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CIVIL EFFECTS STUDY

AERORADIOACTIVITY SURVEY AND RELATED SURFACE GEOLOGY OF PARTS OF THE LOS ANGELES REGION, CALIFORNIA (ARMS-I)

Kenneth G. Books

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AERORADIOACTIVITY SURVEY AND RELATED SURFACE GEOLOGY OF PARTS OF THE LOS ANGELES REGION, CALIFORNIA (ARMS-I)

By

Kenneth G. Books

Approved by: Director
U. S. Geological Survey

Approved by: L. J. DEAL
Acting Chief
Civil Effects Branch

U. S. Geological Survey
and
Division of Biology and Medicine, USAEC
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ABSTRACT

A recent airborne gamma radiation survey in the Los Angeles region, California, shows a moderate range in the levels of natural radioactivity. The lower levels can be related to lowland alluvium and the higher levels can be related to consolidated rocks. The highest radioactivity is associated with granitic intrusions and Tertiary volcanic rocks.

The survey is nearly 2800 square miles in area and was made by the U. S. Geological Survey in cooperation with the Division of Biology and Medicine, U. S. Atomic Energy Commission. Continuous radioactivity profiles were obtained with scintillation counting equipment at approximately 500 ft above the ground on parallel north-south flight lines spaced 1 mile apart. A map of aeroradioactivity levels was prepared from the profiles.

CONTENTS

CONTENTS (Continued)

ILLUSTRATIONS

FIGURES

PLATE

TABLE

AERORADIOACTIVITY SURVEY AND RELATED SURFACE GEOLOGY OF PARTS OF THE LOS ANGELES REGION, CALIFORNIA (ARMS-I)

1. INTRODUCTION

1.1 Location of Area

An aeroradioactivity survey in the Los Angeles area, California, was made by the U. S. Geological Survey in cooperation with the Division of Biology and Medicine, U. S. Atomic Energy Commission during May 1959, as a part of the Aerial Radiological Measurement Survey (ARMS-I) program. The entire Los Angeles region was not surveyed because of the rough topography, but surveys were made of three separate areas with several traverses along the roads between them. In order of increasing size the areas surveyed are, the Oxnard Plain of 120 square miles, the western Mojave Desert of 1200 square miles, and the Los Angeles-San Fernando lowlands of 1400 square miles (Fig. 1). All areas are, at least in part, within a radius of 50 miles of the Atomics International nuclear facility at Burro Flats in the Simi Hills.

1.2 Purpose of Survey

The survey is part of a nationwide program to obtain data on the existing gamma radioactivity for areas in, and adjacent to, nuclear facilities. These data provide information that can be used to detect any future variations in radioactivity that might result from nuclear testing, reactor or other Atomic Energy Commission operations, or radiation accidents.

1.3 Airborne Survey Procedure

The survey was made with scintillation detection equipment installed in a DC-3 type aircraft. Parallel flight lines were spaced

