3

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

GEOLOGY OF A PORTION OF THE
ELSINORE FAULT ZONE
CALIFORNIA

SPECIAL REPORT 43

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO

SPECIAL REPORTS ISSUED BY THE DIVISION OF MINES

1-A. Sierra Blanca limestone in Santa Barbara County, California, by George W. Walker. 1950. 5 pp., 1 pl. Price 25¢.

1-B. The Calera limestone, San Mateo and Santa Clara Counties, California, by George W. Walker. 1950. 8 pp., 1 pl., 6 figs. Price 25¢.

2. Geology of part of the Delta-Mendota Canal near Tracy, California, by Parry Reiche. 1950. 12 pp., 5 figs. Price 25¢.

3. Commercial "black granite" of San Diego County, California, by Richard A. Hoppin and L. A. Norman, Jr. 1950. 19 pp., 18 figs. Price 25¢.

4. Geology of the San Dieguito pyrophyllite area, San Diego County, California, by Richard H. Jahns and John F. Lance. 1950. 32 pp., 2 pls., 21 figs. Price 50¢.

5. Geology of the Jurupa Mountains, San Bernardino and Riverside Counties, California, by Edward M. MacKevett. 1951. 14 pp., 1 pl., 14 figs. Price 25¢.

6. Geology of Bitterwater Creek area, Kern County, California, by Henry H. Heikkila and George M. MacLeod. 1951. 21 pp., 2 pls., 15 figs. Price 35¢.

7-A. Gem- and lithium-bearing pegmatites of the Pala district, San Diego County, California, by Richard H. Jahns and Lauren A. Wright. 1951. 72 pp., 13 pls., 35 figs. Price $2.50.

7-B. Economic geology of the Rincon pegmatites, San Diego County, California, by John B. Hanley. 1951. 24 pp., 1 pl., 5 figs. Price 35¢.

8. Talc deposits of steatite grade, Inyo County, California, by Ben M. Page. 1951. 35 pp., 11 pls., 25 figs. Price 85¢.

9. Type Moreno formation and overlying Eocene strata on the west side of the San Joaquin Valley, Fresno and Merced Counties, California, by Max B. Payne. 1951. 29 pp., 5 pls., 11 figs. Price 60¢.

10-A. Nephrite jade and associated rocks of the Cape San Martin region. Monterey County, California, by Richard A. Crippen, Jr., 2d printing. 1951. 14 pp., 14 figs. Price 25¢.

10-B. Nephrite in Marin County, California, by Charles W. Chesterman. 1951. 11 pp., 16 figs. Price 25¢.

10-C. Jadeite of San Benito County, California, by H. S. Yoder and C. W. Chesterman. 1951. 8 pp., 6 figs. Price 25¢.

11. Guide to the geology of Pfeiffer-Big Sur State Park, Monterey County, California, by Gordon B. Oakeshott. 1951. 16 pp., 1 pl., 28 figs. Price 25¢.

12. Hydraulic filling in metal mines, by William E. Lightfoot. 1951. 28 pp., 15 figs. Price 50¢.

13. Geology of the saline deposits of Bristol Dry Lake, San Bernardino County, California, by Hoyt S. Gale. 1951. 24 pp., 1 pl., 2 figs. Price 35¢.

14. Geology of the massive sulfide deposits at Iron Mountain, Shasta County, California, by A. R. Kinkel, Jr. and J. P. Albers. 1951. 19 pp., 6 pls., 6 figs. Price 75¢.

15. Photogeologic interpretation using photogrammetric dip calculations, by D. H. Elliott. 1952. 21 pp., 9 figs. Price 50¢.

16. Geology of the Shasta King mine, Shasta County, California, by A. R. Kinkel, Jr. and Wayne E. Hall. 1951. 11 pp., 3 pls., 4 figs. Price 50¢.

17. Suggestions for exploration at New Almaden quicksilver mine, California, by Edgar H. Bailey. 1952. 4 pp., 1 pl. Price 25¢.

18. Geology of the Whittier-La Habra area, Los Angeles County, California, by Charles J. Kundert. 1952. 22 pp., 3 pls., 19 figs. Price 50¢.

19. Geology and ceramic properties of the Ione formation, Buena Vista area, Amador County, California, by Joseph A. Pask and Mort D. Turner. 1952. 39 pp., 4 pls., 24 figs. Price 75¢.

20. Geology of the Superior talc area, Death Valley, California, by Lauren A. Wright. 1952. 22 pp., 1 pl., 15 figs. Price 50¢.

21. Geology of Burruel Ridge, northwestern Santa Ana Mountains, California, by James F. Richmond. 1952. 1 pl., 11 figs. Price 50¢.

22. Geology of Las Trampas Ridge, Berkeley Hills, California, by Cornelius K. Ham. 1952. 26 pp., 2 pls., 20 figs. Price 75¢

23. Exploratory wells drilled outside of oil and gas fields in California to December 31, 1950, by Gordon B. Oakeshott, Lewis T. Braun, Charles W. Jennings, and Ruth Wells. 1952. 77 pp., 1 pl., map. Price, map and report, $1.25; map alone, $1.00.

24. Geology of the Lebec quadrangle, California, by John C. Crowell. 1952. 23 pp., 2 pls., 10 figs. Price 75¢.

25. Rocks and structure of the Quartz Spring area, northern Panamint Range, California, by James F. McAllister. 1952. 38 pp., 3 pls., 13 figs. Price 75¢.

26. Geology of the southern Ridge Basin, Los Angeles County, California, by Peter Dehlinger. 1952. 11 pp., 1 pl., 7 figs. Price 50¢.

27. Alkali-aggregate reaction in California concrete aggregates, by Richard Merriam. 1953. 10 pp., 12 figs. Price 35¢.

28. Geology of the Mammoth mine, Shasta County, California, by A. R. Kinkel, Jr. and Wayne E. Hall. 1952. 15 pp., 9 pls., 5 figs. Price 75¢.

29. Geology and ore deposits of the Afterthought mine, Shasta County, California, by John P. Albers. 1953. 18 pp., 6 pls., 9 figs. Price 75¢.

30. Geology of the southern part of the Quail quadrangle, California, by Charles W. Jennings. 1953. 18 pp., 2 pls., 16 figs. Price 75¢.

31. Geology of the Johnston Grade area, San Bernardino County, California, by Robert Barton Guillou. 1953. 18 pp., 1 pl., 1[illegible] figs. Price 75¢.

32. Geological investigations of strontium deposits in southern California, by Cordell Durrell. 1953. 48 pp., 9 pls., 12 figs. Price $1.25.

33. Geology of the Griffith Park area, Los Angeles County, California, by George J. Neuerberg. 1953. 29 pp., 1 pl., 15 figs. Price 50¢.

34. Geology of the Santa Rosa lead mine, Inyo County, California, by Edward M. Mackevett. 1953. 9 pp., 2 pls., 3 figs. Price 50¢.

35. Tungsten deposits of Madera, Fresno, and Tulare Counties, California, by Konrad B. Krauskopf. 1953. 83 pp., 4 pls., 5[illegible] figs. Price $1.25.

36. Geology of the Palen Mountains gypsum deposit, Riverside County, California, by Richard A. Hoppin. 1954. 25 pp., 1 pl., 32 figs., frontis. Price 75¢.

37. Rosamond uranium prospect, Kern County, California, by George W. Walker 1953. 8 pp., 5 figs. Price 25¢.

38. Geology of the Silver Lake talc deposits, San Bernardino County, California, by Lauren A. Wright. 1954. 30 pp., 4 pls., 18 figs. Price $1.00.

39. Barite deposits near Barstow, San Bernardino County, California, by Cordell Durrell. 1954. 8 pp., 4 pls., 1 fig. Price 50¢.

40. Geology and mineral deposits of the Calaveritas quadrangle, Calaveras County, California, by Lorin D. Clark. 1954. 2[illegible] pp., 2 pls., 6 figs. Price $1.75.

41. Geology and mineral deposits of the Angel Camp and Sonora quadrangles, Calaveras and Tuolumne Counties, California, by John H. Eric, Arvid A. Stromquist, and C. Melvin Swinney. 1955. 55 pp., 4 pls., 21 figs. Price $3.75.

42. Geology of mineral deposits in the Ubehebe Peak quadrangle, Inyo County, California, by James F. McAllister. 1955. 6[illegible] pp., 3 pls., 26 figs. Price $2.00.

43. Geology of a portion of the Elsinore fault zone, California, by John F. Mann, Jr. 1955. 22 pp., 2 pls., 5 figs. Price 75¢

STATE OF CALIFORNIA
GOODWIN J. KNIGHT, Governor
DEPARTMENT OF NATURAL RESOURCES
DeWITT NELSON, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO 11
OLAF P. JENKINS, Chief

AN FRANCISCO SPECIAL REPORT 43 OCTOBER 1955

GEOLOGY OF A PORTION OF THE ELSINORE FAULT ZONE CALIFORNIA

By JOHN F. MANN, JR.

Price 75¢

GEOLOGY OF A PORTION OF THE ELSINORE FAULT ZONE, CALIFORNIA

By John F. Mann, Jr.*

OUTLINE OF REPORT

Illustrations

ABSTRACT

The Temecula portion of the Elsinore fault zone includes chiefly the Temecula and Aguanga basins, occupying downfaulted blocks of a Mesozoic basement complex on which late Cenozoic continental sediments have been preserved.

Basement rocks of Paleozoic and Triassic metasediments and Jurassic metavolcanic rocks have been intruded by Cretaceous plutonic rocks. Upon a mature erosional surface of the basement complex were deposited Paleocene (?) arkosic gravels. Small patches of these are preserved under olivine basalt flows of Pliocene (?) age.

Preserved within the basins and in places outside of the basins is the Temecula formation, consisting of more than 600 feet of white to buff arkoses, brown silts, silicified algal marls, and white tuff. Lying above the Temecula formation with marked unconformity is the Pauba formation, including about 250 feet of hardpan—lithified fanglomerates, yellow and red arkoses, brown silts, and diatomite. Slightly younger than the Pauba are the Dripping Springs fanglomerates, typically developed in arroyos in the strongly dissected Pauba fans. Shortly after the Dripping Springs deposition the Nigger Canyon volcanic rocks were erupted. These consist of nepheline basalt flows and dikes, and one or more pyroclastic cones. The youngest deposits are alluvium, in places as much as 120 feet thick.

The structure is complex and consists chiefly of high-angle normal faults, most of which trend northwest. The major movements occurred in the middle Pleistocene and were dominantly vertical. Vertical movements of 3300 feet can be demonstrated, but throws of several thousand feet more are not improbable. Horizontal shifts do not appear to be greater than about 1000 feet. Whereas the major movements involved a general uplift, the Murrieta graben block has been dropped more than 1500 feet below sea level.

During the Pliocene the Temecula region was a broad alluvial surface of low relief with many inselberge. At about the end of the Pliocene or very early in the Pleistocene the Santa Rosa basalts were extruded on this surface. Shortly after these extrusions the first important movements along the Elsinore fault zone occurred. The Temecula arkose was deposited in the early Pleistocene by streams flowing southwest from the vicinity of San Jacinto Mountain.

In the middle Pleistocene another broad alluvial surface was broken by great vertical movements of the Pasadenan orogeny; the Elsinore-Temecula trough was formed. Great exhumation of bedrock surfaces accompanied this uplift, and its progress is marked by several broad erosion surfaces and numerous terraces. The Santa Ana River developed a subsequent tributary down the Elsinore-Temecula trough and captured the San Jacinto and Temecula Rivers. The Pauba formation was deposited. Then a stream eroding headward at Temecula Canyon captured the drainage of the Temecula region. About the same time the basin of Lake Elsinore was downfaulted. Closely following this faulting the Dripping Springs fanglomerates were deposited. In very late Pleistocene time the Nigger Canyon volcanic rocks were erupted during two periods of volcanism separated by several hundred feet of erosion. Minor faulting has continued through the late Pleistocene and Recent.

Principal mineral resources of the area are soils and water. Other mineral commodities which have been produced are sand and gravel, rock, and clay; diatomite is known to occur. Structural control of ground water movements has been important. Springs are common along faults. The Wildomar fault is an important barrier to ground-water movement and has created areas of artesian flow in Pauba and Santa Gertrudis Valleys and also about a mile north of Temecula.

INTRODUCTION

The area mapped for this report is in western Riverside and northern San Diego Counties, in southwestern California (fig. 1). It lies about 25 miles from the coast, 95 miles from Los Angeles, and 70 miles from San Diego. This area, the Temecula region, is irregular in outline, and is included between latitudes 33°-17′N and 33°-25′N, and longitudes 116°-50′W and 117°-15′W. It embraces a portion of the Elsinore fault zone, one of the major features of the Peninsular Ranges physiographic province of Reed (1933).

The Temecula region consists of two basins of relatively low relief surrounded by basement highlands. In the basins the relief rarely amounts to as much as 500 feet. The lowest elevation (less than 1000 feet above sea level) occurs at the east end of Temecula Canyon, through which passes all the drainage of both basins. On Agua Tibia Mountain, the northwestern end of the massive Palomar horst, the elevation is more than 4700 feet. The Temecula basin consists of both alluvial plains and sedimentary mesas. The Aguanga basin, which includes similar alluviated valleys, consists chiefly of large areas of badlands. The basement highlands, though characterized by steep slopes and deep canyons, have many high-standing areas of subdued relief. Numerous stream terraces, cut in both sediments and basement rocks, flank the Temecula River.

The climate of the Temecula region is semi-arid, the average annual rainfall of 13 inches occurring chiefly between November and March. The summers are hot and dry with temperatures commonly 110° F. or more. The winters, however, are normally mild, and freezing temperatures are infrequent. In the basins snow is rare, but on Agua Tibia Mountain snow may remain throughout the winter and early spring. Because of relief, slope

* Assistant Professor of Geology, University of Southern California, Los Angeles.

