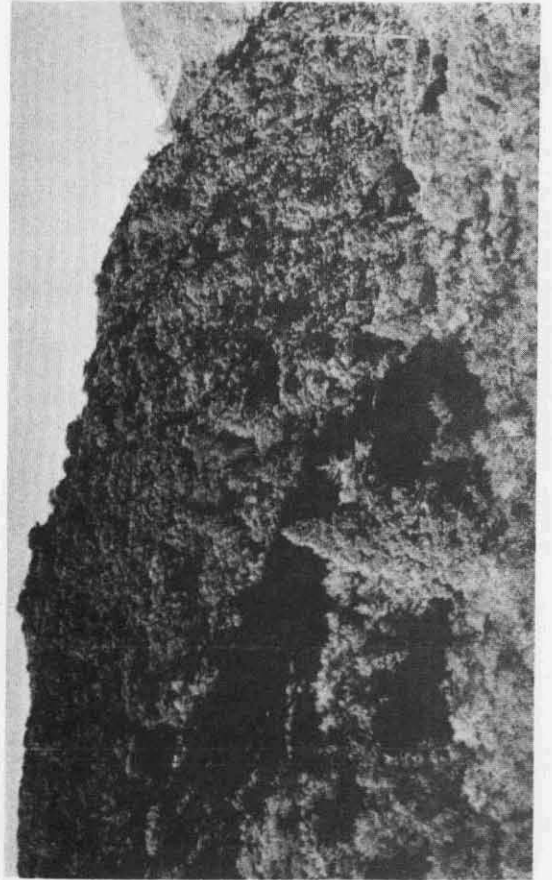
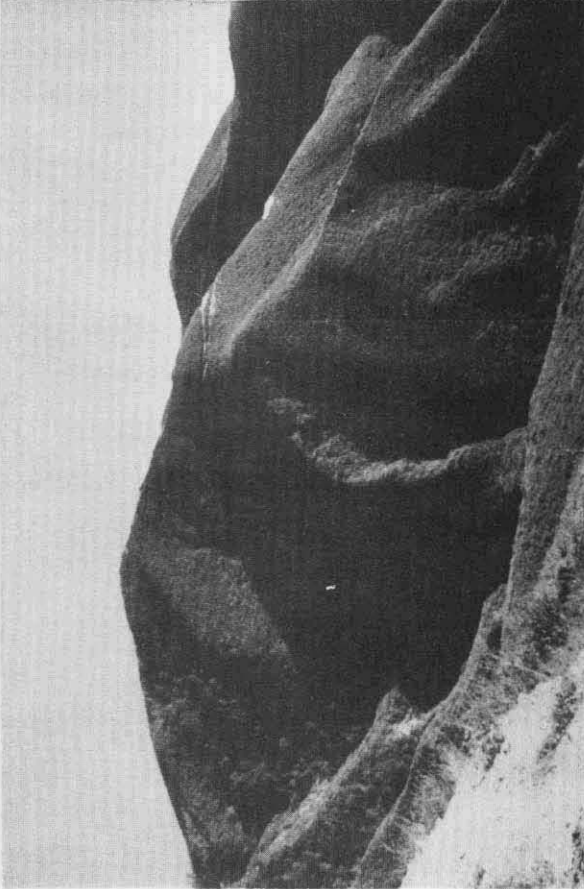
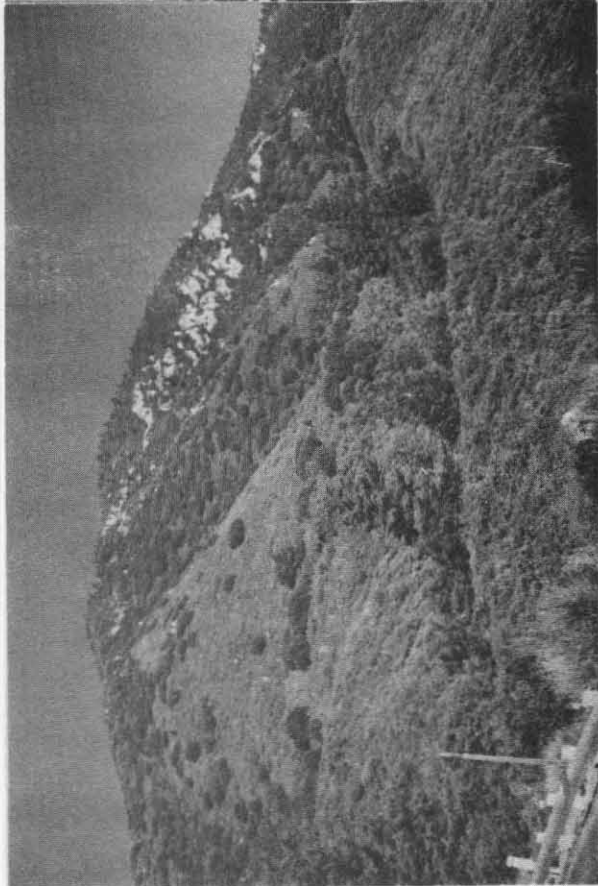
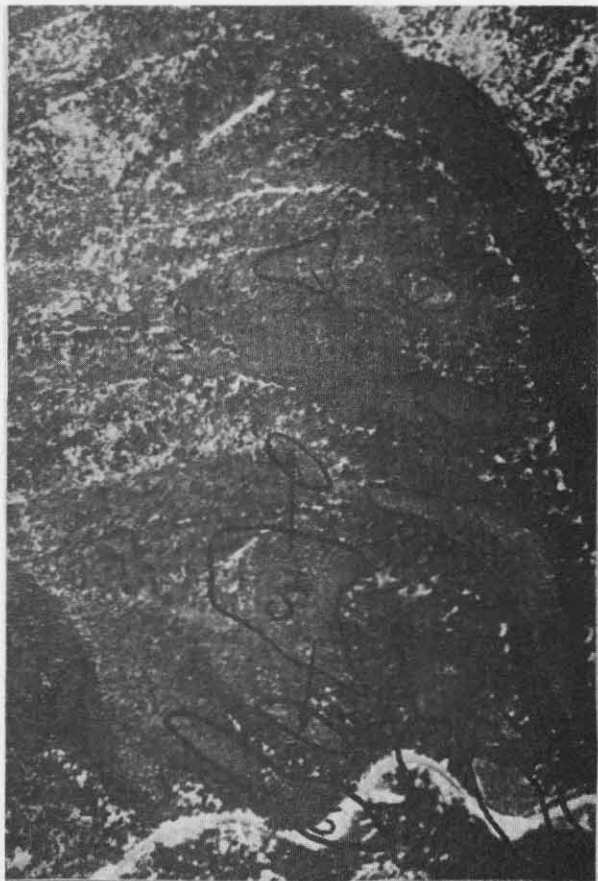


PLATE 7

- a. On south facing slopes above 5000 feet along the coastal front of the San Bernardino Mountains, another more continental oak (Quercus wislizenii), the rounded dark green bush upslope, mixes with Hard Chaparral as scattered to clustered individuals--thus the name "Emergent Oak Woodland in Chaparral."
- b. On CIR imagery this oak is easily identified by the rounded red crowns which contrast sharply to the greenish-red background of the Hard Chaparral brush. This plant grouping is separated from Hard Chaparral by the mere presence of the interior oak.
(Highway 38, near Camp Angelus, 5700 feet, NASA 927, Mission 56, September 1967, 15 only)
- c. Found northwest of Big Bear on a relatively level granitic surface is an exotic plant grouping (Interior Oak Woodland) which is comprised of species from Chaparral, Montane Coniferous Forest, and Pinyon-Juniper Woodland. Because the chief component is the scleriferous oak (Quercus wislizenii) this plant grouping has been included as an unusual form of Chaparral. In fact, except for the scattered Jeffrey and Pinyon Pines (Pinus jeffreyi and P. monophylla), the landscape does simulate the appearance of Chaparral. The absence of Hard Chaparral and the non-continuous cover of the vegetation distinguishes this plant grouping from Emergent Oak Woodland in Chaparral.
- d. The plant unit in c is readily identified by the non-continuous cover of the ground surface and the bright red record of the low rounded crowns of the oaks which dot the terrain. The red tone of Quercus wislizenii contrasts to the brownish-red color to the Pinyon-Juniper Woodland which commonly borders Interior Oak Woodland (lower portion of photograph). The crown of the Pinyon Pine, while also rounded, has smaller horizontal spread. The smaller pinkish bushes in both Pinyon-Juniper Woodland and Interior Oak Woodland is Mountain Mahogany (see Plate 13).
(Six miles northwest of Big Bear near Little Pine Flat, 5300 feet, Western Aerial Survey, Inc., July 1968, 15+808)