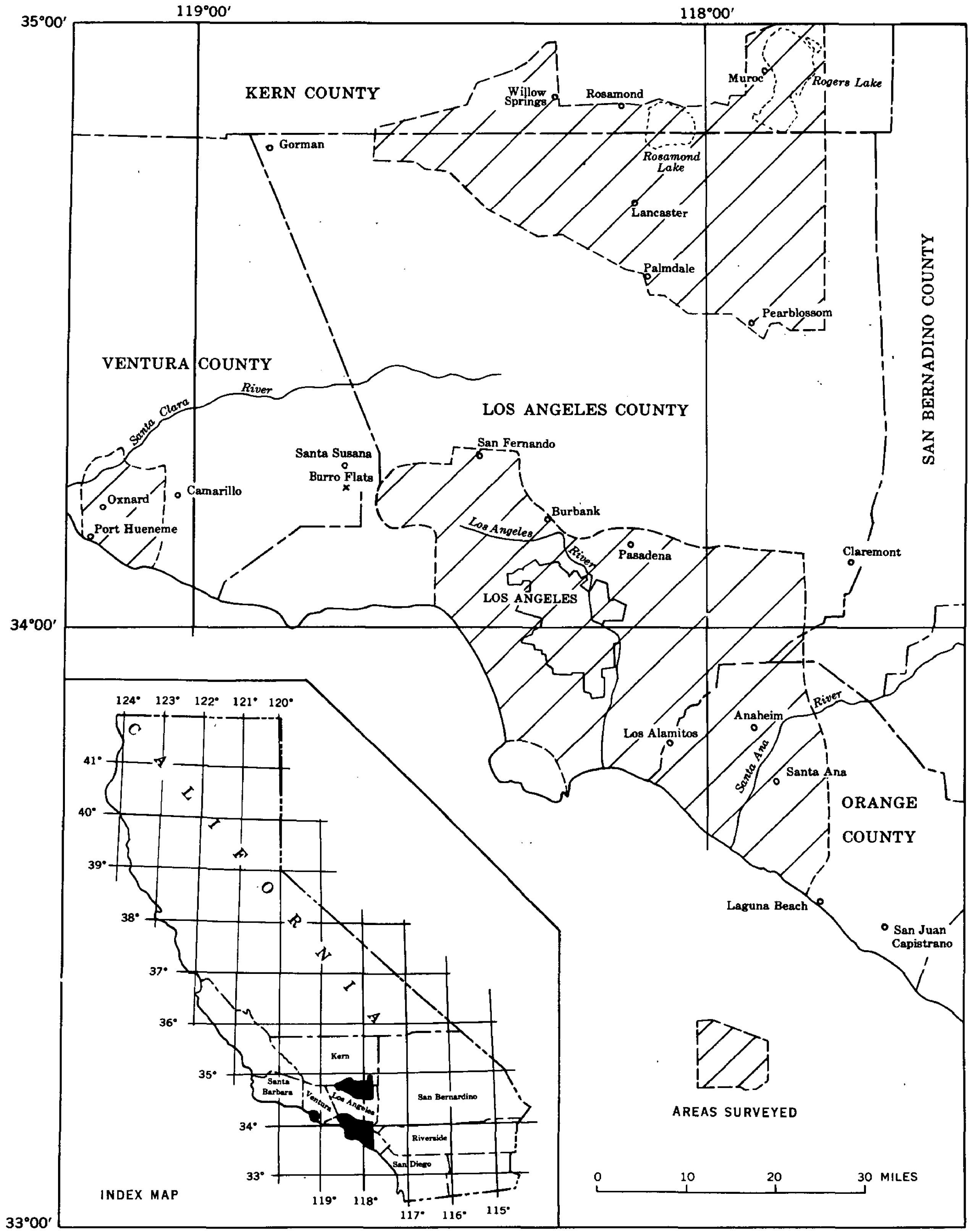

Fig. 1—Areas surveyed in the Los Angeles region, California.

one mile apart and flown north-south to cross the general geologic trend in the area. The plane maintained an approximate altitude of 500 ft above the ground at an average air speed of 150 mph; topographic maps were used for pilot guidance. The flight path of the aircraft was recorded by a gyrostabilized continuous-strip-film camera, and the distance of the aircraft from the ground was measured by a continuously recording radar altimeter. Fiducial markings which provide a common reference for the radiation and altimeter data and the camera film, were made with an electromechanical edge-mark system operated by the flight observer when the aircraft passed over recognizable features on the ground. A more detailed explanation of airborne survey procedures has been published[1].

1.4 Scintillation Detection Equipment

The gamma radiation detection equipment used by the Geological Survey was designed by the Health Physics Division of the Oak Ridge National Laboratory and is described in detail by Davis and Reinhardt[2]. They describe the sensitivity of the equipment in several ways, one being (Ref. 2, p. 717) "...the count rate for a dose rate of one microroentgen per hour due to radium gamma rays is 225 cps (counts per second)." Kermit H. Larsen of the University of California, Los Angeles, determined in 1958[3] that a count rate of about 77,000 cps would be recorded by the Geological Survey equipment flying at 500 ft above a virtually infinite area of fallout that produced a gamma-ray flux of 1 mr/hr (milliroentgen per hour) at 3 ft above the ground.

A diagram of the equipment is shown in Fig. 2. The detecting element consists of six thallium-activated sodium iodide crystals, 4 in. in diameter and 2 in. thick, and six photomultiplier tubes connected in parallel. The signal from the detecting element is fed through amplification stages to a pulse-height discriminator which is usually set to accept only pulses originating from gamma radiation with energies greater than 50 (thousand electron volts) kev. The signal is then fed to two rate meters. One rate meter feeds a circuit that records total radioactivity on a graphic milliammeter. The signal from the other rate meter is recorded by a circuit that includes a variable resistance which is controlled by the radar altimeter servomechanism, thereby approximately compensating the data for deviations from the nominal 500-ft surveying altitude.

The crystals are shielded on the sides by $\frac{1}{2}$ in. of lead, which nullifies any influence of the radium-dial instruments in the aircraft. The effective area of response at an elevation of 500 ft is approximately 1000 ft in diameter and the radiation recorded is an average of the radiation received from within the area. Theoretical aspects of the area of response and other considerations are discussed by Sakakura[4].

The gamma-ray flux at 2000 ft above the ground, which comes from cosmic radiation and to a much lesser extent from radionuclides originating from the ground, is measured twice each day while the survey is being made. This quantity is called the cosmic background at 2000 ft, and is removed from the compensated circuit. The cosmic background measured at 2000 ft during the Los Angeles survey ranged