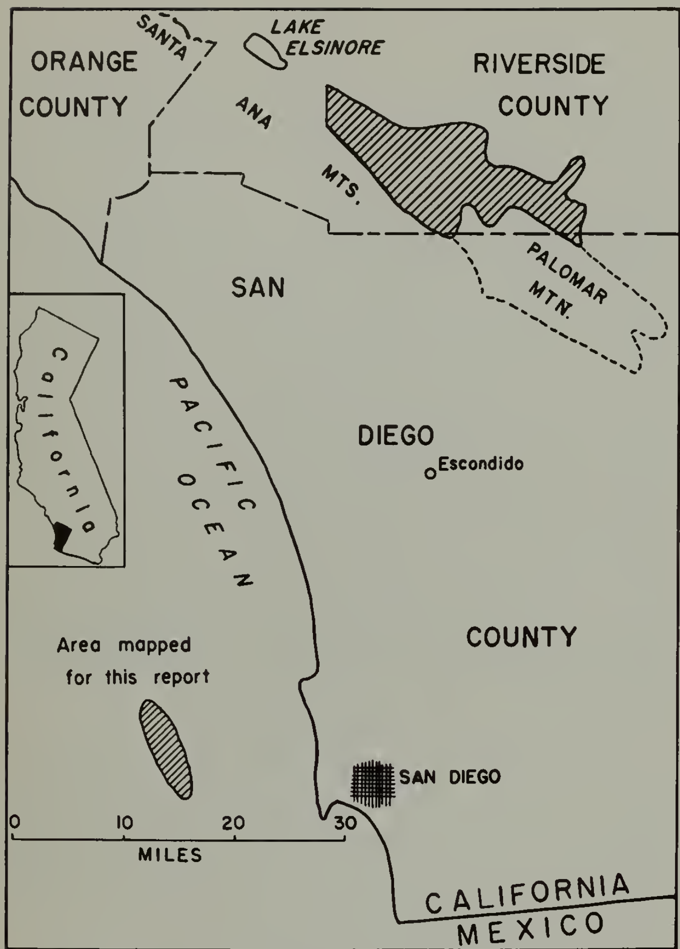

FIGURE 1. Index map showing the location of the Temecula region.

facing, and small areal climatic differences, the vegetation is varied. In the Temecula basin the most abundant plants are chamise, buckwheat, and prickly pear. In the Aguanga basin is a chaparral consisting primarily of chamise, black sage, and mangelar. On the bedrock slopes there is a chaparral of chamise, ceanothus, scrub oak, and manzanita, which is densest on north-facing slopes. Phreatophytic plants occur along fault lines and on alluvium where the water table is close to the surface.

The geologic mapping of the Temecula region (about 150 sq. mi.) was done between November 1948 and June 1949 and involved about 4 months of field work. Aerial photographs were available for the entire area.

The writer expresses his appreciation for numerous suggestions to the following members of the Department of Geology, University of Southern California: Drs. Thomas Clements, K. O. Emery, W. H. Easton, R. H. Merriam, D. A. McNaughton. For the use of drafting and other facilities, the writer is indebted to the Department of Geology and the Allan Hancock Foundation, University of Southern California, and to the Illinois State Geological Survey.

For suggestions as to the ages of the vertebrate fossils collected the writer is indebted to: Childs Frick, the late Chester Stock, R. A. Stirton, T. E. Savage, and Guy E. Hazen. G. Dallas Hanna kindly examined some samples of diatomite, and J. Harlan Johnson some samples of algal limestone. Identifications of the fossil gastropods were made by W. O. Gregg, and by A. B. Leonard. Teng-Chien Yen supplied a statement regarding the age of these gastropods.

PHYSIOGRAPHY

Reed (1933) and Jenkins (1938, 1943) have included the "Peninsular Ranges" as one of the major physiographic provinces of California. Topographically, the Peninsular Ranges may be divided, from west to east, into three belts:

(1) a terraced coastal belt underlain by Cretaceous and Cenozoic sediments, and deeply incised by erosion;
(2) a complex central highland consisting of many fault blocks standing at different elevations. The lowest blocks are sediment-filled valleys. Drainage shows a marked structural control;
(3) a prominent eroded fault scarp which descends to an arid lowland.

The Temecula region is part of the complex central highland.

Few detailed physiographic studies have been undertaken in the Peninsular Ranges province. Ellis and Lee (1919) briefly discussed the physiography of western San Diego County. Sauer (1929) in a highly controversial paper described the physiographic features near Warner's Valley. Miller (1935), in answer to Sauer, reported on his studies in an area near the Mexican border. Other reports are those of Dudley (1936) in the Perris block area, Engel (1949) in the Lake Elsinore quadrangle, and Larsen (1948) in the Corona, Elsinore, and San Luis Rey quadrangles.

Temecula Basin. On a physiographic basis, the Temecula region may be divided into two large basins separated by a discontinuous ridge of basement rocks. The larger western basin is here named the Temecula basin. It has a roughly triangular shape and its boundaries correspond fairly closely with the bounding faults of the structural basin—especially on the southwest and east sides. The northern boundary of the structural basin, however, is obscure. Within the Temecula basin is the downdropped sliver of Murrieta trough, which is reflected at the surface by Murrieta and Temecula Valleys. On the other hand, Pauba Valley is not controlled by structure but by bedrock nodes at Nigger and Temecula Canyons. It is underlain by as much as 120 feet of Recent alluvium. The remainder of the Temecula basin is occupied by the low, rolling topography of the Pauba mesas, which are remnants of alluvial fans formed during late Pleistocene time. Erosion has removed parts of the hardpan-defended surfaces, which typically cap the mesas, and where the Pauba formation was originally thin, erosion has cut through to the underlying Temecula arkose, especially north and east of Murrieta and on the west flank of the Oak Mountain Barrier. Another prominent feature, Temecula Canyon, is the present exit for the drainage of the entire area, and was incised following piracy in late Pleistocene time. Rainbow Gap is chiefly of structural origin but was modified by stream erosion, probably during a short period in late Pleistocene time when part of the drainage of the Temecula basin flowed through it. Pechanga Gap may also represent a former outlet. Farther north, the Wildomar horst is an upfaulted sliver of basement rock flanking the Murrieta trough on the northeast.

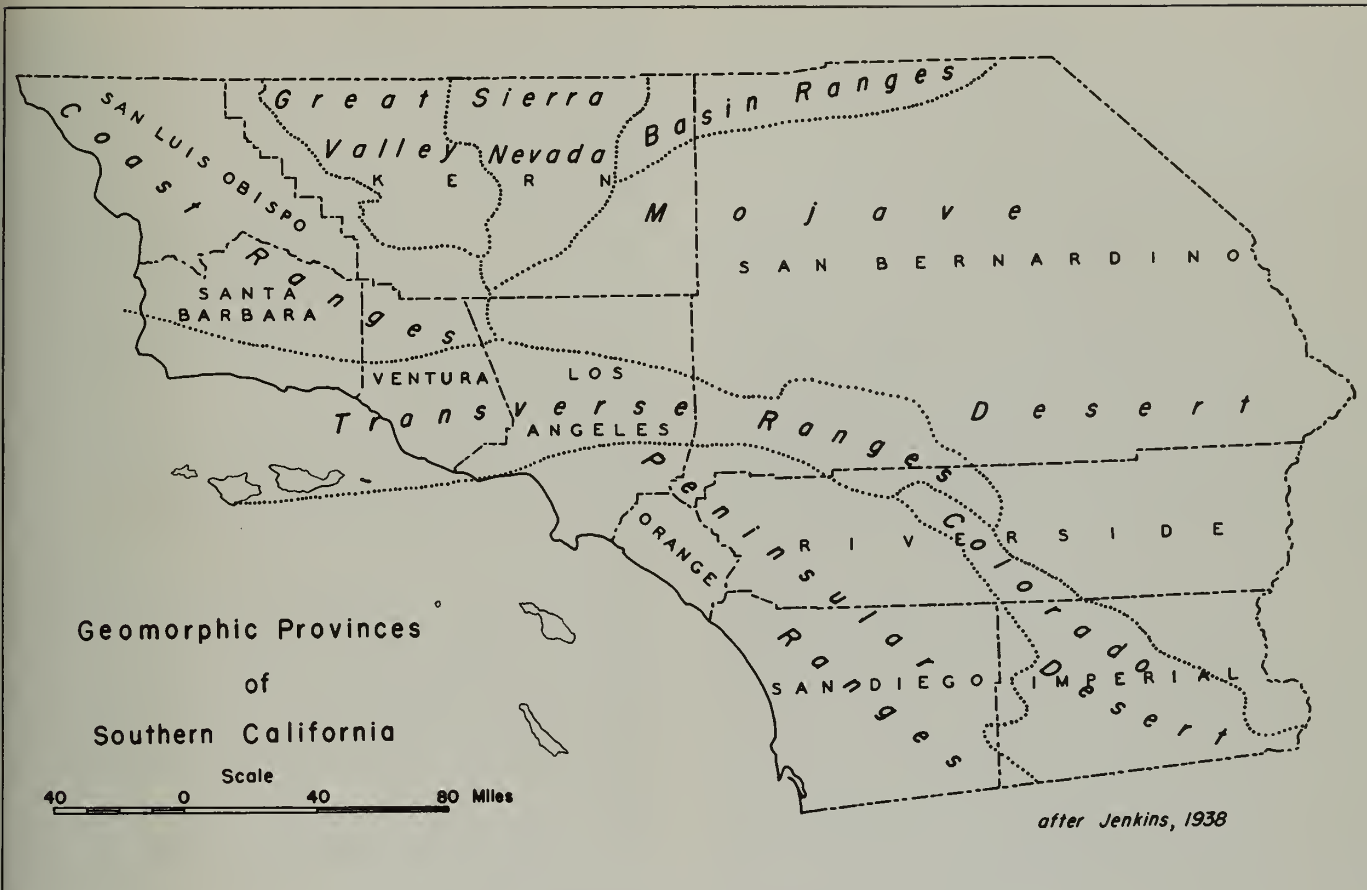

Figure 2. Geomorphic provinces of southern California.

Aguanga Basin. The second large physiographic divi-ion is the Aguanga basin, comprising the eastern part of the Temecula region (fig. 3). This basin consists of several alluviated valleys, bounded in part by fault-line scarps, and separated by bedrock canyons. All of these valleys are part of a single integrated drainage system which flows into the Temecula basin through Nigger Canyon.

Aguanga Valley, in the southeastern part of the basin, s a broad, alluviated flat in the course of Temecula Creek, and represents one of the baselevels suspended between a pair of bedrock canyons. The southwest side of Aguanga Valley is a prominent fault-line scarp with well-developed triangular facets. A parallel fault-line scarp forms the southwest boundary of Radec Valley. The course of Temecula Creek through Nigger Valley s chiefly the result of free-swinging between bedrock nodes, although faults in the Temecula arkose probably have had some influence on this course. Lancaster Valley was eroded along the basement-Temecula arkose contact at the north boundary of the basin.

The Dripping Springs alcove is a large V-shaped re-entrant in the Palomar block. The boundaries as shown on plate 1 are partly fault-line scarps and partly the result of post-faulting deposition. The "badlands" in-clude several areas of Temecula arkose, one of which forms the "backbone" of Aguanga basin. Lewis and Wilson Valleys are mature pre-Temecula arkose valleys, hanging as a result of the post-Temecula faulting and exhumation. Arkose remnants in Crosley Valley suggest a similar origin for the perched mature valleys of the Palomar block.

Oak Mountain Barrier. The Oak Mountain barrier is defined as the bedrock ridge which separates the Temecula and Aguanga basins. It consists of the bed-rock blocks of Oak, Vail, and Dorland Mountains sep-arated by fault zones in Dorland Gap and in Nigger Canyon. The exact limits of the Oak Mountain barrier are difficult to define. Generally speaking, it could be considered a cross-faulted horst with much greater throw on the northwest side than on the southeast side. One series of cross-faults occurs between Oak and Vail Mountains; in this zone of weakness Nigger Canyon has been eroded. Between Vail and Dorland Mountains is another fault zone; the saddle produced here at Dorland Gap appears to be chiefly of tectonic origin. The struc-ture of the Oak Mountain barrier is shown in section C-C′, plate 2. The erosion surfaces topping Oak and Dorland Mountains are about 2,600 feet above sea level, whereas apparently the same surface on Vail Mountain is about 600 feet lower.

Adjoining Physiographic Units. The Perris block is an elevated plain with very low relief, due partly to erosion and partly to sedimentary fill. Above this surface many monadnocks and inselberge rise several hundred feet or more. Southwest of the Elsinore-Temecula trough the Santa Rosa plateau includes the southeastern part of the tilted Santa Ana block. This plateau surface resembles the surface developed on the Perris block and apparently was formed at about the same time. The Palomar block is a huge horst of plutonic and metamorphic rocks uplifted between parallel fault zones of the Elsinore fault zone. Its summit is a surface of very low relief. Similar erosion surfaces, occupying half-height positions on both flanks of the Palomar block, suggest uplift in two stages, or perhaps step faulting.

Drainage. All the drainage from the Temecula and Aguanga basins passes from the basin areas to the ocean through Temecula Canyon. The main stream of the region is the Temecula River (or Temecula Creek), whose name changes in Temecula Canyon to the Santa Margarita River. The chief tributaries in the Temecula basin are Murrieta and Penjango Creeks, which follow the Murrieta trough and join the Temecula River close to the head of Temecula Canyon. In the Aguanga basin, the important tributaries are Lewis, Wilson, and Arroyo Seco Creeks, which rise in areas of high elevation (and therefore high rainfall) and contribute substantially to the annual flow.

Only the largest streams are perennial, but many more flow continuously from November to June. Where the valleys are heavily alluviated, surface flow is uncommon, but underflow in the alluvium is important. Surface flow usually occurs where alluvium is thin or absent, as in bedrock canyons.

Much of the physiographic history of the Temecula region can be determined by a study of the present streams. Low stream gradients characterize the following surfaces: (1) those developed on the soft Pleistocene sediments where baselevels are rigidly controlled by bedrock canyons; and (2) exposed bedrock surfaces of low relief. The streams in (2) usually have a reach of steep gradients as the Temecula or Aguanga basin is approached. Stream piracy is an important process. The obsequent streams of the Santa Ana block have a tremendous slope advantage over the consequent streams and are eroding headward rapidly. The divide is shifting westward, and beheading of some of the consequents seems inevitable. A tributary which joins the San Luis Rey River near Pala has already captured a tributary of Penjango Creek, and further piracy is imminent. In Dorland Gap the tendency is for more drainage to be diverted westward to reach the Temecula River directly rather than pursuing the circuitous route around Vail Mountain through Nigger Canyon. Vail Mountain (pl. 1) illustrates well the relationships of tributaries to a semi-annular trunk stream of medium gradient. The tributaries of Arroyo Seco Creek, on the east side of Vail Mountain, have gentle to moderately steep gradients. Tributaries of Temecula Creek, on the west side of Vail Mountain, though starting at the same elevation as those on the east side, plunge sharply to a baselevel several hundred feet lower.