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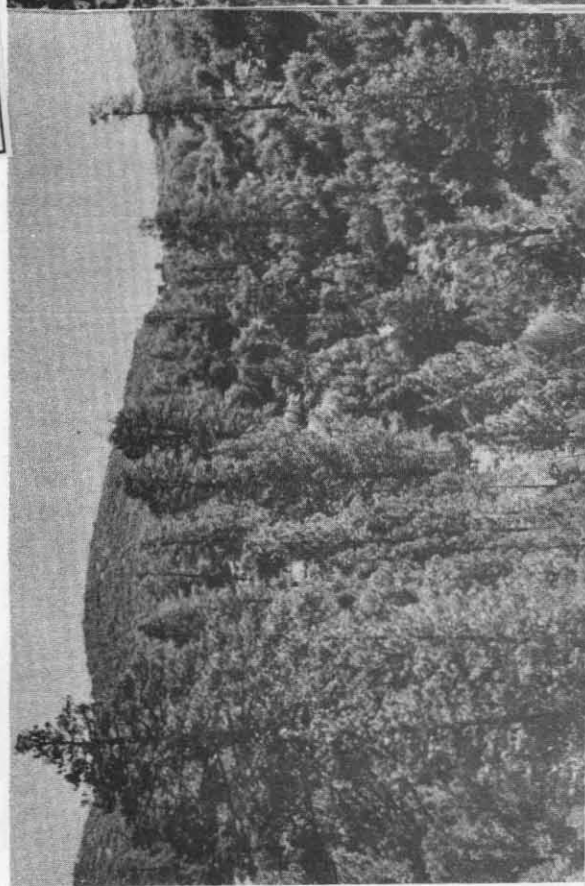
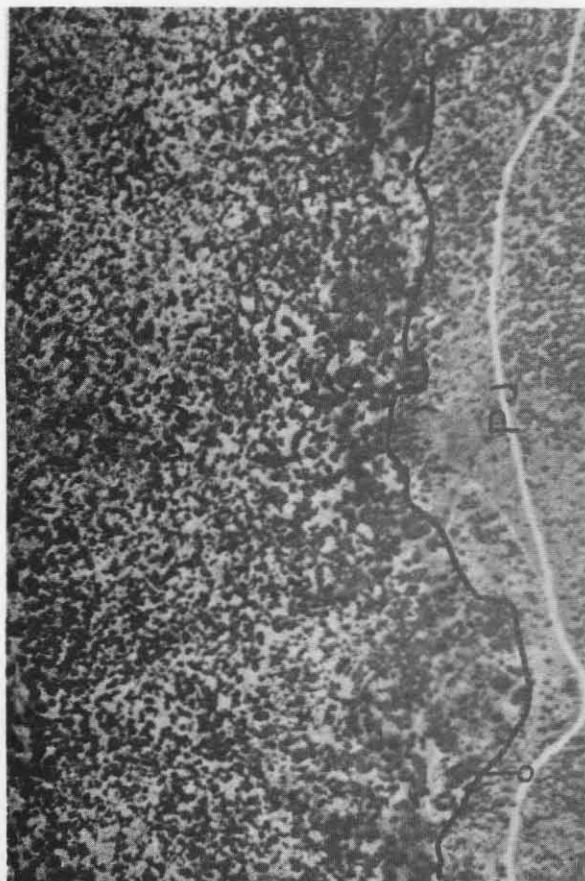


PLATE 8

46

- a. A typical example of a Desert Chaparral landscape. It is separated from Coastal Chaparral by its subcontinuous cover of the ground surface. Floristically, Desert Chaparral is dominated by plants in the same genera as Chaparral (Arctostaphylos, Ceanothus, Quercus) but of different species. Several of the more arid Chaparral plants, such as Fremontia californica, Ceanothus crassifolius, C. greggii, and C. cuneatus also occur as subdominants in Desert Chaparral. While floristically each individual species could not be identified on CIR imagery, as in the case of coastal Chaparral in lower elevations, they coincide with the boundaries between Desert Chaparral and bordering plant groupings having definite floristic contrasts established by field checks.
(Near Los Flores Ranch, 3500 feet, Western Aerial Survey, Inc., July 1968, 15+80B)
- b. On CIR imagery, identification of this group was based on the crown density. Seen here, the open canopy of Desert Chaparral provides a sharp contrast to the continuous cover of Hard Chaparral. Desert Chaparral could be delimited from Desert vegetation (found along its drier margins, see Plate 15) by maintaining some red record as a unit. There is also a heavier concentration of plants per area.
(Four miles northwest of Lake Arrowhead, 5500 feet, Western Aerial Survey, Inc., July 1968, 15+80B)
- c. Found in Chaparral are also three major coniferous trees all of which fail to mix in Montane Coniferous Forest except under unusual circumstances. The most widespread forest enclave is Big Cone Douglas Fir (Pseudotsuga macrocarpa) which is easily identified by its large size (20-40 m) and its conspicuous extended branch structure. Big Cone Douglas Fir enclaves are found on moist north facing slopes, and canyons below 6000 feet. It is considered an enclave because it dominates an entire slope at the expense of Chaparral which was probably present in several stages.
- d. Big Cone Douglas Fir is just as conspicuous on CIR transparencies (refer to individual A, lower right), by recognition of its extended radial branch structure and limited foliage cover of the crown. Its pink tone is sometimes helpful for identification but is not as reliable a criteria as physiognomy.
(Two miles south of Camp Angelus, Highway 38, 5000 feet, Western Aerial Survey, Inc., July 1968, 15+80B)