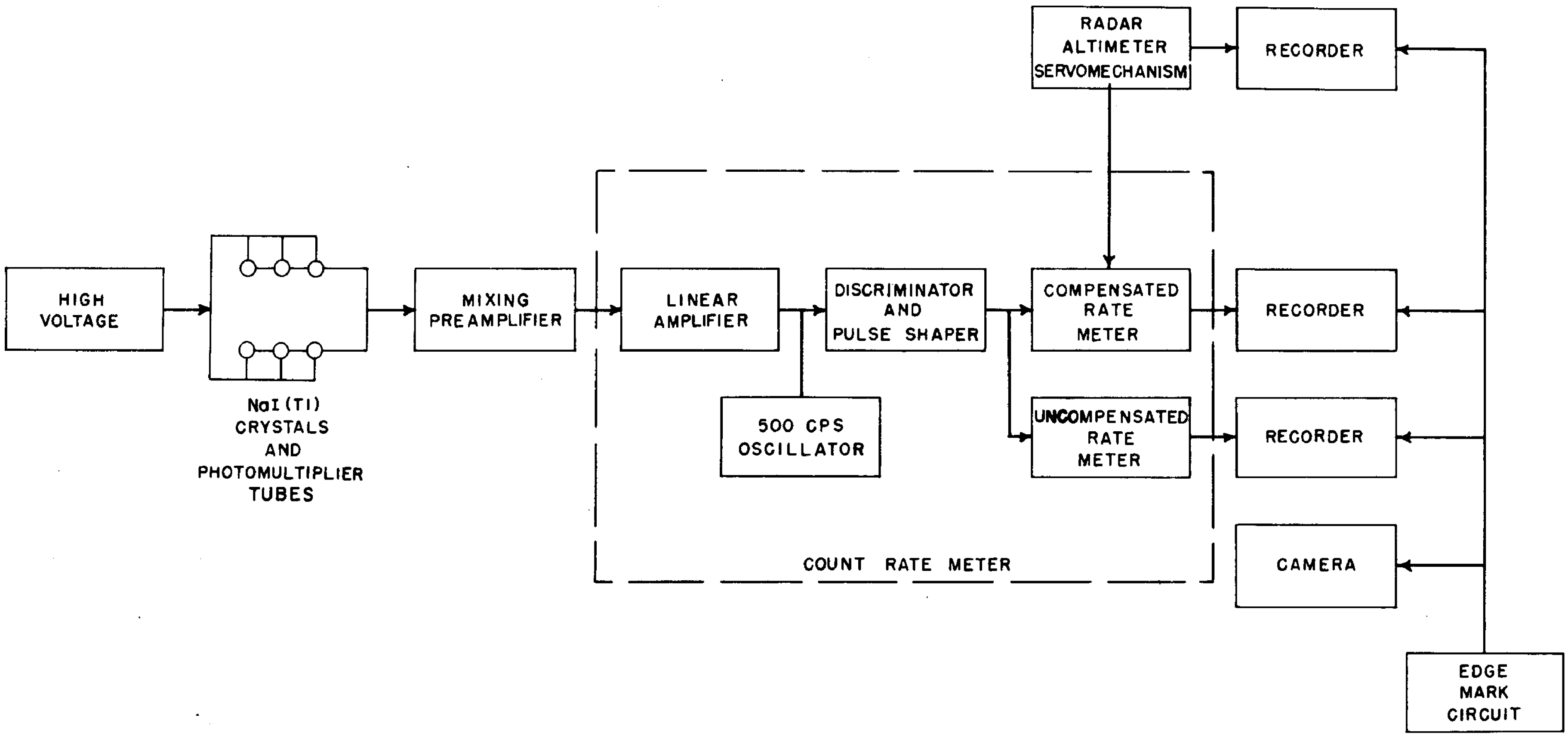

Fig. 2—Diagram of airborne radioactivity survey equipment.

from 340 to 510 cps. A portion of a regular flight line, called a "test line", is flown at the normal survey altitude at the beginning and end of each day's surveying. A comparison of these data will yield an approximation of the amount of diurnal variation of atmospheric radionuclides.

1.5 Theoretical Considerations

The gamma-ray flux at 500 ft above the ground has three principal sources: cosmic radiation, radionuclides in the air (mostly radon daughter products), and radionuclides in the surficial layer of the ground. It is possible to determine the contribution of the cosmic component. However, the component due to radionuclides in the air at 500 ft above the ground cannot be separated from the ground component. It is affected by the meteorological conditions, and a 10-fold change in radon concentration is not unusual under conditions of extreme temperature inversion. The air component, if inversion conditions are avoided, may be considered fairly uniform on a given day in a particular area.

The ground component comes from the upper few inches of the ground and consists of gamma rays from natural radionuclides and radioactive fission products in fallout. Locally, the amount of fallout must be small, because the lowest total radiation measured is 150 cps. Gustafson, Marinelli, and Brar[5] concluded from a study of the radioactivity of soil from Lemont, Ill., that in the spring of 1957 the activity due to fallout was less than one-tenth the total gamma activity of the soil. Although the Plumbbob tests in 1957 produced considerable fallout, data from periodic resurveys of test lines in Virginia, Texas, and New Mexico by the Geological Survey[6] indicate that fallout probably accounted for much less than 100 cps of the background in those areas. The distribution of fallout in the Los Angeles area is assumed to be uniform.

Natural terrestrial radioactivity comes mostly from the uranium and thorium radioactive decay series and from K^{40}. Uranium and thorium and their daughter products are commonly present in rocks and soils in amounts ranging from traces to several parts per million. The content of all potassium isotopes of the surface layer may be as much as several per cent. Approximate averages for the amounts of these elements in common rocks in parts per million are shown in Table 1.

The present distribution and concentration of natural radionuclides in the surface material is determined by the original content and form of the radioactive minerals in the parent rock and by changes due to geologic and soil-forming processes. An important consideration in studying the radioactivity of a soil is whether it is a residual soil derived from the rock beneath it or a transported soil that may be derived from rocks that are entirely different from those on which the soil rests. Although complete studies of the distribution of natural radionuclides in the various soils and rocks of the surface layer have not been made, information concerning individual components is available. Radioactive heavy minerals, such as monazite, a rare-earth phosphate containing as much as 30 per cent thorium, and zircon, a zirconium silicate containing as much as 1 per cent uranium, are

TABLE 1 — APPROXIMATE* AMOUNTS OF URANIUM, THORIUM AND K^{40} IN COMMON ROCKS IN PARTS PER MILLION

Common rocks	Uranium	Thorium	K^{40}**
Ultrabasic	0.001	0.004	0.005
Basaltic	1	4	1
Granitic (high calcium)	3	8.5	3
Granitic (low calcium)	3	17	5
Syenitic	3	13	5.8
Shales	3.7	12	3.2
Sandstones	0.45	1.7	1.3
Carbonates	2.2	1.7	0.3

* From Turekian and Wedepohl[7].

**Amounts of K^{40} are derived from those of potassium by utilizing a conventional abundance of 0.012 per cent K^{40} in potassium.

known to be present in small quantities in many types of rocks and soils. Potassium, with a conventional abundance[8] of 0.012 per cent K^{40}, is also a common component of rocks and soils. The concentration of these or any other radioactive minerals at the surface of a residual soil may be greater or less than their concentration in the parent rock, depending on the interplay of the various soil-forming processes.

