LOS ANGELES BASIN PROVINCE (014)

By Larry A. Beyer

INTRODUCTION

The Los Angeles Basin Province is located in coastal southern California. Its primary geologic feature is a Neogene basin whose foundations were controlled by Cretaceous subduction and Late Cretaceous-Paleogene terrane accretion. Neogene structural development consisted of mid-Miocene to early Pliocene extension, strike-slip faulting and problematic block rotation, and late Pliocene to present north-south compression (Wright, 1991).

The province is bounded on the southwest by the 3-mi offshore limit of state waters, on the north by the Malibu Coast-Santa Monica-Hollywood-Raymond Hill-Duarte Fault System, and on the east and southeast by the onlap of marine rocks on the Southern California Batholith and Santa Ana Mountains and San Joaquin Hills Uplifts (Beyer, 1988).

The principal geologic feature is a northwest-trending central syncline about 45 mi long and 20 mi wide that contains at least 24,000 ft of late middle Miocene and younger marine clastic rocks overlying older Cenozoic sedimentary rocks and (or) Mesozoic basement rocks. The central syncline is bordered on the southwest by the Newport-Inglewood zone of deformation and adjacent southwest structural shelf, on the north by an east-west trending fault and fold belt at the southern edge of the Santa Monica Mountains, and on the northeast by east-west-trending en echelon folds and the Whittier Fault Zone. The overall triangular-shaped province occupies about 2,200 mi^2.

Commercial oil discovery began in the 1880's and 1890's when oil was first produced from oil seeps, hand-dug pits, and shallow wells. The large majority of discovered accumulations occur in marine turbidite sandstones of late Miocene to early Pliocene age (upper Mohnian, Delmontian, and "Repettian" stages). Principal oil accumulations (>100 MMBOE) with discovery year and cumulative production plus estimated reserves through 1992 are (California Division of Oil, Gas and Geothermal Resources, 1993):

Wilmington-Belmont (1932, 2.857 BBO, 1.235 TCFG)

Huntington Beach (1920, 1.138 BBO, 861 BCFG)

Long Beach (1921, 945 MMBO, 1.088 TCFG)

Santa Fe Springs (1919, 634 MMBO, 839 BCFG)

Brea-Olinda (1880, 430 MMBO, 482 BCFG)

Inglewood (1924, 400 MMBO, 285 BCFG)

Dominguez (1923, 277 MMBO, 387 BCFG)

Coyote, West (1909, 256 MMBO, 272 BCFG)

Torrance (1922, 246 MMBO, 158 BCFG)

Seal Beach (1924, 216 MMBO, 225 BCFG)

Richfield (1919, 203 MMBO, 173 BCFG)

Montebello (1917, 202 MMBO, 235 BCFG)

Beverly Hills, East (1966, 130 MMBO, 165 BCFG)

Coyote, East (1911, 122 MMBO, 61 BCFG)

Rosecrans, including Rosecrans South & East (1924, 94 MMBO, 190 BCFG)

Yorba Linda (1930, 106 MMBO, 2 BCFG)

Fifteen of these 16 principal accumulations, which account for 91 percent of province totals, were discovered before 1933. Cumulative production plus estimated reserves from 50 smaller accumulations (including 19 fields with < 1 MMBOE) is 755 MMBO and 1.116 TCFG. Cumulative production plus estimated reserves of the entire province through 1992 are 8.881 BBO, 7.609 TCFG (10,149 MMBOE).

The most recent significant discoveries occurred during the early to mid-1960's (Beverly Hills East, Las Cienegas (Jefferson area), Riviera, San Vicente). Exploration drilling in various parts of the basin, progressively hampered and curtailed by urbanization and drilling bans over the past 40 years, averaged two wells per year from 1975 through 1991.

The Los Angeles Basin Province is divided into seven conventional confirmed plays and one hypothetical unconventional continuous-type play. These plays are Santa Monica Fault System and Las Cienegas Fault and Block Play (1401), Southwestern Shelf and Adjacent Offshore State Lands Play (1402), Newport-Inglewood Deformation Zone and Southwest Flank of Central Syncline Play (1403), Whittier Fault Zone and Fullerton Embayment Play (1404), Northern Shelf and Northern Flank of Central Syncline Play (1405), Anaheim Nose Play (1406), Chino Marginal Basin, Puente and San Jose Hills, and San Gabriel Valley Marginal Basin Play (1407), and Deep, Overpressured Fractured Rocks of the Central Syncline Hypothetical Play (1408).

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CONVENTIONAL PLAYS

1401. SANTA MONICA FAULT SYSTEM AND LAS CIENEGAS FAULT AND BLOCK PLAY

The confirmed structural-stratigraphic play consists of oil and associated gas accumulations largely in turbidite sandstone reservoirs of upper Miocene and Pliocene age located along the northern margin of the Los Angeles Basin in the area controlled by the Malibu Coast-Santa Monica-Hollywood Fault trend. The complicated structural history and turbidite depositional systems of this play have combined to generate complex and varied reservoir traps that generally are distinctive when compared to adjacent province areas.