Topographic Evidences of Faulting. An analysis of the scarps of the Temecula region, using the criteria of Blackwelder (1928) indicates that these scarps are fault-line scarps rather than true fault scarps. The original surface displacements were in Pleistocene sediments and the existing scarps of basement rocks were not exposed until a considerable thickness of those sediments had been removed by erosion. Generally speaking, the scarps in the metamorphic rocks and gabbro are characteristically flat with sharp convex sutures at the top. Those in intermediate plutonic rocks are gentler, with smoothly rounded sutures. In the Temecula region the development of fault-line scarps is controlled chiefly by climate and rock type; the resulting slope would be the same whether the fault were normal or reverse (Hill, 1930, p. 161). After faulting and exhumation, the slope first becomes gentler by rotation about a point above the base of the scarp. In the interfluves, denudation is accomplished by weathering and sheet-wash. After the initial rotation to an inclination of 35 degrees or less, the denudational slope retreats parallel to itself and tends to persist long after its base has left the trace of the fault plane.

FIGURE 3. Physiographic units of the Temecula region.

Springs, both hot and cold, occur in straight-line series along many of the faults. Where there are associated scarps or sharp lithologic breaks, the springs are merely corroboratory evidence of faulting. But where such features are absent, the spring lines are of considerable value in delineating faults. Where there are no springs, fault lines may be shown by phreatophytic vegetation.

Although most of the faulting in the Temecula region occurred at too remote a time for one to expect many sag features, such features may be seen along the Wildomar fault and along the east-trending fault which passes through Murrieta (pl. 1). Subsequent drainage is certainly one of the most typical topographic expressions of faulting, and in the Temecula region, streams flowing for parts of their courses in fault zones are numerous. Alined saddles proved to be one of the most reliable criteria of faulting, especially in the Pleistocene sediments of the Aguanga basin, where offsets were too difficult to detect. Although landslides are not usually confined to areas of faulting, it was found that in the Temecula region, most landslides which do occur are in the areas of the strongest faulting.

Other Physiographic Features. Badland topography is developed on the Temecula arkose throughout the Aguanga basin and in the extreme eastern part of the Temecula basin. Larger areas of badlands occur north of the Temecula region, in the Elsinore and San Jacinto quadrangles (Frick, 1921; Fraser, 1931). The sediments there are in part of the same age and source as the Temecula arkose.

Exhumation of old bedrock surfaces and the removal of unknown thicknesses of Temecula arkose from the areas flanking the Temecula and Aguanga basins is evident. The Temecula arkose now in fault contact with the gabbro of Dorland Mountain contains no gabbroic detritus. Therefore, Dorland Mountain at one time must have been covered completely by the Temecula arkose. The amount of Temecula arkose removed to produce the present topography was at least several hundred feet, possibly 1000 feet or more. Under conditions (as on Dorland Mountain) where the unconsolidated Temecula arkose overlay the basement, stripping may have been complete—leaving no remnant of the sediment which formerly buried this surface. Thus, the absence of Temecula arkose on an uplifted surface of the basement does not preclude its former presence there. The mechanism of exhumation in some places is illustrated very graphically. Near Aguanga, the southern part of Cienaga Rincon is subsequent, because it was eroded along a tonalite-arkose contact. The underlying tonalite block is tilted to the west and the stream in Cienaga Rincon has been uniclinally shifting to the west, following the slope of the basement surface. The exhumation process in operation may be seen along the highway just east of Radec Valley.

Throughout Pleistocene time the Temecula region was characterized by intermittently changing baselevels, and the result is a complex series of stream terraces. The highest flat surfaces, which are outside the boundaries of the basins, are probably parts of the pre-Pleistocene erosion surface. The highest stream terraces are along the north wall of Nigger Canyon, high on the south flank of Oak Mountain, at an elevation of about 2300 feet. The broadest terrace on Oak Mountain is at an elevation of about 2000 feet. On the south wall of Nigger Canyon the terrace remnants are few and small. The presence of many faults and much gouge on the north side of Nigger Canyon probably accounts for the better expression of the terraces there. On the south flank of Oak Mountain, faulting has offset and tilted some of the higher terraces. The terraces of Pauba Valley, which were cut on the Pleistocene sediments, are at a lower physiographic level, and are therefore younger than the terraces in Nigger Canyon.

Remnants of Pleistocene fans are best exposed in the Dripping Springs alcove. The Pauba fanglomerates, which were deposited by north-flowing streams, filled the alcove to a depth of several hundred feet. Diastrophism, accompanied by lowering of the baselevel in Temecula Creek, permitted dissection of these fans near the apices and in the lower reaches, leaving imposing midfan mesas (Eckis, 1928, p. 235). The Dripping Springs fanglomerates were deposited in the arroyos cut in the Pauba fans.

STRATIGRAPHY

Basement Rocks

As this investigation was concerned primarily with the younger sediments of the Temecula region, little detailed work was done on the metamorphic-granitic complex, which is referred to herein frequently as the "basement", or "bedrock". Most of the area of basement rocks in the Temecula region was mapped by Larsen (1948), and the basement geology on plate 1 is in part generalized and modified after his map. His memoir was drawn on freely for the following discussion of the basement rocks.

Rocks believed to be of Paleozoic age have been found in the Peninsular Ranges north and east of the Temecula region (Larsen, 1948, p. 16). The only positive evidence of a Paleozoic age was obtained by Webb (1939, p. 199), who collected a tetracoral in talus at the base of a large marble bed in the upper quarry of the Winchester magnesite mine near Hemet. However, the usual criterion for assigning a Paleozoic age to many of these rock bodies is the degree of regional metamorphism—notably greater in this group than in the fossiliferous Triassic rocks. The Paleozoic rocks consist of mica schists and quartzites; locally, however, there are limestones, such as at the Crestmore and New City quarries near Riverside.

All the rocks of Triassic age in the Santa Ana Mountains and vicinity are included by Larsen (1948, pp. 18-22) in his Bedford Canyon formation. This formation occurs only in the western part of the northern Peninsular Ranges and consists of mildly metamorphosed slates and argillites, with a few beds of quartzite and limestone. This formation is considered Triassic on the basis of sparse, poorly preserved marine fossils from a small area in the northern Santa Ana Mountains.

Larsen (1948, p. 23) includes the Jurassic metamorphics in his Santiago Peak volcanics, equivalent in part to the Black Mountain volcanics of Hanna (1926). These rocks are found in the western half of the northern Peninsular Ranges and are

> predominantly andesites and quartz latites with some rhyolites and probably some basalts. They form a pile of alternating flows, tuffs, and breccias. . . . A little slate and quartzite were found. (Larsen, 1948, pp. 24-25).

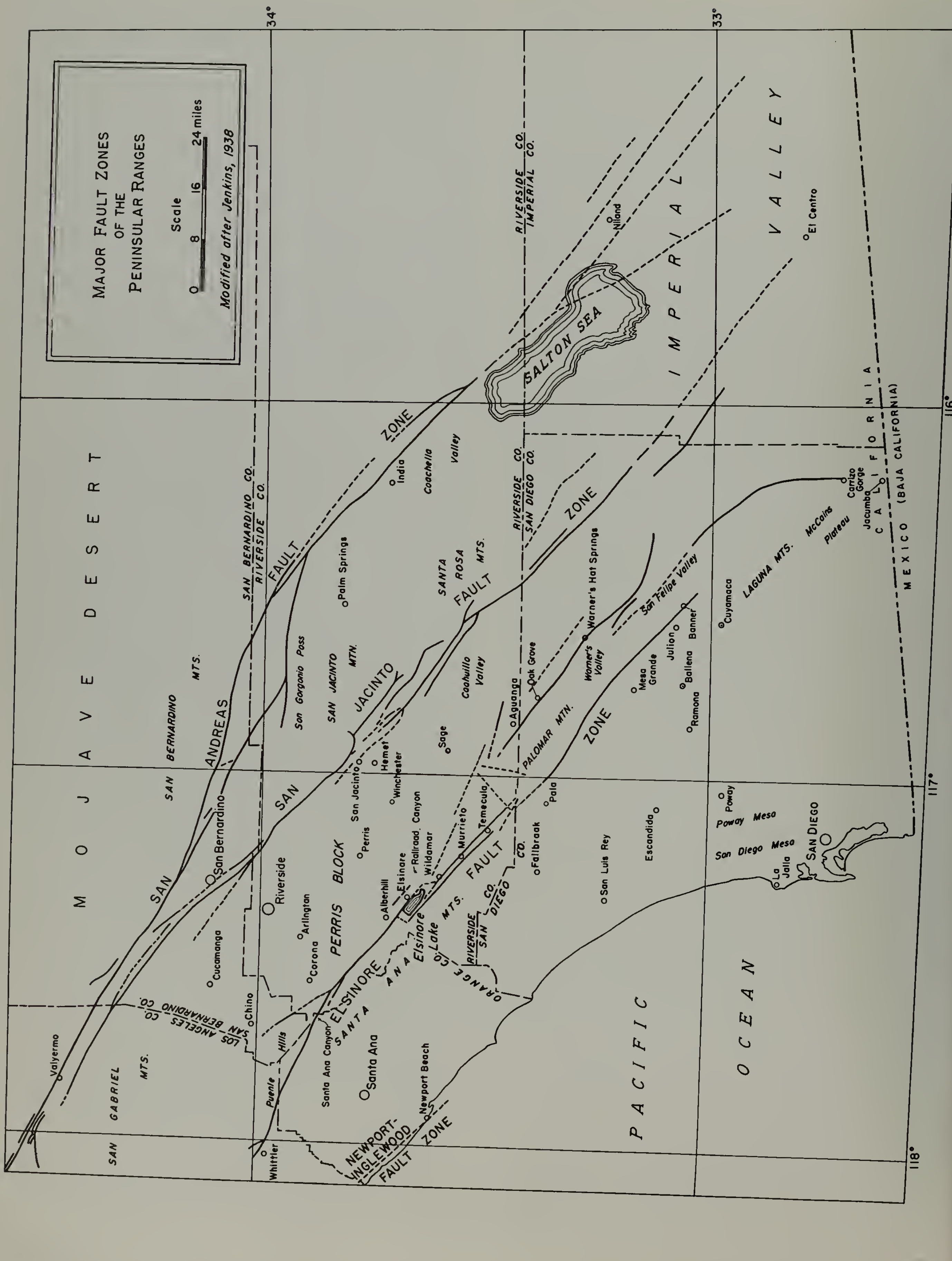

FIGURE 4. Major fault zones of the Peninsular Ranges.

Generalized Geologic Section, Temecula Region.
SEDIMENTARY ROCKS

		Thickness (feet)
Quaternary		
Recent		
Alluvium	Uncemented arkoses and arkosic gravels	0-120+
Terrace gravels	Coarse uncemented gravels of gabbro, metamorphic rocks, tonalite, granodiorite	0- 20+
— — — —	unconformity	— — — —
Pleistocene		
Dripping Springs formation	Coarse fanglomerates of well-weathered gabbro, metamorphic rocks, tonalite, granodiorite. Unconsolidated or cemented by hardpans	0- 30+
— — — —	unconformity	— — — —
Pauba formation	Fanglomerate and hardpan lithologically identical to those in the Dripping Springs. Also yellow arkose, brown iron-cemented arkose, brown silt, diatomite	0-500+
x x x x x	MAJOR UNCONFORMITY	x x x x x
Temecula arkose	White to buff to greenish arkose, buff soil zones, brown silts, silicified algal marls, white tuff	0-600+
— — — —	unconformity	— — — —
Tertiary		
Paleocene (?)		
Martinez (?) formation	Buff, well-cemented arkose and arkosic gravels	0-300+

Generalized Geologic Section, Temecula Region.
IGNEOUS AND METAMORPHIC ROCKS

		Thickness (feet)
Quaternary		
Pleistocene		
Nigger Canyon volcanics	Nepheline basalt flows and dikes. Cinder cone, tuffs, and agglomerate	0-100+
— — — —	unconformity	— — — —
Tertiary		
Pliocene (?)		
Santa Rosa basalt	Olivine basalt flows	0-100+
— — — —	unconformity	— — — —
Cretaceous		
Plutonic rocks	Woodson Mountain granodiorite (Lakeview Mountain tonalite) (Aguanga tonalite), San Marcos gabbro.	
— — — —	unconformity	— — — —
Jurassic		
Santiago Peak volcanic rocks	Flows, tuff, breccia, of andesite, quartz latite, rhyolite, basalt.*	
— — — —	unconformity	— — — —
Triassic		
Bedford Canyon formation	Black to dark-gray argillite and slate; some quartzite and limestone.**	

* "Thousands of feet"—Larsen.
** "20,000 feet"—Larsen.

No fossils have been found in this formation. The Jurassic age is given on the basis of the disconformity between the Bedford Canyon formation and the Santiago Peak volcanics, and by the folding and metamorphism which occurred just prior to the intrusion of the Cretaceous batholith.

The plutonic rocks of the Temecula region constitute part of a huge batholith which extends southeast from Riverside, California, for at least 350 miles, and possibly to the tip of Baja California, 650 miles farther. Although more than 20 distinct rock types were recognized by Larsen in the area he studied in detail, only six of these comprise more than three-fourths of that area. The sequence of intrusions was normal: gabbros, tonalites, granodiorites, granites. True granites do not occur in the Temecula region but the other rock types are well represented. The eastern part of the batholith consists chiefly of tonalites, the western part chiefly of gabbro and granodiorite. The boundaries between these two areas, while not sharp, conform in general to the prevailing northwest structural trends. Fossil evidence for the close dating of the batholithic intrusions is lacking in the Peninsular Ranges of California. In northern Baja California, however, Böse and Wittich (1913) found granitic rocks intruding fossiliferous rocks of early Upper Cretaceous age (Larsen, 1948, p. 136).

Tertiary Sediments

Arkosic sand and gravel, underlying basalt flows, were found by Engel (1949) in the Elsinore Mountains and resting directly upon the basement. On the basis of lithologic similarity between these beds and beds of the Martinez formation near Alberhill, he considers that they are of Paleocene age. Other outcrops of these arkoses and arkosic gravels were found by the writer underlying the Santa Rosa basalt west of Murrieta. Following Engel, they are tentatively considered Paleocene. The Martinez (?) beds are typically better indurated than the Temecula arkose, and where baked by the basalt, are hard and ferruginous. The lithology of some of the cobbles was used by Fairbanks (1893, p. 102) as evidence that they were derived from the east, in this respect resembling similar Eocene gravels farther south in the Peninsular Ranges.