2. GENERAL GEOLOGY

The surface geology is similar in the three separate areas flown in the Los Angeles region, consisting mostly of alluvial deposits, few of which are residual. The surface layer of most of the alluvium is probably derived from the adjacent highlands. However, it has been transported and possibly mixed with other soils, and the mineral components may not be representative of a single parent rock. Bedrock, with adjacent soils that might retain mineral characteristics of the parent rock, is found mainly along the lowland borders.

The surface geologic maps of the following sections (shown on Figs. 3, 4, and 5) are generalizations of the geologic maps of California with suggested ammendments on Fig. 4 by J. E. Schoellhamer[9] and on Fig. 5 by T. W. Dibblee, Jr.[10]. The consolidation of the various sedimentary rock units into marine and nonmarine groupings is simply for convenience and does not imply that one should have a greater radioactivity than the other.

The various sheets of the geologic map of California [11, 12, 13] are published at the same scale (1:250,000) as the aeroradioactivity map (in pocket).

2.1 Surface Geology of the Oxnard Plain

The Oxnard Plain, or delta plain of the Santa Clara river, is the most extensive lowland area of the Ventura Basin. The rocks are complexly folded and faulted beneath a thick alluvial cover, which in the upper foot at least is composed of soils that vary from sand, to sandy loam, to clay adobe near the Camarillo Hills. Gravel, sand, and clay are also present in stream channels and adjacent flood plains.

The one major area of consolidated rocks within the area flown (Fig. 3) lies in the western extension of the Camarillo Hills. Sedimentary deposits there are Pleistocene in age and according to Kew[14] consist of gray marine shaly sandstone in the upper beds and medium-grained tan to buff sandstones in the lower beds.

2.2 Surface Geology of the San Fernando and Los Angeles Lowlands

Surface sedimentary rocks within the area surveyed (Fig. 4) range in age from Mesozoic to Recent. The oldest rocks are found at higher elevations and consist of marine slates, argillites, and quartzites that are assigned a Mesozoic age by J. E. Schoellhamer[9] on the basis of Jurassic fossils. Rocks of Cretaceous through Tertiary ages are mostly marine conglomerate, sandstone, shale, and siltstone with some organic and diatomaceous shale and radiolarian mudstone. Nonmarine sedimentary rocks in this same age span are represented by conglomerate, sandstone, and siltstone, which according to Woodford and others[15] probably range in age from late Eocene to early Miocene. Sediments of Pleistocene age are either marine deposits of sand, silt, and marl, or nonmarine lake and terrace deposits. Recent alluvial gravels, sands, silts, and clays are present at lower elevations and form the youngest and largest group of sedimentary deposits in the area.

Major exposures of igneous rock are also present within the survey area. Quartz diorite believed to be of Cretaceous age[16] crops out in the eastern Santa Monica Mountains as do calcic andesite flows, tuffs, and breccias of Miocene age. The volcanic rocks are also exposed on the eastern edge of the Los Angeles coastal plain.

2.3 Surface Geology of the Western Mojave Desert

Surface sedimentary rocks (Fig. 5) as old as Tertiary (mostly Miocene) age crop out in the Rosamond Hills area north of Rosamond