The northern play boundary is drawn slightly north of the northernmost surface trace of the Santa Monica Fault Zone to include possible oil reservoirs located in footwall blocks beneath north-dipping faults. From the shoreline, the southern play boundary extends eastward just south of the southernmost frontal faults and related structural disturbances of the Santa Monica Fault and past the northwest projection of the Newport-Inglewood zone of deformation and Central Syncline at the "Ballona gap" of Wright (1991). The southern boundary then curves southeastward and thence turns back northward to encompass the footwall block of the Las Cienegas Fault and the "Las Cienegas block" of Wright (1991), including the Los Angeles Downtown and Los Angeles City oil fields in the play.

Westward from the shoreline, the southern play margin coincides with the seaward boundary of offshore State waters and extends to near Point Dume, California to include (1) structural features whose trends seem related to the Malibu Coast Fault Zone and (2) stratigraphic intervals that appear on seismic sections to be genetically related to onshore sections to the east.

Reservoirs: Most discovered and likely undiscovered reservoirs are marine turbidite sandstones of the upper Mohnian, Delmontian, and "Repettian" stages. Oil reservoirs may also occur in fractured principally lower Mohnian shale, particularly in the western and offshore play area. Small amounts of gas, as found in the Los Angeles Downtown field, may occur in upper Pliocene sandstone. Sandstone or fractured rock of the middle Miocene Topanga Formation and older sequences may also be reservoirs, although no accumulations have been discovered in these rocks and their reservoir characteristics may be less favorable when compared to younger rocks.

Source Rocks: Comparatively high sulfur oil (> 2 percent) has been generated in the mature, lower Mohnian basal unit ("nodular shale") of the Modelo Formation, which is sapropelic rich with an average TOC of 5.6 weight percent (Jeffrey and others, 1991). Comparatively low sulfur oil (< 2 percent) found in the eastern play area came from lower sulfur kerogen in mature, Mohnian through "Repettian" shales located in the northernmost part of the Central Syncline (McCulloh and others, 1993).

Timing and migration: Maturation and expulsion of hydrocarbons probably began during early Pliocene or earlier, and trap formation has been more or less continuous since late Miocene in this play.

Traps: Discovered structural traps include west- and northwest-trending anticlines, faulted anticlines, and faulted homoclines. Discovered stratigraphic traps mostly are pinchouts on homoclines, thinning on plunging noses, and lenticular sands. Traps near the Santa Monica Fault Zone occur in the footwall (south) block and are complex structures partly involving overturned folds (Wright, 1991). Other traps on the western part of the northern shelf are related to generally east-west-trending reverse faults that dip steeply toward the north. Seals are low permeability fault zones, claystone and encapsulating shale, and tightly cemented sandstone. Discovered accumulations occur at depths from about 200 to 10,800 ft and range in thickness from about 30 to 2,000 ft.

Exploration status: Exploration in this play is relatively mature, although prohibition against exploratory drilling has prevented a normal progression of exploration since about the late 1960's. Larger oil discoveries (> 50 MMBOE) with discovery year and cumulative production plus estimated reserves through 1992 are: Beverly Hills East (1966,130 MMBO, 165 TCFG), Las Cienegas (1960, 66 MMBO, 56 BCFG), Riviera (1966, undeveloped, 50 MMBO estimated), and Salt Lake (1903, 54 MMBO, 212 BCFG) (California Division of Oil, Gas, and Geothermal Resources, 1993). Eight smaller discoveries, including one accumulation with < 1 MMBOE, contribute an additional 142 MMBO and 242 BCFG for play totals of 442 MMBO and 725 BCFG at the end of 1992. Undiscovered oil is likely to have API gravities in the higher part of the 9û to 35° API range of discovered oils and variable sulfur content. Depths of undiscovered accumulations may be in the depth range of deeper discovered reservoirs or deeper.

Resource potential: The exploratory drilling prohibition combined with the structural and stratigraphic complexity of the play suggest that undiscovered accumulations remain. The number and size of remaining undiscovered accumulations is not great but several accumulations measured in tens of millions of barrels might be found.

Undrilled areas are present onshore and offshore but prohibitions against drilling have curtailed exploration for the foreseeable future.

1402. SOUTHWESTERN SHELF AND ADJACENT OFFSHORE STATE LANDS PLAY

The confirmed structural-stratigraphic play consists of oil and associated gas accumulations largely in turbidite sandstone reservoirs of upper Miocene and Pliocene age located on the western stable shelf of Los Angeles Basin. The comparatively simple structural history, less complex reservoir traps, more distal turbidite facies, higher sulfur oil, and occurrence of some reservoirs in basement rocks are distinctive characteristics of this play.