46A

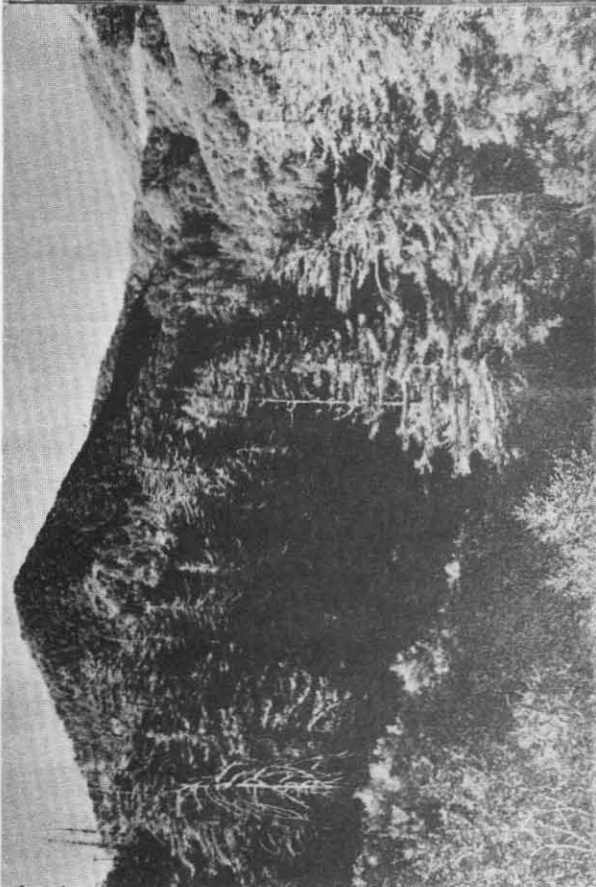
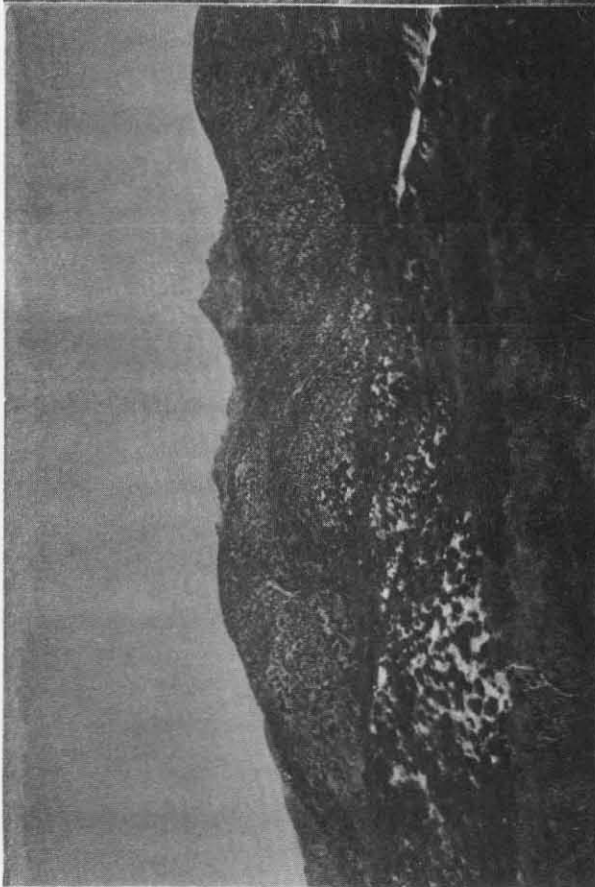
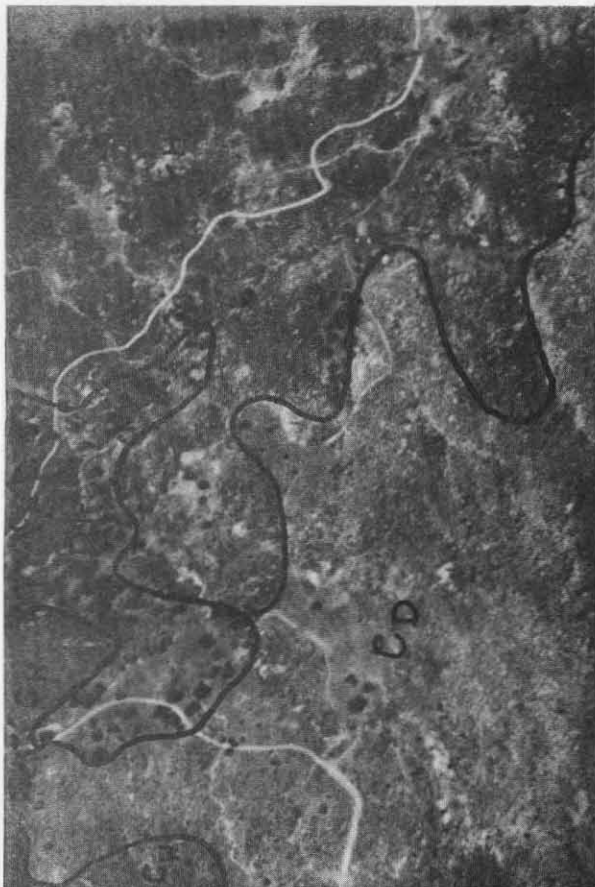
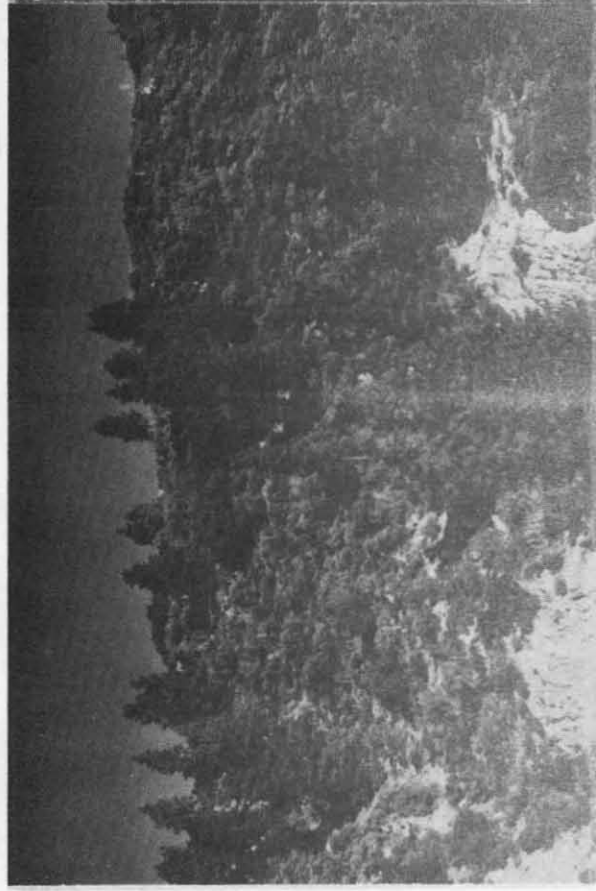


PLATE 9

- a. and c. Chaparral also contains two pines which appear as scattered emergents out of the prevailing brush, Knobcone Pine (Pinus attenuata) and Coulter Pine (Pinus coulteri). Because both are south slope trees, unlike Big Cone Douglas Fir, any trees below 6000 feet on a south exposure can be narrowed down to these two species.
- b. and d. While tonal differences are negligible, they were differentiated on CIR in terms of their contrasting height and spatial distribution. Coulter Pine is larger (5 to 15 m) and appears as widely scattered individual. Knobcone Pine dominates the landscape as dense groves, a product of its direct dependence on fire for reproductive spread.
- (a. and b., City Creek Road, 3700 feet; c. and d., Two miles south of Camp Angelus, 5500 feet;
b., Western Aerial Survey, Inc., July 1968, 15+80B; d., NASA 927, Mission 56, Sept. 1967, 15 only)



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- a. Coulter Pine seems to mix well with Black Oak (Quercus kelloggii). Here Black Oak (already frosted) is dominant spatially with scattered Coulter Pines emerging through the oak canopy. A physiognomic name, Dry Forest, was attached to indicate its marginal appearance as a forest. It has been placed as a separate association because the two coexisting dominants come from contrasting environments. Except in this case, Coulter Pine is limited to Chaparral. Black Oak, an exceptionally tolerant tree, survives in a vast array of plant groupings--notably Montane Forest, but also in wetter margins of Pinyon-Juniper Woodland and Desert Chaparral. Dry Forest seems to occupy a minor ecological niche. In the San Bernardino Mountains and the Peninsular ranges of Southern California, it seems to occur in isolated pockets of relatively level granitic surfaces at elevations of 4500-5500 feet, too low climatically for Montane Coniferous Forest but with inadequate drainage for Chaparral.
- b. While its physiognomic contrast to Chaparral is obvious, delineation of this plant grouping from Montane Coniferous Forest requires some limited experience. Both plant units contain conifers undistinguishable by tone, and Black Oak which is distinct because of its bright red record. Identification was based on two observations in the field: 1) While Black Oak is a codominant in Dry Forest, it is a minor subdominant in Montane Coniferous Forest; 2) Coulter Pine is physically smaller than Montane Forest conifers. The mapper, if he is looking for Dry Forest on CIR imagery should search for an increased incidence of Black Oak and a more diminutive and widely scattered occurrence of conifers.
(Three miles north of Lake Arrowhead, 5000 feet, Western Aerial Survey, Inc., July 1968, 15+80B)
- c. The boundary between Chaparral and Montane Coniferous Forest is often quite sharp, following a ridge or canyon representing a major change of slope exposure. A most pronounced example is the Rim of the World, the ridge separating the south facing front and the old erosional surface to the north. From near Crestline to Keller Peak (about 10 miles) this east-west trending ridge forms a sharp boundary between Chaparral and Montane Coniferous Forest. However, under certain conditions of slope exposure and steepness, limited floristic mixing between the two plant groupings occurs, forming what has been termed Marginal Coniferous Forest. Most significant are steep north facing slopes between 5500 and 6500 feet. Basically, the plant grouping is an ecotone. The most extreme case is Seeley Canyon shown here.
- d. Much of the complexity of this ecotone is evident on CIR. While homogeneous patches of certain species are evident on this north facing slope, such areas are too small to be mapped. The dominant plants seen are 1) Big Cone Douglas Fir (pink); 2) Scrub Oak Chaparral (scattered Big Cone Douglas Fir); 3) Montane Coniferous Forest species with some Black Oak; 4) mostly Black Oak. Coulter Pine is camouflaged by the larger Montane Forest conifers and Black Oak is sometimes confused with the larger Canyon Oaks (Quercus chrysolepis, Q. agrifolia). The one species which could not be confused was Big Cone Douglas Fir (Pseudotsuga macrocarpa). As a result, it was considered an indicator plant for mapping general areas of Marginal Coniferous Forest. Specific mapping required field checking for both plant groupings.
(Seeley Canyon Road, north of Lake Gregory, 3800 feet, Western Aerial Survey, Inc., July 1968, 15+80B)

