GEOLOGY

Baldwin Hills Project

May, 1977

Revised

October, 1982

by

Richard Ramirez, Geologist
Jim Shuttleworth, Geologist
County of Los Angeles
Department of County Engineer
Geology Section

GEOLOGY

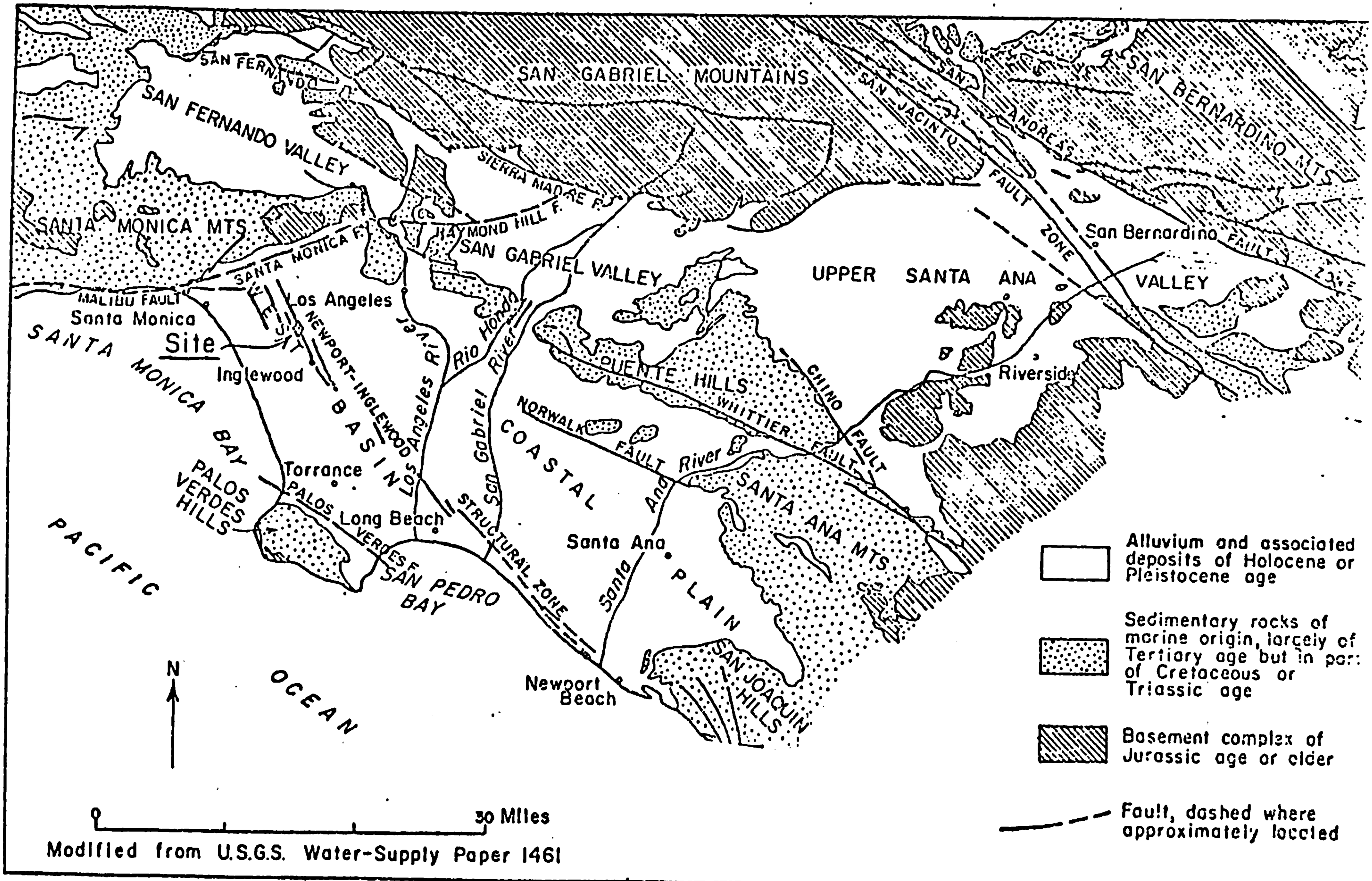
GEOLOGY

INTRODUCTION

The project includes most of the western portion of the Baldwin Hills in the west central part of Los Angeles County. It is characterized by two north-northwest trending ridges and an intervening central valley. Maximum elevation of the site is approximately 155 meters (510 feet) and maximum relief is over 122 meters (400 feet). The natural topography has been extensively modified by grading during oil field development, construction of the Baldwin Hills reservoir, public streets, and other community development.

Many studies related to the Baldwin Hills have been made in the last 30 years owing to heavy oil production, land subsidence, and seismic hazards. The Newport-Inglewood earthquake of 1933 and the 1963 Baldwin Hills reservoir failure are two recent significant events resulting in much study of the Baldwin Hills geology and seismicity. A detailed study of earthquakes associated with the Newport-Inglewood Structural Zone has been performed by Barrows (1970, 1973, and 1974). Local geology of the Baldwin Hills has been investigated by Tieje (1926) and Castle (1960) (map V-1).

Several geologic and tectonic studies of a portion of the Baldwin Hills were also performed in relation to construction and failure of the Baldwin Hills reservoir. These studies were performed by Barris (1944), Department of Water Resources (1964), and Jansen et al (1967). Studies of land surface deformation and subsidence in the Baldwin Hills have been made by Hudson and Scott (1965), Jansen et al (1967), Ramierz (1968), Hamilton and Meehan (1971),



GENERALIZED GEOLOGIC MAP OF A PORTION OF SOUTHERN CALIFORNIA

MAP V - 1

and Castel, Yerks and Youd (1973). Geologic and seismic studies have been made by Los Angeles County Engineer (1974) and Engineering Geology Consultants, Inc. (1975) especially for the proposed Regional County Park in the Baldwin Hills.

Periodic surveys of elevation changes and movement of bench marks in the Baldwin Hills have been made by the Los Angeles Department of Water and Power and Los Angeles County Engineer since 1934.

LITHOLOGIC FEATURES

Underlying the meager soil cover of the Baldwin Hills is a thick stratigraphic section consisting of Tertiary and Quaternary sedimentary rocks. This 3,050 to 4,267 meters (10,000 to 14,000 feet) thick sequence, which for this study is divided into two major categories, rests on a crystalline basement complex.

The first category is composed of the bedrock which lies beneath the surficial deposits, or in some areas crops out on the ground surface. The second category, surficial materials, represent recent deposits, derived from the surrounding parent material emplaced naturally or by man. These materials vary in thickness from a few meters to tens of meters.

Older Rocks (Pre-Tertiary)

At 3,050 to 4,267 meters (10,000 to 14,000 feet) below the ground surface the basement complex is believed to be Mesozoic (65-225 million years old) in age, and composed of igneous metamorphic crystalline rock. The Newport-Inglewood Fault is thought to represent a major crustal break, separating greatly different rock types in the basement complex. Two blocks are believed to have been created by differential lateral movement along the northwest-trending fault. The western block is believed to be composed of metamorphic rocks associated with the Catalina Schist, the eastern block of intrusive granitic and associated metamorphic rocks.

Tertiary Rock Units

Tertiary sedimentary, intrusive and extensive bedrock units overlie the basement complex. From oldest to youngest, they are the Topanga, Puente, Repetto and Pico Formations.

The Topanga Formation, mid-Miocene in age, consists of interbedded marine sandstone, conglomerates, shales and numerous intrusive and extrusive rocks.

The Puente Formation consists primarily of middle to upper Miocene marine sandstones, shales and interbedded siltstones. Generally the unit is massive to thinly bedded. Thickness of the unit ranges from 335 to 854 meters (1,100 to 2,800 feet).

The Repetto Formation is early or lower Pliocene in age and consists primarily of well consolidated marine sandstones, oil sands, shales and siltstones. The unit is 793 to 945 meters (2,600 to 3,100 feet) thick.

The Pico Formation, upper Pliocene to lower Plesitocene, consists of 518 to 915 meters (1,700 to 3,000 feet) of marine and non-marine siltstone, sandstone and interbedded claystone. These materials probably became increasingly well consolidated with depth. The top of the formation consists of gray to grayish blue massive claystone.

Of the Tertiary rock units, only the Pico Formation is exposed within the project area. Exposures are found almost exclusively on the east side of the Inglewood Fault and on the westernmost and north-westernmost slopes of the project.

<u>Quaternary Rock Units</u>

In addition to the Pico Formation, bedrock of the Inglewood and San Pedro Formations of Quaternary age is exposed in the Baldwin Hills. These Formations consisting of sandstone, conglomerates and siltstones are often very weak, crumbling easily under slight hand presure. Starting with the oldest, each unit of "formation" is described below.

The Inglewood Formation unconformably overlies the Plio-Pleistocene Pico Formation. It consists predominantly of well interbedded sandstone and siltstone with some clays. Predominantly a marine sequence, the formation is generally unconsolidated, friable and varies from light gray to reddish brown in color. Thickness of the unit ranges from 46 to 91 meters (150 to 300 feet). Shallow southwest dips of 12 degrees or less and north-west trending strikes predominate in this formation.