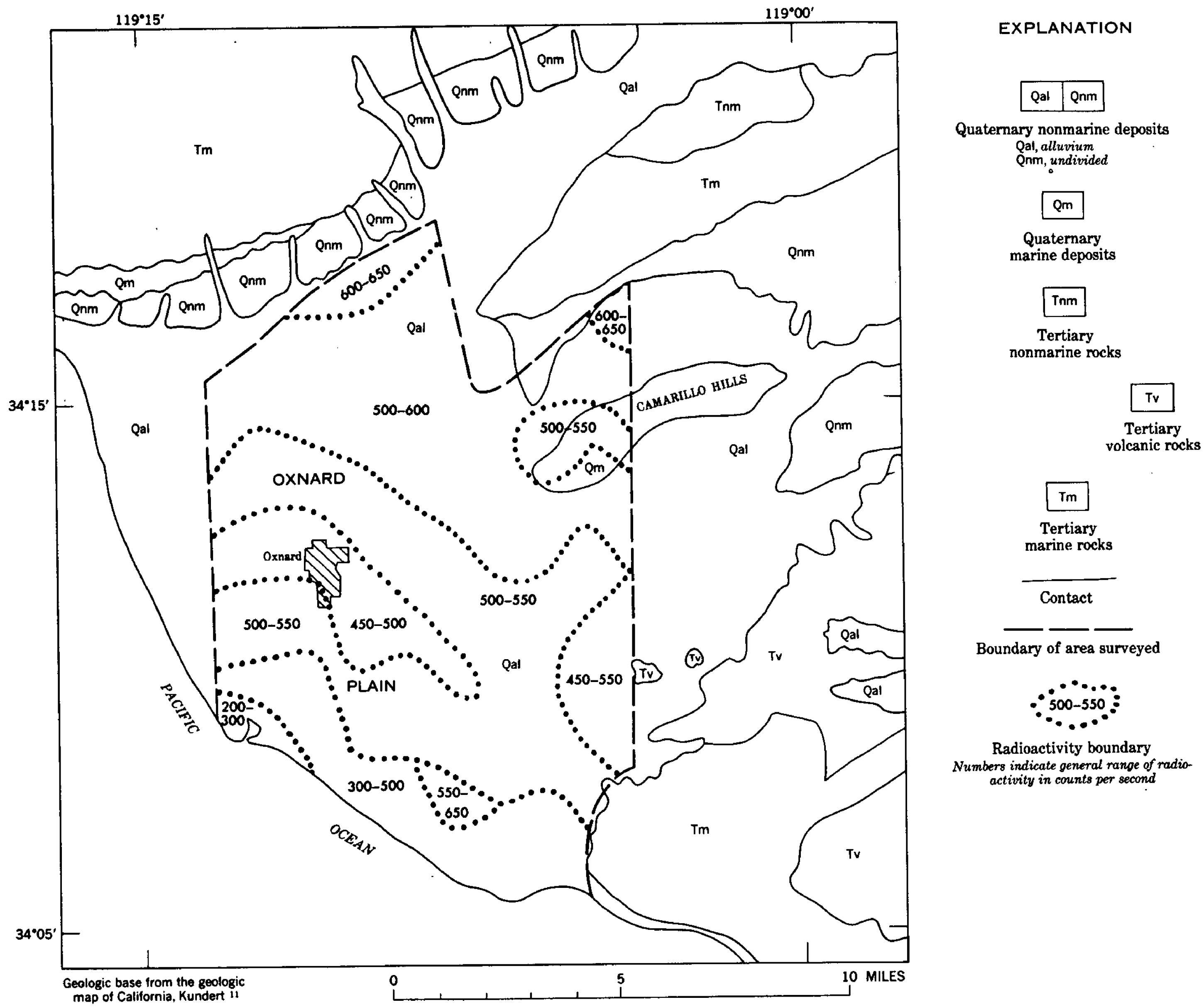

Fig. 3—Generalized surface geology and aeroradioactivity map of the Oxnard Plain area, California.

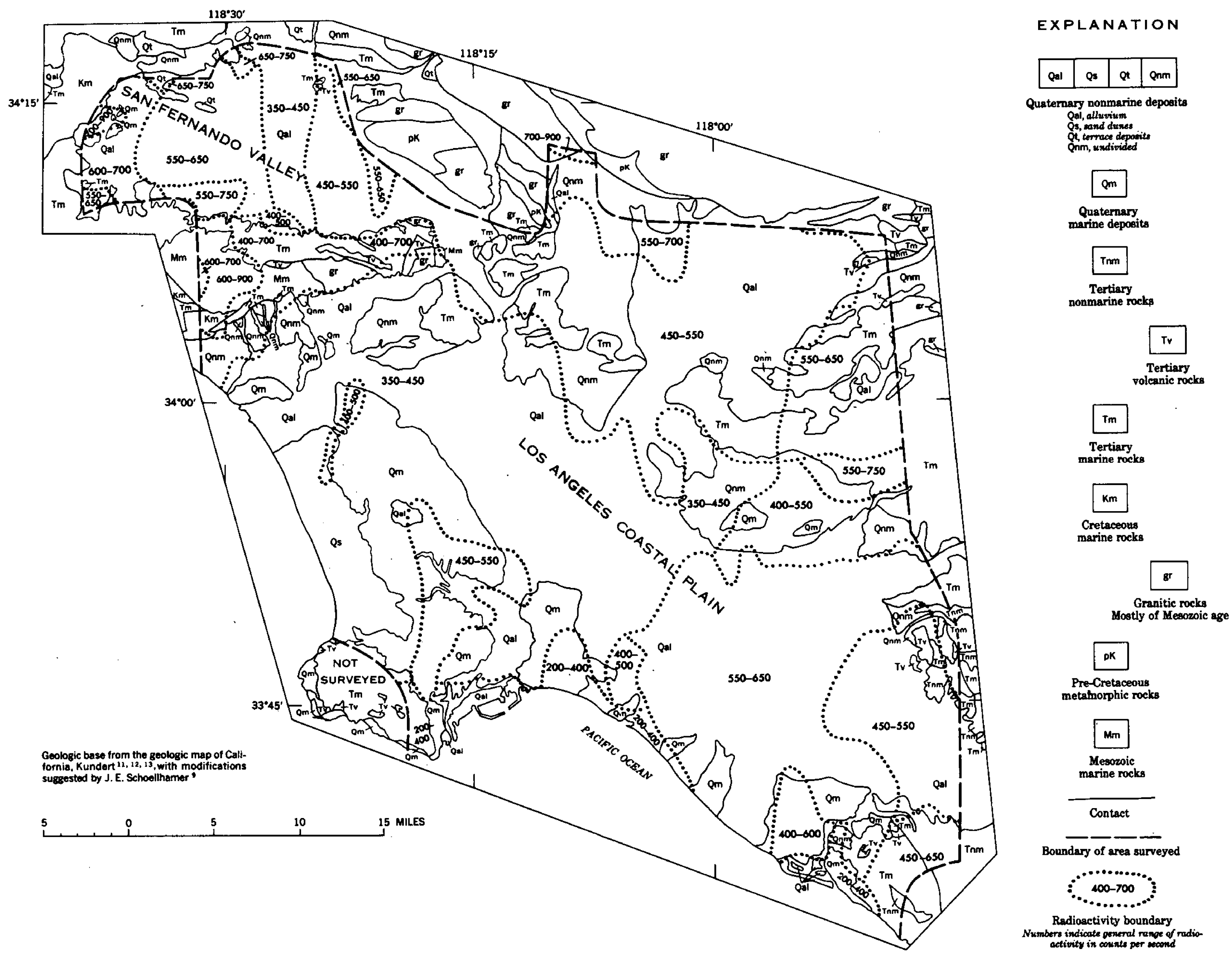

Fig. 4—Generalized surface geology and aeroradioactivity map of the San Fernando–Los Angeles lowland areas, California.