The southwest boundary of this play is the seaward limit of the offshore State waters and the Palos Verdes Hills Fault and its offshore extensions. The northern play boundary is common with the southern boundary of play 1401 and represents the approximate northern limit of the stable shelf. The northeast play boundary is drawn approximately along the structural low that separates the southwest flank of the Newport-Inglewood zone of deformation from the stable shelf and is extended southeastward to the seaward boundary of State tidelands.

The major structural elements of this play are the northwest-trending, doubly plunging anticline that underlies the Palos Verdes Hills, the steeply southwest-dipping Palos Verdes Hills Fault Zone on which the hills are upthrown along their northeast margin, and the buried northwest-trending anticlinal arches in the basement surface and overlying sedimentary rocks where discovered oil fields are located north to southeast of the hills (Yerkes and others, 1965).

Reservoirs: Discovered and likely undiscovered reservoirs are primarily marine turbidite sandstones of the upper Mohnian, Delmontian, and "Repettian" stages. Lesser discovered and possible undiscovered reservoirs are lower Mohnian fractured shale, pre-Mohnian basal conglomerates or breccia derived from the Catalina Schist basement (San Onofre Breccia), and fractured and weathered Catalina Schist basement. Up to 5,000 ft of middle Miocene Topanga Formation present in part of the offshore State lands in the southeastern play area are unlikely to be reservoir rocks because they are stratigraphically and mostly structurally below source rocks.

Source rocks: The generally high sulfur oil (> 2 percent) found in discovered reservoirs of this play has migrated from the lower Mohnian organic-rich basal unit ("nodular shale") of the Monterey Formation (Walker and others, 1983; McCulloh and others, 1993).

Timing and migration: Maturation and expulsion of hydrocarbons probably began during Pliocene, and trap formation has been more or less continuous since early Pliocene time in this play. Some oil has migrated from onlapping lower Mohnian source rocks into the structurally higher schist basement and pre-Mohnian basal conglomerate (Yerkes and others, 1965).

Traps: Discovered traps include (1) anticlines and faulted anticlines that involve basement folding and faulting, (2) fractured and weathered basement rock and basal conglomerate or breccia, and (3) lenticular and overlapped sandstones. Seals are low permeability clastic beds and fault zones. Discovered accumulations occur at depths from about 1,500 to 9,400 feet and range in thickness from about 15 to 1,050 ft.

Exploration status: Exploration onshore is very mature. Drilling in recent decades has been largely prohibited by urbanization and environmental regulations. Except for offshore development of the Torrance-Wilmington-Belmont-Huntington Beach accumulations, few other offshore tests have been made and environmental regulations prohibit drilling outside developed field areas.

Larger oil discoveries (>50 MMBO) with discovery year and cumulative production plus estimated reserves through 1992 are: Huntington Beach (offshore)(1920, 583 MMBO, 321 BCFG), Playa del Rey (1929, 63 MMBO, 62 BCFG), Torrance (onshore & offshore) (1922, 246 MMBO, 158 BCFG), and Wilmington-Belmont (onshore & offshore) (1932, 2.857 BBO, 1.235 TCFG) (California Division of Oil, Gas, and Geothermal Resources, 1993). Six smaller discoveries, including two accumulations each <1 MMBOE, contribute an additional 26 MMBO and 45 BCFG for play totals of 3.775 BBO and 1.821 TCFG at the end of 1992.

Undiscovered oil is likely to have gravities in the higher part of the 10û API to 36û API range of discovered oils and sulfur content of 1 to 2 percent or more. Depths of undiscovered accumulations may be in the depth range of deeper discovered reservoirs or deeper.

Resource potential: Only minor to small accumulations remain undiscovered onshore. Offshore potential north of the Palos Verdes Hills probably is limited to a few mostly small accumulations based on extrapolation of nearby onshore discoveries. South of the Palos Verdes Hills, thick sections of upper Mohnian through "Repettian" distal turbidite sand facies lap in part around a submarine high (Redin, 1991). Nearby charged reservoirs indicate availability of oil but traps are reported to be lacking on proprietary seismic sections. Stratigraphic traps formed against the submarine high might exist. The offshore potential in this area is moderately well tested and, although low, probably is higher than in offshore State waters north of the Palos Verdes Hills. Offshore drilling is banned except in existing field areas.

1403. NEWPORT-INGLEWOOD DEFORMATION ZONE AND SOUTHWESTERN FLANK OF CENTRAL SYNCLINE PLAY

The confirmed structural-stratigraphic play consists of oil and associated gas accumulations largely in turbidite sandstones of upper Miocene and Pliocene age in the Newport-Inglewood zone of deformation (and its southeast extension into offshore State lands) and portions of the adjacent Central Syncline. The adjacent flank of the Central Syncline is included in this play because data from seismic reflection and earthquake seismicity indicate one or more buried fault zones on the southwest flank of the Central Syncline. These faults may be genetically related to the Newport-Inglewood zone of deformation and represent the northeast boundary of the Catalina Schist basement (Wright, 1991). The southeast part of the northern play boundary is drawn to include the Pelican Hills Fault in the San Joaquin Hills and is extended offshore to include the offshore part of the Newport-Inglewood zone of deformation. Evidence for intermittent tectonic activity from at least as early as mid-Miocene to present gives this play a distinctive structural history.