Santa Rosa Basalt

The mesa-forming basalts of the Santa Rosa plateau were first described by Fairbanks (1893, pp. 101-104) who noted also that arkoses and arkosic gravels underlie almost all the basalt flows. The basalts were later reported by Waring (1919, p. 83) and mapped by Engel (1949) and by Larsen (1948). Larsen discovered petrologically similar basalt flows capping Hogback, the high narrow ridge northeast of Murrieta. He suggests (p. 107) that these basalts were formerly more widespread. The present writer found other outcrops of apparently the same basalt on Vail Mountain (pl. 1) and on the Wildomar horst (pl. 1, sec. A-A'). At both these places the basalt rests directly upon basement rocks. The following evidence is offered to support Larsen's suggestion that these basalt flows were once more extensive:

(1) The flow remnants on Hogback, Vail Mountain, and Mesa de Burro are all olivine basalts, in which the olivine phenocrysts are reddish-brown. Larsen (1948, p. 107) says the olivine is more or less altered to iddingsite.
(2) In all three areas the flow remnants are within 300 feet of the same elevation.
(3) In all three areas the flow remnants are nearly horizontal and rest upon a surface which is nearly horizontal. This surface consists partly of Paleocene (?) sediments and partly of basement rocks.

(4) In all three areas the flow remnants end abruptly in steep peripheral cliffs several tens of feet high. Larsen (1948, p. 107) notes that the basalts consist of thin, rather regular flows. The thinness and regularity suggest high fluidity, which would enable the flows to spread over a large surface area. The flows probably thinned gradually and formerly extended well beyond the present eroded edges.

(5) A 16-foot layer of lava was reported in the Barnard No. 2 oil test at a depth of about 2450 feet. The driller's log shows "conglomerate" underlying the lava. The sequence is similar to the Santa Rosa basalt—Martinez (?) as exposed on Mesa de Burro 2.6 miles southwest of Barnard No. 2.

In consideration of the above evidence, the writer believes that the lava in the Barnard No. 2 oil test may with reasonable assurance be correlated with the Santa Rosa basalt flows on Mesa de Burro and on Hogback.

Although the thickness of these basalts may be as much as 100 feet, in the Temecula region it is usually only a few tens of feet. The petrology of the basalts is discussed by Larsen (1948, pp. 107-108).

The age of the Santa Rosa basalts has not yet been determined accurately. Larsen (1948, p. 107) believes their topographic position indicates a late Tertiary age. Engel (1949) mapped them as Pleistocene. North of Murrieta, cobbles of basalt were found by the writer in the Temecula arkose, showing that the basalts were dissected prior to the deposition of part of the Temecula arkose. As the basalts were extruded upon a surface of very low relief, their dissection may have been preceded by faulting, possibly the same faulting which initiated deposition of the Temecula arkose. Based purely on stratigraphic position, the Santa Rosa basalts are of some age between Paleocene and early Pleistocene; however, the relationship of these basalts to the Temecula arkose and to the late Cenozoic surface of low relief suggests late Pliocene as a most likely time for their extrusion.

Temecula Arkose

The name "Temecula arkose" was applied by Hanley (oral communication) to exposures southeast of Temecula, on the Pechanga Indian Reservation. In the area mapped by Hanley, the formation consists almost exclusively of beds of arkose. In the central part of the Aguanga basin, however, where this formation is exposed best, it consists not only of beds of arkose, but also of brown silts, white silicified algal marls, and one or more layers of white rhyolitic tuff.

The Temecula arkose is widely distributed over the area mapped (pl. 1). In much of the rest of the basins, the Temecula arkose is veneered or buried by younger sediments. This formation formerly covered a much larger area, having buried at one time much of the bedrock area surrounding the downdropped blocks. The arkose was preserved on the downdropped blocks but thoroughly stripped from the relatively uplifted blocks. The Pauba formation, developing generally centripetally within the Temecula and Aguanga basins, originally covered almost all of the Temecula arkose. The present exposures of the Temecula arkose are the result of dissection with reference to a low post-Pauba baselevel. The Temecula arkose extends beyond the northwest edge of the mapped area (pl. 1) and is present in the Lake Elsinore quadrangle recently mapped by Engel (1949). It corresponds to his "Older fanglomerate" as exposed just northeast of the Wildomar fault within ¼ mile of the east boundary of the Lake Elsinore quadrangle. The Temecula arkose may be present also in Oak Grove Valley beneath fanglomerates or alluvium, for it seems probable in the light of physiographic evidence, that at one time it extended well southeast and east of Aguanga. Evidence for the former extent of the Temecula arkose southwest of the Willard fault zone can be seen in the southern part of the Pechanga Indian Reservation. Here the Temecula arkose is in fault contact with gabbro, which rises as a ridge several hundred feet high. The faulting is clearly post-Temecula as the arkose contains no evidence whatsoever of gabbro debris. It seems apparent that the Temecula arkose at one time completely covered this gabbro ridge and continued southwest beyond the Elsinore fault zone.

The Temecula arkose was deposited on a surface of fairly low relief, chiefly on basement rocks, but probably to some extent on Paleocene and later Tertiary sediments, and on the Santa Rosa basalts. Everywhere at the base of the Temecula arkose is an unconformity. On the northeast and southwest flanks of the basins in which the Temecula arkose is now preserved, the contacts are usually faults. The northwest and southeast basement contacts, however are commonly depositional. Many of the basement blocks in the Aguanga basin, which were tilted with reference to northeast-southwest axes, are now being exhumed by stripping, which proceeds down the basement-Temecula arkose contact.

Between the Temecula arkose and the basement in the northwestern part of the Murrieta graben, are Tertiary sediments that have been preserved by down-faulting. The Tertiary sediments on the Santa Rosa plateau are preserved under basalt flows. In the graben beneath Murrieta the Temecula arkose may rest directly upon the Santa Rosa basalt or on some unexposed post-basalt sediments. It is possible that beds equivalent to the Miocene and Pliocene formations of the San Jacinto region may be preserved in the Elsinore-Temecula trough completely buried beneath the Pleistocene sediments.

The upper contact of the Temecula arkose is normally an angular unconformity as almost everywhere the formation has been tilted and eroded. Upon this dissected surface, the Pauba fanglomerates were deposited. A relatively rising baselevel permitted the fanglomerate to flood the Temecula arkose and cover all but the highest arkose hills.

The appearance of the arkose beds of the Temecula formation is amazingly uniform within the basins mapped, considering the diversity of rock types which presently flank these basins. The formation consists of pale buff to white arkose beds, buff to brown silts, white to pale gray silicified algal limestones, and one or more beds of white rhyolitic tuff. The mineralogical composition of the sands is somewhat variable, but the following percentages might be considered typical:

Plagioclase	45 percent
(Average composition An_{35})	
Quartz	40 percent
Biotite	10 percent
Orthoclase, microcline hornblende, zircon, sphene	5 percent

The feldspar is andesine—indicating that the Temecula arkose was derived from intermediate plutonic rocks. From the mineralogical composition alone, it is not possible to say what type of intermediate plutonic rock was the source; however, evidence to be presented later indicates that the source terranes were chiefly tonalitic.

A detailed stratigraphic study of the Temecula arkose would be impossible because of poor exposures, a paucity of traceable lithologic units, and highly complex faulting. In the Aguanga basin, where dissection was greatest and induration is best, one or two of the resistant silicified algal marls may be traced for perhaps a mile along the strike. In the Aguanga basin the lower part of the formation consists chiefly of arkoses, the middle part of arkoses and silts, and the upper part of arkoses, silts, and silicified marls. Outcrops of the Temecula arkose in the Temecula basin are so scattered that few lithologic generalizations can be made. Algal limestones which crop out in Dorland Gap and on the Pechanga Indian Reservation are lithologically similar to those exposed in the central part of the Aguanga basin.

A 4-foot bed of rhyolite tuff occurs about half a mile north of the Dripping Springs Ranger Station; a similar bed crops out in the canyons north of Vail Dam. As there is no certain indication of more than one rhyolitic eruption, these exposures are probably part of the same layer; however, faulting and dissection eliminate the possibility of proving this. Possibly the product of the same eruption is the tuff bed which crops out about 3 miles northwest of Murrieta near former U. S. Highway 395. It is referred to by Dietrich (1928, p. 180) as the Wildomar kaolin deposit. Like the tuff near Dripping Springs, it is white and chalky and is associated with white arkose. These tuffs represent either the same eruption, or separate eruptions of the same material during Temecula time.

The Temecula arkose reflects weakly the influence of the backing terranes. The effects can be seen especially in the basal beds and near the edges of the basins. Gravels of any kind are uncommon, but in the large perched outcrop south of Radec Valley (pl. 1) are some pebbles and cobbles of gabbro and metamorphic rocks which might have come from Agua Tibia Mountain. The outcrops in Wilson Valley have the greatest percentages of pebbles and cobbles observed in the Temecula region; the unusual lithology of the rock type precludes a nearby source. Thus, Wilson Valley was apparently a pre-Temecula valley receiving debris from a fairly high range some distance away, probably to the north. The Temecula arkose north of Murrieta contains cobbles of Santa Rosa basalt which were probably derived locally. The dissection of the basalt therefore started before or during Temecula time.

The original thickness of the Temecula arkose is difficult to estimate because the base is poorly exposed, well data are scarce, faulting is complex, and there is no certain way of determining how much of the upper part has been removed by erosion. In the Barnard No. 2 oil test east of Murrieta, basalt was encountered at a depth of about 2450 feet. As the thickness of the Pauba formation here is measurable only in tens of feet, the Temecula arkose may occupy almost the entire section above the lava. As previously suggested, however, part of this section may be late Tertiary sediments. Nevertheless, considering the extensive exhumation which has taken place in the Temecula region, it is not unreasonable to suggest that the original thickness of the Temecula arkose was 2000 feet or more.

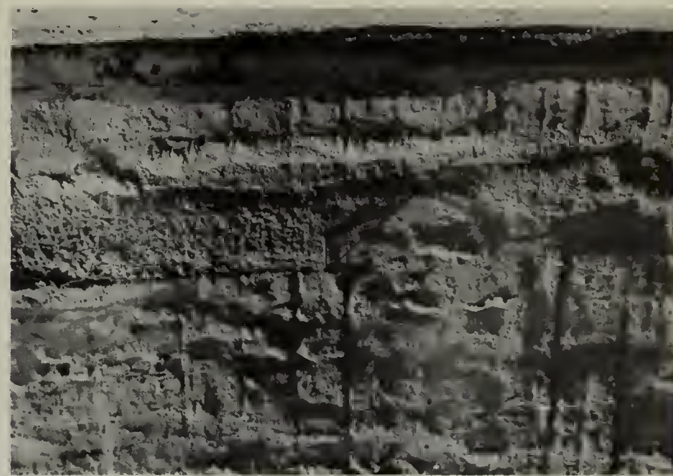

FIGURE 5. Photo of soil zone in Temecula arkose.

Several soil zones were found at different stratigraphic positions in the Temecula arkose. These are layers 3-4 feet thick in which the feldspars of the massive arkose beds have been decomposed to clay minerals. The top contact of the soil is sharp, due mostly to the color break between the buff or brown soil and the pale arkose which overlies it. In some places part or all of the soil zone has been removed and there is a scour-and-fill relationship. The base of the soil zone is much less distinct; nevertheless, the change from soil to arkose takes place in only a few inches. These old soils closely resemble those now developing on arkosic substrata. The colloidal surface of the old soil tends to act as a slip plane during diastrophism, and at several roadcuts in Dorland Gap the eluviated layer has been converted to gouge.

Cross-bedding can best be seen in the roadcuts of the Aguanga basin. Although some of it is torrential—the type that might be expected in a river deposit—much of it is of the festoon type ordinarily associated with wind deposition.

In a number of places in the pale beds of arkose, incipient iron-manganese concretions are found. The oxides occur, not as solid deposits, but as grain coatings, forming discontinuous stringers parallel to the bedding or spheroids disposed in zones parallel to the bedding planes. The spheroids are usually not larger than a few inches in diameter. Although some of the concretions may be spheroids in which all of the grains are coated with the black oxide, many show just a shell of coated grains. A few of the concretions consist of several concentric shells. These concretions are called ''incipient'' because cementation is poor; in fact, there is little more cohesion among the coated grains than among the uncoated grains.

One of the most characteristic and distinctive features of the Temecula arkose is the presence of calcareous concretions. Some appear to be associated with faults; however, both the concretions and the faults are so widespread that the correlation is difficult to substantiate. The concretions occur throughout the area mapped and are amazingly similar everywhere. In places they weather out in such numbers that they literally pave the bottoms of the gulleys. They range in diameter from 1 inch to 12 inches and are spheroidal in shape, although some of the spheroids are markedly flattened. The spheroids tend to grow together, assuming potato-like shapes. Where many small concretions have grown together, the appearance is botryoidal. In certain localities they have grown together so completely that a bed of carbonate-cemented arkose results; the original spheroidal shapes are then no longer evident. Such a bed usually breaks into blocks as if reflecting a subsequently induced joint pattern. Certain of these cemented masses appear to be disposed vertically, suggesting fault-controlled cementation rather than a bed. However, conclusive evidence of this origin was not found. These calcareous concretions are obviously of epigenetic origin; many have bedding-plane equators and parallels, and show evidence of progressive calcification. Although they do not ordinarily have a nucleus, a few were found which enclosed silicified bone fragments.

In the highest arkose cliff on the south side of the Temecula River, about a mile west of the bridge of highway 71, there are large masses of a fine-grained sediment completely enclosed by arkose. These irregular brownish masses are as much as 5 feet across and do not always have their long axes parallel to the bedding. They are disposed in a zone a few feet above and parallel to a prominent scour-and-fill surface. In spite of the softness of the material which comprises them, they are not rounded but have many sharp angles. It is believed that these boulders represent masses of an old soil zone which slumped into a gulley in which a younger layer of arkose was being deposited. In the soft arkose they were able to assume a somewhat unstable angle. The currents carrying more arkosic debris were not strong enough to adjust the boulder to the maximum stability, i.e., with the two longest axes parallel to the bedding. These boulders could not have been transported far; a current capable of carrying a mass of boulder dimensions would quickly round it, break it into smaller pieces, or destroy it completely. The process postulated can be seen at work in existing gulleys. Furthermore, the lithology of the boulders is the same as in the older soil zones. Smaller masses of similar material occur in scattered layers throughout the Temecula arkose. The smaller masses are somewhat rounded and appear to have been transported an appreciable distance.