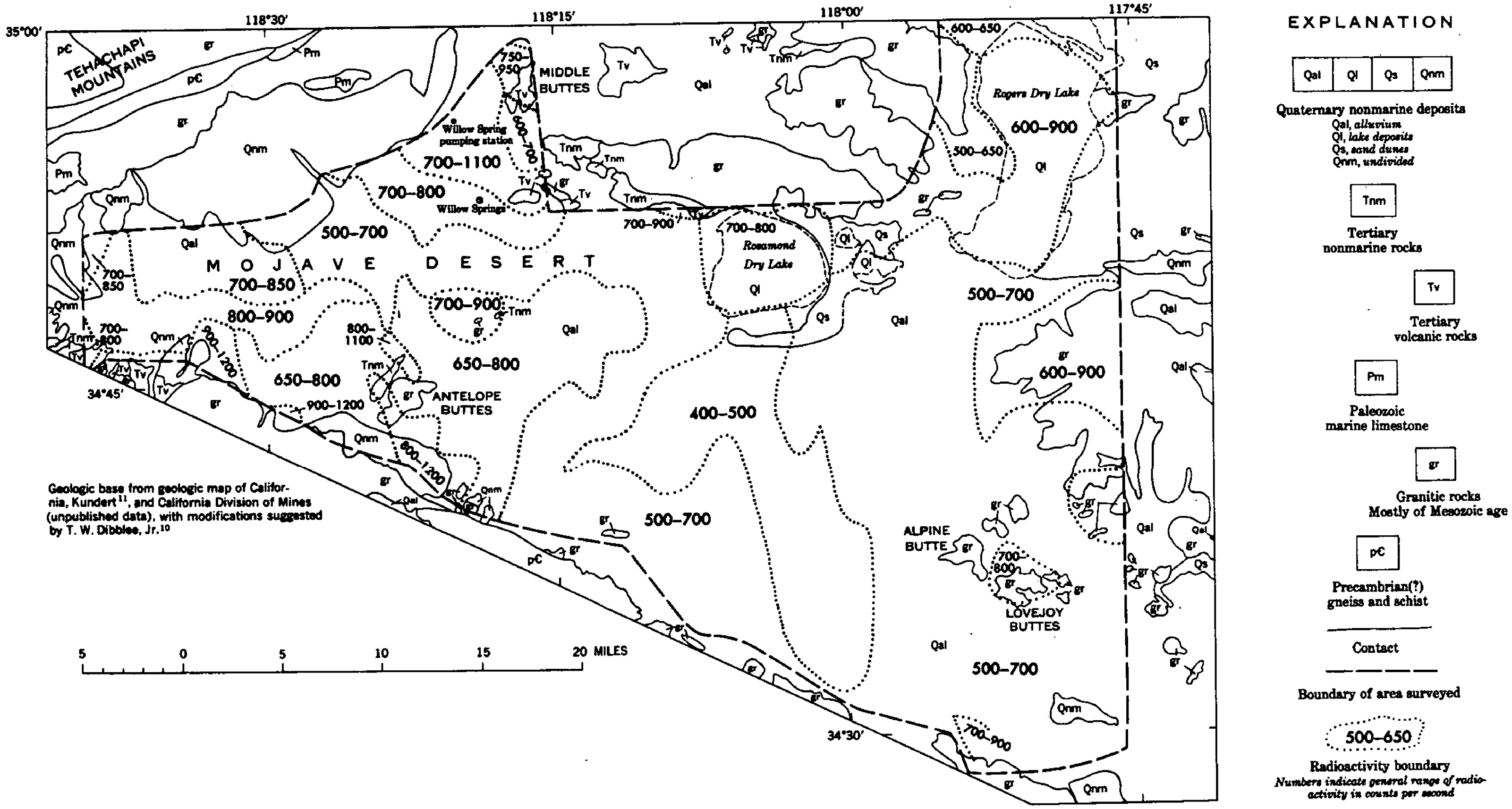

Fig. 5—Generalized surface geology and aeroradioactivity map of the western Mojave Desert area, California.

and in the hills about 15 miles southwest of Rosamond. According to Wright and Traxel[17], the lower sequence in the Rosamond Hills is a light-colored rhyolite tuff cut by intrusive plugs of reddish rhyolite and containing some rhyolite breccias originating from the plugs; the upper sequence is conglomerate of rhyolitic volcanic debris. The sequence of rocks in the hills 15 miles southwest across the desert from Rosamond is similar, but the lower sequence includes some andesitic flows in addition to rhyolitic rocks.

Most of the surface sedimentary deposits in the western Mojave Desert region are composed of Quarternary alluvial gravels, sands, silts, and clays, very little of which is residual. On the desert floor there are undissected alluvial sediments, playa clays of the Rosamond and Rogers dry lakes, and dune sands adjacent to these lakes. Near the San Gabriel and Tehachapi Mountains the deposits are mostly dissected fan gravels and sands.

Crystalline rocks of pre-Tertiary age exposed in parts of the desert region and in the San Gabriel and Tehachapi Mountains are mainly plutonic igneous, mostly quartz monzonite of Mesozoic age. These rocks are intrusive into metamorphic rocks of Paleozoic(?) and Precambrian(?) ages, of which only small bodies remain as roof pendants[10].

3. COMPILATION OF AERORADIOACTIVITY DATA

Flight-line locations from strip-film obtained during the survey were plotted on compilation base maps (scale: 1 in. equals 1 mile). The altitude-compensated radioactivity profiles from adjacent flight lines were examined, and changes or breaks in the level of the radioactivity record were correlated from line to line. Changes on the radioactivity record are indicated on the map (in pocket) by solid or dashed lines, depending on the degree of correlation. The difference between the lines is a matter of degree; the solid lines denote distinct major changes in the level of radioactivity and the dashed lines denote relatively less distinct, generally transitional changes. Areas between the lines of change were assigned general ranges of radioactivity levels by scanning the records obtained over the specific areas. The lines of change and the radioactivity levels were plotted along flight lines on transparent overlays of the compilation base maps. The overlays were reduced to a scale of 1 in. equals 4 miles (1:250,000) and the data were plotted on the final base map. The final base map was derived from Army Map Service, Corps of Engineers, 1:250,000 topographic map series, Long Beach, Los Angeles, San Bernardino, and Santa Ana sheets.