48A

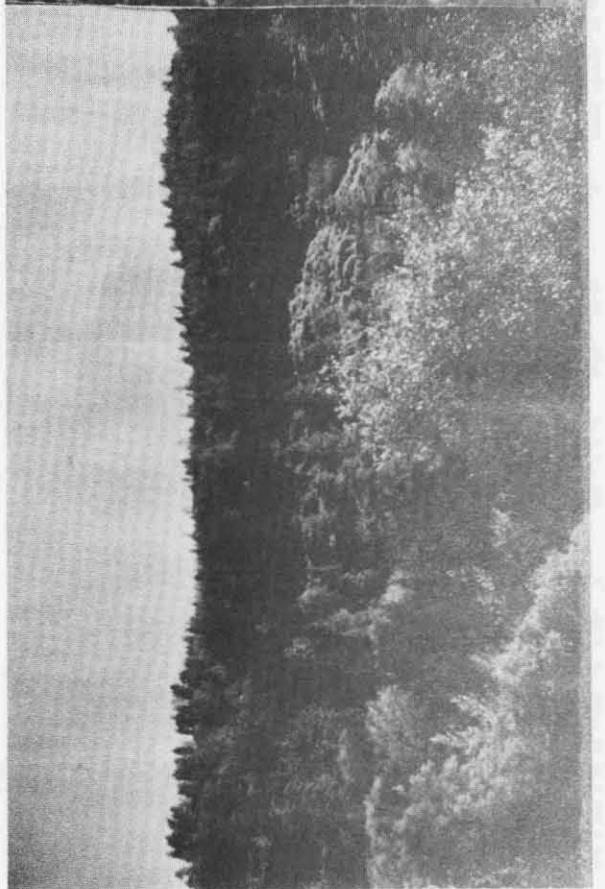
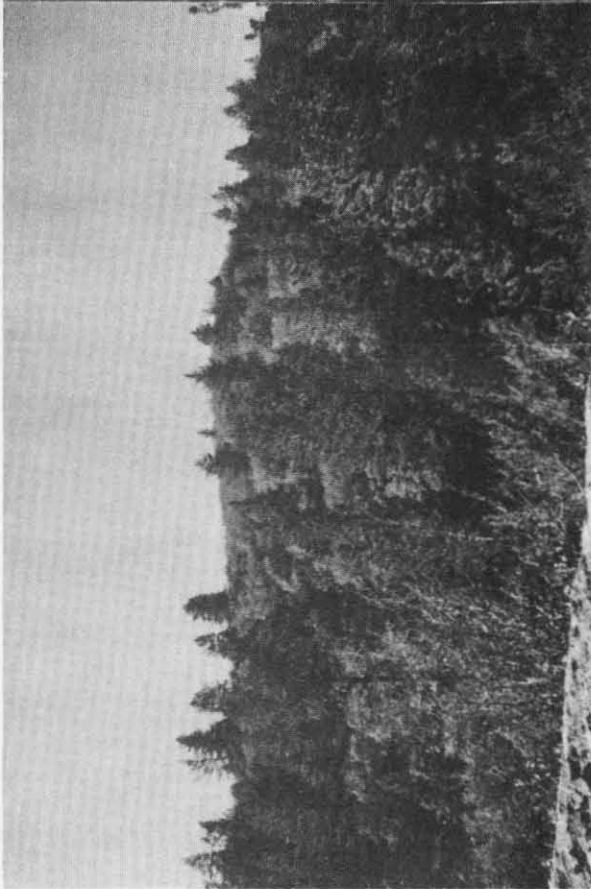
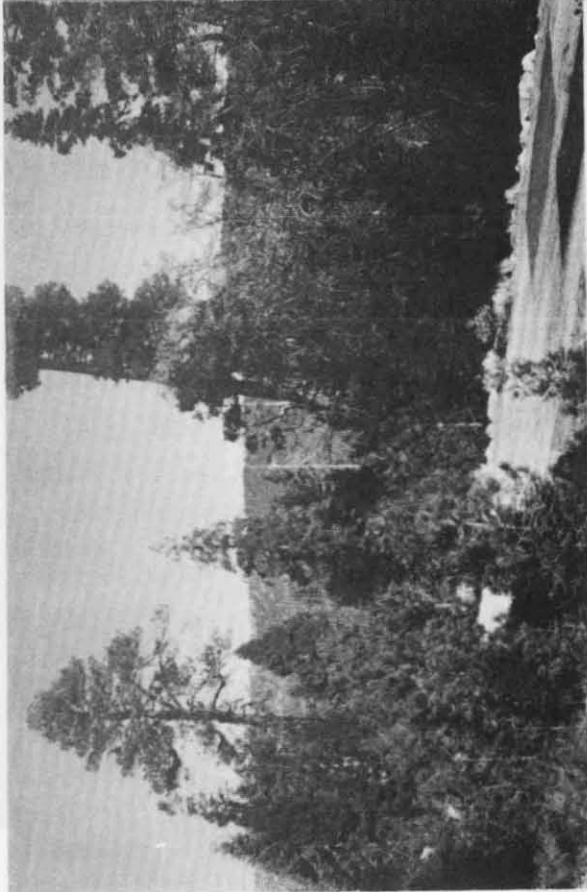
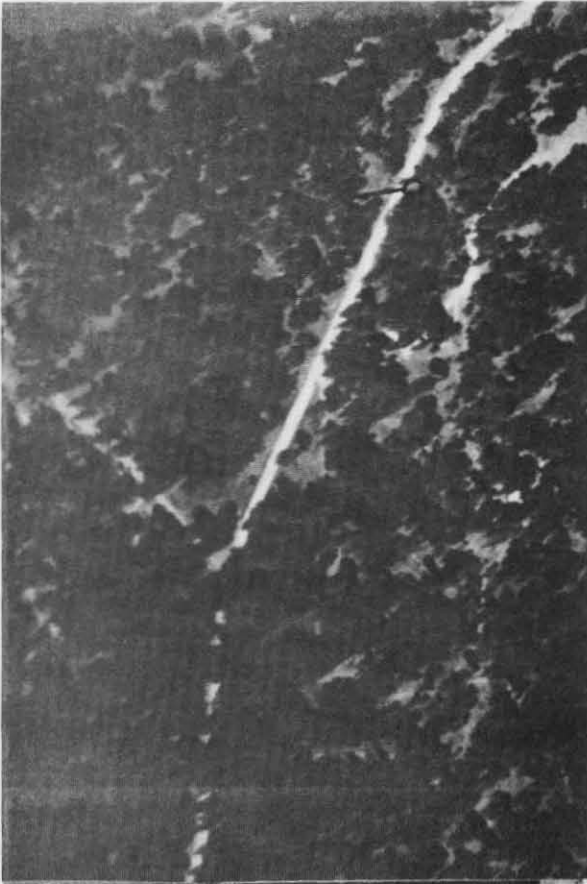