The basis of the stratigraphic divisions and nomenclature used in this study are the U.S. Geological Survey and California Department of Water Resources (DWR) literature. A third source, Engineering Geology Consultants, Inc. (EGC), was also used. The San Pedro Formation includes EGC's Cap and B Formations and the upper portion of their "A Formation" also includes the Inglewood and the upper meters of the Pico Formations.

The San Pedro Formation consists of poorly interbedded, light gray to yellow and reddish brown non-marine Pleistocene sands, gravels and conglomerates. Cross-bedding and iron-oxide staining is common. With the exception of the cap deposit identified by EGC, which exhibits some resistance due to cementation, this material is generally uncemented to poorly cemented and friable. Consolidation ranges from moderate to poor. The formation exposures vary in thickness from 0 to 61 meters (0 to 200 feet). Bedding strikes to the northwest with gentle dips to the southwest, averaging less than 10 degrees.

Surficial Materials

Surficial materials in the Baldwin Hills include the following: artificial fill, slopewash (colluvium), alluvium, landscape and slump debris and soil. The artificial fill, slopewash and alluvium are shown as one unit on the Geology map. Landslides and slumps are shown as another unit. Soils are shown on the Soils map (map VI-1).

Soils:

The soils in the Baldwin Hills are primarily of the Ramona Series. A detailed discussion on soils can be found in the section entitled "Soils".

Landslide and Slump Debris:

Landslide (Qls) and Slump (Qs) debris is relatively insignificant within the site. Only minor slides and slumps have been identified and mapped (map V-2).

Alluvium:

Alluvium (Qal) is sometimes difficult to distinguish from slopewash in the Baldwin Hills. As mapped by Engineering Geology Consultants, alluvium occurs extensively throughout the project. Generally, it would be found on the floor of the major valleys, drainage courses, and lowland areas. Some lowland areas mapped by Engineering Geology Consultants as slopewash, were previously mapped by others as alluvium and may indeed actually be alluvium. The question, however, is really only academic for this report since the two materials, slopewash and alluvium are similar in physical properties at this locality and have been mapped as one unit, regardless. The Baldwin Hills alluvium consists of brown, poorly sorted, possibly poorly consolidated, sands with intermixed clay, silt and gravel. Thicknesses range from a few meters to approximately 15 meters (50 feet), and it contains minor amounts of organic matter. Thicker accumulations occur primarily on the extreme western edge of the project.

NORTH

0 400 1200 1600 feet

GEOLOGY

BALDWIN HILLS PROJECT

MAP V-2

Slope Wash:

As the name implies, slopewash (Qsw) is material derived from an upslope area, transported down slope by sheet flow and mass wasting action. Slopewash, also termed "colluvium", tends to concentrate in swales, at the base of steep slopes, and on gently sloping ground where the influence of gravity is minimized. It is derived, as might be expected, from the surrounding elevated exposures of bedrock and soil. Slopewash occurs throughout the Baldwin Hills in varying thicknesses from a few meters to 15 meters (50 feet). Where it exceeded 1.2 meters (4 feet) in thickness, slopewash was included in the consolidation of surficial materials, shown on the Geology map (map V-2).

Slopewash consists of assorted shades of brown silt to silty sand, with varying amounts of clay and gravel. Typically porous and loose to poorly consolidated, some older and thicker accumulations of slopewash appear to be more consolidated. This old, more consolidated slopewash is primarily found in the lowland, intervening central valley of the hills. The largest accumulation, 12 to 15 meters (40 to 50 feet) thick, is also found in this central valley, northwest of the reservoir and east of La Cienega Boulevard.

Artificial Fills:

Artificial fills (af) are comprised of earth materials emplaced by man generally from grading operations. Occurrence of artificial fill in the area is varied and extensive. Artificial fill represents roughly 20 percent, of the exposed materials within the project. Thin narrow strips of artificial fill are found along the sides of many access roads throughout the project. Larger concentrations, ranging up to major canyon fills, are also found in the project.

Within the subject area, fills are divided into two groups, engineered and non-engineered fills. Engineered fills would normally conform to accepted standards of compaction and would be capable of supporting permanent structures. Non-engineered fills have simply been "dumped" in place, some undergoing varying degrees of unsupervised compacting. Testing would be required to determine the quality of these non-engineered fills. Due to the lack of information, no attempt has been made to differentiate between engineered and non-engineered artificial fills within the project area. For purposes of this study, both categories have been grouped together on the Geology map under one of the four major groupings (map V-2). The generalized Soils map shows most of the undifferentiated artificial fill as a separate unit. Numerous non-engineered fills associated with oil field operations occur within the project, but were too small to be shown on the Soils map (map VI-1). Some of the engineered fills, if they could be identified, would require testing because of their age. While these old fills may have been "engineered" they were placed prior to significant improvements in current grading code requirements.

Composition of the artificial fill varies greatly. It ranges from petroleum waste products and inorganic trash to imported material from surrounding communities in the larger fills. Generally the fill materials have been obtained from nearby sources and are related to oil field or roadway cut and fill operations. Commonly, the fill material consists of mottled brown, loose to well compacted, sandy silt to sand containing varying amounts of clay, silt and gravels.

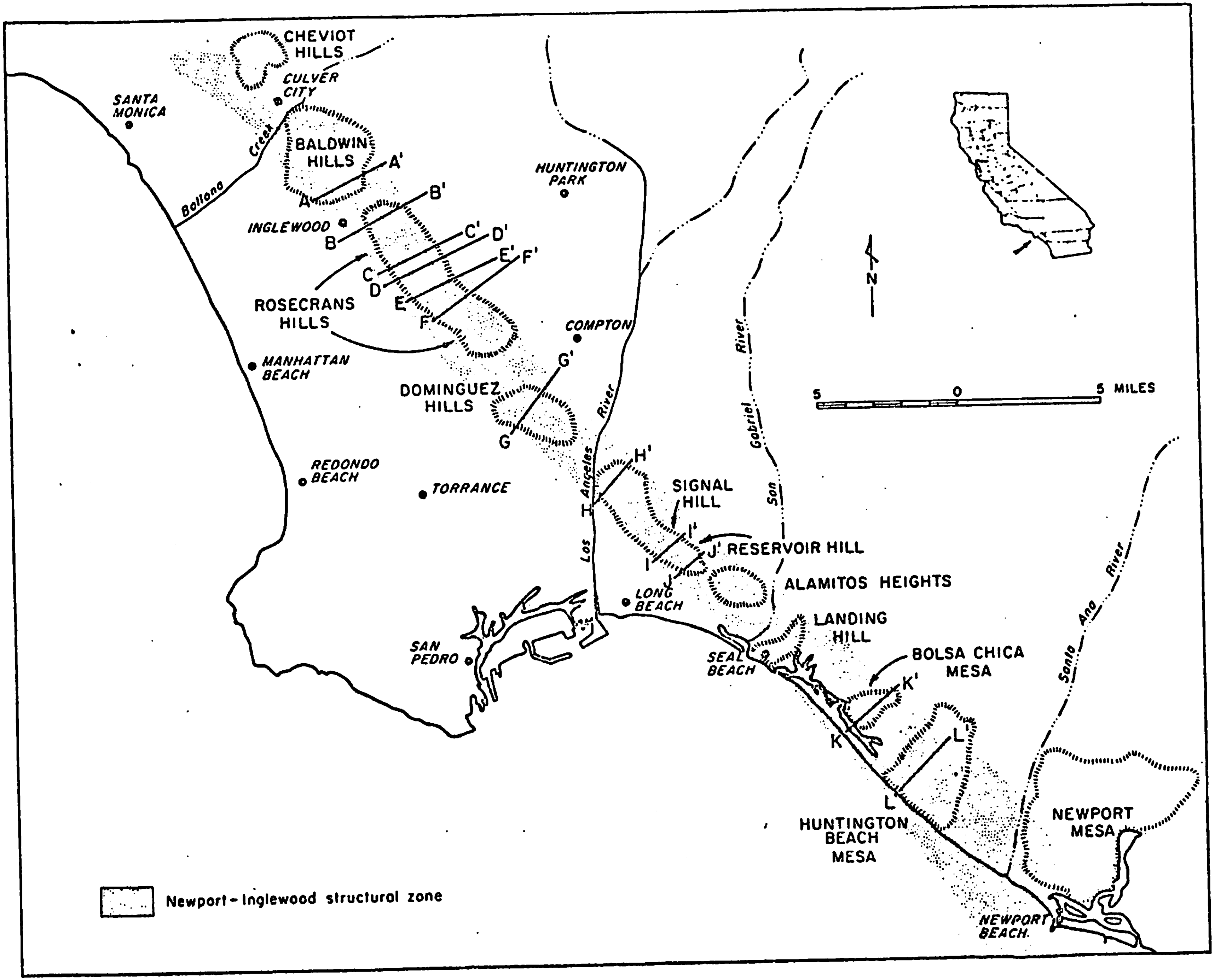
STRUCTURAL FEATURES

The names of the various structural features involved in this subject are similar. Therefore, to avoid confusion of the reader, they are listed here together to show their similarities. They are: 1) the Newport-Inglewood Structural Zone, 2) the Newport-Inglewood Fault, and 3) the Inglewood Fault. A description of each follows. (See also Earthquake History)

Newport-Inglewood Structural Zone

Any discussion of the geologic structure of the Baldwin Hills must include a discussion of the Newport-Inglewood Structural Zone. This zone is one of the major structural elements in the Los Angeles Basin, stretching 40 miles from the Cheviot Hills southeasterly to Newport Mesa. From this point it continues offshore, roughly paralleling the coastline.