4. GENERAL DISTRIBUTION OF AERORADIOACTIVITY

Although there is some correlation between the surficial rock and soil and the general intensity of natural gamma radiation, there are too many exceptions to the relation for a broad generalization.

In the several areas flown, there is a generally lower radioactivity level associated with the alluvium than with the consolidated rocks. This is true even in the Mojave Desert area, where radioactivity levels are higher for both alluvium and consolidated rocks. The highest radioactivity (up to 900 cps in the Los Angeles area and 1200 cps in the Mojave Desert area) is found over igneous rocks, which in the Mojave Desert area at least, are predominantly quartz monzonite.

4.1 Distribution of Radioactivity Relative to Surface Geology in the Oxnard Plain

Radioactivity levels range between 200 and 650 cps. The lowest levels are near the shore line where the range is from 200 to 500 cps; the decreased radioactivity is probably due to the masking influence of water. Farther inland the radioactivity is generally a little greater (450 to 650 cps), but the range is less than near the seashore. There is no obvious correlation with surface sediments other than the radioactivity level associated with the western extension of the Camarillo Hills. This is not surprising because most of the area is one of alluvial deltaic and flood-plain deposits that have been reworked many times.

4.2 Distribution of Radioactivity Relative to Surface Geology in the San Fernando and Los Angeles Lowlands

4.2.1 San Fernando Valley

Radioactivity levels within the San Fernando valley range between 350 and 650 cps. In the central part of the valley, levels are 350 to 450 and 450 to 550 cps. In the eastern end of the valley near the Verdugo Mountains where large areas of granitic rock crop out, the radioactivity level is 550 to 650 cps. To the west and northwest near the Santa Susana and Santa Monica Mountains, where Miocene marine rocks are exposed, the level is also 550 to 650 cps. On the south flank of the valley, where the eastern extension of the Santa Monica Mountains separates the San Fernando valley from the Los Angeles coastal plain, the radioactivity level is 400 to 700 cps. This level outlines the mountains where Miocene marine rocks, Mesozoic metamorphic rocks, and quartz diorite of Cretaceous age crop out. Farther west the level increases to 600 to 900 cps and is associated with a larger area of slate and schist of Mesozoic age that has been intruded by quartz diorite. In general, the San Fernando valley is outlined by a change in radioactivity between the alluvium of the valley floor and the rocks at higher elevations on the valley flanks.

4.2.2 Los Angeles Coastal Plain

Within the Los Angeles coastal plain radioactivity levels range between 350 and 650 cps. These levels increase to 400 to 700 cps on the interior flanks of the plain with levels up to 750 cps farther inland. In the northwestern part of the area surveyed, there is a break in radioactivity along the Santa Monica Mountains, and the radioactivity is greater toward the mountains. Terrace deposits (fanglomerate and terrace gravels) fall partly within the greater radioactivity level, and they appear to be more closely associated with the rocks of the mountains than with the alluvium of the valley floor. Radioactivity levels within the northwestern half of the coastal plain are mostly a uniform 350 to 450 cps. Two slightly higher levels within this area (450 to 550 and 400 to 500 cps) are associated with areas that are shown on Fig. 4 as Quaternary marine deposits, but which are actually mostly covered by a nonmarine terrace cover of varying thickness[9]. Near the seashore radioactivity levels are generally lower than in the rest of the survey area (200 to 400 cps), probably owing to the masking effect of water. In general, the coastal plain is outlined by lines of changes between radioactivity levels.

In the southeastern quarter of the Los Angeles coastal plain, in an area extending as much as 11 miles northwest of the Santa Ana river, the radioactivity level is greater (550 to 650 cps) than in the rest of the plain, probably because of the type of soil present. Fig. 6 shows a comparison of radioactivity levels with soils as mapped by Eckmann, Strahorn, and Holmes[18]. The radioactivity level of 550 to 650 cps correlates generally with soils derived from upland areas occupied by granites.

4.3 Distribution of Radioactivity Relative to Surface Geology in the Western Mojave Desert

There is considerable variation in radioactivity in this area. Levels range from 400 to 500 cps to as high as 900 to 1200 cps over some of the monzonitic rocks. The lowest levels are found within areas of alluvium, but even there radioactivity may be as high as 900 cps. Two playa lakes (Rosamond, 700 to 800 cps, and Rogers, 600 to 900 cps) are outlined by a change in radioactivity level. How these dry lakes acquired a slightly greater natural gamma radioactivity is not clear. However, the restriction of the greater radioactivity levels to the areas covered by dry lake beds does indicate a greater abundance of radioactive minerals in the dry lake deposits than in the surrounding sedimentary deposits. This suggests an association with the intermittent waters of the lakes, but whether the greater abundance of radioactive minerals is due to their being carried in as fragmental particles or in solution is not known.