Reservoirs: Discovered accumulations are primarily marine turbidite sandstones of late Miocene and early Pliocene age (upper Mohnian, Delmontian, “Repettian” stages). Some oil production (Inglewood and Sunset Beach fields) is obtained from the middle Miocene sandstone of the Topanga Formation. Lower Mohnian fractured shale, pre-Mohnian basal conglomerate or breccia derived from the Catalina Schist, and weathered or fractured Catalina Schist may be potential reservoir rocks in some areas of the Newport-Inglewood Fault Zone, such as the Huntington Beach-Newport area.

Source Rocks: Reservoir hydrocarbons are believed to be sourced from adjacent structurally lower areas to the southwest and northeast. Comparatively low-sulfur oil (< 2 percent) from lower Mohnian organic-rich shales of the Puente Formation on the southwest flank of the central Syncline migrated vertically and southwestward. Relatively high-sulfur oil (> 2 percent) from the organic-rich lower Mohnian basal unit ("nodular shale") of the Monterey Formation on the southwestern shelf migrated vertically and northeastward into the reservoirs along the Newport-Inglewood Fault Zone (McCulloh and others, 1993).

Timing and migration: Maturation and expulsion of hydrocarbons as early as late Miocene from selected areas southwest of the Newport-Inglewood zone of deformation was followed by mid-Pliocene to present expulsion and migration from the Central Syncline. Trap formation has been episodic since at least lower Mohnian time.

Traps: Discovered traps are predominantly youthful faulted anticlines with lesser numbers of fault and stratigraphic traps on anticlinal noses and homoclines. Seals are low-permeability fault zones and clastic beds. Discovered accumulations occur at depths from about 500 to 9,750 ft and range in thickness from about 15 to 1,200 ft.

Exploration status: Exploration onshore is very mature and exploratory drilling is largely prohibited by urbanization and environmental regulations. Larger oil discoveries (>50 MMBO) with discovery year and cumulative production plus estimated reserves through 1992 are: (California Division of Oil, Gas and Geothermal Resources, 1993) Dominguez (1923, 277 MMBO, 387 BCFG), Huntington Beach (onshore) (1920, 555 MMBO, 540 BCFG), Inglewood (1924, 400 MMBO, 285 BCFG), Long Beach (1921, 945 MMBO, 1.088 TCFG), Newport West (1943, 78 MMBO, 8 BCFG), Rosecrans (including Rosecrans South and Rosecrans East) (1924, 94 MMBO, 190 BCFG), and Seal Beach (1924, 216 MMBO, 225 BCFG) (California Division of Oil, Gas and Geothermal Resources, 1993). Six smaller discoveries, including two each < 1 MMBOE, contribute 41 MMBO and 147 BCFG for play totals of 2.606 BBO and 2.870 TCFG. Undiscovered oil is likely to have API gravities in the higher part of the 9û to 60û API range of discovered oils and partly may have comparatively high sulfur content. Depths of undiscovered accumulations may be in the depth range of deeper discovered reservoirs or deeper.

Resource potential: Only small accumulations remain undiscovered onshore. Most likely onshore prospects lie down the flanks of the structurally high Newport-Inglewood zone of deformation, and possibly in comparatively young fault traps. The Long Beach Airport field is an example of this type of accumulation, although future discoveries will be even more subtle and deeper. Mostly small to subeconomic accumulations may exist in the offshore state lands of this play because of increasing distance from known source rocks and more distal facies of upper Mohnian through "Repettian" turbidite sands (Redin, 1991). Traps related to the offshore portion of the Newport-Inglewood zone of deformation may be present but the thickness of upper Mohnian and younger sandstones decreases sharply southeast of the Huntington Beachfeld in offshore State lands. Stratigraphic traps involving sands associated with the San Onofre Member of the upper Topanga Formation of middle Miocene age may be present in this southeast part of the play.

1404. WHITTIER FAULT ZONE AND FULLERTON EMBAYMENT PLAY

This confirmed structural-stratigraphic play consists of oil and associated gas accumulations in mostly turbidite sandstones of upper Miocene and Pliocene age in the (1) Whittier Fault Zone, (2) Fullerton embayment of Wright (1991), and (3) Coyote Hills-Yorba Linda and Richfield–Kraemer Uplifts. The play is characterized by structures along the west-northwest-trending Whittier Fault and, to the south, east-west-trending uplifted folds.