The zone is not a single fault, but rather a complex series of faults, and both surface and subsurface structures. However, at great depth in the basement complex, it is believed, there is a master through-going fault, the Newport-Inglewood Fault. Movement along this master fault is believed to have caused the deformation in the overlying sedimentary rocks of the Newport-Inglewood Structural Zone.



MAP V - 3

NEWPORT - INGLEWOOD STRUCTURAL ZONE

On the ground surface this deformation is expressed by a linear series of low, eroded en-echelon fault scarps and a chain of low, right-hand en-echelon anticlinal hills and mesas. As a result of this deformation, numerous oil traps such as the Wilmington, Signal Hill, and Inglewood Oil Fields, have been formed.

Not much is really known about the Newport-Inglewood Structural Zone and the nature of the movements along it. The existence of the Newport-Inglewood Fault, supposedly at great depth, is even questioned by some geologists.

Within the zone there are several well documented faults, including the Inglewood, Charnock, Avalon-Compton, Cherry Hill, and others.

GEOLOGIC HISTORY

An igneous-metamorphic basement complex believed to be Mesosoic in age uncomformably underlies the sedimentary bedrock within the Los Angeles Basin. At the beginning of Pliocene time, a deep marine trough existed which subsequently was filled with a thick accumulation of sediments containing fossils characteristic of successively shallower seas. Marine and non-marine deposition is characteristic of the uppermost Pliocene and Pleistocene strata indicating regressing and transgressing seas.

Deformation in the Baldwin Hills is believed to have started between 10 to 26 million years ago during middle Miocene time or possibly earlier. It continued at least intermittently through Quaternary time and is still occurring. Recent deformation is evidenced by the prominent Inglewood Fault scarp, arching and offset of Pleistocene (geologically young) deposits, and by other youthful topographic features of the hills.

The uplifted Baldwin Hills were formed by the warping of Tertiary and Pleistocene sedimentary deposits, as a result of movement along the Newport-Inglewood Structural Zone. The gently arched deposits were shaped into an elongated northwest trending doubly plunging anticline or dome. Later, or during formation of this dome, it was fractured by numerous faults, creating a graben (actually a complex of grabens) across the top of the anticline. (A graben is formed when a block, usually of elongated shape, drops down, to a lower position relative to the surrounding rocks) (Chart V-3).

CONSTRAINTS AND SENSITIVITIES

Faults

In the Baldwin Hills, the Inglewood Fault is the main structural feature. It extends for at least 9 miles northwesterly from Rosecrans Hills, through the Baldwin Hills to the Beverly Hills area. It is actually a zone ranging from a few meters to 183 meters (600 feet) wide, of fractures with a main break. Another zone of fracturing parallels this zone to the west (map V-7). Numerous small en-echelon faults dissect, offsetting slightly, loose parallel faults.

The main fracture of the Inglewood Fault is located in the central portion of Site No. 2 along the east side of the northwest trending central valley, where it forms a prominent 84 meter (275 foot) high scarp.

It is between these two zones that the graben developed across the top of the anticline. Northwest trending gullies in this graben area may be the topographic expression of the numerous faults in these two zones.

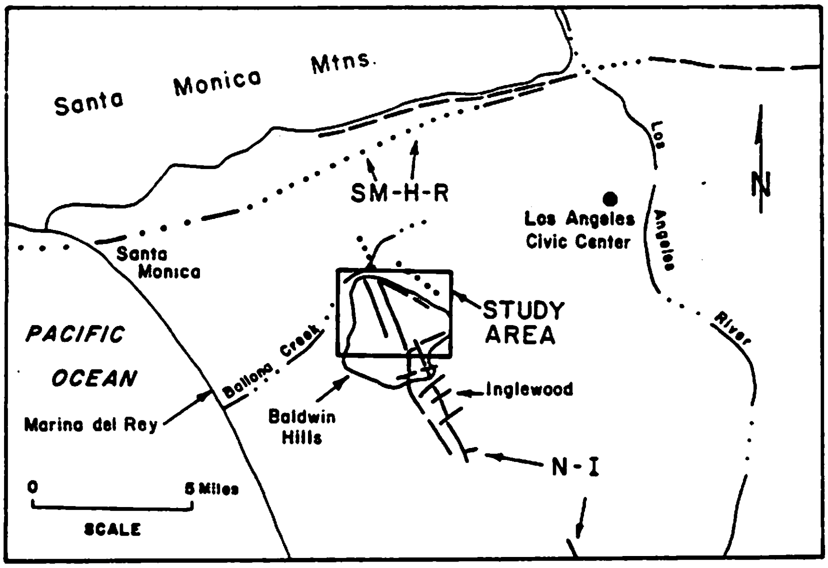
In addition to the two principal fault zones, many other faults transect the project area, either parallel to the Inglewood Fault or trending northeast across it. Most of these faults, and those in the two principal zones dip steeply from 50 degrees to 90 degrees.

Slope and/or Foundation Instability

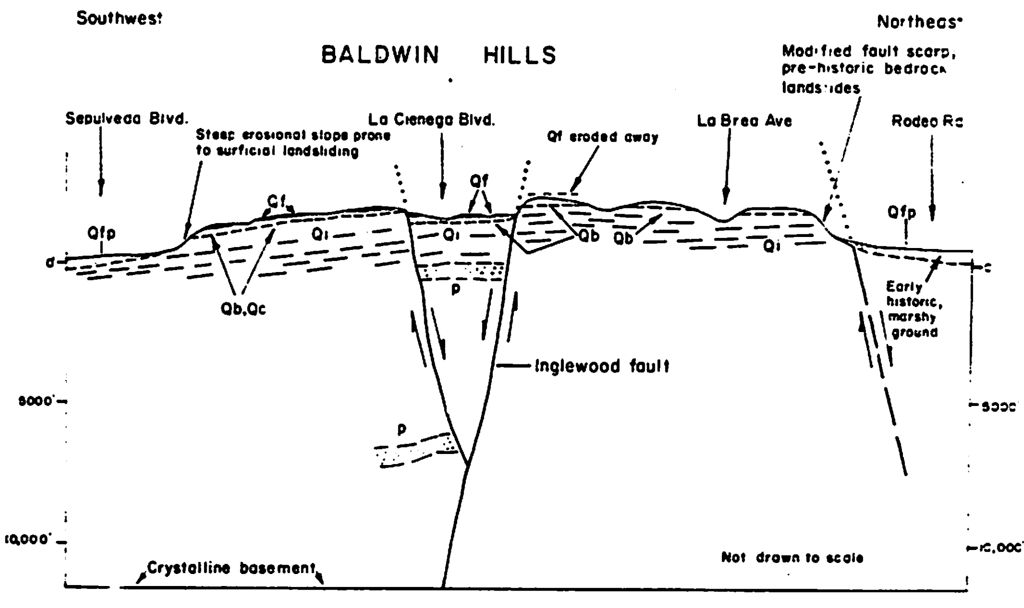
Residential tracts of the Baldwin Hills have suffered widespread damage from slope failures triggered by torrential rains in 1969, 1978 and 1980. Less widespread failures have occurred in other years. Most of these failures have taken place in the northern part of the hills, between La Cienega Boulevard and Stocker Street, in the City of Los Angeles, but they have also occurred in the western part of the hills which comprises part of Culver City and an unincorporated part of the County of Los Angeles.

The problems of slope instability are particularly severe in the Baldwin Hills for two reasons. First, the hills were mostly developed in the very late 1940s and the 1950s, prior to enactment of stringent grading codes by local governments. Second, the terrain developed consisted mostly of steep natural slopes underlain by soft sedimentary rocks. The resulting tracts contain graded and natural slopes with angles as steep as 45 degrees (1:1), or even steeper, commonly without proper drainage devices and retaining walls. (Modern grading codes require that cut and fill slopes be designed no steeper than 26 1/2 degrees (2:1), unless steeper angles can be shown to be stable). Additionally, fills were not emplaced as effectively as they would have been under today's more stringent compaction and supervision requirements.