The formation of the arkosic debris or "gruss" may be clearly observed in the Temecula region today. As gruss is produced, spheroidal boulders are formed. Larsen (1948, p. 115) strongly favors the chemical origin of these boulders in the Peninsular Ranges. Larsen (1948, pp. 118-119) has discussed the chemical changes which occur during the production of gruss from the Woodson Mountain granodiorite and from the Green Valley tonalite. His discussion is of special interest because the Temecula arkose was derived from rocks of similar composition. Larsen believes that a slight hydration of biotite and other minerals is probably sufficient to cause the necessary change in volume and to produce the boulders. In the early stages of weathering the biotite oxidizes, takes on water, and alters to vermiculite. Orthoclase remains fresh but plagioclase alters to a clay mineral. The chemical changes which produced the tonalitic gruss that was deposited as the Temecula arkose were probably much the same.

A very conspicuous feature of the Temecula arkose is its rather uniform mineralogical composition, which is incompatible with the terranes that presently enclose th basins in which it has been preserved. The followin points regarding the origin of the arkose seem fairl well established:

(1) the arkosic material was derived principally from outsid the Temecula region;
(2) the source rocks were chiefly intermediate plutonic rocks
(3) the deposition occurred in broad valleys rather than i narrow channels.

With regard to (1) the following quotation from Larse (1948, pp. 67-68) is significant:

> Thus, granodiorites rich in orthoclase, and gabbros are i large part confined to the western half of the batholith. Thei eastern limit extends roughly from near Julian, northwest to a few miles east of the southeastern corner of the Elsinore quad rangle, thence northward to Diamond Valley and northwest t Riverside. To the east of this line the rocks of the batholith ar almost entirely tonalites grading to granodiorites with less tha 10 per cent of orthoclase and microcline.

On a petrological basis, the areas east and northeast o the Temecula region appear to be the most favorabl source areas. Furthermore, isolated patches of arkos between the Elsinore and San Jacinto fault zones, i Wilson Valley (pl. 1) and in Weber Valley, northeas of Sage suggest that the Temecula arkose and the Bautista beds were once co-extensive. The lithology of th cobbles in the outcrop of Temecula arkose in Wilson Valley is such that these cobbles could only have come from the northeast.

It appears likely that Palomar Mountain was a barrier during the deposition of the Temecula arkose because in Sawyer Valley the arkose contains cobbles of gabbro and metamorphic rocks which apparently were derived from the higher portions of the Palomar block. If the Palomar block had been a barrier during Temecula time, waters flowing southwest in Wilson Valley must have been diverted northwest, at least beyond Agua Tibia Mountain, before resuming their southwest course. It was previously shown that deposition of the Temecula arkose extended well southwest of the Elsinore fault zone south of Temecula.

Considerable evidence supports a lower Pleistocene age for the Temecula arkose and correlation with the Bautista beds of Frick (1921). The present writer examined the type locality of the Bautista beds east of Hemet, and noted striking similarities to the Temecula arkose with regard to a dearth of gravels, presence of caliche-like stringers and calcareous concretions, color, soil zones, bedding, and manner of erosion. The "lake beds" which occur in the middle and upper portions of the Bautista beds (Frick, 1921, p. 291) represent the same type of deposition as the silicified algal marls in the upper part of the Temecula arkose in the central part of the Aguanga basin. Both the Bautista and Temecula formations rest upon a basement surface of low relief, both were strongly faulted by the mid-Pleistocene deformation, and both are overlain by coarse fanglomerates which have been faulted but little. Isolated patches of similar arkose occur between the two areas, in Wilson and Weber Valleys.

Although many bone fragments of vertebrates were found by the writer, none could be identified specifically. It is the opinion of Drs. R. A. Stirton and T. E. Savage of the University of California that the fauna is post-Blancan (post-late Pliocene). They identified the following forms (oral communication, 1949):

Equus
Bison?
Antilocapra or Tetrameryx
proboscidean
large cat
coyote-size carnivore
Odocoileus?

few small gastropods were collected at the Wildomar aolin deposit. Wendell O. Gregg, M.D., of Los Angeles, dentified the following species:

Gyraulus similaris (Baker)
Physella virgata (Gould)
Succinea avara Say

r. A. B. Leonard, Department of Zoology, University f Kansas (letter, 1949) says "the beds are *probably* no lder than mid-Pleistocene." Dr. Teng-Chien Yen of the . S. National Museum, reports (letter, 1950):

> . . . the fossil-bearing bed may well be considered to be of Pleistocene age. There is no reliable ground to assume, on the basis of these identified species of mollusks, any subdivision of age within the Pleistocene time to which this bed may be assigned.

ietrich (1928, p. 180) inferred an Eocene age for the Vildomar kaolin deposit and Larsen (1948, p. 107) asigned this ash deposit to the Miocene.

Diatomaceous shale found on the Pechanga Indian eservation, probably in the Temecula arkose, contains he following genera of diatoms (G. Dallas Hanna, leter, 1949):

Cocconeis
Melosira
Cymbella
Epithemia
Pinnularia

Vith regard to the age of this deposit, Hanna states:

> Obviously the deposits are very young. Certainly they are not older than Pliocene and it is my opinion that they are late Pleistocene or even post-Pleistocene. The material is very similar to that which is found in Meteor Crater, Arizona. Dr. Blackwelder thought this was interglacial.

Lithologic evidence points to a relatively dry climate uring Temecula time—probably not much different rom the present. The upward transition in the Temecula ormation from arkosic beds to silts to marls suggests ncreasing rainfall, such as might occur in the change rom an interglacial to a glacial climate. A similar cliatic change to increasing wetness is also shown by the equence of lithologies in the Bautista beds (Frick, 1921, . 291) and in the La Habra conglomerate (Dudley, 943, p. 350).

Pauba Formation

The Pauba formation is here named from the Pauba ancho, east of Temecula, where it is thickest. The Pauba ormation consists of a series of coarse fanglomerates and nterbedded sands and silts which were deposited with eference to a baselevel well above that of the present. his formation formerly flooded or veneered most of the emecula and Aguanga basins, but now remains in only part of the original area. The fanglomerates are best xposed in the Dripping Springs alcove, whereas the ands and silts are best developed in the Temecula basin vhere they cap the relatively undissected tablelands. eds of much the same character were mapped by Engel 1949) as *Qf*, fanglomerate and terrace deposits. The auba fanglomerates probably have correlatives farther orthwest in the Elsinore-Temecula trough to Corona, s all were deposited not long after a strong uplift of the anta Ana Mountains. Although the Pauba formation was studied in detail along only a small part of the periphery of the Palomar block, it seems probable, considering the magnitude of the uplift which initiated this deposition, that there are similar contemporaneous sediments surrounding the entire block. The tablelands of Warner's Valley were examined by the writer and found to consist of sediments lithologically similar to the Pauba formation as developed on the mesas of the Pauba Rancho. The Pala conglomerate, described by Ellis and Lee (1919, p. 70), appears to be the result of the same uplift. Older alluvial deposits occur in Coahuilla Valley and near Sage. These were deposited during either Pauba or Dripping Springs time as indicated by their physiographic position and degree of induration.

The Pauba formation unconformably overlies the Temecula arkose. Before Pauba deposition the Temecula arkose was faulted and tilted but not extensively folded. The Temecula arkose was then dissected to a relief of several hundred feet, and upon this irregular surface the Pauba fans encroached. At first the developing fans tended to restrict themselves to valleys in the Temecula arkose, but after valleys became filled with debris, the deposits were spread over smooth fan surfaces. The moderate diastrophic activity which followed Pauba deposition was contemporaneous with or succeeded by a sharp lowering of baselevel of several hundred feet. The Dripping Springs fanglomerates (described hereafter) which were deposited at this lower baselevel, are found in valleys which have been eroded in the Pauba formation. Although no Dripping Springs deposits are shown in the Temecula basin away from the flanks of Agua Tibia Mountain, the deposits mapped as Pauba in the Temecula basin may well include beds of Dripping Springs age.

The Pauba fanglomerate reflects accurately the rocks of the backing terranes and the lithology, therefore, is highly variable. Nevertheless, there are many common characteristics which enable them to be distinguished from the Temecula arkose. The following features are typical of both the Pauba and Dripping Springs formations:

(1) much oxidized iron which manifests itself as red or brown soils, as limonite streaks in beds of arkose, or as iron oxide films around grains of quartz and feldspar;
(2) hardpans, ranging in color from pale buff to reddish. These may be near the top of the formation or distributed through as much as 100 feet of section.
(3) abundant cobble and boulder beds.

In contrast, the following features are distinctive of the Temecula arkose:

(1) prevailing pale color—only in the silty beds are buffs and browns common;
(2) calcareous concretions and lime-cemented arkosic beds;
(3) beds of silicified algal marls;
(4) chalky white exposures in plowed fields due to layers of caliche and marls.

The soil developed on the Temecula arkose is usually soft, porous, and buff. The fanglomerate soils are pink to red, with much gruss, and commonly with cobbles and boulders. In some places it was not possible to differentiate the Temecula arkose from the medium-grained phases of the Pauba formation.

In the Temecula basin the Pauba formation consists of a series of coalescing fans, the main fan formerly having its apex at the mouth of Nigger Canyon at a point several hundred feet above the present canyon bottom. Among the centripetally developing fans was a system of through drainage which left medium-grained alluvial deposits at lower gradients. Thus basalt-rich fanglomerates flanking the Santa Ana Mountains are interbedded with arkoses from a lateral source.

The cobbles and boulders of the Pauba formation are characteristically well-weathered, and much of the weathering appears to have taken place after deposition. The resistance to chemical weathering of the constituent minerals usually determines the degree of decomposition; however, this is not always apparent. For example, some gabbro boulders appear somewhat fresh, whereas nearby granodiorite boulders disintegrate to gruss with a single blow of the hammer. Roadcuts exposing bouldery hardpans show that the boulders are of about the same hardness as the matrix, as the excavation face is a fairly smooth surface.

As the Pauba formation is to a large extent a series of fans, the thickness is variable. Had these fans been deposited on a flat surface, the thickness might be predicted accurately with a small amount of well data. As previously noted, however, the Pauba formation was deposited on an irregular topography eroded in the Temecula arkose. Close to the mouth of Nigger Canyon, near the apex of the main Pauba fan, the surface relief in the Pauba formation is 250 feet. Scant well data suggest that the maximum thickness is on the order of 500 feet.

By far the most characteristic sedimentary features of the Pauba formation are the hardpans. North of Aguanga, where the Pauba formation has an exclusively tonalitic source, the hardpans offer the only certain way of differentiating this formation from the Temecula arkose. In most places the only conspicuous hardpan is at the surface, i.e., at the top of the exposed Pauba. However, on the Pauba Rancho, underlying the mesas on both sides of the river, the hardpans are numerous and are distributed through more than 100 feet of section. These hardpans closely resemble those in the San Joaquin Valley described by Nikiforoff and Alexander (1942). The hardpans range in thickness from a few inches to several feet, and develop at a depth ranging from a few inches to several feet below the surface of the soil. The uppermost part is hardest and the upper boundary is abrupt; the lower boundary is indistinct. The color is bright red to buff, and is intense near the top, fading with depth. The hardpans have a weakly developed, coarse, platy structure, most conspicuous near the top. According to Nikiforoff and Alexander the formation of these hardpans may be due to an annual deposit of films of cementing material, including free silica and iron oxides, which saturate a thin layer of soil and paste it to the surface of the previously indurated layer. This process takes place during the rainy winter months and hardening occurs during the dry summer and early fall months. The induration of the fresh film is apparently accomplished by the oxidation and dehydration of the iron oxides, which produce the reddish color. The hardpans which underlie the surface of Rainbow Valley (about 6 miles south of Temecula) are similar to those of the Pauba formation. Before fruit trees can be planted in parts of this valley, the hardpan must be blasted so the roots may have a chance to develop.

The soil zones of the Pauba formation, excluding the hardpans, are usually harder and redder than those of the Temecula arkose. Another feature is "outcrop plaster", a term here employed to designate the hard clayey layer that covers many roadcuts, gullies, and other exposures of the Temecula arkose and the Pauba formation. This feature is especially well developed in the roadcuts on the oiled road leading north from Aguanga. It is much better developed on outcrops of the Pauba formation than on those of the Temecula arkose. The following conditions seem to favor the development of outcrop plaster:

(1) a source above the outcrop of some colloidal material, such as a soil;
(2) a fairly steep outcrop. Although in the Temecula region outcrop plaster is found on surfaces undergoing a vertical fluting type of erosion, it has been seen elsewhere by the writer where this type of erosion was not evident;
(3) fairly heavy rains and intermittent dry spells. The rains must be heavy enough to cause flowage of the colloidal material. Periodic dryness allows desiccation and hardening of the plaster;
(4) a porous bed. This is believed necessary to make a greater surface area available to the viscous suspension, and effect greater cohesion. Fine-grained sediments, with some clay minerals, may allow a zone of weakness due to wetting to form just inside the plaster layer and allow the plaster to scale off.

The intermittent flowing of the mud produces a layered structure in the plaster. The thickness of the plaster is usually about a quarter to half an inch thick, although it may be much thicker.

A layer of caliche about 4 feet thick occurs on the south slope of Oak Mountain at a very high level. Although physiographic level indicates a Pauba age, caliche was not found at any other place in the Temecula region in the Pauba formation.

The best evidence of the age of the Pauba formation comes from the contained vertebrate fossils. In the large washout on the northwest bank of Santa Gertrudis Creek, about a mile northeast of U. S. Highway 395 (pl. 1), several horse teeth and a tapir tooth were found. The horse teeth are modern in every respect and are much less indurated than the horse teeth found in the Temecula arkose. A Pleistocene age is indicated by the vertebrates. Undisturbed Pauba beds in places overlap faults of the major mid-Pleistocene disturbance, which strongly faulted the Temecula arkose, previously assigned to the lower Pleistocene. The complex series of events which followed the Pauba deposition tend to place the formation early in the late Pleistocene rather than late.

The climate of Pauba time as suggested by the vertebrates was not greatly different from that of Temecula time, even to the extent of increasing wetness, as shown by the diatomaceous deposits near the top of the Pauba. However, the extreme oxidizing conditions, especially late in Pauba time find no counterpart during Temecula time.