The northern play boundary is drawn slightly northeast of the Whittier Fault Zone to include possible oil reservoirs located in footwall blocks beneath north-dipping faults. The eastern play boundary is drawn approximately to include the easternmost extent of possible Neogene reservoir rocks within migration distance of mature lower Mohnian or younger source rocks. From west to east, the southern play boundary is drawn around the Santa Fe Springs High, along the northern boundary of the Anaheim Nose to just east of the Olive field, and then northeastward along the edge of the Santa Ana Mountains Uplift. The western play boundary coincides approximately with the structural low in the Neogene section and the axis of the northern element of the Puente submarine fan system that was the dominant source of sands to the basin during late Miocene and Pliocene time.

Reservoirs: Most discovered reservoirs are marine turbidite sandstones of the upper Mohnian, Delmontian, and "Repettian" stages. These marine turbidite sequences range from proximal conglomeratic sandstone, generally in the north, to more distal turbidite sandstone toward the south. Minor sandstone reservoirs have been discovered in the middle Miocene (Topanga Formation in Brea Olinda field), upper Pliocene (Pico Formation in Santa Fe Springs field), and Pleistocene (La Habra Formation in Yorba Linda field).

Source rocks: The predominant source for discovered accumulations of comparatively low sulfur (< 2 percent) oil are lower Mohnian shales in the Fullerton embayment and possibly the structural troughs to the south that separate the east-west-trending uplifts.

Timing and migration: Maturation and expulsion of hydrocarbons probably began during early Pliocene or earlier, and trap formation has been more or less continuous in the Whittier Fault Zone area since middle Miocene. Trap formation in the east-west-trending uplifts to the south of the Whittier Fault Zone has occurred since late Pliocene time. Oil apparently migrated from the Fullerton embayment (1) northward to charge reservoirs along the Whittier Fault Zone and (2) southward to charge reservoirs in the Yorba Linda-Coyote Hills, and Kraemer-Richfield Uplifts. Long-range migration of oil from the Central Syncline probably was blocked from the eastern play area by the Anaheim Nose that was structurally high during late Miocene and early Pliocene time. In the western play area, source rocks in the western Fullerton embayment, and later in the adjacent Central Syncline, have contributed to the accumulation at the Santa Fe Springs field since middle Pliocene time.

Traps: In the central and eastern play area, discovered traps include faults, faulted anticlines, plunging anticlinal noses, domes, updip closure by fault truncation and unconformity, and stratigraphic lenses. Seals are low-permeability fault zones, clastic beds, unconformities, and tar seals. Discovered accumulations occur at depths from about 350 to 10,000 ft and range in thickness from about 20 to 900 ft.

Exploration status: Exploration is mature in most this play, except for the pre-Mohnian section. Urbanization and environmental regulations have hampered drilling for several decades.

Larger oil discoveries (>50 MMBO) with discovery year and cumulative production plus estimated reserves through 1992 are: Brea-Olinda (1880, 439 MMBO, 482 BCFG), Coyote East (1911, 122 MMBO, 61 BCFG), Coyote West (1909, 256 MMBO, 272 BCFG), Richfield (1919, 203 MMBO, 173 BCFG), Sansinena (1945, 62 MMBO, 76 BCFG), Santa Fe Springs (1919, 634 MMBO, 839 BCFG), Whittier (1898, 54 MMBO, 50 BCFG), and Yorba Linda (1937, 106 MMBO, 2 BCFG) (California Division of Oil, Gas, and Geothermal Resources, 1993). Six smaller discoveries, including three each < 1 MMBOE, contribute 9 MMBO and 4 BCFG for play totals of 1.885 BBO and 1.959 TCFG.

Undiscovered oil is likely to have gravities in the higher part of the 12û API to 44û API range of discovered oil and comparatively low sulfur content. Depths of undiscovered accumulations may be in the depth range of deeper discovered reservoirs or deeper.

Resource potential: A limited number of accumulations ranging in size up to tens of millions of barrels of oil may be discovered in the vicinity of the Whittier and Santa Fe Springs fields in the western part of the play. Pre-Mohnian rocks may be prospective in the eastern play area but are higher risk objectives because of likely poorer reservoir quality and uncertain migration pathways and seals.

1405. NORTHERN SHELF AND NORTHERN FLANK OF CENTRAL SYNCLINE PLAY

The confirmed structural-stratigraphic play consists of oil and associated gas accumulations largely in turbidite sandstone reservoirs of upper Miocene and Pliocene age located in the northern shelf area (Wright, 1991). The play also includes the central part of the northern flank of the Central Syncline. The structural setting of the younger Neogene section is somewhat distinct from the Santa Monica Fault System to the west and the Whittier Fault Zone to the southeast. The play is characterized by generally east-west-trending structures in the Pliocene section and slightly more northeast-southwest-trending structures in the Miocene section. Subtle structures in the younger section may indicate larger structures in the underlying older rocks.