PLATE 11

- a. Widespread at elevations 5500 to 8000 feet in the San Bernardino Mountains is Montane Coniferous Forest. Physiognomically it is dominated by larger coniferous trees, often 30-50 m tall with robust crowns. Undergrowth is essentially absent except for limited herbaceous plants. The chief dominants are Yellow Pine (*Pinus ponderosa*), Jeffrey Pine (*P. jeffreyi*), Sugar Pine (*P. lambertiana*), Incense Cedar (*Lebocedras decurrens*), and White Fir (*Abies concolor*). Despite the floristically rich mixture, the five species of this plant grouping could not be segregated due to similar physiognomy and crown structure, and tone. The only discernible tree species was Black Oak which is characterized by a high red record. Montane Coniferous Forest was therefore delimited according to the presence or absence of Black Oak.
- b. With CIR imagery, the interpreter simply mapped Montane Coniferous Forest to those areas where tall trees with full crowns were dominant, segregating it according to the distribution of Black Oak. Black Oak (broad red crowns) was absent under three situations: at elevations above 7500-8000 feet; toward the arid margins of the forest; and throughout the bottom 200 feet of the Big Bear Basin (Plate 1b).
(Barton Flats near Jenk's Lake, 6500 feet, Western Aerial Survey, Inc., July 1968, 15+80B)
- c. Montane Coniferous Forest is characterized by little woody undergrowth except for moderately steep south facing slopes, and clearings. In such instances, Timberland Chaparral is prevalent. While it can be asserted this plant grouping should be included with "Chaparral," empirical evidence from CIR imagery indicated Timberland Chaparral to be geographically isolated from Chaparral. Timberland Chaparral must also withstand a more rigorous winter time environment where snow is an important factor. Timberland Chaparral, unlike Chaparral, has Montane Coniferous Forest species mixed into the brush as scattered individuals. On this plate the dominant species is *Ceanothus integerrimus* (Deer Brush). Note its flattened appearance and the very dense network of branches, typical for all Timberland Chaparral species which is considered by some scientists a morphological adaptation to snow cover.
- d. Timberland Chaparral is easily identified on CIR by a high red color record, appearing redder than any Chaparral or other brush form. If the infrared reflectance ratio is a function of new growth, then this could be the major variable for the color signature since the growing season of Timberland Chaparral, unlike coastal Chaparral, is summer.
(Horse Meadows, three miles east of Barton Flats, 7600 feet, Western Aerial Survey, Inc., July 1968, 15+80B)



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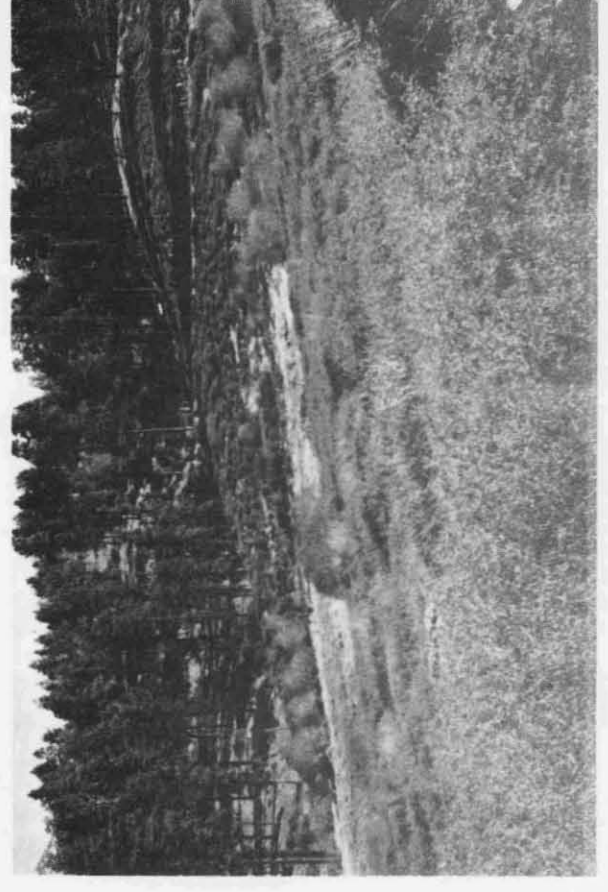
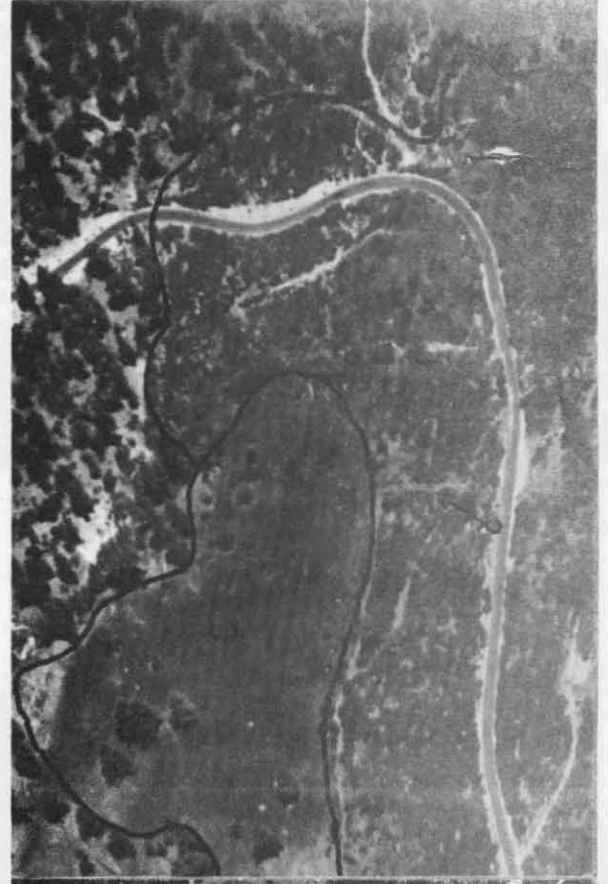
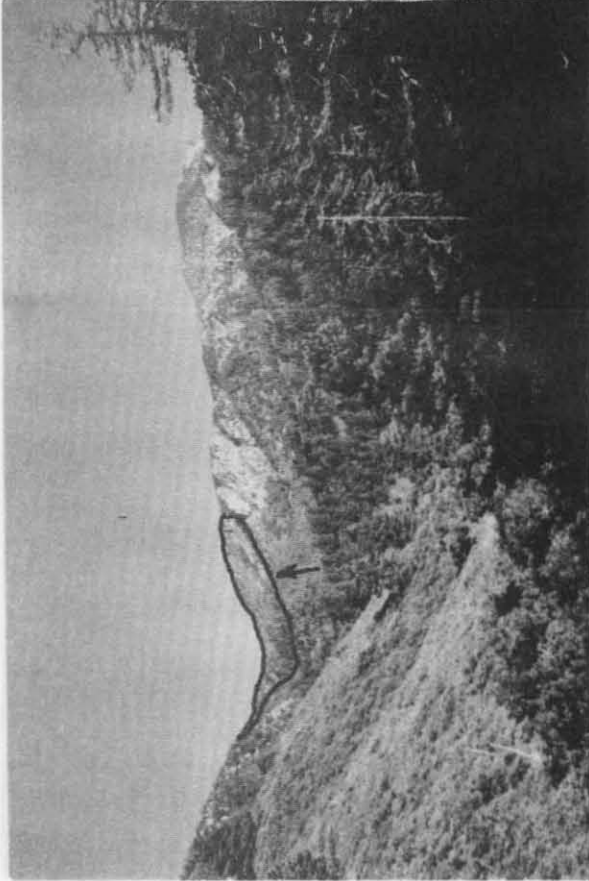
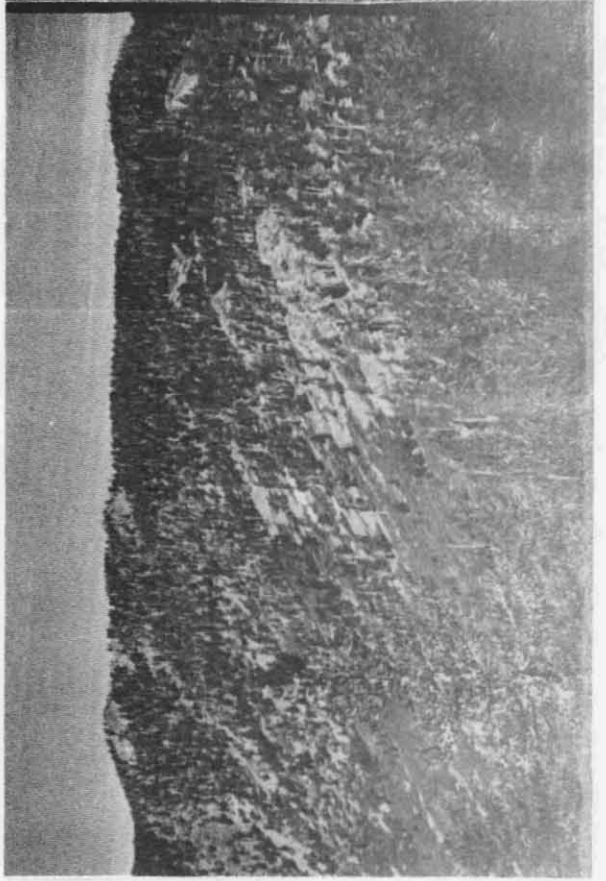