With some exceptions, those areas near or at monzonitic and volcanic rock exposures have the highest radioactivity readings. Lovejoy Buttes are indicated by a higher radioactivity level, as are the monzonites to the northeast, but the nearby monzonite of Alpine Buttes has a lower level. Higher levels also mark the area of granitic rocks northeast of the San Andreas fault, the volcanic rocks of Middle Butte northeast of the Willow Spring pumping station, and the igneous rocks in the area of the Tropico mine east of Willow Springs. In the latter area anomalous radioactivity was discovered by an earlier airborne radioactivity survey and reported by R. M. Moxham[19] of the Geological Survey. From 1954 to 1956 a search for radioactive

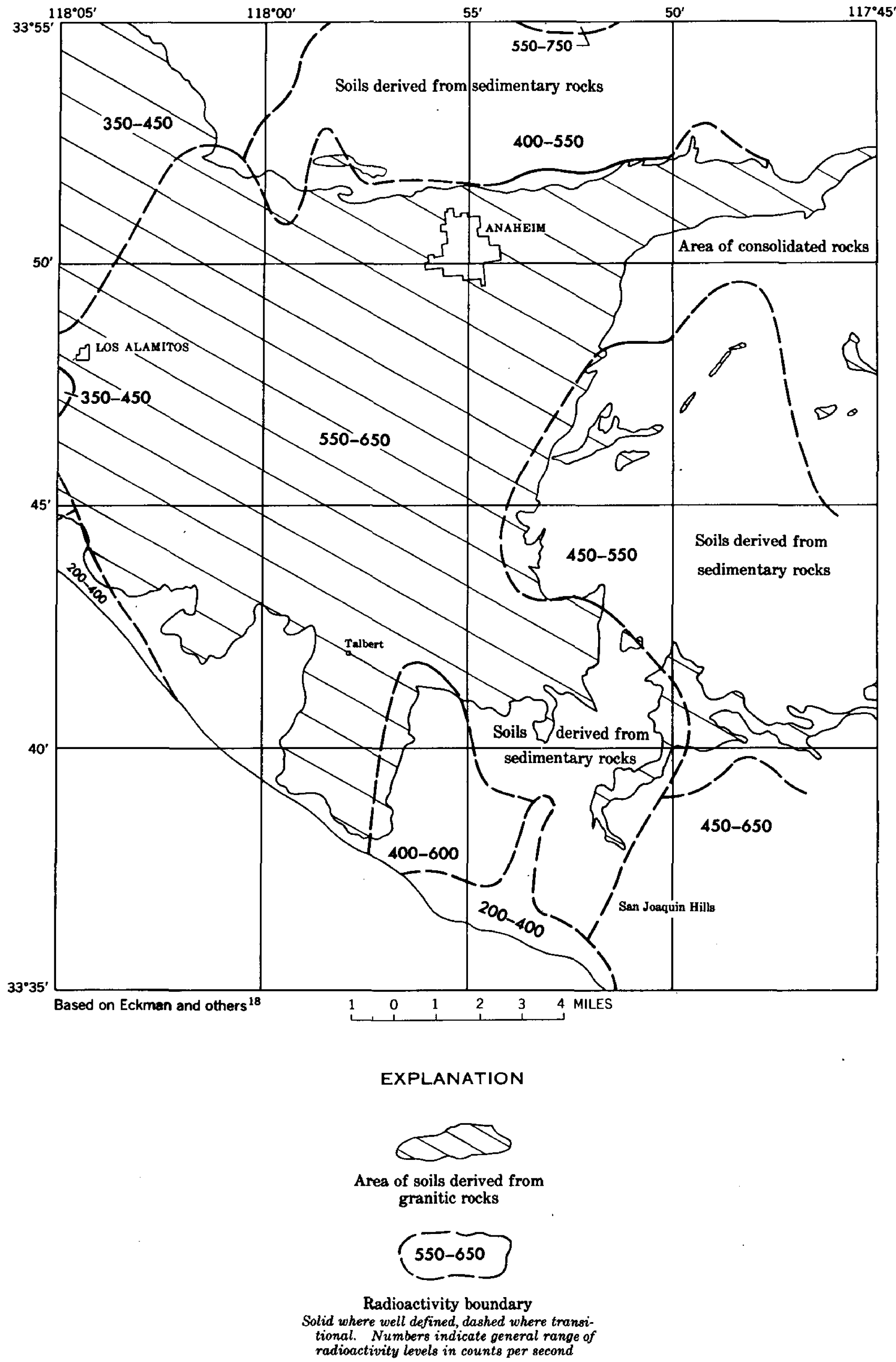

Fig. 6—Generalized soils map and aeroradioactivity of the Anaheim-Los Alamitos-Talbert area, California.

materials was made by the Atomic Energy Commission[20]. Surface excavation at two areas of anomalous radioactivity has disclosed minor quantities of uranium minerals.

5. BURRO FLATS NUCLEAR FACILITY

The Atomic International nuclear facility is located at Burro Flats in the Simi Hills, approximately $3\frac{1}{2}$ miles south of Santa Susana (see map in pocket).

Rough topography prevented surveying in the vicinity of the facility, but the aircraft was able to make several flights at 500 ft above the ground over the immediate Burro Flats area. Natural background radioactivity in the area is 800 to 1000 cps over bedrock mapped as Upper Cretaceous marine rocks. This same general radioactivity level is found over Cretaceous marine rocks in the vicinity of the Chatsworth reservoir 4 miles to the east.

Two anomalies were measured over the facility area, one about twice background, and one about four times background. The latter was from an intermittent source. Both readings result from normal atomic energy operations at the nuclear facility and the fact that the Geological Survey equipment (instrumentation) used is extremely sensitive to small changes in radioactivity levels. Information on radioactivity levels in the environs and outside the plant boundaries of Atomic Energy Commission and contractor installations are reported in special periodic reports from each installation. These reports are published in the U. S. Health Service series titled "RADIOLOGICAL HEALTH DATA", issued monthly and available from the Government Printing Office, Washington 25, D. C.

6. SUMMARY

The aerial radioactivity measurements in the Los Angeles area were collected largely over nonresidual alluvium and consequently do not correlate well with local geology. However, where soils are mapped as "derived from igneous rocks", they can be distinguished by their radioactivity level. In general, the alluvial lowlands are outlined and can be distinguished from the consolidated rocks at higher elevations by a lower radioactivity, especially where the adjacent rocks are igneous in origin. Most areas of igneous rock are also distinguishable by a higher radioactivity.

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