Slope failures in the Baldwin Hills have occurred in the form of landslides and erosion, associated with unusually heavy winter rainfall. The landslides have consisted principally of surficial debris slides ("mudslides," including soil slips) and debris flows ("mudflows"). These failures are derived partly from the mantle of soil and slope wash that overlies the bedrock of natural slopes and partly from weathered bedrock and fill. Slopes underlain by the Inglewood Formation are particularly vulnerable to surficial slides and flows, because the surficial mantle developed on bedrock of this formation contains abundant clay material. Deep-seated landsliding as a cause of damage has been uncommon, although ancient landslides, previously unrecognized, were mapped. Erosion has consisted of rilling and gullying that commonly has occurred in slopes where the surficial mantle has been stripped away by surficial landsliding. Slopes underlain by the Culver sand are particularly vulnerable to erosion. Most of the slope failures mapped have damaged more than one property (chart V-1) (California Division of Mines and Geology Staff, 1982).



Detail of Figure 1 showing study area and other features of the west Los Angeles region. (Faults: N-I, Newport-Inglewood [structural zone]; SM-H-R, Santa Monica-Hollywood-Raymond [fault zone].)



Schematic cross section from southwest to northeast through the Baldwin Hills showing simplified geologic and topographic relationships. (Explanation: Qi, Inglewood Formation; Qb, Baldwin Hills sandy gravel; Qc, Culver sand; Qf, Fox Hills relict paleosol; Qfp, flood plain deposits; P, sands from which petroleum has been recovered.)

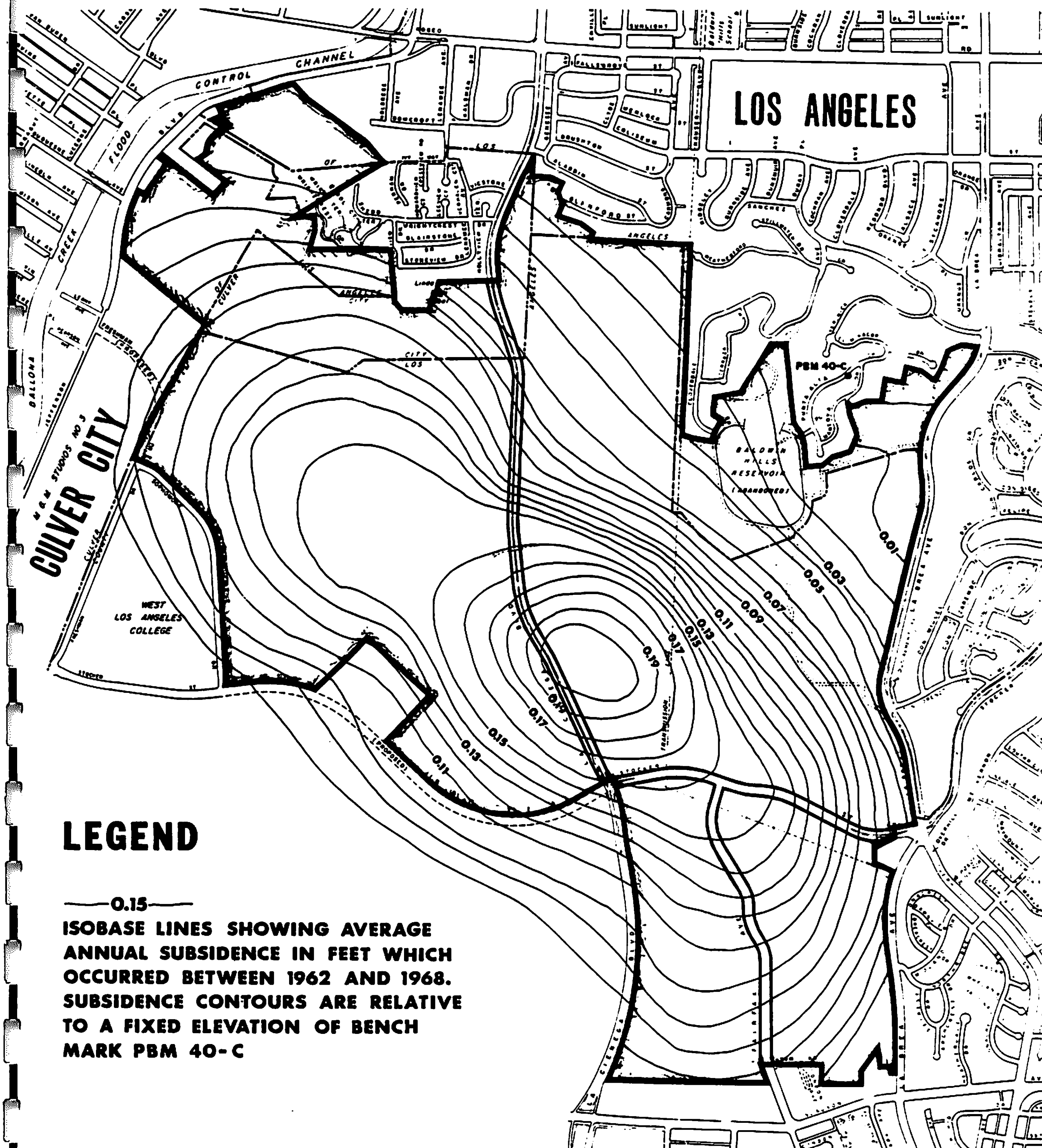
Land Subsidence

Subsidence, or vertical downward movement, of the ground surface related to operation of the Inglewood Oil Field (Castle and Yerkes, 1976, p. 92) has affected the site. The primary effect of the subsidence is decrease of ground surface elevations with some associated horizontal movements. Secondary geologic effects are earth cracking and fault displacements. Other relatively minor destructive effects include cracking of pavement and retaining walls as well as possible breaking of utility pipes (map V-4).

The accompanying subsidence map indicates the average annual rate in feet of vertical movement occurring between 1962 and 1968. Isobase lines based on a fixed elevation of bench mark PBM 40-C represent the annual, vertical movement rate on the map. The variation of the subsidence rate, represented by the isobase lines, indicates differential amount of vertical movement as a function of time. This differential amount of vertical movement as well as associated horizontal movement creates stresses on long horizontal structures in the subsidence area. When the stresses exceed the strength of the structure, rupture by cracking generally results (chart V-2).

According to Castle and Yerkes, the following associations indicate the reason for attributing the subsidence in the Northern Baldwin Hills to exploitation of the Inglewood oil field (1976, p.64):

1. The well-defined spatial association between the pattern of subsidence and the outlines of the oil field.
2. The centering of the subsidence bowl over the centers of both the oil field and the producing structure.



LEGEND

——0.15——

ISOBASE LINES SHOWING AVERAGE ANNUAL SUBSIDENCE IN FEET WHICH OCCURRED BETWEEN 1962 AND 1968. SUBSIDENCE CONTOURS ARE RELATIVE TO A FIXED ELEVATION OF BENCH MARK PBM 40-C

NORTH

0 400 1200 1600 feet

SUBSIDENCE

BALDWIN HILLS PROJECT

MAP V-4

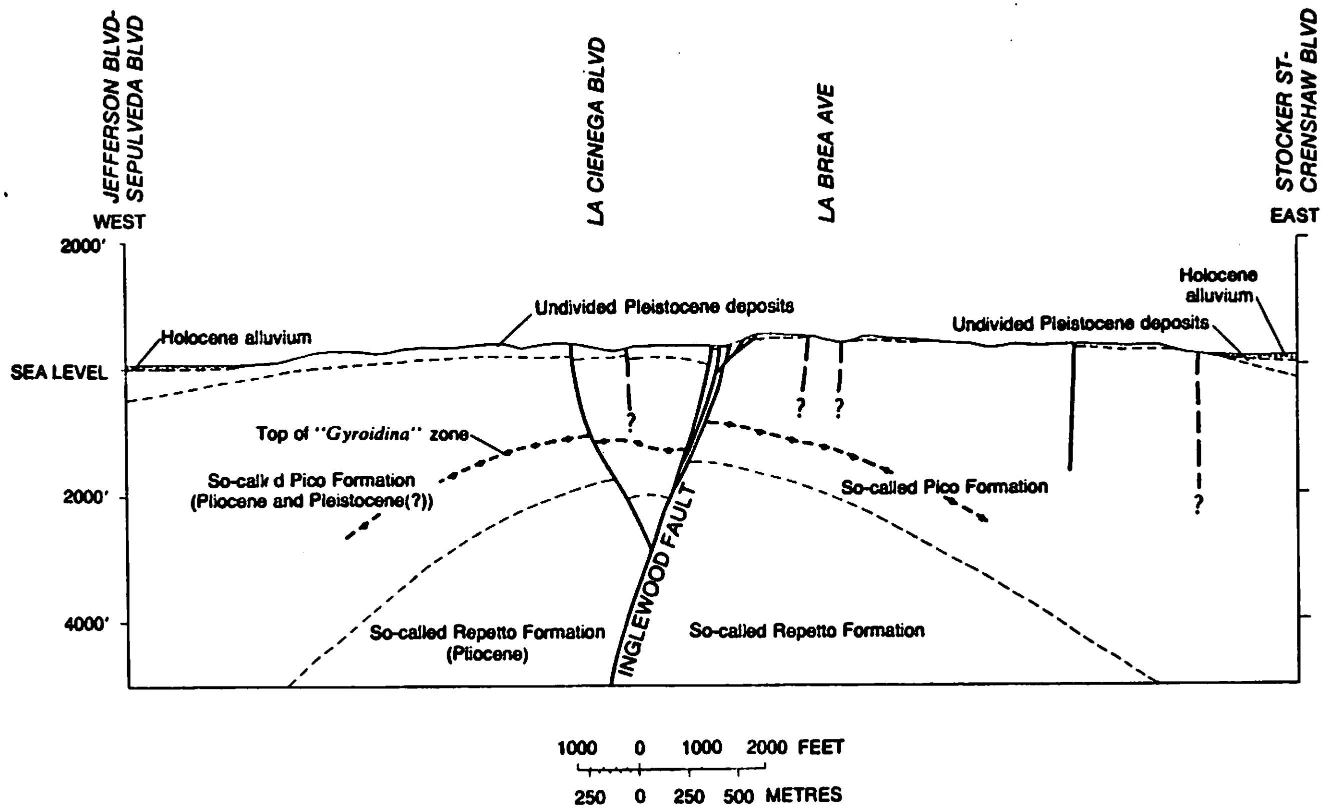


CHART V - 2

GENERALIZED GEOLOGIC SECTION OF THE NORTHERN BALDWIN HILLS (CASTLE & YERKES, 1976)