PLATE 12

- a. On the west face of San Bernardino Peak is another large area of Timberland Chaparral. It can be identified at a distance (near ridge) by its pale green color which contrasts against the darker green of the Emergent Oak Woodland beneath.
- b. Note again the scattering of conifers and the relatively red tone of the brush. This slope is one of the few areas in the San Bernardino Mountains where Chaparral and Timberland Chaparral meet. Such mixing is considered only marginal since the Timberland Chaparral is competing primarily against the rather high altitude continental oak (Quercus wislizenii). Boundaries between them are enhanced by the brighter red record of the Oak.
(West face of the San Bernardino Ridge, 8000 feet, NASA 927, Mission 56, September 1967, 15 only)
- c. Mountain summits above 8000 feet contain areas of Subalpine Forest. It can be separated from Montane Coniferous Forest because the chief dominants, Lodgepole Pine (Pinus murrayana) and Limber Pine (P. flexilis) rarely mixes with Montane Coniferous Forest. As a result the two plant units form exceptionally sharp floristic boundaries. Both trees have remarkably similar physiognomy with well defined robust trunks and narrow spindly crowns. At a distance neither can be separated in the field or on the imagery.
(October 1966)
- d. While Subalpine Forest often has a browner color record than lower altitude conifers, more certain identification is made in terms of physiognomy. Most impressive from the vertical is the homogeneity of trees size, shape, and spacing. The most important morphological difference between Subalpine Forest and Montane Coniferous Forest is the much smaller crown of the Lodgepole and Limber Pines.
(East San Bernardino Ridge, 10,400 feet, NASA 927, Mission 56, September 1967, 15 only)



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a. Along the arid east and north flanks of the San Bernardino Mountains is a major vegetation boundary dividing Montane Coniferous Forest from Desert Woodland. While woody and herbaceous undergrowth overlaps both plant groupings, an obvious break in the observable dominants is evident on CIR transparencies. Montane Forest Conifers are replaced by a Pinyon Pine (Pinus monophylla), the outstanding dominant of the Desert Woodland association. Because of its overwhelming dominance, most categories have been placed under the name Pinyon-Juniper Woodland. The classic image of Pinyon-Juniper Woodland is seen here. Like Subalpine Forest, Pinyon-Juniper Woodland has a very homogeneous appearance in the field, trees often displaying an orchard like appearance.

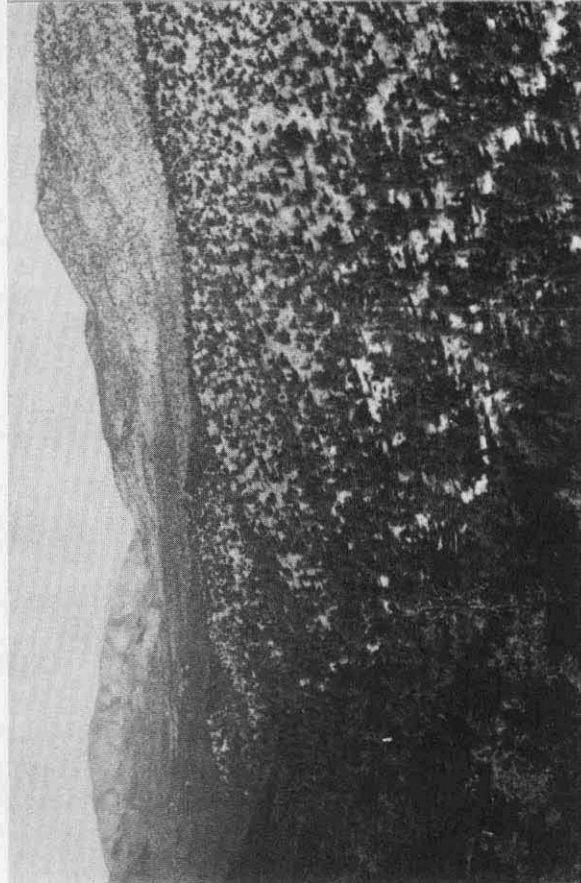
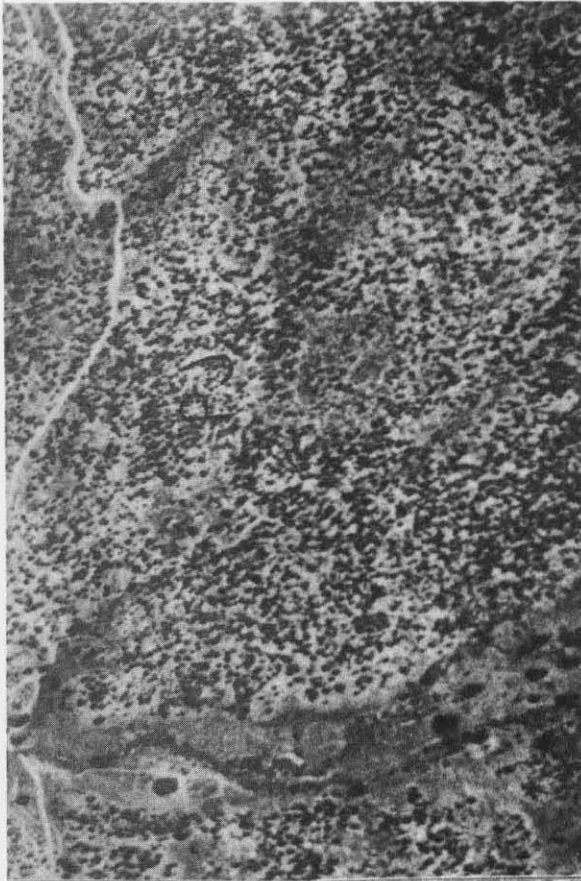
b. The conifers in Pinyon-Juniper Woodland are delineated from other conifers by their small size and very regular appearance and distribution. Their rounded crowns also exhibit a dingy brown color. The trees along the wash, Ponderosa and Jeffrey Pine, exemplify the contrasting physiognomy between Montane Coniferous Forest and Desert Woodland.