Dripping Springs Formation

The Dripping Springs formation is here defined as the fanglomerates in the Temecula region deposited with reference to a baselevel not greatly above the present baselevel, as opposed to the Pauba fanglomerates which were deposited at a much higher baselevel. The Dripping Springs formation is best seen in the Dripping Springs alcove, especially in roadcuts along Highway 71. These ıglomerates occupy rather small areas southeast of the changa fault zone, which separates the Temecula basin om the Palomar horst and the Oak Mountain barrier. w-level fanglomerates are associated with the basin-unding faults both north and south of Aguanga. Sevıl patches occur in Nigger Valley, and in Arroyo Seco, iich connects the Dripping Springs alcove with Nigger nyon. Gravels of this approximate level were excated from both abutments of the recently completed il Dam at the head of Nigger Canyon. A filled channel s discovered while excavating for the spillway, and was necessary to put in a small concrete arch to span s channel. At the mouth of Nigger Canyon, gravels re found beneath the volcanics at the end of the agomerate-capped ridge about two hundred feet above e present stream bed. Other low level fanglomerates re mapped on the north side of Penjango Creek.

In the Dripping Springs alcove, where the Pauba ıglomerates are thick, younger fanglomerates were posited in arroyos cut in the Pauba fans. Elsewhere e Pauba formation was in places originally thin, d the post-Pauba dissection was thorough enough to nove much or all of the older fanglomerate before the unger fanglomerate was deposited. The Dripping orings fan surfaces are always appreciably higher than e Recent alluvium, but exact differences in elevation tween younger and older fanglomerates and the alluım are difficult to state.

The Dripping Springs fanglomerate can not be disıguished on a lithologic basis from the Pauba fangloerates. Although minor diastrophism occurred between e depositions of the two fanglomerates, the initiation Dripping Springs deposition was not necessarily the sult of that diastrophism. Instead, a lowering of basevel in the Temecula basin, possibly related to piracy at mecula Canyon was the cause of the dissection of the uba fans and renewed deposition at lower levels. Thus ere was no appreciable change of source area between uba and Dripping Springs times.

The Dripping Springs fanglomerate is strictly a superial deposit and the thickness probably nowhere exceeds few tens of feet. Although mild faulting and erosion curred between Pauba and Dripping Springs time, the gree of weathering of the contained boulders suggests at the formations are close to the same age.

Nigger Canyon Volcanics

The name Nigger Canyon volcanics is applied to a ries of tuffs, agglomerates, dikes and flows, which are und near the mouth of Nigger Canyon. Basalt of about e same age and composition crops out along Murrieta eek about 2 miles northwest of Murrieta (Larsen, 48, p. 112). The volcanic rocks near the mouth of igger Canyon were extruded from a series of fractures ending N. 45° E. On the south side of the canyon outh is a cinder cone of buff tuffs and brick-red agglomates. Many bombs of scoriaceous basalt, up to several et across, are contained in the agglomerates, which ırsen (1948, p. 112) believes are partly flow or welded eccias. The cinder cone was formed on the present ope of Vail Mountain, and rests directly on metaorphic rocks. The pyroclastics were derived from a ssure well up the flank of the mountain, and the cone is ymmetric, as a parasitic cone would be. The agglomerates of the cone plunge steeply beneath the Recent alluvium, and the cone is covered with alluvium for several tens of feet above the base. The cone was formed and partly dissected prior to the last heavy alluviation. Several basalt flows are found less than a mile southwest of the cone and may have come out the same fissure as the pyroclastics. The toes of these flows have been eroded by lateral sweeping of the Temecula River while at the low pre-alluviation baselevel.

On the same structural trend as the flows and the cinder cone is a northeast-trending ridge capped by a basalt flow, and agglomerates apparently identical with those of the cinder cone. The keel of the ridge is a fault which separates Temecula arkose on the northwest from metamorphics on the southeast. The fault is about coincident with the northwest scarp in the agglomerates. Just east of this ridge, on the north wall of the canyon, and several hundred feet above the canyon floor, is a veneer of red agglomerate which appears to have been welded to the wall of the canyon. The agglomerates on the ridge overlie a small patch of water-worn gravels which can be seen only at the southwest tip of the ridge, more than 200 feet above the canyon floor.

The petrology of these volcanics has been studied by Larsen (1948, pp. 111-113). He classifies the flows near the mouth of Nigger Canyon as nepheline basalts, and notes their petrologic similarity to the basalt dike northwest of Murrieta. The latter contains sparse but large (up to 3 cm) phenocrysts of glassy oligoclase in a fairly dense groundmass.

The Nigger Canyon volcanics were extruded at two different times. They are of upper Pleistocene or sub-Recent age and are appreciably younger than the Pauba formation. The first extrusion occurred at about the end of Dripping Springs time when the Temecula River was flowing at a level at least 200 feet higher than at present, approximately at the spillway level of Vail Dam. The first agglomerates may have choked the mouth of the canyon and may have dammed the river long enough to produce the sharp turn that the river makes at this point. The second eruption occurred after the Temecula River had become entrenched more than 200 feet below its level at the time of the first eruption. The cinder cone was formed just southwest of the canyon mouth as were also the flows farther southwest. Faulting has been considered as a means of explaining the difference in level of the volcanics on opposite sides of the river; although there is evidence of some faulting in post-Nigger Canyon time, displacements of several hundred feet are difficult to substantiate.

The Nigger Canyon volcanics are significant in that they indicate deep-seated readjustments in the Temecula region. They are located along the major transverse physiographic and structural break of the region—separating the Temecula basin and the Oak Mountain barrier. Although a few earthquake epicenters have been plotted in this vicinity (Wood, 1947), the concentration is not as great as might be expected.

Terrace Gravels and Recent Alluvium

Terrace gravels occur at very low levels, especially just above the head of Nigger Canyon. Their low level and lack of induration suggest a very late Pleistocene or Recent age.

Excavation for the foundation of Vail Dam revealed 20 feet of alluvium overlying the metamorphic bedrock. The thickness of this alluvium increases downstream and is as much as 120 feet in Pauba Valley. Recent alluviation has been reported from numerous places in southern California, inland as well as along the coast. Alluvial backfilling of late Pleistocene valleys was found by Poland and Piper (1945) in the Los Angeles plain area. Similar alluviation has occurred along the southern California coast in the valleys of Santa Margarita, San Luis Rey, San Dieguito, and San Diego Rivers. Moore (1930) noted 100 feet of alluvium in Santiago Creek, east of Santa Ana.

STRUCTURE

The Temecula region, a portion of the Elsinore fault zone, includes the Temecula and Aguanga structural basins which are downfaulted blocks of a Mesozoic basement complex on which late Cenozoic continental sediments have been preserved. Between these two basins is a horst, expressed topographically as the Oak Mountain barrier.

Within the Temecula region the Elsinore fault zone widens from about 3 miles at the west boundary to more than 10 miles near Aguanga. In the western part of this region the Elsinore fault zone is marked chiefly by a structurally depressed area—the Temecula basin. Southeast of the Temecula basin, however, the Elsinore fault zone is for the most part structurally positive, consisting of the Palomar horst flanked on the northeast by a relatively narrow graben. The Aguanga basin occupies the northwest end of this graben.

In the Temecula region the individual faults are almost invariably of the high-angle normal type. Movements have been chiefly vertical and throws of a mile or more are indicated. Horizontal movements are shown by a few faults, but horizontal displacements have probably not exceeded a few thousand feet. Many faults involve rotational movements. Although faulting of the Cenozoic sediments has been extensive, folding is uncommon. However, near faults of strong throw, the sediments in places show drag.

The regional trend of the Elsinore fault zone is approximately N.45°W., and the strike of 60 percent of the faults mapped in the Temecula region is between N.40° W. and N.80°W.

The present Elsinore fault zone was apparently originally delineated at about the end of the Pliocene. However, the major vertical movements did not occur until the middle Pleistocene. Smaller movements have continued from the middle Pleistocene to the present.

Previous structural studies in the Elsinore fault zone, all northwest of the Temecula region, are those of English (1926), Larsen (1948), and Engel (1949).

Major Structural Features of the Temecula Region

The Temecula Basin. The Temecula basin, which is a structural as well as topographic basin, is bounded on the southwest by the eroded scarp of the Willard fault zone and on the southeast by the irregular scarps of the Pechanga fault zone. The hypotenuse of this roughly right-triangular basin is poorly defined because the topographic evidence of faulting is obscure.

The Willard fault zone has been named by Engel (1949) to signify the bedrock displacements which mark the northeastern boundary of the Santa Ana Mountai from Lake Elsinore southeast. Although Engel shows th as a single fault, its extension into the Temecula regic appears as a *zone* of faulting (pl. 1). The Willard fau zone trends about N.45°W. and is one of the most pe sistent strands of the Elsinore system.

The Wildomar fault, which was named by Eng (1949), extends southeast into the Temecula regic (pl. 1) beyond the Temecula River. Gouge zones ne the western boundary of the mapped area are nearl vertical.

The term "Wildomar horst" is applied here to tl upthrust block of bedrock and Temecula arkose, whic is best seen just northeast of former U. S. Highway 3 halfway between Wildomar and Murrieta. Its southwe boundary is the Wildomar fault, and a nearly paralle less extensive fault bounds it on the northeast (sec. A-A pl. 2). The horst is not expressed topographically sout east of Murrieta.

The name "Temecula-Elsinore trough" has alread been used by Larsen (1948, p. 3) for the entire line valley extending from near Corona southeast beyon Temecula. For clarity it is suggested that the grabe northwest of Lake Elsinore be referred to as the "Teme cal graben". For the narrow downdropped block exten ing from near Rome Hill (Lake Elsinore quadrangl southeast to the Pechanga Indian Reservation (pl. 1 the name "Murrieta graben" is proposed.

The Murrieta graben is a structural depression abo 18 miles long, averaging a mile in width, and is include between the Wildomar fault and the Willard fault zon The basement surface in the graben dips southeast, an the thickness of the sedimentary fill increases in th direction.

The name "Pechanga fault zone" is proposed he for the complex fault zone of great throw which bound the Temecula basin on the southeast.

Aguanga Basin. The Aguanga basin, in the nort western part of the Agua Caliente graben, was mappe in detail for this report. The term "Agua Calien fault" has been generally applied to the fault boundi the Palomar horst on the northeast. Field study clear shows that this is not a single fault but a series of su parallel faults which have produced a graben. Th graben should properly be called the "Agua Calien graben" to preserve the essence of the original name.

The name "Aguanga fault zone" is proposed for tl fault zone marked by the prominent scarp south and we of Aguanga. South of Aguanga the main fault tren N.62°W. but father west it joins a persistent fault tren ing N.44°W. (pl. 1). The same zone of faulting tren southeast and forms at least part of the northeast boun ary of the Palomar horst. Exposures of some of the fau planes of this zone, directly south of Aguanga, sho northeast dips of more than 80 degrees.

The Lancaster fault zone, along which Lancaster Va ley has been eroded, bounds the Aguanga basin on tl north. Strikes do not conform to the regional tren and the zone converges toward the Aguanga fault zo to the west. Where the Lancaster fault zone cross Highway 79, a horst marks the zone of faulting (pl. 1

Oak Mountain Barrier. Faults with many hundre of feet throw bound the Oak Mountain barrier on tl west and east; these have produced a horst transver to the regional trend of the Elsinore fault zone.

Nature and Magnitude of Displacements

Criteria of Faulting. In the Temecula region, physi-raphic evidence must be relied on heavily to indicate ılting, as direct evidence of faulting is sparse. How-er, detailed field study will usually reveal some sort direct or indirect evidence to support the physio-aphic evidence.

Numerous breccia and gouge zones were located, ne of them many feet wide. At more than a dozen alities, the attitudes of fault planes and gouge zones ıld be measured. Most of these faults were at or near sement-sediment contacts. Dislacements of strata were en and measured in the Aguanga basin where the mecula arkose contains resistant marl and silt layers. milarly, many displacements were observed in the nglomerates. Slickensides were noted only in the first uble roadcut north of Radec. Less positive evidence faults may be represented by linear topographic ends of carbonate-cemented arkose. In general, high ps in the Temecula arkose are reliable indicators of arby faulting.

Vertical Movements. At most places where it was ssible to measure the dips of the fault planes and uge zones, the dips were 70 degrees or more and e faults were normal. In the few reverse faults that re found the displacements were only a few tens of et. The preponderance of high-angle normal faults the Elsinore fault zone is also recorded by Engel 949) in the Lake Elsinore quadrangle.

In the Oak Mountain barrier, the level summits of ık Mountain and Dorland Mountain are at an eleva-on of 2600 feet; Vail Mountain, topped by apparently e same erosion surface, is about 600 feet lower. At any places minimum throws of basement-sediment ults may be obtained by determining the height of e fault scarp. This estimate may be increased by ratigraphic studies and by examination of well logs, ıt deep wells are so few that the data rarely indicate creasing this minimum by more than a few hundred et.

The lava layer recorded in the Barnard no. 2 oil st (pl. 1) at a depth of about 2450 feet is correlated ith the Santa Rosa basalt capping Mesa de Burro and ogback. The minimum vertical displacement shown tween Mesa de Burro and the Murrieta graben is 00 feet. The basement surface in the Murrieta graben this vicinity is therefore more than 1500 feet below a level—clearly demonstrating absolute downdropping ther than a relative depression in a general uplift. nother oil test (Murrieta Valley Oil Co. no. 1) 1 mile uth of Murrieta Hot Springs, reached bedrock at out 1025 feet; at Murrieta Hot Springs basement rock at the surface. The Bennett water well (pl. 1) drilled June 1953 in the graben just northeast of the Wildo-ar horst apparently encountered about 10 feet of ısalt at a depth of 1210 feet and went into the base-ent at a depth of 1355 feet.

The greatest vertical displacements are probably ong the Pechanga fault zone in the Pechanga Indian eservation. The surface relief from Temecula Valley the top of Agua Tibia Mountain is about 3000 feet, ıt as Temecula Valley contains a considerable amount fill, the actual vertical displacement in the basement ırface may be several thousand feet more. A water well drilled in 1951 by the U. S. Navy (pl. 1) in Pauba Valley, a few hundred feet northeast of the Wildomar fault, went to a depth of 2478 feet without reaching the basement.

About 2 miles northwest of Murrieta, in the Murrieta graben, basement rocks are exposed at the surface. East of Murrieta, in the Barnard no. 2 oil test, basalt was encountered at a depth of about 2450 feet. As the complete driller's log was not made available, the exact depth-to-basement could not be determined. This test hole is not in the Murrieta graben, but in a higher block northeast of the Wildomar fault; thus a minimum depth-to-basement of 2500 feet in the graben near the test hole seems reasonable. It is believed that the basement surface in the Murrieta graben is of low relief, similar to that exposed nearby on the Santa Rosa plateau.