3. The approximate coincidence between the beginning of production and the beginning subsidence.
4. The nearly linear relations between liquid production and subsidence.
5. The sharp deceleration of subsidence in the east block associated with the establishment of a water-flooding program there.
6. The numerous oil fields having a recognized spatial and, to a lesser degree, temporal association between production and differential subsidence.
7. The many similarities between the Inglewood subsidence and the exploitation-related subsidence in the Wilmington oil field.
8. The mechanical compatibility of subsidence with liquid production and attendant reservoir pressure decline.

These associations and theoretical considerations (Castle and Yerkes, 1970, pp. 63, 64, 90 and 123-125) suggest ultimate com- compaction of the Vickers Zone of the Inglewood oil field should be about 3 meters (10 feet) (Castle and Yerkes, 1970, p.2). Between November 1911 and June 1962, the amount near the center of subsidence is calculated to be about 2 meters (6 feet). The amount of ultimate compaction depends on the production rate, the amount of flooding, and other technical recovery methods used. Economic fluctuations in the petroleum industry govern all of these factors of ultimate compaction and are not readily predictable.

Loss of Mineral Resources

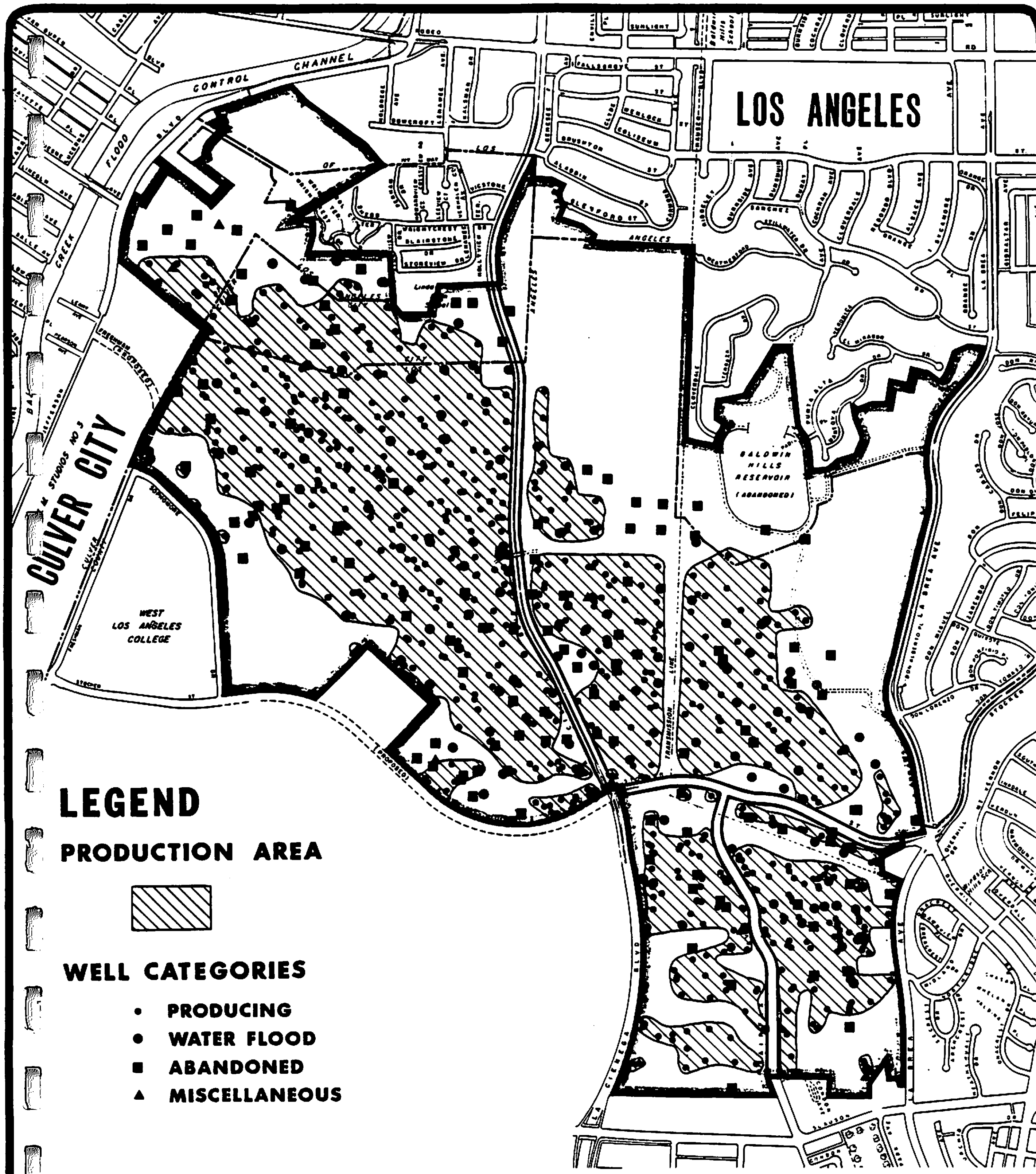
History:

Standard Oil Company of California discovered the Inglewood Oil Field in September of 1924. Development of the field proceeded rapidly with peak annual production of 18,371,536 barrels of oil and 377,643 million cubic meters (13,344,284 million cubic feet) of gas, occurring in 1925. In this year 150 wells were in production, many producing over 1,000 barrels of oil per day. "Rubel" 9 was the largest initial producing well at 4,614 barrels per day (map V-5).

The oil field includes 477.5 hectares (1,180 acres), in the western part of Baldwin Hills. The Inglewood Fault bisects the oil field into two separate components known as the east and west blocks. Essentially, these two blocks are separate oil fields, with nine separate oil bearing zones, one on top of another (charts V-3 and V-4). These nine zones range in depth from 290 to 3,049 meters (950 to 10,000 feet).

Production:

Between 1924 and 1976 approximately 304 million barrels of oil were extracted from the Inglewood Oil Field. During this same period 6.82 trillion cubic meters (241 trillion cubic feet) of gas was produced from the field. There are roughly 720 operable wells in the field. Of these, only about 440 are actually producing. During 1976, 3.4 million barrels of oil and 48 billion cubic meters (1,700 billion cubic feet) of gas were produced.