The western play boundary is the approximate eastern extent of the structural imprint of the Santa Monica Fault System in the Neogene section. From west to east, the northern play boundary is drawn just north of the Hollywood-Raymond Hill Fault Zones and slightly northeast of the East Montebello Fault and its northwest projection (Wright, 1991) that separates Wright's subsurface "Alhambra high" from the Elysian Park Anticline. The southeast boundary is drawn partly along the structural low in the Neogene section that separates the northern shelf from the Fullerton embayment region. This boundary also corresponds approximately to the axis of the northern element of the Puente submarine fan system that was the dominant source of sediment to the basin during late Miocene and Pliocene time. This southeast boundary is curved somewhat arbitrarily southeastward around the Santa Fe Springs High to meet the boundary of the Anaheim Nose Play (1406) in order to include most of the deep north flank of the Central Syncline in the play. The southwest play boundary coincides approximately with the axis of the Central Syncline so that postulated southeast projections of the Las Cienegas Fault Zone are included in the play.

Reservoirs: Most discovered reservoirs are marine turbidite sandstones of the upper Mohnian, Delmontian, and "Repettian" stages. These marine turbidite sequences range from proximal conglomeratic sandstone, generally in the north, to more distal turbidite sandstone toward the south.

Source rocks: Source rocks are lower Mohnian organic-rich shales located within the play area itself and in the nearby portion of the Central Syncline that have generated comparatively low sulfur (< 2 percent) oil.

Timing and migration: Maturation and expulsion of hydrocarbons probably began during early Pliocene or earlier, and trap formation has been more or less continuous since latest Miocene or early Pliocene time.

Traps: Discovered traps include east-west-trending anticlines, domes, and flexures, either with symmetrical flanks or steeper south flanks in the western area. Faulting and rapid facies changes influence some accumulations. Seals are low-permeability fault zones, clastic beds, unconformities, and tar seals. Discovered accumulations occur at depths of about 2,200 to 8,560 ft and range in thickness from about 12 to 1,960 ft.

Exploration status: The play is mature in the younger Neogene section and only moderately well tested in the Mohnian section at greater depth. Drilling has been partly restricted for decades by urbanization and environmental regulations.

The only large oil discovery (>50 MMBOE) with discovery year and cumulative production plus estimated reserves through 1992 is Montebello (1917, 202 MMBO, 235 BCFG) (California Division of Oil, Gas, and Geothermal Resources, 1993). Four smaller discoveries, including one with < 1 MMBOE, contribute 15 MMBO and 31 BCFG for play totals of 217 MMBO and 266 TCFG. Undiscovered oil is likely to have API gravities in the higher part of the 20û to 44û API range of discovered oil and comparatively low sulfur content. Undiscovered accumulations will be at depths comparable to the greater depths of discovered reservoirs or deeper.

Resource potential: Possible traps beneath structures in the younger Neogene section may hold accumulations ranging in size up to tens of millions of barrels of oil. Source rocks and reservoir sandstones are present in the older Neogene section, but reservoir quality and traps are uncertain.

1406. ANAHEIM NOSE PLAY

The confirmed structural-stratigraphic play consists of oil and associated gas accumulations primarily in turbidite sandstone reservoirs of Miocene and Pliocene age and secondarily in pre-Mohnian rocks located on the Anaheim Nose. The Anaheim Nose is a distinct, northwest-plunging block in the eastern Los Angeles Basin Province that was structurally high during the Mohnian, Delmontian, and early "Repettian" stages. Eocene, Oligocene (Sespe Formation), early Miocene (Vaqueros Formation), and middle Miocene (Topanga Formation) rocks have been encountered by drilling and are unconformably overlain by progressive onlap of lower, middle, and upper “Repettian beds” (Wright, 1991). Mohnian and Delmontian rocks pinch out around the margins of the block and the play boundary is drawn approximately where these units thin to less than 1,600 ft and (or) consist predominantly of low sand overbank facies (Redin, 1991).

Reservoirs: Discovered reservoirs are sandstones of the "Repettian" stage and, in one case, in the upper Pliocene Pico Formation. Potential reservoirs may exist in sandstone units of both Paleogene and Neogene strata, although upper Mohnian and Delmontian sandstones that are so prolific throughout the Los Angeles Basin are largely absent in this play.

Source rocks: The minor fields on the Anaheim Nose may have been charged from lower Mohnian source rocks either in the Fullerton embayment on the north or the Central Syncline on the southwest, depending on the structural position of the trap.

Timing and migration: Maturation and expulsion of hydrocarbons in adjacent source rock areas probably began during early Pliocene time. Intermittent trap formation appears to have occurred since before maturation of hydrocarbons. The absence of lower Mohnian source rocks beneath much of the play area may partly explain the poor record of oil discoveries. Greater lateral migration distances are required for this play than other plays in the province.