Assuming a regular dip of the basement surface and the absence of warping and faulting, this sloping surface would reach a depth of 5000 feet near Temecula, and 8000 feet at the southeast end of Temecula Valley. Another possible interpretation is that the maximum depth occurs near Temecula and the basement surface slopes upward to the southeast beneath Temecula Valley. The reversal in slope or a sharp decrease in depth might be associated with the cross-faults which formed Rainbow Gap (pl. 1).

On the basis of the above evidence it seems likely that the throw along the Pechanga fault zone is a mile or more. Although warping of the basement surface may explain part of this throw, many northeast-trending faults indicate that faulting has been the chief cause of this sharp topographic break. Furthermore, the alignment of the Nigger Canyon volcanics along several of the northeast-trending faults indicates profound fracturing.

On plate 1, a number of faults are shown to intersect without offset. It is acknowledged that this is a special case and would occur only rarely in nature. Some of the faults were determined purely from physiographic evidence, and the movements may have been too small to be detectable by surface or aerial photographic studies. The faults flanking Dorland Mountain are believed to fit the necessary special conditions inasmuch as the fault planes are close to vertical, and the movements have been almost exclusively vertical.

Horizontal Movements. Evidences of horizontal movements in the Temecula region are uncommon, and measured displacements are not more than about 1000 feet. A fault northeast of Oak Mountain (pl. 1) has a horizontal displacement of about 1000 feet, as shown by offsets in stream courses. On Vail Mountain, an isolated remnant of Temecula arkose shows an offset of about 600 feet. Horizontal slickensides occur in the double roadcut one mile north of Radec. There are a few other faults along which there are indications of horizontal displacement, but the field evidence is, for the most part, inconclusive.

Rotational Movements. Faults with changing throw along the strike are common in the Temecula region. Comparison of the southeast slope of the basement surface in the Murrieta graben with the basement slopes on the Santa Rosa plateau and on the Wildomar horst strongly suggests that the movements on both the Willard fault zone (acting as a unit) and the Wildomar fault have been rotational. In the Aguanga basin the large fault south of the Lancaster fault zone decreases in throw to the west as do many other west-trending faults of this basin.

Age of the Faulting

Northwest-trending structures in the Temecula region probably date back at least to the Paleozoic (Larsen, 1948, p. 119). However, in this region it is difficult to demonstrate Cenozoic diastrophism before the deposition of the early Pleistocene Temecula arkose. In Crosley Valley, cobbles in the Temecula arkose may indicate that the central part of the Palomar block had at least moderate relief at the start of the Pleistocene. Engel (1949) notes that the first moderately strong movements along the Elsinore fault zone were in Plio-Pleistocene time, and it may be that the Palomar horst was upfaulted at this time.

The most profound faulting in the Temecula region occurred during the middle Pleistocene, apparently contemporaneously with the Coast Range or Pasadenan orogeny which was widespread in California. This faulting produced great displacements in the basement surface and in the Temecula arkose, but it has not disturbed the Pauba fanglomerates. The present relief dates largely from the middle Pleistocene displacements.

In the late Pleistocene there were minor movements in the Temecula region along pre-existing fault lines. During the late Pleistocene several periods of faulting are evident. In the Dripping Springs alcove, several northwest-trending faults of small displacement may be traced through the Pauba fanglomerates, but not through the Dripping Springs fanglomerates. North and east of Vail Dam some of the higher stream-cut terraces have been faulted and tilted. In the graben 2 miles north of Aguanga a few patches of fanglomerates have been downfaulted.

Very late movements are shown by faulted low-level fanglomerates in Nigger Valley. The straight northwest boundary of the agglomerate-capped ridge near the mouth of Nigger Canyon suggests renewed movements along the major transverse fault which previously had downfaulted Temecula arkose against the metamorphics of the basement. Two northwest-trending faults have also disturbed this agglomerate.

Faulting, especially along the Wildomar fault, has continued to the present. The exhibits of the Rancho Santa Margarita vs. Vail litigation contain photographs of sand craters which were formed in the alluvium of the Temecula River along the trace of the Wildomar fault. These apparently were a result of the San Jacinto earthquake of 1918.

On December 4, 1948, while the field work for this investigation was in progress, a strong earthquake shook the Temecula region. The epicenter was located in Coachella Valley. In Temecula, bottles were knocked to the floor from shelves alined northeast but not from those alined northwest. A few ceiling cracks, oriented northwest, were observed in one building. At the time of the earthquake (4:44 P.M., PST) the writer was walking on the alluvium of the Temecula River about one mile west of the bridge of Highway 71. The alluvium did not noticeably transmit the seismic shocks.

MINERAL RESOURCES

Soil

Agriculture and cattle raising are the chief industr of the Temecula region; therefore, the most importa mineral resource is the soil. In the Temecula basin, so suitable for farming have formed on Recent alluviu on the Pauba formation, and on the Temecula arko The chief crops are wheat, oats, barley, and alfal which are usually farmed dry. Small areas in Pauba a Santa Gertrudis Valleys are irrigated, and in those v leys alfalfa, peaches, and truck crops grow well. So on the Pauba formation tend to become hard due to ir oxide cementation, but deep plowing and treatment w ammonia keep the soil loose.

In the Aguanga basin only the Recent alluvium farmed extensively as slopes eroded in Pleistocene forn tions are usually too steep. Dry farming is success even in alluvial fingers of the badlands. Some of th fingers are irrigated by portable sprinkling systems.

Those areas not under cultivation and those plant to forage crops are devoted to grazing several thousa head of cattle.

Water

Next in importance only to the soils are the surf and ground waters of the Temecula region. The wat resources were studied by Waring (1919) in conjuncti with a larger investigation of the drainage basins of t San Jacinto and Temecula Rivers. The California Di sion of Water Resources has recently completed a surv of the ground water resources of the Temecula Riv drainage basin. Voluminous data on water resources the Temecula region and vicinity were collected duri the water rights litigation between Rancho Santa M garita and the Vail Company. The litigation continu for 3 years and the records of testimony and exhib aggregate several tons. Parts of these data were co sulted during the present investigation; however, a tailed water resources study would require a thorou analysis of this information. Although the water sources were not studied in detail for this report, co siderable attention was given to the structural control ground water movements.

Springs are common along faults. Some are fou along the contacts between basement and sedimenta rocks; others are found entirely in sediments, where t faulting is less obvious. Many of these springs have be developed for domestic supplies, for watering cattle, a for irrigation; many remain undeveloped.

The Wildomar fault (pl. 1) is an important barr to ground-water movement. In the Temecula bas ground water moves southwest under both water ta and artesian conditions. At the Wildomar fault, grou water movement is effectively stopped and a grou water cascade is produced. An obvious result of this co dition is the line of springs along the northeast edge Murrieta and Temecula Valleys. Even though the hi water table northeast of the Wildomar fault may r reach the surface, its effects on vegetation may still noticeable.

In the deeper aquifers of the Temecula arkose, t Wildomar fault creates areas of artesian flow in Pau and Santa Gertrudis Valleys, and also about a mile no of Temecula. Though some of the wells no longer flo these are still areas of high water levels.

Recharge into the Murrieta graben is poor, except in e Recent alluvium. In Temecula Valley, Waring .919) shows the water table 80 feet below the surface st southwest of the Wildomar fault. It does not appear kely that large water supplies will be obtainable from e Pleistocene sediments of the Murrieta graben.

Many of the large capacity wells are in the alluvium Pauba Valley, where, despite recent faulting, hy-raulic continuity of the shallow material has not been ipaired. Elsewhere it is to be expected that the freely charged alluvium will reliably offer larger supplies an the complexly faulted older sediments.

ot Springs

Hot springs are found along both the San Jacinto and lsinore fault zones. Murrieta Hot Springs is a large alth resort east of Murrieta. The springs issue along large east-trending fault along which the Temecula kose has been down-faulted about 1000 feet against e basement. The springs have temperatures as high as 6°F and are mineralized chiefly with sodium chloride. milar waters are used for bathing at Temecula Hot prings, about a mile to the southwest, but reportedly e cooler.

Sand and Gravel

Sand and gravel to a depth of several tens of feet are und in all the alluvial valleys. Large quantities from rroyo Seco were used in the concrete for Vail Dam. umerous other sites for gravel pits could be located.

Granodiorite gruss has been used extensively for road ilding, and there are many places where this "decom-osed granite" could be exploited.

Rock

At one time unweathered Woodson Mountain grano-orite in large residual boulders was quarried near emecula for use as a building and monumental stone. ence posts of this rock are still being used. The coarse guanga tonalite and the San Marcos gabbro or "black anite" would be excellent for monumental stone. iere are several favorable sites for quarries.

Clay

The Wildomar kaolin deposit has been mined for many ars although the quantity removed has been small—ly about 150 tons per year. If the demand for such ay increases there is a bed of similar material in the guanga basin just north of the Dripping Springs anger Station which could be exploited.

Diatomite

A bed of fairly pure diatomite crops out near the top the mesa due north of Temecula. It is about 3 or 4 et thick and appears to be fairly extensive. It is not orked commercially at present.

Oil and Gas

At least two oil tests have been drilled on the mesa tween Murrieta and Murrieta Hot Springs. Murrieta alley Oil Co. no. 1 was drilled in 1923 on the south side the highway near Murrieta Hot Springs. It was drilled 1120 feet after having reached basement at about 1015 et. Barnard no. 2 was started in 1938, and in the sum-er of 1949 had been drilled to about 3300 feet. The mplete log of Barnard no. 2 was not made available it the driller's log indicated a 16-foot flow of lava at a depth of about 2450 feet. At a depth of 3300 feet it seems certain that the well has penetrated several hundred feet of basement rocks. Nevertheless, it is planned to continue drilling.

Terrell no. 1 was drilled in Radec Valley in 1947. This oil test was started in Temecula arkose within a few hundred yards of a tonalite outcrop, reached the basement at 312 feet and was drilled to a total depth of 2588 feet. The Temecula arkose-basement contact is clearly shown on the electric log, a copy of which was examined by the writer. The well is reported to have trapped a reservoir of gas under high pressure.

No marine sediments were found in the Temecula region, although there are marine Paleocene sediments near Elsinore. Marine sediments may yet be found in the deep fill of the Temecula basin, but their presence in the Aguanga basin is unlikely.

LATE CENOZOIC GEOLOGIC HISTORY

Pliocene. Early in the Pliocene the northern end of the Peninsula Ranges was apparently in late maturity. The "early land form" of Dudley (1936) had been heavily alluviated by Paleocene and possibly later sediments. Above broad alluvial plains inselberge rose several hundred feet, but they supplied very little clastic material larger than sand. Bellemin (1940, p. 670) reports that during the early Pliocene the Perris block was not an important contributor of cobbles to conglomerates in the Puente Hills.

The Mt. Eden beds of late lower or early upper Pliocene age (Frick, 1921) represent this sandy deposition in the San Jacinto region. In the Puente Hills the Pliocene consists of the sandstones and siltstones of the Repetto and Pico formations (Dudley, 1943). Local uplift in the San Jacinto region may have caused a change from sandy deposits of the Mt. Eden to gravelly deposits of the San Timoteo (Fraser, 1931).

During Pliocene time the drainage of the Perris and San Jacinto blocks was probably northeast or north, as suggested by the following evidence:

(1) the Mt. Eden beds are found only on the northwest flank of San Jacinto Mountain, the probable source area;
(2) the Mt. Eden beds now dip northeast and rest upon a basement surface which slopes northeast. This inclination is not easily explained by tilting;
(3) the two erosion surfaces near the top of San Jacinto Mountain described by Fraser (1931, p. 503) slope northeast. The present writer suggests that the highest surface (elevation 10,500 feet) was eroded during Mt. Eden time.

Tahquitz Valley (elevation 8100 to 6500 feet) may have been formed following the uplift which resulted in the deposition of the San Timoteo beds, as suggested by the faulting which Fraser (1931) records for the Mt. Eden-San Timoteo interval.

No Pliocene sediments have yet been found in the Temecula region, or anywhere else in the Elsinore fault zone between Aguanga and the northern part of the Temescal graben. It was established by Bellemin that the Santa Ana Mountains contributed almost no cobbles to the lower Pliocene conglomerates of the Puente Hills. There is little evidence that the Santa Ana Mountains were upfaulted during the Pliocene before the end of that epoch. The uplift which occurred in the Mt. Eden-San Timoteo interval was apparently an uplift of the Peninsular Ranges block as a unit along the eastern boundary faults.

Plio-Pleistocene. The Santa Rosa basalts appear to have been extruded upon a surface of low relief formed at about the end of San Timoteo (late Pliocene) time. Near Temecula this surface is underlain in part by Paleocene sediments and in part by bedrock. The Santa Rosa basalts could be of any age from Paleocene to lower Pleistocene if stratigraphic position alone were considered. However, freshness of the basalt, topographic position, and probable contemporaneity with wide-spread volcanism suggest a late Pliocene or early Pleistocene age.

Not long after the Santa Rosa basalt extrusions the first important uplift of the Santa Ana block took place. Engel (1949) gives the age of these movements as Plio-Pleistocene. The Peninsular Ranges block continued its upward movement along the eastern boundary faults and continued its tilting to the west. The Perris block was relatively depressed and tilted northwest between the Santa Ana and San Jacinto blocks along the Elsinore and San Jacinto fault zones. The Elsinore-Temecula trough was apparently only a minor feature at this time, but the Palomar block was uplifted to form a long narrow horst.

Early Pleistocene. Relative depression of the Perris block permitted accumulation of the Bautista and Temecula formations. These formations were derived from the San Jacinto Mountain block and vicinity and they buried the southeastern part of the Perris block; streams probably flowed southwest to the ocean across the low southeastern end of the Santa Ana block which had been tilted south during the Plio-Pleistocene uplift.

The La Habra conglomerate was derived largely from the Puente Hills (Dudley, 1943), although the Santa Ana Mountains may have contributed some detritus. Probably during the deposition of the Bautista beds the prominent southwest bench (elevation ca. 5200 feet) on San Jacinto Mountain was formed, as suggested by its slope to the southwest, the direction of drainage during Bautista-Temecula time.

At the end of early Pleistocene time, the northwestern part of the Peninsular Ranges was chiefly an alluvial plain formed at the top of the Bautista-Temecula sediments. San Jacinto Mountain, Palomar Mountain, and the northwestern end of the Santa Ana Mountains were apparently inselberge. The area just southeast of the Perris block, as suggested by the present topography, was probably relatively high, with thinner sediments and more inselberge.