NORTH

0 400 1200 1600 feet

OIL WELL LOCATIONS

BALDWIN HILLS PROJECT

MAP V-5

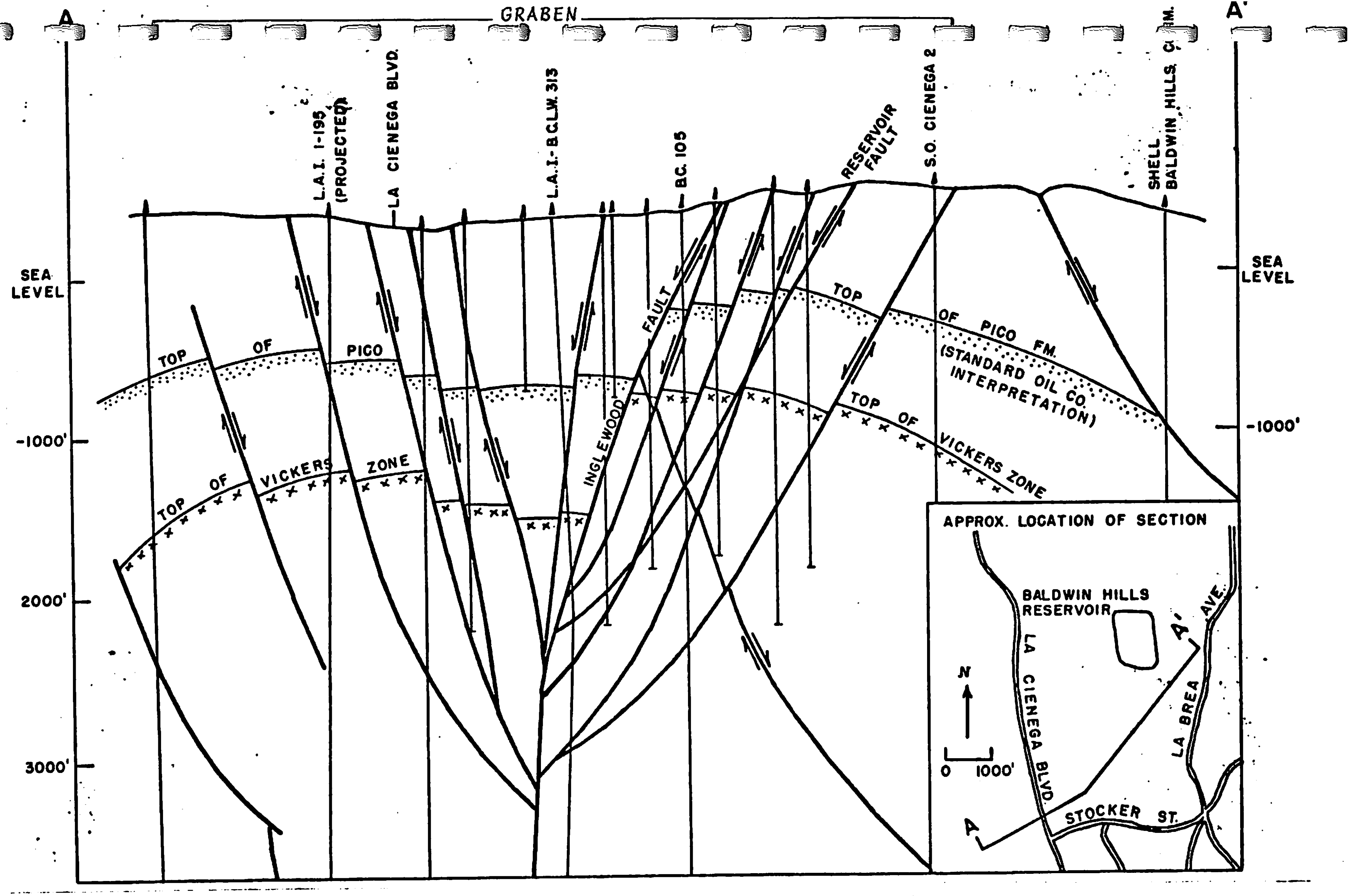


CHART V - 3

GEOLOGIC SECTION THROUGH INGLEWOOD OIL FIELD (AFTER CALIF. DWR 1964)

(Compiled by California Dept. of Water Resources, 1964, from information received from Standard Oil Co. of California.)

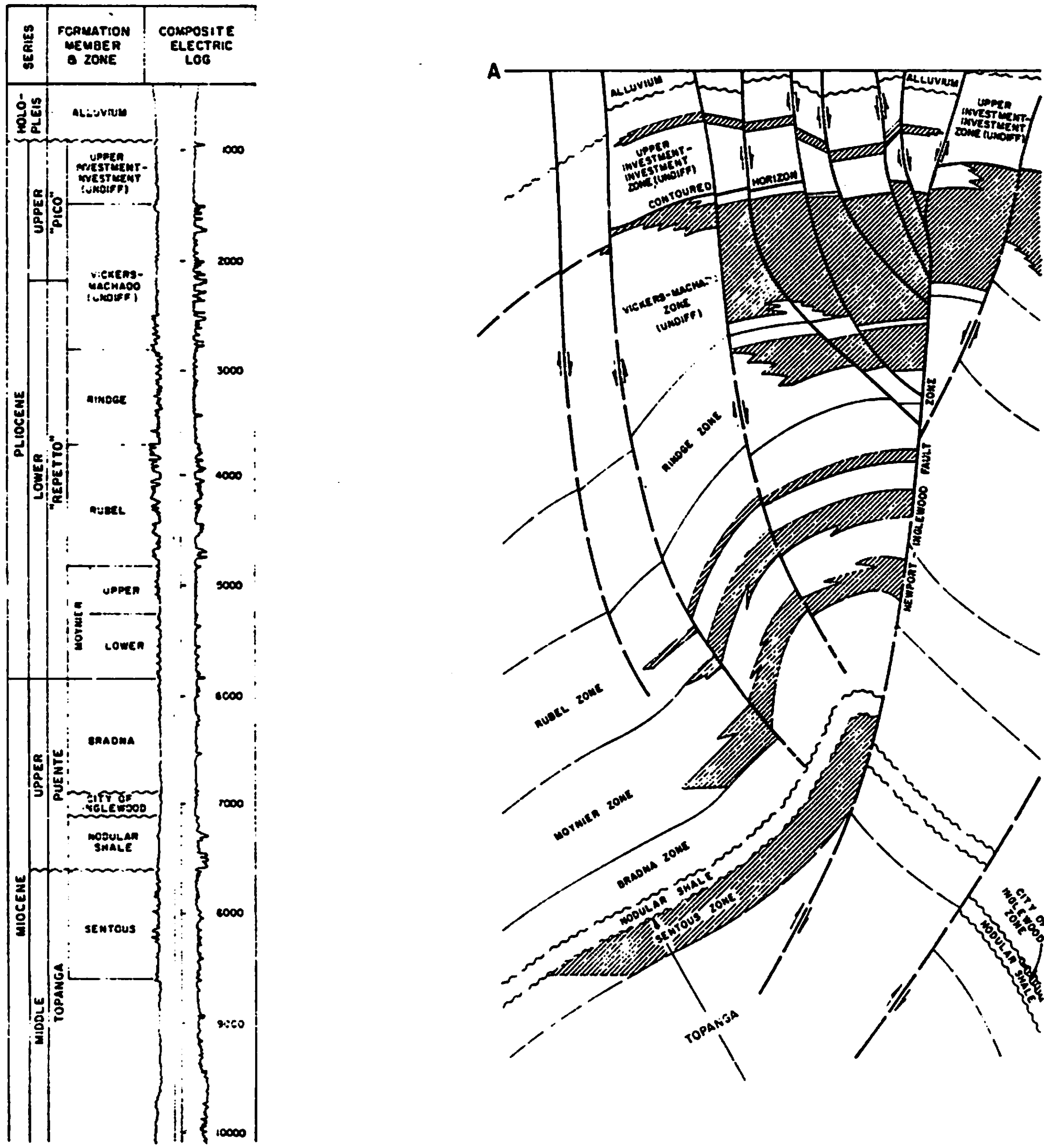


CHART V - 4

GEOLOGIC COLUMN & SECTION - INGLEWOOD OIL FIELD

In 1954 a water flooding (water injection) test program for secondary recovery was initiated. Full scale water flooding began in 1957 and has continued through the present. This technique is used to increase the oil yield. As a side benefit it has also decreased the rate of ground surface subsidence at the site.

Life of the Inglewood Oil Field:

The life of an oil field is based on the size of the field's oil reserve. A "reserve" is the amount of oil which can be removed profitably. The size of the reserve will, therefore, change as a function of the price of oil and the cost of operating the well. As the price of oil increases the size of the reserve increases, thereby extending the life of the field. This increase is offset to some degree by increases in the well operating costs.

Today, the Inglewood Oil Field has a reserve of approximately 58 billion barrels of oil and 509 billion cubic meters (18,000 billion cubic feet) of gas. The current trend and the trend for the foreeseeable future is for an increasing price of oil. If this is the case, the Inglewood Oil Field's reserve will increase extending its economic life.

Economic Impacts:

A January 1977 report, Estimated Life of Production Inglewood Oil Field, by Consulting Petroleum Engineer N. van Wingen, calculated the estimated life of Inglewood Oil Field based on hydrocarbon prices and costs of operation in effect for October and November 1974. Because different oil-bearing zones reach their economic limit at different times, the estimate is by well groupings rather than the entire field or individual wells (Some wells are listed separately). This estimate was as follows (Refer to maps with van Wingen report for well group locations).

Project Standard Oil Company	Estimated year when Economic Limit is Reached
Vickers East	1978
East Rubel	1988
Investment	1982
West Vickers-Rindge	1984
West Moynier Footwall Block	1986
West Rubel Zone Unit	1989
Vickers-Rindge Unit	1992
Getty Oil Company	
Vickers-Machado Rindge	1989

Non-Project Zone Standard Oil Company	Estimated year when Economic Limit is Reached
Moynier	1984
Bradna	1980
City of Inglewood	1977
Vickers	1988
Rindge	1989
Sentous	Uneconomical
Machado Lease	
Moynier	1978
Sentous	1977
Getty Oil Company	
Rubel-Moynier-Sentous	1988

Getty may instigate a water flood project for their Rubel zone in 1977.

Estimated life 15 years or to 1992.