(Rattlesnake Canyon, east of Big Bear Basin, 6400 feet, Western Aerial Survey, Inc., July 1968, 15+80B)

c. While an undergrowth of Great Basin Sage (Artemesia tridentata, A. spp.) and Mountain Mahogany (Cercocarpus ledifolius) form an undercover in large portions of Pinyon-Juniper Woodland, it is seldom dominant enough to be positively identified on CIR transparencies. A major anomaly is the Onyx Summit area and the higher mountains north of Big Bear Basin, areas characterized by abnormally low precipitation. In these areas the above mentioned plants and Western Juniper (Juniperus occidentalis) become prominent. Scattered individuals of Montane Coniferous Forest may also be present.

d. Pinyon-Juniper Woodland was initially spotted by physiognomy. While average tree size is smaller than Montane Forest, it forms a much heavier woodland canopy than "pure" Pinyon-Juniper Woodland. Western Juniper can be distinguished by its pointed crown at young age and slightly greater size over Pinyon Pine. It also exhibits a slightly redder tone signature (see individual A). Mountain Mahogany is recognized by its erect bush to tree structure and sparsely leafed crown (individual B). Most small bushes with a red-purple color are Mountain Mahogany.

(Near Onyx Summit, 8500 feet, Western Aerial Survey, Inc., July 1968, 15+80B)



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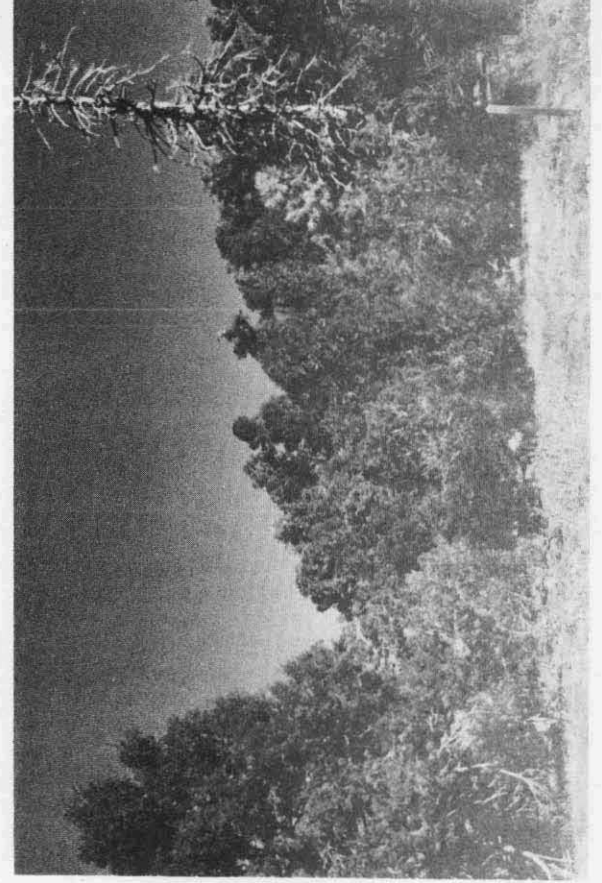
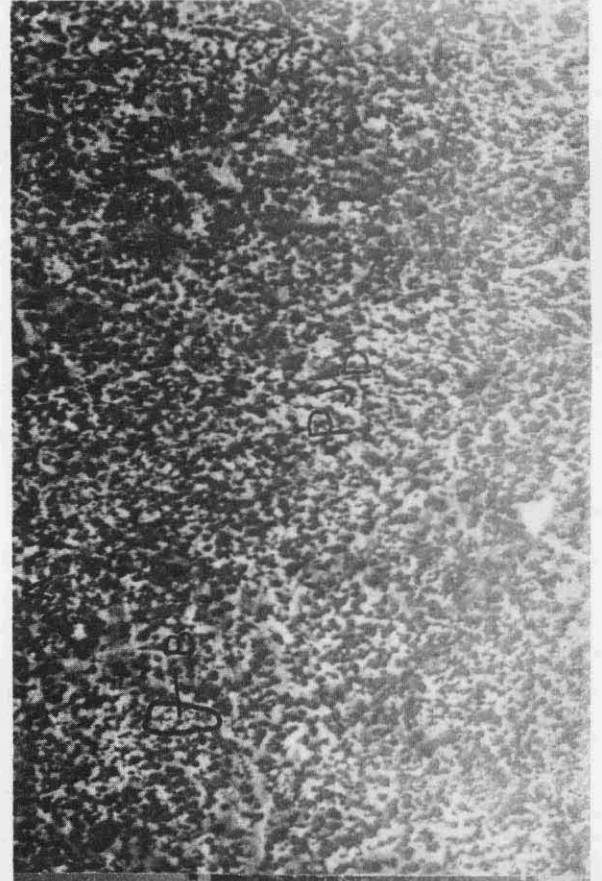


PLATE 14

- a. In Desert Woodland, the only detectable brush form other than Mountain Mahogany is Great Basin Sage (Artemisia tridentata, Artemisia spp., Chrysothamnus nauseosus). Great Basin Sage is found chiefly on interior sediment flats, as an undergrowth in Pinyon-Juniper Woodland, and occasionally in Montane Coniferous Forest above 6000 ft. elevation. (August 1967)
- b. Great Basin Sage is readily identified on CIR imagery by its marked purple tone, and relatively dense cover of the landscape compared to all other interior brush types. The reddish areas in the lower right are chiefly grasses.
(Near Big Bear City, 6700 feet, Western Aerial Survey, Inc., July 1968, 15+80B)
- c. Toward the arid margins of Pinyon-Juniper Woodland the dominant species, Pinus monophylla, decreases in size and gradually thins out. This trend warns the interpreter to be aware of the morphological plasticity of a species. Physiognomic variation within a species may confuse floristic identification. While desert plants become increasingly predominant, they are of little use to the interpreter due to their diminutive size and homogeneity in color signature (all desert vegetation appeared blue or purple). "Open" Pinyon-Juniper Woodland was segregated from "pure" Pinyon-Juniper if Pinus monophylla or Juniperus californica became widely scattered and if Quercus wislizenii were present.
- d. Pinyon Pine is again identified by its dull brown color signature. Note its smaller size. The more reddish bushes (see individual A) are Quercus wislizenii.
(Burns' Canyon, two miles west of Rimrock, 4400 feet, Western Aerial Survey, Inc., July 1968, 15+80B)