Middle Pleistocene. The mid-Pleistocene orogeny profoundly affected the Temecula region. Uplift and tilting westward of the provincial block continued, with further relative depression of the Perris block. The Santa Ana Mountains were uplifted and tilted south, while the Elsinore-Temecula trough was being formed by the downdropping of basement blocks more than a thousand feet below sea level.

Though relatively depressed, the Perris block was uplifted with reference to sea level, and its exhumation was started. As exhumation proceeded, downfaulted areas were probably filled continuously. Major streams may not have been affected immediately by the uplift, but probably became antecedent and maintained a southwest direction of flow. As exhumation continued, the Santa Ana Mountains were intermittently uplifted
and tilted. The higher erosion surfaces of the Santa Ar
Mountains are described by Engel (1949) who notes th
they are all tilted south or southwest; each surface
lower and farther southeast than the next older surfac
In contrast, the Perris block was stable, at least durir
and after the erosion of the Gavilan-Lakeview surfa
which is apparently horizontal. During a static bas
level the Perris surface was formed. The Temecu
River, which may have been flowing across buried Oa
Mountain, was superposed at Nigger Canyon; its dow
cutting is marked by many terraces on Oak Mountai
The Gavilan-Lakeview and Perris surfaces probably ha
equivalent terraces in Nigger Canyon, but subsequen
downcutting has obscured the relationships there.

The San Jacinto River, after being superposed b
tween two inselberge of metamorphics, became e
trenched at Railroad Canyon. While the Perris surfa
was being eroded, the San Jacinto River did not ha
sufficient elevation to flow directly across the Santa Ar
Mountains as it had during the formation of the Gavila
Lakeview surface. Instead, the trend of Railroad Canyo
suggests it may have flowed southeast in the Elsinor
Temecula trough to join the Temecula River, which a
parently left the trough through Pechanga Gap. Durin
the formation of the Perris surface, the Santa Ro
surface, which slopes northeast, was exhumed by strear
flowing northeast to join the subsequent drainage
the Elsinore-Temecula trough. The Santa Rosa surfa
dates from pre-Paleocene (?) time and was re-expos
by stripping of several hundred feet of sands and gra
els and the overlying Santa Rosa basalt flows.

During the exhumation, the Santa Ana River, whi
had kept north to avoid the metamorphic core of t
Santa Ana Mountains, vigorously maintained its ant
cedent course. Earlier in the exhumation it probab
had been a superposed stream. Owing to relatively rap
incision, the Santa Ana River developed a subseque
tributary system which eroded headward in the Elsinor
Temecula trough and captured first the San Jacin
River, then the Temecula River. An apparent elbow
capture just downstream from Railroad Canyon (La
Elsinore quadrangle) may have resulted at this time.

Early Late Pleistocene. During the early late Ple
tocene time the Temecula region was the scene of in
portant drainage changes. Although the sequence
events is not completely clear, the writer tentatively su
gests the following outline of events.

A possible increase of rainfall initiated deposition
the Pauba formation after large blocks of basement h
been exhumed. Large fans were formed in the Drippi
Springs alcove and elsewhere in the Aguanga basin.
stream flowed from the Aguanga basin through a supe
posed course at Nigger Canyon; it had to flow in t
Elsinore-Temecula trough to Santa Ana Canyon, as t
exit at Temecula Canyon was not yet in existence. T
main Pauba fan, with its apex at the mouth of Nigg
Canyon, was developed with reference to an east-we
axis of symmetry, showing no relationship to a li
joining Nigger and Temecula Canyons as does the pr
ent Temecula River. The hardpans suggest that t
climate was seasonally dry and the drainage restricte

The major ancient subsequent stream, which is nam
here the Pauba River, was joined by the San Jacin
River just below Railroad Canyon. The Pauba Riv

ıs probably confined to the northeast side of the ɔugh by huge alluvial fans spreading northeast from ɘ scarp of the Santa Ana Mountains. This river probly flowed through the bedrock gap just east of Elsinore d up the trough, roughly following the present course Temescal Wash. The waters from the present draine area of Penjango Creek at this time may well have wed out Pechanga Gap just south of the Pechanga dian Reservation.

The climate toward the end of Pauba time may ve been wetter than during earlier Pauba time, as sugsted by the presence of fairly pure diatomite deposits. ssibly at the end of Pauba time, sedimentation in a ke or lakes on the Perris block produced the level val- floors near Hemet. Such a lake, though possibly not the same age as suggested here, was previously sugsted by Larsen (1948, p. 13).

Headward erosion in Temecula Canyon reached the mecula basin presumably near the end of Pauba time. ıe Pauba River was captured quickly and the Temecula sin was again dissected. The factors which accelerated adward erosion along the course of Temecula Canyon e as follows:

(1) The canyon is cut in Bonsall tonalite which forms a narrow screen between the Bedford Canyon metamorphics and the Woodson Mountain granodiorite. Contact metamorphism is greatest in these thin screens.

(2) Larsen (1948, p. 60) states: "Although the fresh Bonsall tonalite is a rather hard rock, it is more readily disintegrated by weathering than most of the other granitic rocks of the area."

(3) Faulting along the canyon course is suggested by: (a) the straight contacts of the basement rocks; (b) a trend of N. 45° E., one of the prominent joint directions; (c) an offset erosion surface, which is higher southeast of the canyon than northwest of it.

ıe stream valleys in the Pauba mesa north and east of mecula in their upper courses trend west or a little uth of west (pl. 1). As these valleys approach Murta Creek they curve and flow southwest, suggesting ɔows of capture. Before the major capture at Temecula ınyon, there may have been temporary diversion of ırt or all the drainage of the Temecula basin through ainbow Gap—a fault zone which apparently has been odified by erosion of a throughgoing river.

At the same time or slightly before the capture at mecula Canyon, there was diastrophism in the Elsinore ult zone. Minor faulting occurred in the Dripping prings alcove. As a result of faulting at the end of auba (early late Pleistocene) time, it is suggested here, e basin of Lake Elsinore was formed. The huge fans hich had been deposited along the scarp of the Elsinore ountains during Pauba time were downfaulted. This gging caused the San Jacinto River to be diverted into e newly formed basin, creating a lake in this basin, ıd leaving a wind gap just east of the town of Elsinore. n outlet was formed on the northeast lip of the lake ısin and the overflow again joined the northwest-flowg subsequent drainage. The apices of these fans were ɔt downdropped; they were subjected to strong erosion, ıt a few patches remain (Engel, 1949, map).

Latest Pleistocene. After considerable dissection of ıe Pauba formation, the Dripping Springs formation as deposited during a period of relative crustal stabily. During Dripping Springs time, terraces were formed ı Nigger Canyon, the Temecula basin, and Temecula Canyon. At about the end of Dripping Springs time the first extrusion of the Nigger Canyon volcanics occurred. A large cinder cone at the mouth of Nigger Canyon may have dammed the Temecula River temporarily. Erosion probably quickly cut through this cone, however, and Nigger Canyon was cut down about 300 feet in response to a lowering of baselevel in Temecula Canyon. Several paired terraces flanking the Temecula River in the Temecula basin attest to the fact that this downward erosion was not at a uniform rate. The Quaternary terrace gravels (pl. 1) represent one of the lowest temporary baselevels.

Just before Nigger Canyon was cut to its lowest level, there was another eruption of flows and pyroclastics at the mouth of Nigger Canyon. The cinder cone was a result of this eruption. Further erosion dissected the cone and removed the toes of the flows.

Recent. The latest event in the Temecula region has been alluviation, especially in the basin areas. In Pauba Valley, well records indicate this alluvium is as much as 120 feet thick. Diastrophism has continued throughout the late Pleistocene and up to the present, as indicated by Recent faulting. However, in the Temecula region, latest Pleistocene and Recent faults with more than a few tens of feet of displacement are rare.

Summary of Late Cenozoic Events, Temecula Region and Vicinity.

Pliocene
- Broad alluvial surface of low relief with inselberge. Perris block and Santa Ana Mountains low.
- Mt. Eden beds deposited. Highest erosion surface on San Jacinto Mountain formed. Drainage northeast or north.
- Upfaulting of San Jacinto Mountain block.
- San Timoteo beds deposited. Tahquitz Valley formed. Drainage northeast or north.

Plio-Pleistocene
- Santa Rosa basalt extruded upon a surface of low relief.
- First important uplift of Santa Ana Mts. along Elsinore fault zone. San Jacinto Mtn. uplifted, Perris block depressed. Palomar Mtn. uplifted.

Early Pleistocene
- Deposition of Bautista-Temecula sediments. Southwest bench formed on San Jacinto Mtn. Drainage southwest across Perris block and Temecula region. Broad alluvial surface formed with relatively few inselberge.

Middle Pleistocene
- Pasadenan orogeny. Uplift and exhumation. San Jacinto Mtn., Santa Ana Mts., Palomar Mtn. uplifted; Perris block uplifted but relatively depressed. Elsinore-Temecula trough downfaulted.
- As exhumation proceeded, high erosion surfaces in Santa Ana Mts., Gavilan-Lakeview surface, high terraces in Nigger Canyon eroded.
- Perris and Santa Rosa surfaces formed, also terraces in Nigger Canyon.
- Santa Ana River developed subsequent tributary in the Elsinore-Temecula trough, captured San Jacinto and Temecula Rivers.

Early late Pleistocene
- Pauba deposition.
- Faulting. Stream eroding headward at Temecula Canyon captured ancient Pauba River. Basin of Lake Elsinore downfaulted.
- Dripping Springs fanglomerates deposited. Terraces formed in Nigger Canyon, Temecula Canyon, and Pauba Valley.

Latest Pleistocene
- First eruption of Nigger Canyon volcanics.
- Erosion. Terraces formed in Pauba Valley.
- Second eruption of Nigger Canyon volcanics.

Recent
- Alluvial deposits up to 120 feet thick.
- Faulting. Minor faulting continued throughout late Pleistocene and Recent.

REFERENCES

Bellemin, G. J., 1940, Petrology of Whittier conglomerates southern California: Am. Assoc. Petroleum Geologists Bull., vol. 24, no. 4, pp. 649-671.

Blackwelder, Eliot, 1928, The recognition of fault scarps: Jour. Geology, vol. 36, no. 4, pp. 289-312.

Böse, E. and Wittich, E., 1913, Informe relativo a la exploracion de la region norte de la costa occidental de la Baja California: Parergones del Inst. Geol. Mexico, vol. 4, pp. 307-529.

Dietrich, W. F., 1928, The clay resources and the ceramic industry of California: California Div. Mines Bull. 99, 383 pp.

Dudley, P. H., 1936, Physiographic history of a portion of the Perris block, southern California: Jour. Geology, vol. 44, pp. 358-378.

Dudley, P. H., 1943, East Coyote area of the Coyote Hills oil field: Calif. Div. Mines Bull. 118, pp. 349-354.

Eckis, Rollin, 1928, Alluvial fans of the Cucamonga district, southern California: Jour. Geology, vol. 36, pp. 224-247.

Ellis, A. J. and Lee, C. H., 1919, Geology and ground waters of the western part of San Diego County, California: U. S. Geol. Survey Water Supply Paper 446, 321 pp.

Engel, Rene, 1949, Geology and economic resources of the Lake Elsinore quadrangle: Calif. Div. Mines Bull. 146, in preparation. Geologic map printed in advance, 1949.

English, W. A., 1926, Geology and oil resources of the Puente Hills region, southern California: U. S. Geol. Survey Bull. 768, 110 pp.

Fairbanks, H. W., 1893, Geology of San Diego County; also of portions of Orange and San Bernardino counties: California Min. Bur. Rept. 11, pp. 76-120.

Fraser, D. M., 1931, Geology of the San Jacinto quadrangle south of San Gorgonio Pass, California: California Div. Mines Rept. 27, pp. 494-540.

Frick, Childs, 1921, Extinct vertebrate faunas of the badlands of Bautista Creek and San Timoteo Canyon, southern California: Univ. California, Dept. Geol. Sci., Bull., vol. 12, no. 5, pp. 277-424.

Hanna, M. A., 1926, Geology of the La Jolla quadrangle, Cal fornia: Univ. California, Dept. Geol. Sci., Bull., vol. 16, no. 7 pp. 187-246.

Hill, M. L., 1930, Structure of the San Gabriel Mountains nort of Los Angeles, California: Univ. California, Dept. Geol. Sci Bull., vol. 19, no. 6, pp. 137-170.

Jenkins, O. P., 1938, Geologic map of California: California Div Mines, San Francisco.

Jenkins, O. P., 1943, Geomorphic provinces of California: Califor nia Div. Mines Bull. 118, pp. 83-88.

Larsen, E. S., 1948, Batholith and associated rocks of Corona Elsinore, and San Luis Rey quadrangles, southern California Geol. Soc. Am. Mem. 29, 182 pp.

Miller, W. J., 1935, Geomorphology of the southern Peninsula Range of California: Geol. Soc. America Bull., vol. 46, pp 1535-1562.

Moore, B. N., 1930, Geology of the southern Santa Ana Mountains Orange County, California: unpublished dissertation, Californi Inst. Technology.

Nikiforoff, C. C. and Alexander, L. T., 1942, The hardpan and th claypan in a San Joaquin soil: Soil Sci., vol. 53, pp. 157-172.

Poland, J. F., Piper, A. M., and others, 1945, Geologic features i the coastal zone of the Long Beach-Santa Ana area, California with particular respect to groundwater conditions: U. S. Geo Survey mimeographed rept.

Reed, R. D., 1933, Geology of California: Am. Assoc. Petroleum Geologists, Tulsa, 355 pp.

Sauer, C. O., 1929, Land forms in the Peninsular Range of Cali fornia as developed about Warner's Hot Springs and Mes Grande: Univ. California, Dept. Geography, Bull., vol. 3, no. 4 pp. 199-290.

Waring, G. A., 1919, Ground water in the San Jacinto an Temecula basins, California: U. S. Geol. Survey Water-Suppl Paper 429, 113 pp.

Webb, R. W., 1939, Evidence of the age of a crystalline limeston in southern California: Jour. Geology, vol. 47, pp. 198-201.

Wood, H. O., 1947, Earthquakes in southern California wit geologic relations: Seismol. Soc. America Bull., vol. 37, no. 2 pp. 107-158; vol. 37, no. 3, pp. 217-258.

o

printed in CALIFORNIA STATE PRINTING OFFICE

17302 5-55 2,500