Block Oil Company	
Moynier	1978
Vickers	1986
Sentous	1977

California Southern Oil Company	
Moynier	1981

Sentous 1981

Federal Oil Company

Sentous est. 1981

As can be seen under the economic conditions of October/November 1974, the last well group would reach its economic limit in 1992, with the remaining wells group reaching their economic limits between 1977 and 1989.

Since the January 1977 report, the estimated life of production has changed. Increasing oil prices are making it profitable to operate low producing wells for a longer period of time. It is now profitable to operate a ten barrel per day well: whereas before it might not have been. Idle or abandoned wells can be re-drilled and commence production. Non-economic wells can be used to stimulate other wells by using them for water flooding, gas, steam, or chemical injection. Remedial work alone might extend the life of some wells by four to five years.

New Technology:

Historically, improved technology has improved oil and gas recovery. New hydrocarbon recovery technology has two effects on production. First, new technology may result in decreased lifting costs (operating costs), thus extending the economic limit. Second, new technology may increase the yield of oil and or gas, also extending the economic limit.

Technology exists today that was too costly to be profitable at former oil and gas prices. However, in many cases these methods are now profitable to use, thereby extending the life of the oil field. Caustic flooding and injection of oil solvents, and other chemical flooding are a few of the methods now being developed to increase recovery.

In summary, the Inglewood Oil Field will probably not reach its economic limit until sometime past the year 2000. While some date when the oil field will reach its economic limit might be estimated now, the probability is that with the advent of new technology and higher oil and gas prices, the date will be pushed further and further into the future.

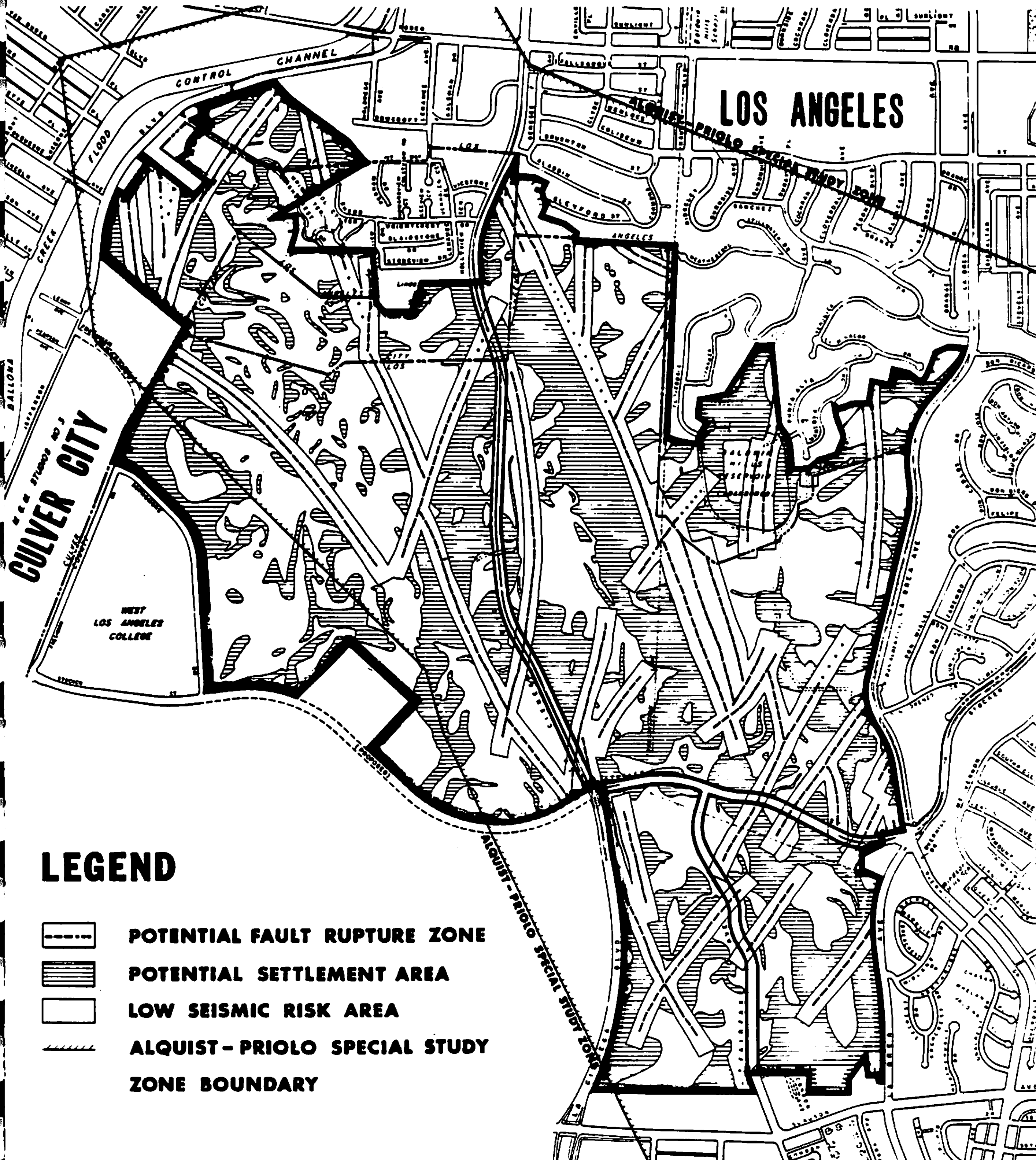
Abandoned Wells:

Present day state regulations regarding capping and abandonment of of oil wells were put into effect in 1950. Prior to 1950 many wells were not abandoned in accordance with acceptable standards. There are over 50 wells in the Inglewood Oil Field that were abandoned prior to 1950. The State of California has jurisdiction over abandonment of oil wells. It does not require re-abandonment of oil wells abandoned prior to 1950.

Earthquake History

The Baldwin Hills lie across and are an expression of, the Newport Inglewood structural zone. This zone comprises the complex system of faults and folds that extend from West Los Angeles southeastward through the Inglewood-Long Beach areas of Los Angeles County, into Orange County. It may extend offshore southeastward toward the San Diego area and perhaps beyond. The Baldwin Hills is a gently arched dome, slightly elongated in a northwesterly direction. It is breached by a north-northeast trending graben (a down-dropped block). Within this graben, late Quaternary sediments are displaced downward along the Inglewood fault on the east side and an unnamed fault on the west side (chart V-1). Castle and Yerkes (1976, p. 5) indicate that 914 to 1,219 meters (3,000 to 4,000 feet) of right lateral displacement has occurred along the Inglewood fault since middle or late Pleistocene time. A 457 to 610 meter (1,500 to 2,000 foot) right lateral displacement in Quaternary time is also suggested by the apparent offset along the fault of topographic features of the Baldwin Hills (map V-6).

The youthfulness of movement along the Inglewood fault is expressed by a well-developed scarp that lies along the east side of the graben in the central Baldwin Hills. This scarp extends almost continuously south-southeasterly from La Cienega Boulevard to about Stocker Street, where the Inglewood fault apparently is displaced slightly to the northeast by a series of Northeast-trending faults. The fault and accompanying scarp continue south-southeasterly to beyond the south edge of the study area. Geologic investigations (Engineering Geology Consultants, Inc. 1975) have indicated that Holocene materials have been displaced at the ground surface along the Inglewood fault and certain other faults of the Baldwin Hills-Inglewood region. These faults are considered to be capable of rupturing the ground during moderate to large earthquakes and have been included in "special studies zones" by the State of California (Hart, 1980). The study was mandated by the Alquist-Priolo Special Studies Zones Act (map V-7). Castle (1960a) shows the Inglewood