Traps: Discovered traps are mostly stratigraphic pinchouts in the Delmontian and "Repettian" section. A small fault trap in the Pliocene Pico Formation constitutes the Anaheim field. Small undiscovered traps may exist that formed by pinchout of the lower Mohnian sandstones (La Mirada field) and bounding faults in Miocene formations around the periphery of Anaheim Nose. Seals are low-permeability strata and, in some cases, fault zones. Discovered accumulations occur at depths from about 4,300 to 11,900 ft and range in thickness from about 30 to 500 ft.

Exploration status: The play is well explored and has questionable to low potential, principally because of absence of abundant reservoir rocks. The only oil discovery > 1 MMBOE is the Olive field which was discovered in 1953 and has cumulative production plus estimated reserves through 1992 of 3 MMBO and 1 BCFG (California Division of Oil, Gas, and Geothermal Resources, 1993). Four other oil discoveries, each <1 MMBOE, do not significantly add to the play total. Undiscovered oil is likely to have API gravities in the 11û to 30û API range of discovered oil and variable sulfur content. Depths of undiscovered accumulations probably are in the depth range of discovered reservoirs or deeper.

Resource potential: Several mostly small accumulations may exist in the Puente Formation around the periphery of the play area, in post-unconformity onlapping "Repettian" and younger rocks, and, to a lesser extent, in the pre-unconformity Topanga and older formations.

1407. CHINO MARGINAL BASIN, PUENTE AND SAN JOSE HILLS, AND SAN GABRIEL VALLEY MARGINAL BASIN PLAY

The confirmed play consists of oil and associated gas accumulations in proximal turbidite sandstone reservoirs of Miocene and Pliocene age located in the region north and northeast of the Whittier Fault Zone and the northwest extension of the East Montebello fault of Wright (1991). Oil migration from the Fullerton embayment, northern shelf, and Central Syncline probably was largely blocked by these fault zones and their associated structures. The Puente Hills and Chino Basin areas are distinctive because they received little or no marine deposition during or after early Pliocene time, have been partly uplifted with unknown amounts of overburden removed, and have a structural style that is distinct from the region southwest of the Whittier Fault Zone. The San Gabriel Valley Marginal Basin received several thousand feet of late Miocene Puente Formation and lower Pliocene marine rocks before marine regression and deposition of up to 6,000 ft of post-lower Pliocene nonmarine sediments (Wright, 1991).

The play is bounded on the southwest by the Whittier and East Montebello Fault Zones, on the north by the Raymond Hill-Duarte Fault Zones, and on the northeast and east by the onlap edge of Neogene marine rocks on middle Miocene volcanic or sedimentary rocks and Mesozoic intrusive rocks.

Reservoirs: Discovered accumulations are mostly upper Mohnian marine turbidite sandstones of the Puente Formation in the western Puente Hills and Chino Basin. Fractured rocks, which occur in the Yorba Member of the Puente Formation in the Mahala field, may also be reservoir rock in other parts of the Chino Basin and parts of the Puente Hills. The reservoir of the Lapworth field is a Pliocene conglomeratic sandstone. Possible reservoir rocks in the San Gabriel Valley Basin include Puente and lower Pliocene shelfal marine sandstones and younger nonmarine sands or gravels.

Source rocks: Lower Mohnian organic-rich shale locally were buried deeply enough to generate oil. It is unknown if mature Mohnian source rocks exist between the Chino basin accumulations and the western accumulations near the San Gabriel Valley. It is possible that mature source rocks are lacking in this central part of the play. Puente shales are reported to be mature in the southern part of the San Gabriel Valley basin where at least one exploratory well tested oil prior to abandonment.

Timing and migration: Small discovered accumulations of oil appear to be associated with local small "kitchens" where generation of hydrocarbons is plausible. This suggests that migration distances were short. It is also possible that oil migrated northward into the San Gabriel Valley basin from south of the East Montebello Fault. The timing of maturation and migration of hydrocarbons appears to be variable but presumably began at least by mid-Pliocene time.

Traps: Discovered traps are (1) faulted anticlines, anticlinal noses, and homoclines, (2) truncated units associated with faulting, and (3) a lenticular conglomeratic sandstone on a homocline. Known seals are low permeability clastic beds, unconformities, and fault zones. Tar seals may also be postulated. Traps and seals in the San Gabriel Valley Basin are problematical. Speculative traps associated with faulting or folding near the East Montebello Fault, and stratigraphic traps associated with rapid changes in proximal submarine canyon/fan facies, seem plausible. Seals may be less certain in the proximal marine and nonmarine rocks of the San Gabriel Valley Basin. Discovered accumulations occur at depths from about 1,000 to 4,400 ft and range in thickness from about 20 to 600 ft.

Exploration status: Exploration is mature for a region that has low potential. Oil discoveries >1 MMBOE with discovery year and cumulation production plus estimated reserves through 1992 are: Mahala (1921, 4 MMBO, 2 BCFG) and Prado-Corona (1966, 1 MMBO, 4 BCFG) (California Division of Oil, Gas, and Geothermal Resources, 1993). Six oil discoveries each <1 MMBOE contribute 2 MMBO and 1 BCFG for play totals of 7 MMBO and 7 BCFG at the end of 1992.