52A

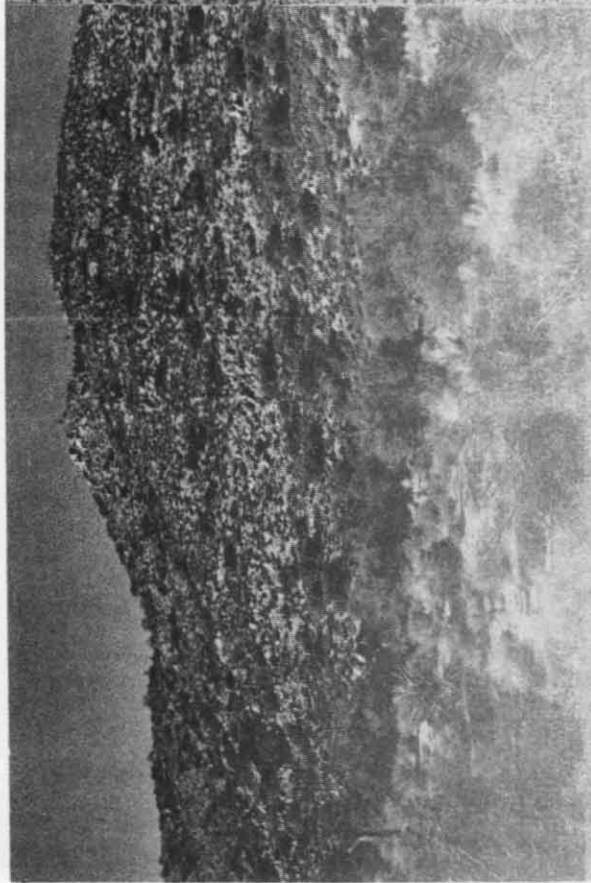
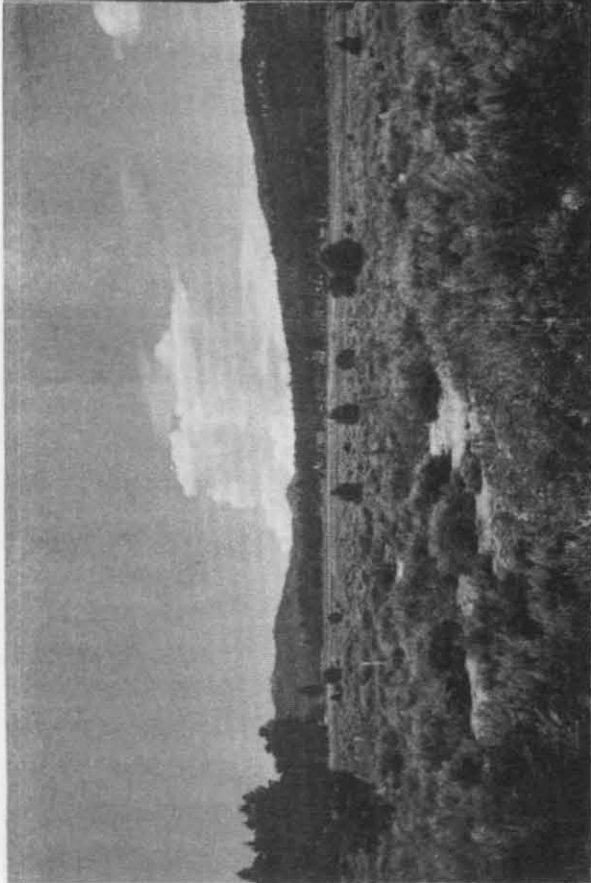
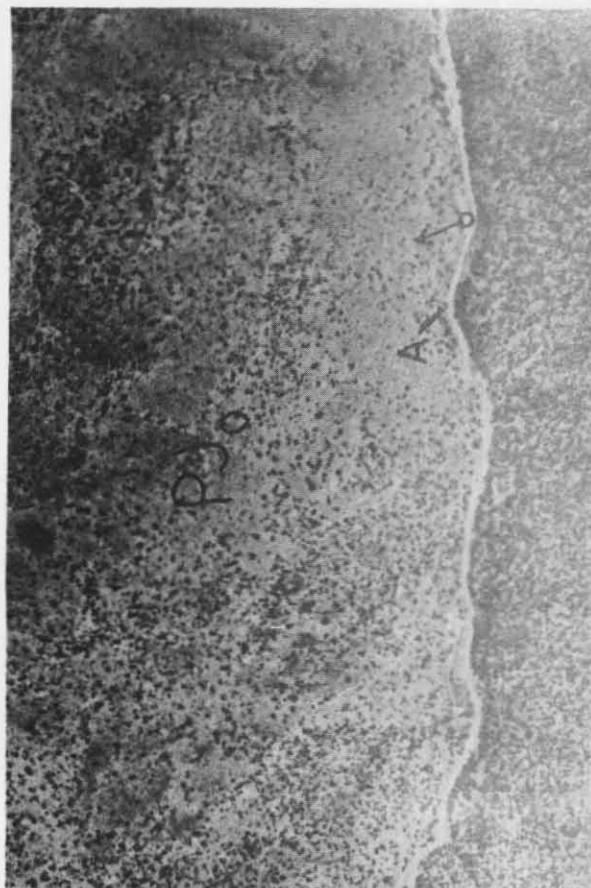
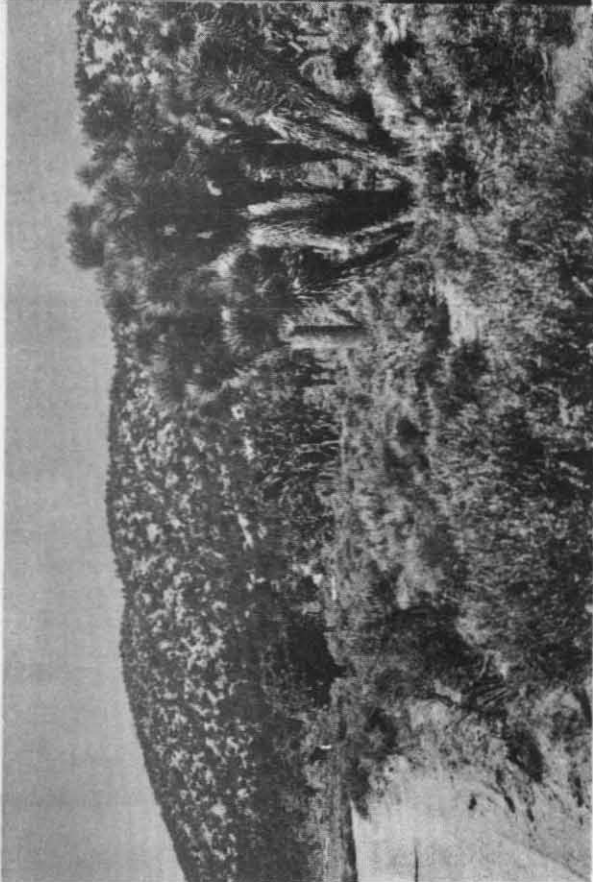
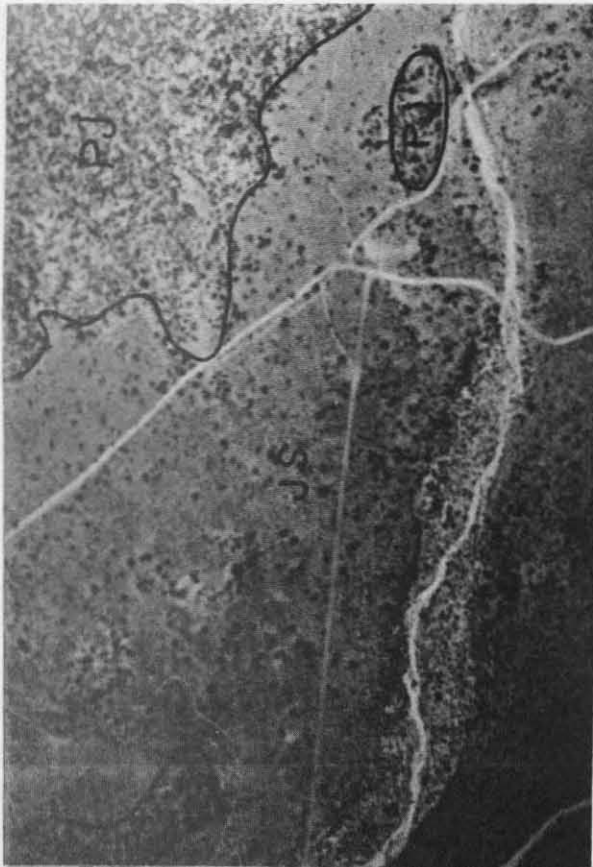


PLATE 15

- a. Also associated with Great Basin vegetation on sediment flats is Joshua Tree Woodland. Because the Joshua Tree (Yucca brevifolia) is small, it can rarely be identified by physiognomy. However, because Joshua is prominent in interior sediment flats below 6500 feet, the identification problem is lessened considerably.
- b. Joshua trees contrast from Pinyon-Juniper Woodland (upper right) by their wide orchard-like spacing and narrow rounded crowns.
(near Rose Mine, east of Big Bear, 6500 feet, Western Aerial Survey, Inc., July 1968, 15+808)
- c. The only remaining desert species large enough to be observed on available CIR imagery is California Juniper (Juniperus californica) which invariably coexists with Yucca brevifolia as shown here. Because both species are present over relatively large areas of the Mojave Desert, this plant grouping and Joshua Tree Woodland have been subcategorized under Desert vegetation.
- d. California Juniper can be distinguished from other Junipers by its bush appearance. California Juniper also possess an irregular subrounded crown (A). These patterns, however, were subtle enough to require further field checking. Note again the very rounded crowns of the Joshua Trees (B).
(six miles north northeast of Cajon Pass, 4000 feet, Western Aerial Survey, Inc., July 1968, 15+808)



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