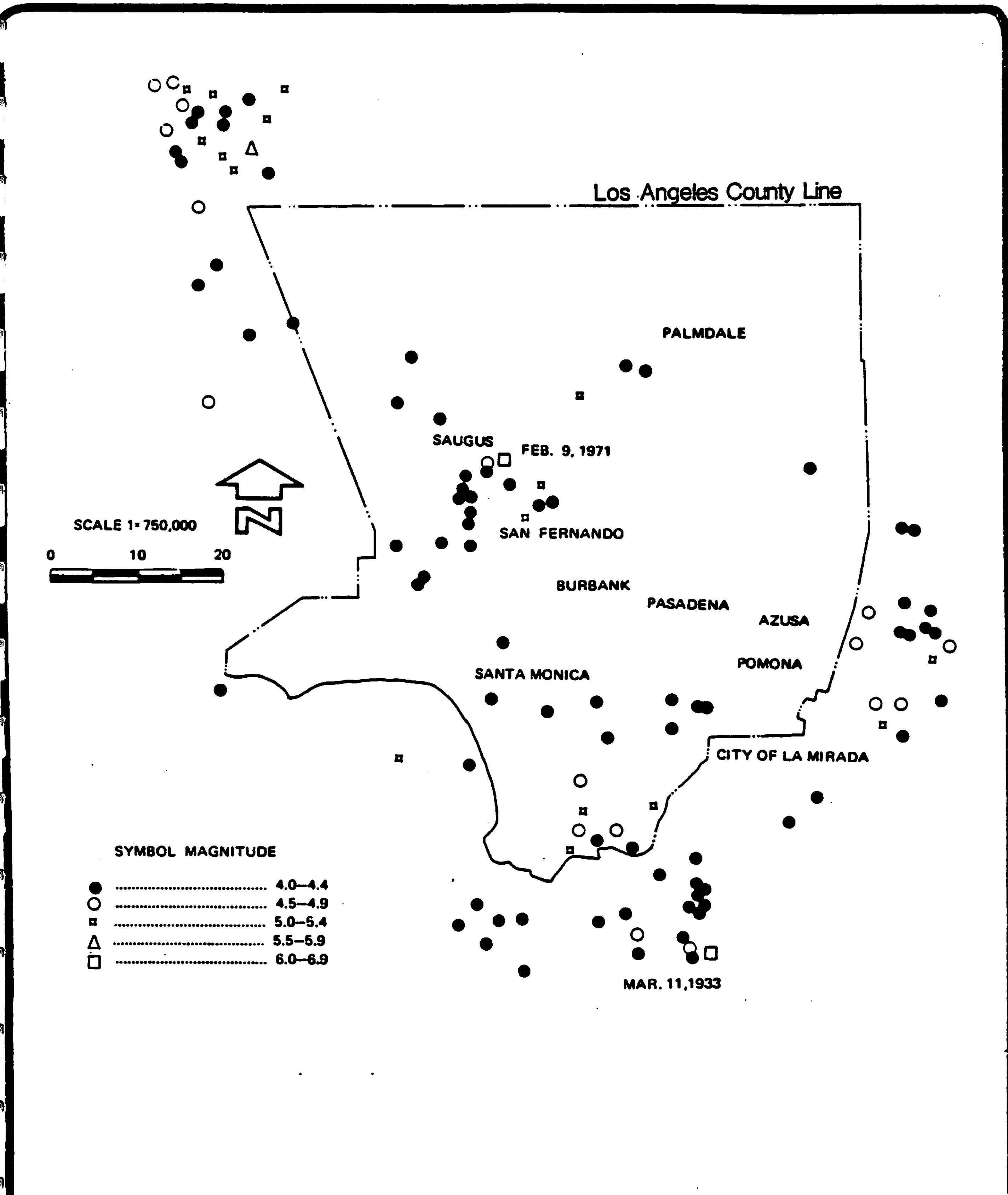
NORTH

0 400 1200 1600 feet

SEISMIC ZONE

BALDWIN HILLS PROJECT

MAP V-6



NORTH 0 10 20

SCALE 1: 750,000

EARTHQUAKE EPICENTERS

BALDWIN HILLS PROJECT

MAP V-7

fault to be offset by northeast-trending faults in the general vicinity of where it crosses Stocker Street. Chevron USA, Incorporated research indicates that faults splay or branch from the Inglewood fault in the vicinity of Stocker Street, but that the fault is essentially throughgoing in the present study area (R.C. Erickson, Chevron USA Inc., personal communication, 1981). There is no evidence of surface faulting caused by historic earthquakes along the Inglewood or other faults in the study area (table V-1).

Historic damaging earthquakes have occurred along the Newport-Inglewood structural zone, but not in the study area. The closest of these occurred on June 21, 1920, probably on the Inglewood fault, and surely within the Newport-Inglewood structural zone. The magnitude of the Inglewood earthquake was calculated later by Richter (1970) at 4.9. Though of small magnitude, the earthquake may have caused damage locally, because it occurred at a relatively shallow depth. Small earthquakes in the area in recent years have occurred at relatively shallow depths of 4.8 to 8 kilometers (3 to 5 miles) (based on the work of Teng and others, 1973 and 1978).

Ground shaking during the Inglewood earthquake was reported by Taber (1920) to have resulted in some ground effects (including lurch cracks) caused by liquefaction in the floodplains of Ballona and Centinella creeks in the southwest corner of the project area. The Baldwin Hills were undeveloped at the time of the Inglewood earthquake. Although unrecorded, small, surficial landslides may have been triggered by seismic shaking in the steepest terrain.

TABLE V - 1

NAMED ACTIVE FAULTS IN LOS ANGELES COUNTY

FAULT	DATE OF ACTIVITY	MAGNITUDE OF EARTHQUAKE	DISTANCE FROM SITE TO NEAREST POINT ON FAULT
Newport-Inglewood	1933	6.3	0 miles (0 km)
Norwalk	1929	4.7	20 miles (32 km)
Raymond Hill	3000 years	unknown	14 miles (22 km)
San Andreas	1857	8.0	40 miles (64 km)
San Fernando	1971	6.4	20 miles (32 km)
San Jacinto	1918	unknown	40 miles (64 km)

Both surficial and bedrock landslides in the hills could be triggered by strong groundshaking during future earthquakes, especially during rainy periods when the ground is saturated.

The Long Beach earthquake, magnitude 6.3, occurred along the Newport-Inglewood structural zone offshore from Huntington Beach on March 10, 1933. This earthquake caused heavy destruction in the Long Beach-Compton area and more than 100 deaths (Barrows, 1973, 1974). The effects of this earthquake apparently were not experienced in the Baldwin Hills area.

Surficial landslides and reactivation of large, deep-seated landslides were caused by severe ground shaking during the February 9, 1971 San Fernando earthquake (Morton, 1975). Most of these landslides were in very sparsely developed foothills of the San Gabriel Mountains north of the western San Fernando Valley. Even though the landslides were relatively widespread, the ground was nearly dry; if the ground had been saturated by rainfall, landsliding could have been much more severe. The results of possible future, severe ground shaking in the Baldwin Hills could be similar to what happened in the hills north of San Fernando. It is possible that larger, deep-seated landslides could be activated, causing severe property damage, especially if the ground is saturated following prolonged rainfall. If the ground were to be saturated, fill slumps and settlement also could be common (California Divison of Mines and Geology Staff, 1982).

RECOMMENDATIONS

Additional or more detailed geology and/or soils reports would depend on the nature of the proposed development.

Where graded slopes are proposed, an analysis of the slopes from both a geological and a soils standpoint should be required to determine their stability.

Subsurface geological mapping would be required in the area of proposed structures to determine that they would not be located directly upon a fault trace.

Any grading associated with the development of the project should conform to chapter 70 of the Los Angeles County Unified Building Code.

No structure should be located upon uncompacted or uncertified fill without the recommendations of a qualified Soils Engineer.

Structures should be designed for both seismic and subsidence potential.

Subsidence monitoring should continue.

Seismic monitoring should continue.

REFERENCES

Barrows, A.G., 1973, Earthquakes along the Newport-Inglewood structural zone: California Geology, v. 26, no. 3, p. 60-68.

Barrows, A.G., 1974, A review of the geology and earthquake history of the Newport-Inglewood structural zone, Southern California: California Division of Mines and Geology Special Report 114, 115p.

California Division of Mines and Geology staff, 1980, Slope stability study of the Baldwin Hills, Los Angeles County, California: California Division of Mines and Geology Open-File Report 80-14 LA, 162 p.

California Division of Mines and Geology staff, 1982, Slope Stability and Geology of the Baldwin Hills, Los Angeles County, California: California Division of Mines and Geology Special Report 152, p. 3-6.

Castle, R.O. 1960a, Geologic map of the Baldwin Hills area, California: U.S. Geological Survey Open-File Report, map scale 1:12,000.

Castle, R.O. and Yerkes, R.F., 1976, Recent surface movements in the Baldwin Hills, Los Angeles County, California: U.S. Geological Survey Professional Paper 882, 125p.

County of Los Angeles, Department of County Engineer, 1975, Geologic-Seismic Report of Proposed Baldwin Hills Regional Park, dated August 22, 1975.

Guptill, Paul D. and Heath Edward G. 1981. Surface Faulting Along the Newport-Inglewood Zone of Deformation: California Geology, V. 34, No. 7, p. 142-148.

Engineering Geology Consultants, Inc. 1975, Geologic-seismic investigation of proposed Baldwin Hills regional park sites: Unpublished geotechnical report for Los Angeles County Counsel, Engineering Geology Consultants, Inc., Van Nuys, California.

Hart, E.W., 1980, Fault rupture hazard zones in California: Alquist-Priolo Special Studies Zones Act of 1972 with index to special studies zones maps. California Division of Mines and Geology Special Publication 42; revised March 1980, 25 p. (Newport-Inglewood fault zone; Figures 1 and 5e).

Kovacs-Byer and Associates, 1982, Geologic and Soils Engineering Investigation, Phase 1, Baldwin Hills Regional County Park, South and West of Baldwin Hills Reservoir, Los Angeles County California: Kovacs-Byer and Associates, p. 32, plus tables and plates.

Taber, Stephen, 1920, The Inglewood earthquake in Southern California, June 21, 1920: Seismological Society of America Bulletin, v. 10, no. 3, p. 129-145.

Yerkes, R.F., McCulloh, T.H., Schoellhamer, J.E. and Vedder J.G., 1965, Geology of the Los Angeles Basin, California - An Introduction: USGS, pp. 420-A., p. 57.