Undiscovered oil is likely to have gravities in the 16û API to 31û API range of discovered oil and comparatively low sulfur content. Oils may be biodegraded. Depths of undiscovered accumulations will be in the depth range of discovered reservoirs or deeper.

Resource potential: Several, mostly small, accumulations may exist in the Puente Formation and younger rocks in the southernmost San Gabriel Valley Basin, in the vicinity of the Whittier Heights and Workman Mill faults of Wright (1991), and in the Chino Marginal Basin. Absence of abundant nearby mature source rocks and reservoir seals are discouraging factors.

UNCONVENTIONAL PLAY

Continuous-Type

1408. DEEP, OVERPRESSURED FRACTURED ROCKS OF CENTRAL SYNCLINE PLAY (HYPOTHETICAL)

This probable continuous type, unconventional and hypothetical Play, Deep Overpressured Fractured Rocks of Central Syncline, is based largely on the American Petrofina Central Core Hole well (sec. 4, T. 3 S., R. 13 W.) which encountered overpressured rocks, tested moderately high gravity oil, and bottomed in lowermost Delmontian rocks at 21,215 ft measured depth in the central syncline. The conceptual reservoir is fractured rock. The Mohnian section has not been reached by drill in the central syncline. Based on inferred depth to basement in the Central Syncline (Yerkes and others, 1965) and projected thicknesses of upper Miocene rocks northeast and southwest of the Central Syncline, the lower Mohnian section probably is less than 3,000 to 7,000 ft thick in the syncline.

The play boundary is liberally drawn to include most of the Central Syncline and its deep flanks, although the southwestern deep flank probably is the most favorable location for reservoirs.

Stresses responsible for postulated fracturing of reservoir rocks are likely to be caused by fluid overpressuring during maturation of kerogen in the organic-rich shales. Late Miocene and early Pliocene extensional faulting and more recent north-south compression of the southwest flank of the Central Syncline may also have contributed to fracturing. The compressional tectonics since the Pliocene may have locally enhanced fracturing along the deep syncline-bounding faults. This faulting also could have provided expulsion routes except where diagenetic alteration kept seals intact. The presence of overpressuring in the American Petrofina Central Core Hole well suggests some seals remain intact. Price (1994) studied basins worldwide and suggested that large amounts of generated hydrocarbons may remain in or near source rocks in basins where expulsion routes have not been provided by tectonism.

Reservoirs: Reservoirs are postulated to be fractured rocks of lower Mohnian or older age.

Source rocks: Source rocks are lower Mohnian shales. Source rocks may be the less terrigenous parts of the lower Mohnian section, possibly analogous to the organic-rich basal unit ("nodular shale") on the southwestern shelf, if indeed less-terrigenous rocks are present northeast of the Newport Inglewood zone of deformation. The "nodular shale" is reported to occur northeast of the Newport-Inglewood zone of deformation in the Inglewood field (Wright, 1991). Vitrinite reflectance values are reported to be increasing rapidly toward the bottom of the American Petrofina Central Core Hole well where values >1.2 percent were observed (N.H. Bostick, 1994, personal commun.)

Timing and migration: Maturation of hydrocarbons probably began during early Pliocene time or earlier and continues today. Migration is not necessary for postulated self-sourcing reservoirs and, for other postulated reservoirs, probably commenced during middle Pliocene.

Traps: Unknown but postulated to be (1) deep, continuous volume reservoir without clear structural boundaries, (2) localized reservoir intervals where fracturing is a function of lithofacies, (3) structurally bounded reservoirs due to faulting or folding along the deep flanks of the Central Syncline, such as along the postulated Compton-Los Alamitos Fault Zone, or (4) traps caused by diagenetically sealed rocks adjacent to bodies of fractured rocks. Laumontite is reported at depth in the American Petrofina well and may degrade the quality of possible reservoir rocks or even help form reservoir seals (T.H. McCulloh, 1994, person commun.).

Exploration status: Unexplored except for American Petrofina Central Core Hole well, which confirmed the presence of hydrocarbons but does not confirm that reservoir rocks are present. The American Petrofina Central Core Hole tested oil of 43û API gravity with moderate to high gas-oil ratio near total depth. Other, not as deep, wells on the east flank of the Newport-Inglewood zone of deformation penetrated important amounts of interbedded sandstone and shale with type II kerogen in the lower Mohnian section. Condensate or gas also are likely at the depths of this hypothetical play.

Resource potential: Because of the known organic richness of Luisian and lower Mohnian source rocks along the northeast and southwest margins of the Central Syncline, one can infer that large amounts of hydrocarbons have been generated in the Central Syncline where these organic-rich rocks are presumed to be present. The possibility that some of this generated petroleum remains trapped at great depth in suitable reservoir rocks is very problematical and a quantitative analysis is not possible.

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